To investigate targeted, selective treatment for parasites in ruminant livestock



Operational Group: Anthelmintic TST Group

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Abstract

Helminth (worm) infections are responsible for considerable reductions in production efficiency in grass-based ruminant systems such as those prevalent in Northern Ireland (NI). At present the control of parasitic helminths relies on the use of anthelmintic drugs, but their widespread application at whole-herd / whole-flock level is leading to anthelmintic resistance (AR), reducing their effectiveness.

To tackle AR, successive EU-funded research projects have investigated new strategies for sustainable worm control, primarily through changes to routine whole-herd / whole-flock anthelmintic treatment protocols. These focus on the integration of targeted, selective treatment (TST) of parasites in both cattle and sheep. Although these approaches have been shown to be viable on commercial farms, uptake remains limited, and many farms continue to rely on whole-herd / whole-flock anthelmintic treatments, with an inevitable trajectory towards AR and treatment failure.

This project aimed to determine the feasibility and practicality of implementing targeted selective treatment of parasitic helminths on Northern Ireland commercial farms. In doing so, bridging the gap between research and implementation, and through the sharing of advice and experiences, encourage wider uptake across the sector.

Seven farmers from across the dairy, beef and sheep sectors in Northern Ireland were enrolled on the project with support provided by partners from Queen's University Belfast, the Agri-Food and Biosciences Institute (AFBI) and Animal Health and Welfare Northern Ireland (AHWNI). Group members co-designed, utilised and evaluated multiple, tailored TST strategies to better understand the feasibility of implementation on commercial farms. These strategies were integrated throughout the 2021 and 2022 grazing season, alongside monitoring of parasitic helminth prevalence using faecal egg counting (FEC). TST strategies consisted of assessing multiple parameters including parasite presence (FEC), liveweight and daily liveweight gain and visual observations of animal health (e.g., scouring and body condition scoring). Group members made alterations to these strategies as the season progressed or as parasite burden altered to maintain a high standard of animal welfare.

All seven farms delayed and reduced the number of anthelmintic treatments in each grazing season relative to pre-project levels. Although this occasionally resulted in small decreases in productivity, farmers agreed that these short-term losses were at an acceptable level. At certain points in the grazing season it was necessary to implement whole-herd / whole-flock anthelmintic treatments on a targeted treatment (TT) basis to maintain productivity, safeguard animal health and welfare or to limit the contamination of grazing pastures with parasitic helminths. For example, application of anthelmintic treatments on a TT basis were necessary for both *Nematodirus battus* control in lambs and *Dictyocaulus viviparus* (cattle lungworm) control. Where possible, livestock tracked in the 2021 grazing were observed during the 2022 grazing with no obvious decreases in productivity noted. Results of the project have been disseminated through online webinars, media coverage and on-farm events.

This project has demonstrated that TST strategies are feasible on sheep and cattle farms in Northern Ireland. TST strategies must be tailored relative to the farm's long-term goals for parasite management and anthelmintic treatment reduction whilst considering available infrastructure. These strategies must also be flexible to changes in annual weather conditions and parasite dynamics.

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Project Aims

Helminth (worm) infections are responsible for considerable reductions in production efficiency in grass-based ruminant systems such as those prevalent in Northern Ireland (NI). At present the control of parasitic helminths relies upon anthelmintic drugs, but their widespread application at whole-herd / whole-flock level is leading to anthelmintic resistance (AR), reducing their effectiveness.

Problems with AR are well documented globally on sheep farms and increasingly throughout the cattle industry (Rose et al. 2015). In Northern Ireland, AR was detected on most sheep farms studied (McMahon et al., 2013), whilst no data is yet available for cattle. A recent study in the Republic of Ireland found reduced drug efficacy on most beef and dairy farms studied, including all 16 farms on which ivermectin was assessed, with both *Cooperia oncophora* and *Ostertagia ostertagi* species surviving anthelmintic treatment (Kelleher et al., 2020).

To tackle AR, successive EU-funded research projects have investigated new strategies for sustainable worm control, primarily through changes to routine whole-herd / whole-flock treatment protocols (Charlier et al., 2014). These focus on targeted, selective treatment (TST) which involves:

- Targeting anthelmintics at the right time to maximise epidemiological benefits, and avoid unnecessary treatments; and/or
- Leaving a proportion of the flock or herd untreated, making use of the fact that most worms are concentrated in a few individuals, and removing them will have large effects on worm transmission and herd health while reducing the number of treatments needed.

Although these approaches have been shown to be viable on commercial farms (e.g. Busin et al., 2014), uptake remains limited, and many farms continue to rely on whole-herd / whole-flock anthelmintic treatments, with an inevitable trajectory towards AR and treatment failure. Whilst a targeted, selective anthelmintic treatment approach can deliver suitable helminth control, widescale uptake of the approach and its success will largely depend on its on-farm practicality and wider economic benefit. This has not yet been evaluated in Northern Ireland.

This project therefore aimed to determine the feasibility and practicality of implementing targeted selective treatment of sheep and cattle parasitic helminths on commercial farms in Northern Ireland. In doing so, bridging the gap between research and implementation, and through the sharing of advice and experiences, encourage wider uptake across the sector.

The core objectives of the project were to:

- Determine suitable TST approaches for each participant farm
- Implement TST approach on each participant farm
- Assess the impact of implementing a TST approach
- Assess the feasibility and practicality of undertaking anthelmintic TST on farms in Northern Ireland
- Disseminate project activity and results

The Operational Group

Following a presentation on anthelmintic resistance and strategies to tackle it given by Professor Eric Morgan (QUB) to farmers participating in GrassCheckNI, multiple farmers expressed an interest in finding out more and trialling some targeted treatment strategies on-farm. When funding became available under the European Innovation Partnership initiative the Anthelmintic TST Group was formed.

AgriSearch brought together seven farmers from across the dairy, beef and sheep sectors in Northern Ireland alongside expertise from Queen's University Belfast (QUB), the Agri-Food and Biosciences Institute (AFBI) and Animal Health and Welfare Northern Ireland (AHWNI).

The members of the operational group are:

- John Martin – Greyabbey, Co Down (Sheep)
- Jayme Carvill – Hilltown, Co. Down (Sheep)
- Martin Craig – Crumlin, Co. Antrim (Sheep)
- Trevor Somerville – Dungannon, Co. Tyrone (Beef)
- Oliver McKenna – Eskra, Co. Tyrone (Beef)
- Ian McClelland – Banbridge, Co. Down (Dairy)
- Albert O'Neill – Artigarvan, Co. Tyrone (Dairy)
- Professor Eric Morgan – QUB
- Dr Christopher McFarland – QUB
- Dr Francis Lively – AFBI
- Dr Sam Strain – AHWNI
- Jason Rankin – AgriSearch (Lead Partner)

Parasitologists Prof. Eric Morgan and Dr Christopher McFarland (QUB) took on the role of scientific leads in the project having previous experience in the epidemiology of parasitic infections in animals, and sustainable approaches to parasite control. Dr Francis Lively (AFBI) and Dr Sam Strain (AHWNI) provided oversight from a ruminant research and veterinary perspective.

The group was administered by AgriSearch who took on the role of project lead and provided an innovation broker to support the delivery of the project aims and objectives. AgriSearch also led on all dissemination activity for the project.

Members signed a partnership agreement declaring their intentions to work cohesively to deliver the objectives listed in the project action plan. Each member contributed to the compilation of the action plan and its delivery. Roles and responsibilities were assigned to each member to ensure clarity regarding their expected input.

The group met on a regular basis to plan activity, discuss progress and report results. Meetings were often held remotely via online platforms to allow members to easily attend. One-to-one virtual and in-person meetings also took place between QUB and the farmer participants as part of the on-farm trial aspects of the project.

All farmer group members had previously worked together on the GrassCheckNI project and so were known to each other, AgriSearch and AFBI were familiar with on-farm projects which was beneficial to the group.

Project Details

To meet the aims of the project several actions were planned and undertaken for the delivery of individual objectives.

Objective 1: Determine Suitable TST Approaches for each Participant Farm

To develop tailored TT/TST approaches for each of the project farms, baseline information was gathered in relation to the participant's enterprise type (sheep, beef or dairy youngstock), stocking numbers, current parasite management on farm, livestock performance monitoring strategies and personal, long-term on-farm goals for parasite control.

To streamline data collection participants were asked to complete the BigWorm NI survey, a survey which the QUB team were associated with. Information gathering was also supplemented by video conferencing between participants and the authors to gather further information on farm technology and feasibility of TT/TST approaches.

A series of three tailored TT/TST options were co-designed for each participant farm based on the information collected. Within these options, the authors highlighted the benefits of implementing the proposed strategy, suggested actions for altered parasite management, clearly defined risks associated with implementing the proposed strategy and guidance on how these risks could be mitigated for successful implementation. Following the creation of the tailored options an additional video conferencing call was performed between the authors and participants to discuss the specifics of each option and refine further based on participant consultation.

Objective 2: Implement TST approaches on each Participant Farm

Once tailored options were created, the participants were instructed to implement these strategies in the 2021 grazing season. Participants were offered the flexibility to switch between the three TT/TST options as the grazing season progressed and modifications were made in situ. Tailored TT/TST approaches were also implemented throughout the 2022 grazing season. All participants were progressive in their ideology of TT/TST strategies and were willing to implement the changes discussed.

Tailored TT/TST options required the collection of data pertaining to parasite burden, possible impacts of parasitism on livestock productivity, infection risk monitoring by grazing management and anthelmintic applications.

To collect information on parasite burden, faecal worm egg counts (FECs) were employed for host animals on each farm. The collection and analysis of FEC samples can be labour intensive, particularly in larger flocks/herds, and on occasion requires adequately trained staff. It was therefore decided that project participants would avail of the services of Techion using the FECPAK^{G2} faecal egg counting system. All participant farms received a FECPAK^{G2} system with an annual subscription of 100 sampling events and were provided with adequate training on dung sample collection, sample preparation and software support. On one farm, due to logistical reasons, the participant availed of a FECPAK^{G2} system available in a local merchant with samples analysed by an in-house vet. Additional FEC analyses were also provided by Queen's University Belfast (QUB) technical staff for the further analysis of gastrointestinal nematodes (GINs) as well as cattle lungworm and liver fluke presence within samples, services not available on the FECPAK^{G2} system throughout the project. All GIN FECs at QUB were completed using the mini-FLOTAC system following manufacturer's guidelines for ruminant hosts (Cringoli et al. 2017).

To monitor and record animal performance, participants were encouraged to regularly weigh livestock in study groups. Some tailored TT/TST options also explicitly required the use of liveweight to determine animals requiring anthelmintic treatment. On participant farms the provision of capital funding enabled the integration of new weighing systems or calibration/updating of original systems. Thus, improving the accuracy of liveweight data collection and accessibility of data for decision support. Participants were also asked to closely monitor livestock in study groups for any adverse alterations in condition relative to outgroups.

To monitor the effect of anthelmintic treatment method on parasite infection risk and associated grazing management, participants recorded field movement dates, number of livestock moved, age of livestock and recent field grazing history. A field-based GIN prediction model (McFarland et al., 2022) was populated using data collected (e.g. FECs, liveweight and grazing management) by participants to create maps of GIN risk on a field-by-field basis, relative to the anthelmintic treatment options applied. The development and analysis of which is ongoing.

To investigate the effect of altered parasite management on anthelmintic applications, participants recorded information at each anthelmintic treatment event. Information collected included drug active agent, date of application, application method and decision process rationalised for applying the treatment.

To investigate new technology options aiding animal health decisions on farm one participant farm received a subscription to the SmartWorm application from Cotter Agritech in late summer 2022. SmartWorm is a world-first app which aims to enable sheep farmers to conduct targeted selective worm treatment (TST). It makes recommendations for treatment in real time based on an advanced algorithm which identifies, via connection to an EID enabled weigh system, animals that would or would not benefit from a wormer treatment. The algorithm calculates a lambs potential growth rate based on assessment of livestock weight, physiological and environmental (pasture, weather) factors and generates a treatment threshold score. If the individual animals do not reach this predicted target, anthelmintic treatment is recommended. The use of decision support tools via mobile app technology on farms is increasing and members of the group were keen to see if this provided an additional real-time support for TST decisions on farm.

Objective 3: Assess the impact of Implementing a TST Approach

To assess the impacts of implementing targeted anthelmintic treatment approaches on each farm, regular communication was maintained between project participants and the project lead, with data gathered regularly. Data was gathered by email or through the sharing of images e.g. weight recording booklets. Data from FECPAK^{G2} submissions were collated by Techion and sent as a monthly update email throughout each of the grazing seasons. QUB also visited participant farms throughout the duration of the project to discuss further options and/or collect dung samples for analyses not available on the FECPAK^{G2} platform.

Objective 4: Assess the feasibility and practicality of undertaking targeted, selective treatment of anthelmintics on farms in Northern Ireland

Data collected and analysed within the project was reviewed following both year one (2021) and year two (2022) of the project and the opinions and feedback from the participant farmers collated. To specifically collect information on how each participant farmer interpreted their involvement in the project, QUB completed a second video conferencing interview with each farmer throughout May and June 2023. A question list was established and distributed to each participant prior to meeting and the responses compiled.

To provide wider context reviews of the on-farm project activity and outcomes were also undertaken by AHWNI and AFBI with reflections provided with regards to the question of ‘What recommendations could be made to allow TT and TST approaches to be used wide scale in Northern Ireland?’ and the impact of TT/TST uptake at scale on NI farms.

Objective 5: Dissemination of Project Activity and Results

A suite of dissemination activity was planned and undertaken throughout the course of the project to share both generalist information on anthelmintic resistance and targeted selective treatment but also project activity and outcomes as they arose.

Project Funding

The delivery of this project was supported via the European Innovation Partnership (EIP) Scheme in Northern Ireland which is jointly funded by the European Agricultural Fund for Rural Development (EAFRD) and the Department of Agriculture, Environment and Rural Affairs (DAERA).

Each project had a maximum budget of £120,000 available for the delivery of planned activity over the duration of the project.

Total project spend – £96178 TBC

Approximately 15% of funding was allocated to project dissemination and promotion and 20% allocated to project dissemination. The remainder was allocated to direct activity in the delivery of the project.

Any ineligible costs, not able to be claimed under the available EIP budget, were funded by AgriSearch, the lead partner within the Anthelmintic TST operational group.

Additional capital funding was also obtained for this EIP project. Upon receiving EIP funding the operational group members reviewed their on-farm needs and the requirements of the project, and assessed what capital grant funding and expenditure options were available to them. Each operational group member chose to invest in capital items that would make the regular weighing of livestock (essential for effective implementation of anthelmintic targeted selective treatment) quicker, easier, safer, and more accurate. Items were chosen specific to their own farm set up and livestock type. A 50% Grant rate was available with each participant farmer funding the remaining 50% of the cost of their chosen items.

Total capital spend - £47,343.60 (£23,671.80 claimed)

The farmers experienced some difficulties in obtaining capital item quotes due to the implementation of BREXIT on 1st January 2021 and the resulting impact on the movement of goods between GB and Northern Ireland. Farmers often found GB suppliers unwilling to quote as they were not confident in the delivery costs and new procedures for shipment. Suppliers in NI were also reluctant to quote as they were experiencing difficulty in obtaining items from GB for resale. Many were only willing to quote based on items currently in stock as price increases may be a reality in future if delivery costs are passed onto them from suppliers.

Project Results and Outcomes

Objective 1: Determine Suitable TST Approaches for each Participant Farm

As an outcome of the BigWorm NI survey completed by participant farmers it was highlighted that there was limited information available on TT/TST and the use of in refugia parasite populations for prevention of anthelmintic resistance.

Targeted Treatments (TT) is defined as when whole flock/herd treatments are applied based on knowledge of parasite risk or following diagnosis and estimation of infection severity. Targeted Selective Treatments (TST) is defined as when a proportion of individuals within the flock/herd are treated based on a single, or combination of treatment indicators, such as faecal egg counts (FEC), weight gain, body condition or milk yields. The ultimate aim of these strategies is a reduction in anthelmintic treatment frequency whilst maintaining or improving productivity: this has the potential to decrease costs of worm control, as well as prolonging wormer effectiveness.

The key principle of drug resistance prevention is the maintenance of in refugia parasite populations. The term in refugia refers to keeping a part of the parasite population unexposed to wormer when the herd or flock is treated. This can include parasite eggs and immature worms established on the pasture prior to treatment, and also worms residing within animals that are not treated. Structured treatment regimens (e.g. treating only those individuals most in need) and planned grazing to avoid infection can help maintain in refugia populations and encourage the dilution of resistant worms on the pasture.

Communication of these definitions and background theory became a core component of any dissemination activity going forward both within and out with operational group.

The results of the BigWorm NI survey also highlighted beneficial parasite management strategies already being employed on the participant farms as well as allowing operational group members at QUB to determine potential areas for improvement.

Beneficial parasite management strategies were already applied on most of the participant farms, but the extent and type varied between each. Strategies included:

- Calibration of dosing equipment.
- Movement of livestock to fields with some parasite contamination post-anthelmintic treatment.
- Adequate quarantine of Introduced livestock.
- Anthelmintic treatments applied accurately according to animal weight.
- Previous discussion of anthelmintic resistance with vet.
- Regular FECs carried out with local vet.
- Good nematodirus vigilance including use of SCOPS forecast.

Each participant farm was also provided with a list of areas for potential optimisation relative to parasite management during the EIP project. The intention was to highlight parasite management practices that could be improved to increase the likelihood of successful TT/TST strategies. Suggestions included but were not limited to:

- Consider changes to pre-set treatment plans over the course of the grazing season.
- Use of FECs for treatment decision making.
- Reduction in anthelmintic treatments per grazing season via TT/TST strategies.
- Use of refugia for parasite management.
- Consideration of the Huskvac lungworm vaccine for cattle.
- Improvement of weighing facilities available on the farm to allow for better tracking of daily live weight gain and allow for dosing of individuals to the correct weight.

- Conducting tests for the presence of anthelmintic resistance on farm.
- Calibration of dosing equipment.

For each participant farm a series of three tailored TT/TST options were created. The information provided highlighted the benefits of implementing the proposed strategy, suggested actions for altered parasite management, clearly defined risks associated with implementing the proposed strategy and guidance on how these risks could be mitigated for successful implementation. An example of an option provided to one of the beef farms is illustrated in *figure 1*. Options for each farm can be found in *appendix 4*.

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:
- Turn out without treatment.
- **Assess group pooled FEC every 2 weeks:**
  - FEC 0-100 eggs per gram (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-200 epg, don't treat, but re-sample group again 5-7 days later.
  - FEC >200 epg, treat whole group (TT).

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 2: TST – Treatment based on individual FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turn out without treatment.
- **Assess individual FEC every 2 weeks:**
  - FEC <100 epg, don't treat, re-sample 2 weeks later.
  - FEC 100-200 epg, don't treat, but re-sample again 5-7 days later.
  - FEC >200 epg, apply treatment.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 3: TST – Treatment based on individual DLWG/weight targets

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess ability to reach individualised targets by weighing every 2 weeks.**
  - Treat according to traditional farm weight targets, i.e. treat individuals not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- Group pooled FEC every 2-3 weeks after turnout.
- Switch to a **TT** strategy if infection spike observed i.e. treat the whole group.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Figure 1 - Farm specific, tailored TT/TST options provided to participant farms in 2021. Benefits, actions, risks and risk mitigation strategies were highlighted for each option.

Objective 2: Implement TST approaches on each Participant Farm

Participating farmers together with QUB devised a range of TT/TST strategies for use on each farm. These took account of a range of conditions on the farm such as handling facilities, group sizes, labour availability etc. The planned TT/TST strategies were implemented on participant farms in the 2021 and 2022 grazing seasons. All participants were progressive in their ideology of TT/TST strategies and were willing to implement the changes discussed. Participants were offered the flexibility to switch between the three TT/TST options as the grazing season progressed and modifications were made in situ. Changes were also made between grazing seasons with many of the participant farms being more confident and experienced the second year.

It is clear from on farm activity that the participant farmers were more confident in the second year of the study; thereby providing evidence that practical experience is also important to encourage farmers to change their management practices. However, during this project the advice and guidance provided by QUB was high and for similar activity to be taken up at an industry level a closer and improved working relationship with veterinary practitioners or anthelmintic suppliers would be required to ensure farmers can interpret information such as FEC results received correctly.

A summary of 2021 and 2022 activity on each participant farm is provided below with full details available in *appendix 4*.

Farm 1 – Dairy Cattle

2021	• Tracked two batches of cattle under rotational grazing – first grazing season (FGS) and second grazing season (SGS) calves. • New weighing system integrated on farm – five weighing time-points. • Gastrointestinal nematode (GIN) faecal egg counts (FECs) low throughout season. • 13 FECPAK^{G2} submissions. Additional FECs completed by QUB. • FGS calves were dosed twice in 2021 guided by FECPAK^{G2} and liveweight.
2022	• Tracking a new batch of FGS (n = 26), also following the SGS (n = 25) from the first grazing season of the project. • Liveweight measurements at 14 timepoints throughout the grazing season for FGS calves. Weighing on a 1-week to 2-week basis throughout most of the grazing season. • SGS cattle (FGS from 2021) were weighed at seven timepoints during the 2022 grazing season. • 17 FECPAK^{G2} submissions by participant farmer throughout the grazing season • FECPAK^{G2} submission of FGS calves on 11/05/2022 showed an egg count of 360 eggs per gram (EPG). Grazing same youngstock fields as 2021. Decision was therefore taken to treat with ivermectin to reduce pasture contamination. • FGS calves dosed three times in 2022 guided by FECPAK^{G2} and liveweight. Anthelmintic applications now accurately provided according to animal weight. • FECs of SGS heifers remained at 0 – 20 EPG (four FECPAKG2 timepoints), however participant farmer dosed with albendazole 3 weeks prior to calving under normal farm management. This was the first anthelmintic treatment of 2022.

Farm 2 – Beef Cattle

2021	• Tracked two batches of FGS cattle under rotational grazing across out-farms. • A smaller batch of FGS calves and two SGS batches were also followed but not tracked in the same detail as Batch 1 and Batch 2. • Batch 1 spent ~10 months housed before first grazing event; Batch 2 spent ~6 months housed before first grazing event. • Batch 1 (n =35) were vaccinated with Huskvac lungworm vaccine and Batch 2 (n = 36) were not vaccinated with Huskvac. • Batch 1 calves were weighed at four time-points and Batch 2 were weighed at five time-points. • 8 FECPAK ^{G2} submissions with FECs supplemented by multiple QUB visits. • Farmer applied one anthelmintic treatment to Batch 1 and two treatments to Batch 2 during the 2021 grazing season. Farmer stated they wanted to develop natural immunity in cattle. This appeared to have adverse effects from August onwards. Delay in anthelmintic treatment for too long resulted in gradual buildup of parasites on pasture. • Fears of lungworm outbreaks prevented application of TST on farm. TT options were more applicable. • The distribution of cattle on out-farms away from weighing facilities reduced ability to employ weight-based strategies.

2022	• Tracked three batches of FGS calves:
	  o Batch 1: 42 bull calves mixed breed
	  o Batch 2: 33 Wagyu calves
	  o Batch 3: 9 small calves (Wagyu)
	• No batches were vaccinated using the Huskvac vaccine for lungworm in 2022 or 2023 due to practicalities and additional cost of sourcing/applying the vaccine.
	• Batch 1 = five weighing time-points and Batch 2 = five weighing time-points
	• An additional batch of suckler calves and cows born 2022 were recorded using FECPAK^{G2}.
	• 22 FECPAK^{G2} submissions were supplemented by multiple QUB visits.
	• Each batch of FGS calves received four anthelmintic treatments in 2022, largely driven by outbreaks of lungworm on farm as opposed to GIN concerns.

Farm 3 – Sheep

2021	• Tracked 1 batch of lambs and ewes. • 11 FECPAK^{G2} submissions used alongside liveweight to investigate drops in DLWG (six liveweight time-points). • QUB visit on 01/06/2021 to collect dung samples for FEC analysis. • Anthelmintic treatments for lambs maintained at two per grazing season. • *Moniezia expansa* tapeworm cysts identified in samples alongside GINs.
2022	• Tracked 3 batches of lambs and ewes. All were managed the same way due to logistical difficulties. • Farmer was experiencing intermittent connectivity issues with the FECPAK^{G2} system throughout the grazing. Zero submissions in 2022. Multiple QUB visits were therefore required to collect dung samples for FEC analysis. • Liveweight data in 2022 consisted of six weighing timepoints. • Anthelmintic treatments were maintained at same level as first year of the project with the addition of a Vecoxan coccidia treatment as a preventative measure based on high oocysts counts early in the season of 2021.

Farm 4 – Sheep

2021	• Tracking two batches of ewes and lambs in 2021 – Batch 1 and Batch 2. • Lambs weaned and formed one large batch on 20/07/2021. • 25 FECPAK^{G2} system used alongside liveweight to investigate drops in DLWG. Liveweight data stored on Datamars system (data not shown here). • Additional QUB visits to collect dung samples for FEC analysis. • Anthelmintic treatments maintained at four per season for lambs. However at least one treatment (Noromectin) was applied for GINs when it may not have been required.
2022	• Tracking four batches of ewes and lambs in 2022 – Batch 1, Batch 2, Batch 3 and Batch 4. • Batch 1 and 2 were formed on 18/04/2022. Batch 3 on 25/04/2022. Approx. 65 ewes in each batch with Batch 3 consisting of 50% 1st time lambers. Batch 1 and Batch 2

	consisted of 112 and 100 lambs, respectively. Batch 3 consisted of 70 lambs. Batch 4 was 1st time lambers in a smaller batch. • Batch 2 and Batch 3 were combined at weaning on 19/07/2022 to form a batch of 170 lambs renamed Batch 2. • The farmer was interested in integrating co-grazing with cattle into the system. Sheep in Batch 1 were therefore grazed with 10 SGS beef cattle and 7 FGS cattle until 04/10/2022. • The farmer also decided to integrate co-grazing for the 2023 grazing season with cattle now grazed alongside three sheep batches. • Liveweight of lambs was only recorded at weaning in 2022. The farmer suggested this was due to the increased labour associated with regular weighing and therefore decided to select alternative parameters to determine performance i.e. scouring + FECPAK^{G2}. • 22 FECPAK^{G2} submissions in the 2022 grazing season and QUB visit on 05/04/2022 to sample ewes in Batch 1 and Batch 2 • Detailed records of pasture grazing rotations maintained by farmer

Farm 5 – Beef Cattle

2021	• Tracked three batches of cattle. Batch 1: weanling heifers (n = 8) 2020 spring born. Batch 2: SGS calves (n = 14) nine 2020 spring born and five 2019 autumn born. Batch 3: dams and calves (n = 38) 19 of each. • 20 FECPAK^{G2} submissions were completed by the farmer in 2021. FECs were often performed on an individual animal basis. Supplementary QUB FECs completed. Liver and rumen fluke diagnostics performed on 23/09/2021. Low numbers of rumen fluke eggs detected; no liver fluke eggs detected. • FEC based TT applied during the grazing season. • Regular dung samples were sent by post to QUB for lungworm analysis. • Anthelmintic treatments were reduced and delayed – but applied treatments when coughing heard in batches.
2022	• Tracked three batches of cattle. FGS batch and two SGS batches (FGS in 2021). • 18 FECPAK^{G2} submissions by farmer and supplemented by QUB FECs on 25/04/2022. Additional dung samples were sent to QUB by post for lungworm and fluke analysis. • Increased regularity of weighing. Liveweight gains of many individuals documented to be below target weight at multiple points in the season.

Farm 6 – Sheep

2021	• Tracked one batch of lambs in detail. The second TST batch was sampled more irregularly. • 19 FECPAK^{G2} submissions with additional QUB FECs completed. FECs remained high throughout grazing season. • Zolvix 'break dose' applied mid-August. Zolvix drug efficacy checked pre- and post-treatment using tied samples. Rectal dung samples collected by farmer. 16 pre- and post-treatment dung samples collected from individuals by farmer on 25/06/2021 and 09/07/2021.

	• TST applied on two separate occasions based on FECPAK and dag score or DLWG. For example, in June 2021 lambs were thriving but *Nematodirus battus* remained at 35 EPG. Farmer took decision to apply TST, only treating individuals that were scouring. • Liveweight measurements at multiple time points. • Anthelmintic treatments maintained at four per season. • Mortality of some January born lambs with suspected *Nematodirus battus* when treatment withheld. Lambs grazed previous years pasture for two weeks before going onto Redstart in early February. Possible that some *Nematodirus battus* L3 survived overwinter as conditions would not have allowed L3 hatching from developed eggs already on pasture.
2022	• Multiple groups of lambs and ewes were tracked. • 11 FECPAK^{G2} submissions. Reduction in FECPAK^{G2} use due to the time required to collect and analyse the results – multiple gatherings of lambs. • QUB FECs were completed on 01/04/2021 in a batch of January born lambs and a batch of ewes that lambed in March. • Anthelmintic treatment of ewes at lambing removed. However, in 2023 the farmer decided to reintroduce targeted treatments of ewes, treating only twin or triplet ewes. • Anthelmintic treatments provided on a targeted basis using liveweight with treatment applied to lambs growing <200 g/day. This was reduced to those <180 g/day as the season progressed as all liveweight gains reduced due to weather and feed quality. • SmartWorm App tested on 09/09/2022 for selection of individuals requiring anthelmintic treatment. • Challenging year from a grass growth perspective with extra feed required. Growth rates of lambs slower than average. • Zolvix anthelmintic treatment implemented as a 'break dose' in June. • At the start of the 2023 grazing season a coccidiosis outbreak resulted in 10 lambs dying. Lambs were all March born and from the same batch which had grazed a particularly muddy field grazed by lambs in the previous grazing season. Samples were sent to VSD for analysis.

Farm 7 – Dairy Cattle

2021	• Followed two batches of FGS calves:
	  o Batch 1: Turnout on 13/04/2021. 30 individuals. Treated with Cydectin LA at turnout.
	  o Batch 2 = Turnout 21/04/2021. 30 individuals. No treatment at turnout
	• At the start of the project the farmer opted to use a mixed approach of FEC and liveweight data for targeting anthelmintic treatments.
	• Calves were weighed every four weeks with the new weighing system integrated on farm – six weighing time-points for Batch 1 and five time-points for Batch 2. However, farmer noted disagreements with farm workers on the cost benefits of increased effort required for liveweight monitoring compared to routine anthelmintic treatments.
	• 7 FECPAKG2 submissions with additional QUB FECs completed. First three FECPAKG2 submissions completed by farmer before opting to outsource FECPAKG2 analyses to local merchants due to time constraints.
	• Due to weather conditions at the start of the 2021 grazing season the farmer took the decision to rehouse cattle for a short period in May before turning back out again.

2022	• Two batches of FGS calves and three batches of SGS calves (FGS from 2021) were tracked. • The farmer noted that some SGS individuals were behind at the start of 2022 but caught up again quickly. • All FGS and SGS calves received the Huskvac lungworm vaccine in 2022. • The farmer implemented the vaccine for a second time at the start of the 2023 grazing season to FGS calves. • 22 FECPAK^{G2} submissions were completed at a local merchant. • Weight data only available for SGS cattle in 2022 due to labour constraints.

Across the two seasons, participating farmers did reduce their anthelmintic usage, however, other health concerns limited the potential for further reductions, for example, lungworm in cattle. Unless vaccines for lungworm have been administered it is likely that anthelmintic treatment will be required to control the lungworm even though there might be no or limited gastrointestinal nematodes present. From an economical perspective, the availability and cost of the lung-worm vaccine could be more expensive that the product cost for several administrations of anthelmintics. Consequently, this could be a barrier to adoption in bovine youngstock.

Where TST strategies were adopted on farm, the more regular handling of livestock to weigh the livestock or to collect the samples for FEC increased labour requirements. In some cases, treatment of visually underperforming groups trumped the time period for waiting on the FEC results as the farmers were concerned that they would have to repeat the handling process within a short period of time.

Objective 3: Assess the impact of Implementing a TST Approach

Each participant farm was able to utilise TT and TST strategies to either reduce the number of anthelmintic treatments over the course of the grazing season or maintain already low treatment rates with confidence. Treatments were administered based on pre-determined parameters such as weight, FEC results or visual indicators (often in combination) as opposed to being based on time of year as had been a common approach before the project started.

When we consider overall reductions in the number of anthelmintic treatments it is important to note the variability in the time it takes individual animals to make culling target weight. For example, high performing individuals may only receive a single anthelmintic treatment, whilst slower growing individuals could receive multiple anthelmintic treatments in a grazing season. This will ultimately be determined by complex interactions of multiple variables including parasites, non-parasite diseases, genetics, feed quality etc.

Concerns regarding potential reductions in liveweight gain as a result of TT/TST approaches were raised at the start of the project and this was monitored. Some of the farms did not observe any obvious difference in the time it took to rear livestock to target weight in each grazing season, despite a reduction in anthelmintic treatments. Meanwhile, others noticed some differences compared to pre-project outputs, but these were made up over the course of the following winter. Where possible, livestock tracked in the 2021 grazing were observed during the 2022 grazing with no obvious decreases in productivity noted.

Variability in climate and year to year changes also had an impact alongside anthelmintic treatment decisions. In 2021 and 2022 grass growth seemed to be a particularly important factor that reduced liveweight gains later in the grazing season. Despite low FECs some farmers applied anthelmintic treatments in the hope this would improve liveweight gain however this was often unsuccessful.

Farmer involvement in this project increased their knowledge about the use of anthelmintics and increased the generation of data which they could use to inform management decisions. For example as a result of more regular weighing. Where technology is being used to support data collection it is important that guidance on the software usage is obtained from the supplier and proper training is given to maximize the true value of the data. Financial investment in better handling and weighing facilities was a major contributing and encouragement factor for the farmers involved in this project. Future funding for such equipment could be beneficial for maximizing uptake of TST.

Involvement with this project enables some farmers to examine drug efficacy for multiple drug classes. This has important to aid farmers to develop a flexible health plan that can utilize various products rather than relying on the same time after time, season after season. Further education around this is required to better inform farmers as the most suitable product for use on their farm. In general, each farm as a result of the project and investment in improved weighing equipment, were monitoring livestock performance on a more regular basis which also helped identify other factors that may be reducing performance in combination with Gastrointestinal nematodes (GINs).

A summary of the main improvements to parasite management throughout the project and suggested future improvements can be found in *table 1* and *table 2*.

Table 1 – Summary of main improvements to parasite management throughout the project on each participant farm.

	Main Improvements to parasite management throughout the project
Farm 1 – Dairy Cattle	• Did not observe any obvious difference in the time it took to rear livestock to target weight in each grazing season, despite a reduction of at least two anthelmintic treatments per year. • Weighing platform introduced on farm. Regular liveweight measurements performed and now applying anthelmintic treatments according to animal weight.
Farm 2 – Beef Cattle	• Integrated the Huskvac lungworm vaccine to two batches of cattle in the first year of the trial (2021 Batch 1 and Batch 3). The group in which the vaccine was applied only received one anthelmintic treatment throughout the grazing season. This was two treatments less than the batch that did not receive the vaccine. However, it is worth noting that the vaccinated calves were also a few months older than the non-vaccinated batch. • The number of times livestock were weighed throughout the season increased compared to levels before the start of the project. • The farmer developed a better understanding of the theory of refugia based strategies for GIN management, however suggested practically applying these strategies in a rotational grazing system was difficult. • Increase in the number of FECs being carried out on farm. Although FECs were performed by the farmer prior to the start of the project these were often irregular, and farmer suggested waiting times for vet response of results were unworkable.
Farm 3 - Sheep	• The number of annual anthelmintic treatments for lambs was low prior to the start of the trial and this trend was maintained throughout the project. • Anthelmintic treatment of ewes at lambing was removed. • Treatments were provided on a targeted basis rather than based on time of year using a combination of FECPAK^{G2} submissions (2021 only)/QUB FECs alongside assessment of liveweight gains. Going forward the farmer plans to continue sending dung samples to the vet.

	• Mobile crush purchased with capital funding via the project enabled liveweight measurements in the field.
Farm 4 - Sheep	• Anthelmintic treatments in 2021 were largely performed using a TT strategy. However, in 2022 the farmer opted for a combination of TT and TST, applying anthelmintic treatments to individual animals using scouring assessments and associated group level FECPAK^{G2} submissions. • Anthelmintic rotations were introduced during the project due to overreliance on Group 3 (macrocyclic lactones) agents. • Group 4 Zolvix anthelmintic treatments were provided as a break dose in 2021 and 2022. However, the 2021 application was poorly timed as FECs were low and anthelmintic treatment did not improve group liveweights suggesting other factors may have contributed to reduced condition. • The participant farmer suggested regular FECPAK^{G2} submissions had provided the confidence to integrate the changes on farm.
Farm 5 – Beef Cattle	• Regular liveweight measurements and continued dosing of animals to weight. • Reduced anthelmintic treatments by two events per individual per year. • Integration of regular individual FECs and lungworm assessments. • Anthelmintic rotations introduced in 2022 rotating between ivermectin, levamisole and benzimidazole based anthelmintic treatment.
Farm 6 - Sheep	• Anthelmintic treatments were provided on a targeted basis in both the 2021 and 2022 grazing season. This involved TST using DLWG alongside visual observations and group level FECs to inform treatment decision. • Anthelmintic treatments were delayed and reduced at certain times of year due to improved information on species presence from FECPAK^{G2} system. • Group 4 Zolvix anthelmintic treatments provided as a break dose in 2021 and 2022. • On multiple occasions throughout the project the farmer utilised pre- and post-anthelmintic treatment FECPAK^{G2} submissions to examine drug efficacy for multiple drug classes.
Farm 7 – Dairy Cattle	• Anthelmintic treatments on farm were traditionally carried out according to time of year – at turnout and then every six weeks thereafter. Targeted treatments applied throughout 2021 and 2022 grazing season leading to a reduction in the number of anthelmintic treatments given to both first and second grazing season cattle. • Huskvac lungworm vaccine introduced to annual farm management for first grazing season cattle. • The weighing platform purchased during the project has enabled the tracking of liveweight and improved accuracy of treatment application.

Table 2 – Summary of the suggested future improvement for on farm parasite management for each participant farm.

	Suggested future improvements for on farm parasite management
Farm 1 – Dairy Cattle	• Improved rotation of anthelmintic agents required. Ivermectin is currently used regularly on farm and is also used for quarantine treatments. Suggested anthelmintic rotation to benzimidazole treatment in 2022 grazing season was successful.

	• Avoid grazing youngstock on the same fields at the same time each year. However, this is challenging to alter in a dairy herd as youngstock grazed at out-farm.
Farm 2 – Beef Cattle	• Despite applying treatments using a TT strategy based on group FECs, some anthelmintic treatments were still applied when they may not have been required. These additional treatments are largely aimed towards lungworm control as opposed to GINs. Improved lungworm diagnostics and timing of sample collections relative to treatment will help reduce these treatments further. • Group 3 macrocyclic lactone anthelmintics were used very regularly on farm and there appears to be at least some reduction in drug efficacy to GINs given pre- and post-treatment egg count assessment. Rotation to a Group 2 levamisole-based treatment during the 2022 grazing proved to be much more effective at reducing GIN FECs. • The farmer on occasion still employed a dose and move strategy when treating livestock i.e. providing treatment and then moving to clean pasture. This may promote the development of anthelmintic resistance on farm. The authors made the farmer aware of this during the project. • TST was not carried out at any point during the project. This was due to the increased handling required. The farmer suggested they were still unsure of which parameters to use for treatment decision and were fearful of withholding treatment from high performance animals. For example, when applying anthelmintics based on liveweight it may be necessary to dose the high performing individuals a few weeks later when they fall behind. Future trials on farm using smaller batches of liveweight based TST may be feasible.
Farm 3 - Sheep	• Targeted selective treatments (TST) were not employed during the project due to the excess handling required, particularly when animals were grazing hill pastures. Going forward, the famer suggested they may try to use DLWG as a treatment parameter. • Pre-tupping anthelmintic treatments are still applied to ewes however this is the only treatment they receive each year (Cydectin TriclaMox). Due largely to handling issues and desire to not disturb animals for treatment during tupping if it was required. • Early season assessments of coccidia levels are required to ensure levels do not get too high. • Beef cattle are also purchased and grazed on farm. Staggered grazing at present, there may be options to co-graze in the future. • Integration of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.
Farm 4 - Sheep	• Ivermectin appears to have low drug efficacy on farm for GINs at present. In 2022 the farmer switched to using ivermectin only for the treatment of *N. battus*. The farmer also plans to further integrate Group 2 and Group 5 anthelmintics. • Integration of regular weighing of sheep throughout the grazing season would provide further information on performance and could be integrated as a parameter for TST (in discussions with developers of the SmartWorm App). • Assessment of the benefits of co-grazing at different ratios of cattle relative to sheep, taking care of risks associated with liver fluke. • Integration of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.

Farm 5 – Beef Cattle	• Combination fluke and worm anthelmintic treatments are applied in the house early in the year prior to grazing despite the application of a pre-house treatment. Fluke only anthelmintic treatments at this time point may prove more beneficial. • Despite applying treatments using a TT strategy based on group FECs, some anthelmintic treatments were still applied when they may not have been required. These additional treatments are largely aimed towards lungworm control as opposed to GINs. Improved lungworm diagnostics and timing of sample collections relative to treatment will help reduce these treatments further. • TST was not carried out at any point during the project. Future trials on-farm using smaller batches focusing on liveweight based TST may be feasible. • Integration of lungworm vaccine into parasite management. • Calf rearing enterprise started (cattle brought onto farm at three weeks of age). Farmer advised on how to quarantine effectively for older stock bought in that may contain parasites.
Farm 6 - Sheep	• The farmer plans to integrate the SmartWorm App into future TST strategies. • Assess benefits of co-grazing sheep and cattle on farm to reduce sheep parasites, taking care of risks associated with liver fluke. • Continued use of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.
Farm 7 – Dairy Cattle	• The participant farmer has planned to reseed some fields with multi species swards in 2023 to help counter unreliable weather conditions i.e. both increased rainfall and drought. Farmer suggested this may also have additional benefits for livestock health and parasite development. • The farmer is committed to nature friendly farming moving forward and at the centre of this is the continued surveillance of anthelmintic drug use. • Continue with rotation of anthelmintic rotation throughout the grazing season. Anthelmintic treatments in 2022 seen application of macrocyclic lactone based anthelmintics at multiple time points i.e. ivomec pour on and also cydectin triclamox for fluke control.

Objective 4: Assess the feasibility and practicality of undertaking targeted, selective treatment of anthelmintics on farms in Northern Ireland

<u>Participant Feedback</u>

Following the conclusion of the second year of on-farm activity the participant farms were interviewed regarding their opinions on parasite control and the practicality of TT/TST strategies. Their responses are summarised below with full details available in *appendix 4*.

- All of the participant farmers agreed that their knowledge of anthelmintics had improved throughout the duration of the project. All noted that they now thought more carefully about applying an anthelmintic treatment without at least carrying out some further investigations e.g. liveweight measurements and/or FECs.
- All of the participant farmers also agreed that their knowledge of refugia had increased throughout the duration of the project, however, most suggested that while they could understand the theory behind the use of refugia on farm, applying grazing management whilst thinking about refugia maintenance, particularly in a rotational grazing system, was difficult to achieve.

- All of the participant farmers were more aware of the theory behind TT and TST strategies. Some suggested they were not aware of the difference before the start of the project. Application desire for TT/TST strategies varied between the farms. The requirements for improved online resources detailing TT/TST options was noted. TT strategies were preferred over TST strategies on most farms due to the increased labour associated with TST.
- Some of the participant farmers said they were confident to integrate their own TT/TST strategies in the future. However, others suggested they would not be confident integrating TST strategies on farm without the support of the EIP operational group or a veterinarian.
- Use of FECPAK^{G2} submissions varied across the farms. Some farmers suggested that they would often question if they made a mistake with sample preparation if the result came back as a zero value for strongyles at certain points in the season. On one farm the FECPAK^{G2} was only used in the 2021 grazing season. The farmer then opted to complete all FECPAK^{G2} submissions at a local merchant due to the extra time requirements associated with sample analysis. On a second farm, technical difficulties in the 2022 grazing season prevented submission and required alternative methods to be utilised. Some farmers suggested the option of a FECPAK^{G2} system at a local merchant was perhaps more appealing if wait times were short due to the time required to both collect and analyse their own samples. One farmer noted that they also believed FECPAK^{G2} systems could be a useful addition to business development groups (BDGs) to allow sharing of resources and advice. The current inability to detect lungworm on the FECPAK^{G2} system was noted as a limitation by all cattle farmers on the project.
- Participant farms that installed new systems or mobile weighing systems observed an increase in the number of liveweight timepoints relative to pre-project assessments. Some farmers suggested the use of liveweight measurements prompted further investigations into herd or flock health when parasite burdens were perceived as low. Most commented that liveweight measurements were more difficult to collect at certain times of the year for example pre-weaning in sheep and when cows and calves graze together.

Throughout the interviews the participant farmers highlighted a number of obstacles that prevented TT or TST strategies being applied. These included:

- Cattle lungworm mid-season. All cattle farms suggested this was a considerable source of hesitation with TST strategies mid-grazing season. Risk outweighed the benefits, and a TT strategy was preferable once coughing occurred. Noted that current lungworm diagnostics must also be improved.
- Increased labour – one farmer noted that automated in-field weighing systems would be much more beneficial for tracking cattle weights to reduce overall stress of handling for both the farmer and the cattle.
- Group size, particularly pre-weaning in lambs.
- DLWG drops associated with grass quality and provision – difficult to separate from worm burdens.
- Some farmers also suggested that fears of reduced productivity were an obstacle for TT/TST application. For example, not treating high performing individuals and then waiting two weeks for next assessment at which point considerable losses may have occurred. This was deemed particularly concerning on sheep farms with high lamb turnover.
- Similarly, some farmers were concerned that reducing anthelmintic treatments earlier in the season would ultimately lead to more parasites on the grass later in the grazing season.
- One farmer also suggested that it was difficult to justify the additional work required when it is often cheaper and quicker to apply blanket anthelmintic treatments – effects of anthelmintic resistance often not obvious. The difference in cost between different drug classes was also

noted with ivermectin based drugs often working out much cheaper to apply. One farmer also noted that improved information on timing anthelmintic treatments relative to lungworm vaccine was required to improve vaccine efficacy.

Observations from the project found the feasibility and practicality of undertaking TT or TST strategies on farm often depended on the enterprise type. Such differences will need to be taken into account when considering the promotion of such strategies across the wider agricultural sectors in Northern Ireland.

Farms stocking cattle found TT easier to implement than TST simply due to lesser handling requirements. TST often required a team of people for safe movement and assessment of stock. Lungworm in cattle was also a stumbling block to TT/TST approaches based on the farms surveyed. On cattle farms it may be that at high-risk periods of the year a TT approach should be employed in favour of TST to allow treatment of all individuals. The decision to treat in this case would be based on the detection of lungworm L1 in faeces. All cattle farmers on the project suggested that they would consider using a lungworm vaccine or have already applied it throughout the project. However, all noted that the vaccine was difficult to obtain, and more information was required on optimal timing of vaccine application. Better education of veterinarians on the use of the vaccine was also noted as an important factor for uptake.

Farms stocking sheep found the flock size to be an important consideration when determining the feasibility of TT/TST strategies on farm given the increased time and labour input required. The complications of combining batches as the season progresses also means that good anthelmintic treatment records for each individual animal are required. Whilst lambs are easier to handle for TT/TST after weaning participant farmers raised fears that withholding treatments of best performing individuals at one timepoint, particularly in lambs, could set them back to the worst performing individuals after a two-week interval which can have significant impact on profitability.

Parameter selection for making treatment decisions was also a crucial consideration when undertaking TT/TST on farm. Feedback from participants is summarised below:

- TST approaches using individual FEC based methods appear only feasible on smaller farm enterprises or when used in a focused manner in smaller groups due to the associated costs.
- One farmer commented that ‘Farmer’s eye’ was the most useful parameter for determining treatment requirement on their farm. Suggested this may be easier to achieve in a small batch of cattle compared to much larger batches of sheep.
- Using DLWG as a measurement in the case of lambs requires 30-40 individuals to run through the crush before deciding on a treatment threshold. These individuals likely all receive an anthelmintic dose which can impact overall TT/TST objectives.

The use of technology may be able to help going forward with regards parameter selection and decision making. For example, this may include advances in pen-side parasite diagnostics and identification of coinfections with other organisms e.g., bacteria, viruses etc.. The project also highlighted that the increased labour required for regular liveweight measurements may be a stumbling block for the implementation of TT/TST strategies, particularly in cattle. The availability of automated in-field weighing systems may help mitigate these challenges.

Feedback from the participant farm that trialled the SmartWorm app has been positive. As often with technology there were teething issues when trying to get the app setup and connected to existing equipment on farm but once achieved the software was straightforward to use. The app clearly indicates using a red/green colour-based system which animals are below target weight. A record is then kept within the app of which animals have been dosed. Whilst the use of a SmartWorm app is one tool that can help decide which animals to dose the farmer believed it still needs to be used in conjunction with faecal egg counts to identify the best time to dose. Important to note is that investment is required to be able to avail of its benefits such as having suitable weigh scales and an EID reader on site as well as purchasing the annual subscription to the product. He is in no doubt however that the further development of real-time decision support tools such as this will provide confidence to end-users regarding selection of individual animals for anthelmintic treatment. In the longer term the likes of SmartWorm can also have a role to play in helping to identify the sheep in a closed flock which have higher shedding rates for worm eggs and in the medium to longer term it should be possible to breed a flock with greater ability to thrive despite the presence of worm infestations.

Sectoral Review

To determine the feasibility of increased uptake of TT/TST practices the findings of the project were reviewed in the wider context of the NI agricultural sector and it's needs.

Knowledge Gaps

Each of the farms involved in the project are regarded as well run and progressive farms given previous involvement in other projects. However even these farms demonstrated evidence of gaps in knowledge regarding parasite management. If this is true for these participants, then it must represent widespread lack of best practice knowledge across the NI livestock industry. There is clearly much more that could be done to provide farmers with clear best practice knowledge and advice. Examples of knowledge gaps found during the project include:

- Properly adjusted and calibrated dosage equipment ensuring accurate dosing.
- Knowledge of the principle of 'in refugia' when applying strategies for parasite control.
- The dangers of 'test and move' strategies for selecting for anthelmintic resistance.
- Adequate approaches to quarantining introduced animals.
- Knowledge of vaccination options and availability for lungworm control in cattle.

There are several actions that could be taken to assist in addressing the identified knowledge gaps on Northern Ireland farms:

1. Ensuring adequate training of veterinary practitioners in current best practice, paying particular attention to those vets that may have only occasional contact with farm clients (e.g., where only occasional sheep work is carried out).
2. Development of trusted information platforms that are freely available to farmers and their advisors (e.g., better use and visibility of SCOPS materials, development of NI information platforms such as AHWNI, AgriSearch).
3. Ensuring that agriculture students are provided with up-to-date information on best practices for parasite management (e.g., working with CAFRE to ensure the curriculum includes appropriate training and materials).
4. Farmer training should be offered. This should include the principles of TST/TT but also practical training such as in the collection of faeces (e.g., in the case of pooled samples that they are representative) the use of data from FECPAK[G2] or alternatives and where they wish to carry out faecal egg counts themselves that they are suitably trained.
5. Ongoing use of Business Development Groups to ensure best practice knowledge is being disseminated.

Development and Wider Use of Parasite Warning Systems

Two highlighted drivers of whole-herd / whole-flock anthelmintic treatments on farms are the presence of *Nematodirus battus* in lambs and *Dictyocaulus viviparus* (lungworm) in cattle. Farmer concern about both parasites can drive additional anthelmintic use at times where gastro-intestinal parasitism from other nematodes is of lesser concern. For example, on one study farm the implementation of the lungworm vaccine to first grazing season calves resulted in an overall reduction of two less anthelmintic treatments compared to batches of cattle that had not been vaccinated. Tailored preventive measures such as the lungworm vaccine or the better use of parasite forecasting systems such as those available for Nematodirus may assist with allowing more informed and targeted treatment. To facilitate this will require more widespread knowledge of parasite epidemiology, prevention and parasite diagnostics . Industry partners should look at better developed methods of communicating this information to herd and flock keepers.

Faecal Egg Counts

Faecal egg counts remain a valuable tool to investigate parasite burdens and assess the potential for pasture contamination with parasite stages. However, there appears to be challenges in accessing this facility in a timely manner to allow rapid decision making to be made at the farm level. While there in an increasing number of merchants and vets offering this service, there does appear to be challenges in some areas accessing it. The industry may need to consider how to better facilitate the offering of this service with agreed turnaround times.

Considerable faecal egg count data is already generated within NI. However apart from feeding this information back to the farmer it is largely unused. There is an opportunity to use the data already collected to provide generic support to the industry. For example, if the data from FECs was available anonymously but included geographical information such that herds or flocks could not be identified this data could be used as a warning system for other livestock keepers.

It is worth noting that some level of Quality Assurance should be carried out to ensure that the results being provided to farmers are accurate. While systems such as FECPAK[G2] are to some extent automated, there is still a need to ensure that collection and processing techniques are of a sufficient standard to ensure results are accurate. It is also worth noting that FECs should also be considered in combination with other factors such as liveweight and visual observations of animal health.

Development of Farm Specific Solutions

A key finding from the project was that while the principles of targeted selective treatment (TST) are well recognised and documented by specialists, there remains considerable variation in how these principles can be applied optimally to each farm enterprise. The development of bespoke TT/TST strategies for farms must therefore consider farming practices (e.g., grazing strategies), farming infrastructure (e.g., automated weighting and data recording), farm production targets, time, weather, and farmer appetite for ‘risk’ in terms of reducing anthelmintic use and therefore, potentially, increasing the risk from parasitism. This is likely to require a co-designing approach involving the farmer, veterinarian and farming advisors to consider farm specific data including parasite history and management. This must be accompanied by farm longitudinal data capture relating to parasite burden and reporting of results to the farmer with appropriate decision support. Industry should consider developing systems that will further enable automated collection of farm and anthelmintic treatment data, accompanied by bespoke reports to individual farms that can be used for future health planning. For example, in principle it is possible to develop pasture contamination maps that allow farmers to track pasture larval contamination on multiple fields. This information, in combination with the previously mentioned diagnostics, can be used to determine timing of anthelmintic treatments to reduce further contamination of pasture, guide grazing management of livestock groups, and provide a visual aid to monitor potential sources of parasite drug susceptible refugia on farm following anthelmintic treatments. This could provide herd and flock keepers with an evidence base of how successful or otherwise they might be in limiting the development of anthelmintic resistance. Ultimately the configuration of annual parasite control planning should be incorporated into wider herd and flock health planning.

Development of 'Rolling Review' Strategies for Parasite Control

The results from this project indicate that farmers should continually assess and adapt approaches to minimise selection for anthelmintic resistance. A single inflexible approach for each herd or flock is not likely to meet individual farm needs from one year to the next. Factors that influence decision making will vary from year to year, for example climactic conditions may impact grass growth which may ultimately impact liveweight gains. In addition, climatic conditions may also alter fluke and gastrointestinal nematode parasite development and survival which are controlled by both temperature and moisture. Farmers and their advisors should be encouraged to review and adapt their approach over time. Therefore, it is likely that taking only one approach (Targeted Treatment versus Targeted Selective Treatments) may not be optimal for each farm. It is likely to be more practically useful for some farms to take a blended approach, tailoring strategies relative to real-time parasite burdens and management goals. For example, in some circumstances a modest delay in initial annual treatment followed by intensive TST approaches may be viable in some farm settings.

Specialised Veterinary Practitioners

There does appear to be a lack of parasite specialised veterinary practitioners, particularly working in sheep medicine. Therefore, there is a need to encourage or facilitate veterinary specialisation to allow farmers to access the best guidance and advice.

Labour availability

Labour is a scare resource on many farms and there was clear evidence that this was often a limiting factor and influenced how anthelmintics were used within the farm. Anthelmintic treatment often occurs at the time of animal movements to new pasture due to pressures on time needs reconsidered on many farms. Product choice due to longer covering periods that can reduce labour also needs to be reviewed.

Handling and weighing facilities

Good handling facilities to handle livestock safely in a timely manner, particularly on out-farms was identified as an issue influencing the timing and procedure used for parasite control on farm. The procurement of suitable equipment at the outset of the project was a challenge for some of the farmers due to issues relating to Brexit, however, this is now likely to be resolved in the future. Without the procurement of the equipment many farmers would have struggled to participate in this project.

The monitoring of livestock performance is a good husbandry practice on livestock farms. Despite, knowing this, monitoring the performance of cattle at an industry level is not widely practiced in

Northern Ireland. As a result, farmers often guess the weight of cattle whilst administering anthelmintics so could be under or overdosing their animals. Also, farmers are not able to trace the performance of individual animals as well as they could otherwise so it limits the ability for early diagnosis of health issues. The installation of well-designed handling facilities with the ability to weigh cattle during the grazing season will be an important requirement for widespread uptake of targeted selective treatment of anthelmintics. The incorporation of weighing equipment within new facilities is an important consideration to minimize the use of labour requirement.

Within the sheep farms, weighing lambs particularly post weaning is an important management practice to select lambs that are eligible for slaughter. The monitoring of lamb live weight provides good information on the animal's performance. At this stage in the lamb's lifecycle, regular handling is common on farm so TST practices are more likely to happen post weaning than in earlier life.

Ability to interpret and use data

The results from FEC and from animal live weights are vital to influence decision making on the farm but accessing raw animal data from farms can be a challenge. Some farmers record animal live weight information using a pen and paper and then use a rough calculation to estimate performance. Others, have procured software packages that record the information, however many may require additional training to utilise the data better and allow it to inform management decisions. Hence, it is recommended that farmers get improved education on the use of the software and the ability to use the data.

Other Health Issues

The need to use anthelmintics to treat other non gastro intestinal parasites, such as lungworm is a major barrier to reducing their usage on farms. The use of vaccines is paramount to overcome this. Farmers need to be vigilant for the occurrence of these other issues to ensure no negative impact on animal health.

Building bridges between farmers, the research and development community and others supporting the agriculture sector

Operational Group

The membership of the Anthelmintic TST Operational Group was designed specifically to bring together complementary expertise to deliver the objectives of the project. Bridges were built because of the shared interest in tackling the anthelmintic resistance challenge being addressed by the project.

Farmer participation and the trial of TT/TST strategies on NI commercial farms was the core component in the delivery of the project. Each farmer that volunteered to take part the project is an experienced ruminant livestock farmer, focused on efficient production in which maintaining animal health and welfare is a priority. All had prior experience of on farm research conducted in conjunction with AgriSearch and many are active members of their local Business Development Groups. Crucially, all were willing to share their farm information and try new approaches to not only improve their own farming business but also improve information available for others in the NI ruminant sector.

The farmers were supported throughout the project by QUB, AHWNI and AFBI. The team at QUB in particular took the time to understand each individual farming business before suggesting any on-farm activity. By acknowledging the unpredictable nature of farming and providing options for each farmer to choose from ensured their continued participation throughout the project. They also provided the knowledge and guidance to aid on farm decision making throughout the project with regular communication encouraged via group meetings, one-to-one meetings, phone calls and texts.

AgriSearch, who are experienced in on-farm research facilitation acted in the coordination role to bring together the different members of the group. Initial meetings focused on knowledge exchange to create a good foundation for activity. By taking on the administration role AgriSearch also allowed other operational partners to focus on the delivery of project outcomes.

Project Dissemination

In addition to encouraging knowledge exchange between Operational Group members a core objective of the project was to share the aims, objectives and outcomes of the project with the wider agricultural sector in Northern Ireland, with the ultimate intention of increasing awareness of anthelmintic resistance and TT/TST practices. Dissemination activity included the organisation and delivery of events, general media communication and the production of resources. Events included a webinar and in person presentations at two industry events and two farm walks. A poster was also displayed at an industry conference and information shared at individual farmer BDG meetings.

The webinar took place in spring 2022 following the first year of on-farm activity. Key topics including anthelmintic resistance and TT/TST strategies were discussed as well as introducing the project and results obtained. Due to the COVID-19 pandemic webinars had become more prominent and familiar to farmers and industry professionals allowing this project to avail of the wider attendee reach they can provide. A recording of the webinar was made available to view after the event on the AgriSearch YouTube channel. Having a lasting resource is another benefit of the webinar format and has led to additional views since the live event took place.

From feedback sought after the webinar, the majority of attendees were farmers with advisors and consultants also present. When asked what they might do differently or explore as a result of the session a large number indicated they would be changing their worming protocol with some specifically intending to carry out FEC tests, check or update their weigh scales and think more carefully about pasture movements and refugia.

The project was asked to speak at two 'Planning for Performance' events organised in October 2022 taking place at CAFRE Greenmount and CAFRE Enniskillen. As one of a number of speakers, Prof. Eric Morgan (QUB) focused on the production challenge that will arise as a result of anthelmintic resistance and the practical steps farmers could take to optimise parasite management and anthelmintic use on farm. Again, these events were recorded and are available to watch on the AgriSearch YouTube channel.

The project was also asked to speak at a Farm Walk event hosted by the ARCZero EIP project who share a farmer operational group member with this project, Ian McClelland. The event was focused on reduction of on-farm carbon footprint and its association with animal health. Dr Christopher McFarland (QUB) presented the aims of the anthelmintic TST EIP project, the parasite management actions the host farmer had taken during the previous two grazing seasons and the outcomes that arose. Links between the anthelmintic TST EIP project and ARCZero EIP project were also highlighted. For example, parasite management has been shown to reduce the time required for animals to reach slaughter weight, ultimately reducing time on farm, and subsequently reducing overall greenhouse gas emissions (Skuce et al., 2013). Furthermore, anthelmintics have been shown to have negative impacts on dung fauna important to soil cycling (Cooke et al., 2017). The overall reduction in anthelmintic use therefore also has positive benefits for wider biodiversity on farm.

To conclude the project a final farm walk event was held at the farm of operational group member John Martin. The event was organised by AgriSearch in conjunction with the Nature Friendly Farming Network, who brought Bruce Thompson, a Nuffield Scholar and expert on dung beetles to provide a complimentary talk to those given by Dr Christopher McFarland and Prof. Eric Morgan (QUB) and John himself.

Feedback was sought from attendees after the farm walk with the majority finding the farm walk to be very well organised with content that was 'about right' and delivered well. One respondent specifically noted the serious problem that resistance to wormers has become and the point that farmers are only getting to understand it now.

At all dissemination events farmer operational group members were encouraged and asked to contribute/speak as peer-to-peer learning has been found to be most efficient in the agricultural context. The farmer members of the group also showcased what they were doing as part of the project through their own BDG group meetings and hosted events.

In general, it is evident from the questions asked at events and the feedback received that there is an urgent need for knowledge transfer on the principles of limiting anthelmintic resistance, particularly the concept of refugia and steps that can be taken to increase refugia populations of parasites.

General media communication included the issue of Press Releases to local farming media on a regular basis to both promote the project and highlight key activity and findings as it arose, as well as the promotion of planned events. Pick-up of press releases was high across the three primary agricultural publications in Northern Ireland. AgriSearch also consistently promoted the project across its social media channels and website broadening the reach. Specifically, a series of 'Meet the Farmer' videos were issued on social media alongside a number of farmer-written case studies to introduce the participants in the project as well as the activity they were undertaking.

Additional benefits or unintended negative consequences that have arisen from the delivery of the project

Many EIP projects derive some unexpected additional benefits or even unintended negative consequences.

Additional benefits that arose as a result of this project included:

- The integration of weighing systems and FECPAK^{G2} for faecal egg counting encouraged farmers to explore alternative reasons for poor liveweight gain when parasite burdens were low.
- Farmers gained increased knowledge on adequate parasite quarantine protocols when introducing new livestock to the farm. This will also decrease the spread of anthelmintic resistance between farms.
- Participants improved their knowledge of anthelmintic application, storage, and rotation to maximise drug efficacy.
- On some farms anthelmintic resistance assays were performed providing a snapshot of drug efficacy for at least one active agent.
- Possible links identified with Multi-Species Swards and their anthelmintic effect on ruminants

One negative consequence of the project for the participant farmers involved was that on occasion liveweight gains were reduced when anthelmintic treatments were withheld, however, reduced grass growth in both grazing seasons of the project may have accounted for at least some of these reductions.

Conclusions

This project has demonstrated that TST strategies are feasible on sheep and cattle farms in Northern Ireland. TST strategies must however be tailored relative to the farm's long-term goals for parasite management and anthelmintic treatment reduction whilst considering available infrastructure. These strategies must also be flexible to changes in annual weather conditions and parasite dynamics.

All seven farms delayed and reduced the number of anthelmintic treatments in each grazing season relative to pre-project levels. Although this occasionally resulted in small decreases in productivity, farmers agreed that these short-term losses were at an acceptable level. At certain points in the grazing season, it was necessary to implement whole-herd / whole-flock anthelmintic treatments on a targeted treatment (TT) basis to maintain productivity, safeguard animal health and welfare or to limit the contamination of grazing pastures with parasitic helminths. For example, application of anthelmintic treatments on a TT basis were necessary for both *Nematodirus battus* control in lambs and *Dictyocaulus viviparus* (cattle lungworm) control. Where possible, livestock tracked in the 2021 grazing were observed during the 2022 grazing with no obvious decreases in productivity noted.

All farmers agreed that the use of the FECPAK^{G2} system was beneficial when making on farm decisions, providing some reassurance when anthelmintic treatments were delayed. However, farmer impressions of the actual system varied from farm to farm. Many suggested that using the system was still time consuming when considering the collection, processing and reading steps. Some farmers also had continuous issues with internet connectivity throughout the project prompting multiple QUB visits in the absence of reliable connection. Availability of FEC testing in multiple central locations (above and beyond veterinary practices) may prove more attractive for most farmers. One farm in the project decided to only use the FECPAK^{G2} services provided at his local Fane Valley store during the 2022 grazing season because of lack of time availability on farm.

Discussions with farmers also suggested that there is a need to improve farm focused resources for topics such as refugia and TT/TST. All agreed that taking part in the project alongside the farm walks and seminars provided have improved their own understanding of parasite management theory but practically employing management, particularly in a rotational grazing system proves difficult. Having additional support in the background as part of the EIP operational group was invaluable, but this is not available to others.

TT/TST strategies remain limited by the fact that they require at least some optimisation on a farm-by-farm basis – no one size fits all advice. However, this project has designed and implemented a series of TT/TST options that may be transferable to other farms external to the project with only minor modifications. Confidence was built during the project through continued advice and support. Resources to build this confidence in the wider agricultural sector is still required. Multiple levels need to be onboard with fundamental changes including researchers, veterinarians, drug merchants and the farmers themselves.

Widespread, uptake will require farmers and veterinary practitioners having additional education on the use and interpretation of FEC prior to using anthelmintics. Improvement in handling and weighing facilities on farms are also required to assist the likely uptake of this practice in the future.

Recommendations

A number of recommendations for future work, action and research arose as a result of the project and are summarised below.

1. There is evidence of anthelmintic resistance within Northern Ireland. However, this has not been systematically mapped recently. It is important to understand the prevalence of anthelmintic resistance in both sheep and cattle. Such trials must also consider the drug efficacy of multiple active agents to support adequate anthelmintic rotation and maximise cost-benefits of anthelmintic application. This foundational information will also highlight the effectiveness of those anthelmintics with good drug efficacy to inform other strategies for the control of internal parasites including adequate quarantine protocols and TT/TST.
2. While the use of TT/TST is to be recommended, it is clear that applying these approaches in rotational grazing systems is challenging, given the necessary grazing constraints that such approaches lead to. There is therefore a need to undertake research that would investigate optimising these approaches specifically within rotational grazing systems as are present within NI.
3. To improve the practicality of implementing TT/TST strategies on farm there is a clear need to develop systems that incorporate animal liveweight data to quickly and easily identify animals that may benefit from anthelmintic intervention. This will reduce anthelmintic use in animals that are likely to show only minor benefits following anthelmintic treatment. While some systems are now in place and under development, it is not clear if they have been adequately validated for Northern Ireland farming conditions. Some of the proposed solutions are likely to be prohibitively expensive or cumbersome for widescale adoption. Therefore, consideration should be given to developing systems that can use already available information (e.g., from electronic weighing systems) to provide bespoke feedback to farmers on the likely benefit or otherwise of anthelmintic intervention.
4. It was clear that as the project progressed farmer confidence in the approaches recommended increased. It would seem that there would be merit in developing demonstrator farms that use these techniques as a platform for showcasing these approaches to the wider NI farming community as a means of demonstrating the feasibility of these approaches in 'real world' scenarios. The use of the next phase of CAFRE Business Development Groups should also be considered.
5. Simple messages including the calibration of dosing equipment and correct volume administration of product based on the actual live weight of the animal could be easily adopted at a farm level and should be encouraged under the window of a cost saving opportunity for the farm.
6. CAFRE should consider developing training programmes in the use of animal recording software and the ability to use and interpret the data from this and other sources such as faecal egg counts.
7. Establishment of a Northern Ireland anthelmintic resistance forum including representatives of farming organisations, veterinary organisations, NIMEA, DairyUK, AHWNI, LMC, DAERA, CAFRE, QUB & AFBI, AgriSearch and suppliers of anthelmintics to meet twice a year and co-ordinate future activities and to ensure consistency of messaging.
8. The partners within the project should investigate how the outcomes from this project could be integrated with other current projects or those that may be developed in the future. For example, AHWNI is currently involved in a BBSRC funded project on the experiences of sheep farmers of parasite control in their flocks. The outcomes from this project should be incorporated into any future outputs from this project in order to maximise the potential benefits that could be accrued to farmers. Key to achieving this will be the ongoing collaboration of key

partners within Northern Ireland, notably, AgriSearch, QUB, AFBI and AHWNI whether that be through formal joint research projects or through more informal networking.

9. Continued and improved capital support for items that aid parasite management on farm such as weigh scales, mobile handling facilities, EID readers etc.. This could also be linked to the proposed new beef support scheme which will require the regular weighing of cattle. Data from other sources (such as BovIS Mart & Slaughter data) should also be exploited where possible.
10. The installation of well-designed handling facilities with the ability to weigh cattle and sheep during the grazing season will be an important requirement for widespread uptake of targeted selective treatment of anthelmintics. The incorporation of weighing equipment within new facilities is an important consideration to minimize the use of labour requirement. CAFRE and AgriSearch should consider working together to provide material on the design and installation of effective, efficient and above all safe animal handling facilities.

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Appendix 1 - Operational Group members

Operational Group Member	Operational Group Member's Business	Role within the Operational Group
John Martin	Ruminant Livestock Farmer (Sheep)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Jayme Carvill	Ruminant Livestock Farmer (Sheep)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Trevor Somerville	Ruminant Livestock Farmer (Beef)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Martin Craig	Ruminant Livestock Farmer (Beef)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Ian McClelland	Ruminant Livestock Farmer (Dairy)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Oliver McKenna	Ruminant Livestock Farmer (Beef)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Albert O'Neill	Ruminant Livestock Farmer (Dairy)	Participatory Role - Assessing feasibility and practicality on farm, sharing outcomes and participating in dissemination activity
Professor Eric Morgan	Academic Scientist - QUB	Advisory & Participatory Role - Assisting in on-farm activity design, analysing data and evaluating outcomes
Dr Christopher McFarland	Academic Scientist - QUB	Advisory & Participatory Role - Assisting in on-farm activity design, analysing data and evaluating outcomes
Dr Francis Lively	Research Scientist - AFBI	Advisory Role - Assisting in on-farm activity design and evaluation of outcomes
Dr Sam Strain BVMS PhD MRCVS	Veterinary Surgeon - Animal Health and Welfare Northern Ireland	Advisory Role - Assisting in on-farm activity design and evaluation of outcomes
Jason Rankin	General Manager - AgriSearch	Organisational and Promotional Role - Project Lead coordinating and managing both group members and group activity alongside project dissemination.

Appendix 2 - Organisations who delivered services to the project

Organisation	Service Provided
AgriSearch	Innovation Broker Promotion and Dissemination
QUB	Scientific Services
AFBI	Advisory Services
AHWNI	Advisory Services
Techion	FECPAK^{G2}

Appendix 3 – Dissemination Events

1. **Webinar – 7 February 2022**

   AgriSearch hosted a webinar on Monday 7th February to outline the practical steps Northern Ireland farmers can take to minimise the risk of anthelmintic resistance.

   The webinar commenced with an introduction to Anthelmintic Resistance and its importance to the NI agricultural industry from Dr Sam Strain from AHWNI. It was then followed with an explanation of TST methods and how they can be used to tackle AR from Prof. Eric Morgan at QUB. A summary of the first year results from the EIP project were then be provided by his QUB colleague Dr Christopher McFarland.

   The webinar also featured first-hand accounts of using TST approaches on farm from two of the participating farmers in the EIP project – Ian McClelland (Dairy) and Martin Craig (Beef and Sheep).

   The webinar recording is available to watch at:
   https://www.youtube.com/watch?v=Vs4M5CN6ET8&list=PLuXkEMvinOk0UwCX-6Y9eAR4Y8aywa40q

2. **Planning for Performance Event Series – 4th & 6th October 2022**

   AgriSearch, CAFRE and AFBI along with the NI Sheep SOS (Stamp out Scab) initiative joined forces to hold two ‘Planning for Performance’ events on Tuesday 4th October at CAFRE’s Greenmount Campus and Thursday 6th October at CAFRE’s Enniskillen Campus. Prof. Eric Morgan (QUB), as one of a number of speakers, presented an introduction to targeted treatment of anthelmintics alongside members of the Anthelmintic Targeted Selective Treatment (TST) EIP project who have been trying out TST approaches on farm over the past two grazing seasons.

   Copies of the slides presented can be downloaded here:
   https://agrisearch.org/publications/farmer-booklets/publications/farmer-booklets/planning-for-performance-event-slides

3. **Farm Walk – 26 April 2023**

   The EIP project and on-farm results were showcased at a farm walk event held on the farm of Ian McClelland one of the EIP Anthelmintic Targeted Selective Treatment project operational group members.

   The event was focused on ‘Net-Zero and Animal Health’ and Dr Christopher McFarland presented to the groups an overview of Anthelmintic Resistance, the principles of Targeted

Selective Treatment and the outcomes from Ian's on-farm trials as part of the project over the previous two grazing seasons.

The farm walk booklet is available to download here:
https://www.arczeroni.org/_files/ugd/be7aee_c0896f87345341e7b8ce547174a4050c.pdf

4. **Farm Walk – 26th June 2023**

AgriSearch and the Nature Friendly Farming Network (NFFN) held a farm walk on Parasite Control at the farm of John Martin, Greyabbey on the 26th June 2023.
John Martin is one of the operational group members of the Anthelmintic Targeted Selective Treatment EIP project who has been looking at the practicality of implementing targeted and selective use of anthelmintics on commercial farms. At the event John discussed the reasons he got involved in the project, the benefits and challenges that arose and the decision making processes on his farm with regards parasite control. John was joined by Prof. Eric Morgan and Dr Christopher McFarland from Queen's University Belfast who provided an overview of the wider findings of the EIP project across the Dairy, Beef and Sheep sectors as well as providing an overview of the practical steps that can be taken when beginning to consider targeted selective treatment of anthelmintics on farm, such as taking samples for faecal egg counts. In addition, Bruce Thompson, a Nuffield scholar from Portlaoise shared his experience of how dung beetles have helped reduce parasite burdens and anthelmintic use on his farm. He provided a practical demonstration of how to identify dung beetles in the field.
Farm walk posters are available to view here: www.agrisearch.org/eip/anthelmintic-targeted-selective-treatment-for-ruminant-livestock

Appendix 4 – Project Summary

Contents:

Acronym list:

TT = Targeted Treatment

TST = Targeted Selective Treatment

GIN = Gastrointestinal nematode

FEC = Faecal worm egg count

DLWG = Daily liveweight gain

QUB = Queen's University Belfast

FGS = First grazing season

SGS = Second grazing season

Project background:

7 farmers (2 sheep, 3 beef and 2 dairy)

This project aims to determine the feasibility and practicality of implementing targeted treatment (TT) and targeted selective treatment (TST) of helminths on Northern Ireland commercial farms. In doing so it will bridge the gap between research and implementation, enabling advice to be shared to encourage wider uptake across the sector. Group members assisted in the design, utilisation and evaluation of relevant TT/TST strategies to better understand the feasibility of widespread use on-farm.

Project objectives

1. Determine suitable TST approaches for each participant farm.
2. Implement TST approach on each participant farm.
3. Assess the impact of implementing a TST approach.
4. Assess the feasibility and practicality of undertaking targeted, selective treatment of anthelmintics on farms in Northern Ireland.
5. Disseminate project activity and results.

1. **Determine suitable TST approaches for each participant farm**

To develop tailored TT/TST approaches for each of the project farms, baseline information was gathered in relation to the participant's enterprise type (sheep, beef or dairy youngstock), stocking numbers, current parasite management on farm, livestock performance monitoring strategies and personal, long-term on-farm goals for parasite control. To streamline data collection participants were asked to complete the BigWorm NI survey, a survey with which the authors were also associated with. BigWorm survey NI responses for the participants of the current study are shown in the Supplementary data file 1. Information gathering was also supplemented by video conferencing between participants and the authors to gather further information on farm technology and feasibility of TT/TST approaches.

To disseminate further information about the project to the participants and illustrate how individual questionnaire responses compared to other participants in the group, a summary document was sent to each participant in January 2021.

The document contained the following sections:

1. Background theory on gastrointestinal nematode control using refugia.
2. Definitions of TT and TST.
3. Results from the BigWorm survey and comparison of individual responses.
4. Summary of beneficial parasite management strategies already employed on farm.
5. Potential areas for optimisation of on farm parasite management.
6. Links to additional information sources e.g. SCOPS, COWS and NADIS.

A series of three tailored TT/TST options were created for each participant farm based on the information collected. Within these options the authors highlighted the benefits of implementing the proposed strategy, suggested actions for altered parasite management, clearly defined risks associated with implementing the proposed strategy and guidance on how these risks could be mitigated for successful implementation. Following the creation of the tailored options an additional video conferencing call was performed between the authors and participants to discuss the specifics of each option and refine further based on participant consultation. Once tailored options were created the participants were instructed to implement these strategies in the 2021 grazing season. Participants were offered the flexibility to switch between the three TT/TST options as the grazing season progressed and modifications were made in situ. Tailored TT/TST approaches were also implemented throughout the 2022 grazing season. All participants were progressive in their ideology of TT/TST strategies and were willing to implement the changes discussed. It was however noted that improved information resources on TT/TST strategies are required. The ability to achieve this is limited by the fact that strategies require at least some optimisation on a farm-by-farm basis.

2. **Implement TST approach on each participant farm**

Tailored TT/TST options required the collection of data pertaining to parasite burden, possible impacts of parasitism on livestock productivity, infection risk monitoring by grazing management and anthelmintic applications.

To collect information on parasite burden, faecal worm egg counts (FECs) were employed for host animals on each farm. The collection and analysis of FEC samples can be labour intensive, particularly in larger flocks/herds, and on occasion requires adequately trained staff. It was therefore decided that project participants would avail of the services of Techion using the FECPAK^{G2} faecal egg counting system. All participant farms received a FECPAK^{G2} system with an annual subscription of 100 sampling events and were provided with adequate training on dung sample collection, sample preparation and software support. On one farm, due to logistical reasons, the participant availed of a FECPAK^{G2} system available in a local merchant with samples analysed by an in-house vet. Additional FEC analyses were also provided by Queen's University Belfast (QUB) technical staff for the further analysis of gastrointestinal nematodes (GINs) as well as cattle lungworm and liver fluke presence within samples, services not available on the FECPAK^{G2} system throughout the project. All GIN FECs at QUB were completed using the mini-FLOTAC system following manufacturer's guidelines for ruminant hosts (Cringoli et al. 2017).

To monitor and record animal performance, participants were encouraged to regularly weigh livestock in study groups. Some tailored TT/TST options also explicitly required the use of liveweight to determine animals requiring anthelmintic treatment. On participant farms the project enabled the implementation of new weighing systems or calibration/updating of original systems. Thus, improving the accuracy of liveweight data collection and accessibility of data for decision support. Participants were also asked to closely monitor livestock in study groups for any adverse alterations in condition relative to outgroups.

To monitor the effect of treatment method on parasite infection risk and associated grazing management, participants recorded field movement dates, number of livestock moved, age of livestock and recent field grazing history. A field-based GIN prediction model (McFarland et al., 2022) was populated using data collected (e.g. FECs, liveweight and grazing management) by participants to create maps of GIN risk on a field-by-field basis, relative to the anthelmintic treatment options applied. The development and analysis of which is ongoing.

To investigate the effect of altered parasite management on anthelmintic applications, participants recorded information at each treatment event. Information collected included drug active agent, date of application, application method and decision process rationalised for applying the treatment.

3. **Assess the impact of implementing a TST approach**

To assess the impacts of implementing targeted approaches on each farm the authors-maintained contact with the project participants. Data was gathered by email or through the sharing of images e.g. weight recording booklets. Data from FECPAK^{G2} submissions were collated by Techion and sent as a monthly update email throughout each of the grazing seasons. QUB also visited participant farms throughout the duration of the project to discuss further option and/or collect dung samples for analyses not available on the FECPAK^{G2} platform.

The proceeding sections will provide information on the results gathered from each of the study farms during the 2021 and 2022 grazing season. To collect information on how each participant farmer interpreted their involvement in the project a second video conferencing interview was completed between the authors and each farmer throughout May and June 2023. A question list was established and distributed to each participant prior to meeting. The question list developed is available in Supplementary data file 2.

Farm 1 – Ian McClelland

Farm background

Dairy cattle. Semi-closed with low numbers of bought in replacements. Autumn calving (September/October). Rotational grazing of youngstock at out-farm. Milking cows on home-farm. Before project start there was an average of >3 anthelmintic treatments for first grazing season (FGS) calves and 2 treatments for second grazing season (SGS) cattle. Youngstock would receive anthelmintic treatment after 5 weeks post turnout and then at a 4–5-week interval thereafter.

Identified positive parasite management strategies on farm prior to project start:

- Calibration of dosing equipment at each anthelmintic treatment
- Movement of livestock to fields with some parasite contamination post-treatment
- Introduced stock quarantined adequately

Identified areas of improvement for parasite management strategies prior to project start:

- Not aware of or using the lungworm Huskvac vaccine
- Estimation of individual animal weight prior to anthelmintic application
- Limited use of FECs for treatment decision - only when animals sick or poor condition.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:
- Turn out without treatment.
- **Assess group pooled FEC every 2 weeks:**
    - FEC 0-100 eggs per gram (epg), don't treat, re-sample 2 weeks later.
    - FEC 100-200 epg, don't treat, but re-sample group again 5-7 days later.
    - FEC >200 epg, treat whole group (TT).

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 2: TST – Treatment based on individual FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turn out without treatment.
- **Assess individual FEC every 2 weeks:**
    - FEC <100 epg, don't treat, re-sample 2 weeks later.
    - FEC 100-200 epg, don't treat, but re-sample again 5-7 days later.
    - FEC >200 epg, apply treatment.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 3: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC every 2 weeks:**
    - FEC 0-100 epg, don't treat, re-sample 2 weeks later.
    - FEC >200 epg, treat whole group (**TT**).
    - FEC 100-200 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

2021 grazing season summary

- Tracked two batches of cattle under rotational grazing – first grazing season (FGS) and second grazing season (SGS) calves.

- New weighing system integrated on farm – 5 weighing time-points (**Fig. 1** and **Fig. 2**).
- GIN FECs low throughout season.
- 13 FECPAK^{G2} submissions (**Fig. 3**). FECs completed by QUB are shown in **Fig. 4**.
- FGS calves were dosed twice in 2021 guided by FECPAK^{G2} and liveweight.
- Anthelmintic treatments reduced and delayed in 2021 grazing season – previous season treatment regime: five weeks post turnout, 4–5-week interval thereafter.

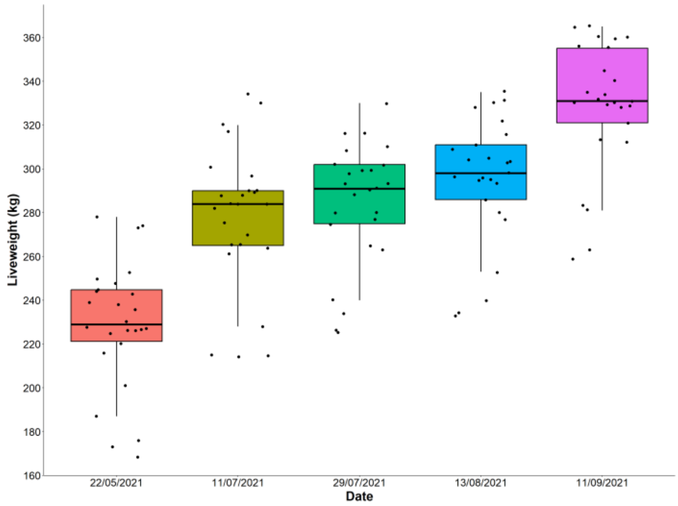


Fig. 1. Liveweight (kg) of FGS calves throughout the 2021 grazing season.

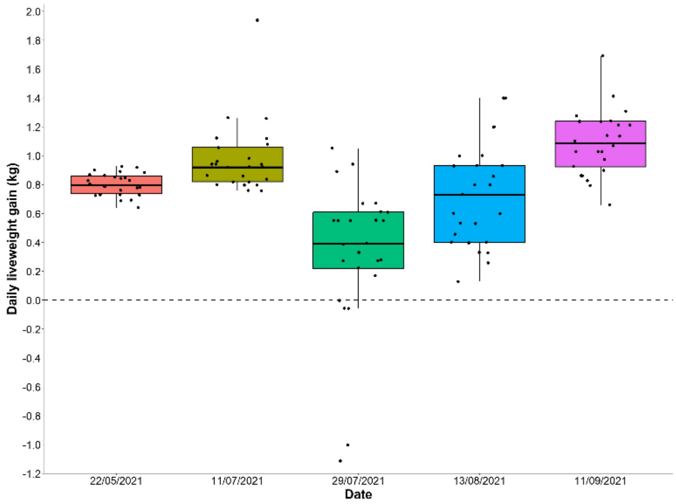


Fig. 2. Daily liveweight gain (kg) of FGS calves throughout the 2021 grazing season.

January	February	March	April	May	June	July	August	September	October
	1	2		1	3	1	1	4	

Recieved	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	A		Cattle	295097	92701	Dairy Heifers	Excellent	Animec 1% Injection	27/11/2020	0	0	0	**0**
01/03/2021	A		Cattle	297056	92793	Heifers	Excellent	Animec 1% Injection	01/11/2020	0	0	0	**0**
02/03/2021	Individual Only		Cattle	297524	92838	Heifer Cows	Excellent	Animec Pour-On	01/10/2020	0	0	0	**0**
04/05/2021	A		Cattle	313966	94605	Calves	Excellent	-	-	0	0	0	**0**
24/06/2021	A		Cattle	319230	96513	Calves, heifers	Excellent	-	-	0	20	0	**20**
28/06/2021	A		Cattle	319506	96627	Calves, heifers	Good	-	-	20	20	0	**40**
28/06/2021	A		Cattle	319543	96656	Calves, heifers	Good	-	-	0	40	0	**40**
23/07/2021	A		Cattle	324190	98435	Calves, heifers	Excellent	Animec Pour-On	03/07/2021	0	0	0	**0**
03/08/2021	A		Cattle	324189	98434	Calves, heifers	Good	Animec Pour-On	02/07/2021	0	20	0	**20**
13/09/2021	A	Paddock 2	Cattle		100392	Calves, heifers	Excellent	Ivomec classic injection Cattle and Sheep	03/08/2021	0	0	0	**0**
13/09/2021	J	Paddock 2	Cattle		100393	Calves, heifers	Excellent	Ivomec classic injection Cattle and Sheep	05/08/2021	0	0	0	**0**
25/09/2021	A		Cattle	332917	100965	Calves, heifers	Excellent	Animec 1% Injection	03/08/2021	0	0	0	**0**
27/09/2021	A		Cattle	333107	101010	Calves, heifers	Excellent	Animec 1% Injection	05/08/2021	0	0	0	**0**

Fig. 3. FECPAK^{G2} submissions by the participant farmer throughout the 2021 grazing season.

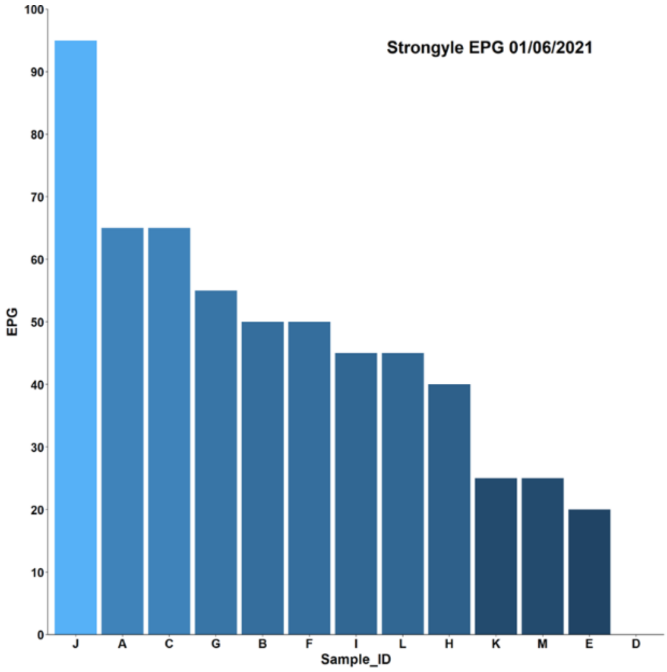


Fig. 4. FGS FECs carried out by QUB on 01/06/2021. 13 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Anthelmintic treatments: reduced and delayed relative to pre-project levels. However anthelmintic treatments were all ivermectin based during the season. Animec pour on 01/07/2021 and 03/07/2021 to FGS and SGS, respectively. This anthelmintic treatment was applied by the farmer due to dung being loose despite the cattle being in good condition and growing well. FGS Calves were observed to be in good condition, but some growth rates were slow. Anthelmintic treatment with animec injection applied on 05/08/2021 due to coughing throughout group. Brought 11 individual FGS to home farm on 16/08/2021 or 17/08/2021 to provide additional feed.

2022 grazing season summary

- Tracking a new batch of FGS (n = 26), also following the SGS (n = 25) from the first grazing season of the project.
- Liveweight measurements at 14 timepoints throughout the grazing season for FGS calves. Weighing on a 1-week to 2-week basis throughout most of the grazing season. (**Fig. 5** and **Fig. 6**)
- SGS cattle (FGS from 2021) were weighed at 7 timepoints during the 2022 grazing season (**Fig. 7** and **Fig. 8**).
- 17 FECPAK^{G2} submissions by participant farmer throughout the grazing season (**Fig. 9**).
- FECPAK^{G2} submission of FGS calves on 11/05/2022 showed an egg count of 360 eggs per gram (EPG).
- Grazing same youngstock fields as 2021. Decision was therefore taken to treat with ivermectin to reduce pasture contamination.
- FGS calves dosed three times in 2022 guided by FECPAK^{G2} and liveweight. Anthelmintic applications now accurately provided according to animal weight.
- FECs of SGS heifers remained at 0 - 20 EPG (four FECPAKG2 timepoints), however participant farmer dosed with albendazole 3 weeks prior to calving under normal farm management. This was the first anthelmintic treatment of 2022.

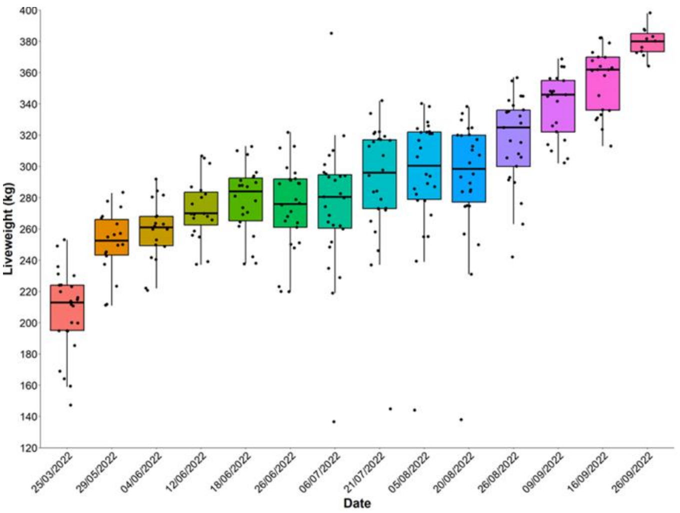


Fig. 5. Liveweight (kg) of FGS calves throughout the 2022 grazing season.

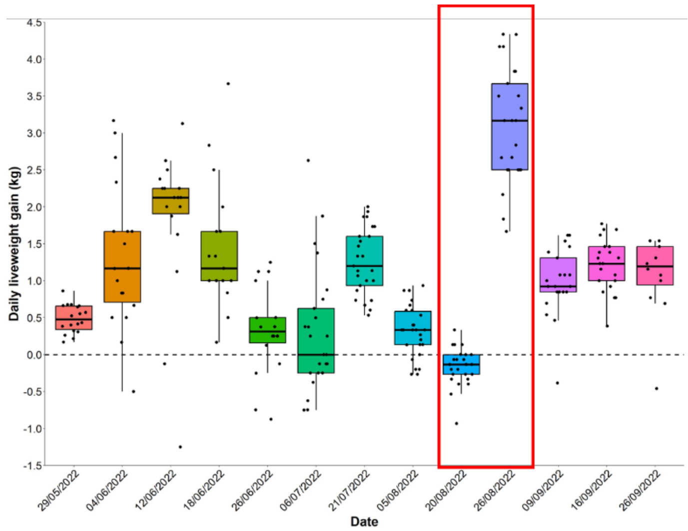


Fig. 6. Daily liveweight gain (kg) of FGS calves throughout the 2022 grazing season.

Cattle appeared to considerably increase daily liveweight gain between 20th August and 26th August 2022 (red box **Fig. 6**). However, on discussion with farmer it was noted that on week 20/08/2022 stock were weighed much earlier in the day than at previous weighing events. 1 kg of meal was also introduced to push the cattle on as growth had slowed. This was at the time put down to the heat and poor grass growth. Once again, as occurred in 2021, the smaller stock (n = 7) were removed and brought back to the home farm for additional supplemental feeding. Cattle were housed for the winter from October 2022. Farmer highlighted that measurements of liveweight were not only beneficial for parasite management i.e. dosing to weight but also for general herd health and management e.g. deciding when to supply extra meal. For example, cattle may look good in good condition at observation, but the scales were telling a different story.

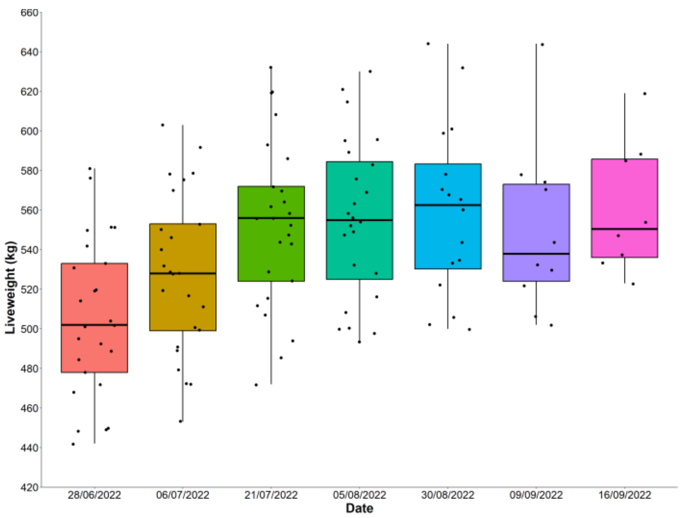


Fig. 7. Liveweight (kg) of SGS calves throughout the 2022 grazing season. These individuals were the FGS calves from the 2021 grazing season.

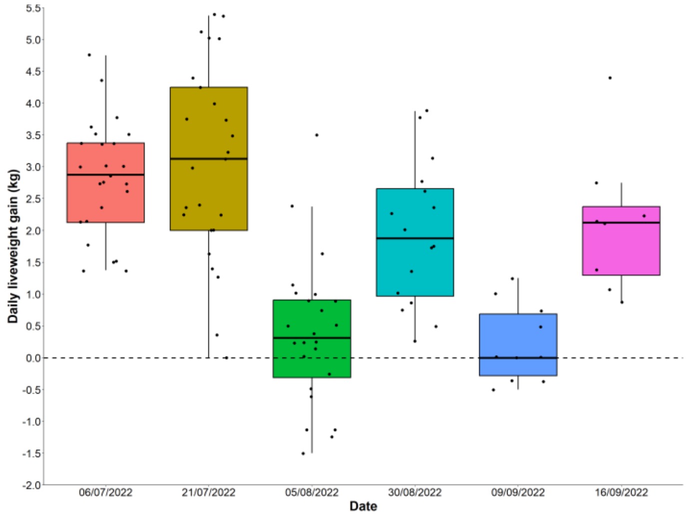


Fig. 8. Daily liveweight gain (kg) of SGS calves throughout the 2022 grazing season. These individuals were the FGS calves from the 2021 grazing season.

January	February	March	April	May	June	July	August	September	October
			1	2	7	5	2		

Sample Collected	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus FEC	Strongyle FEC	Strongyloides FEC	Total FEC
18/04/2022	A		Cattle	365664	107412	Calves, heifers	Excellent	No	-	0	0	0	**0**
11/05/2022	B		Cattle	370782	108235	Calves, heifers	Excellent	-	-	0	120	0	**120**
11/05/2022	A		Cattle	370783	108236	Calves, heifers	Excellent	-	-	0	360	0	**360**
01/06/2022	A		Cattle	374915	109113	Calves, heifers	Good	-	14/05/2022	0	0	0	**0**
05/06/2022	C		Cattle	375320	109194	Dairy Heifers	Excellent	-	-	0	0	0	**0**
05/06/2022	B		Cattle	375321	109195	Calves, heifers	Excellent	Ivomec Classic Injection for Cattle and Sheep	21/05/2022	0	100	0	**100**
06/06/2022	A		Cattle	375376	109240	Calves, heifers	Good	Ivomec Classic Injection for Cattle and Sheep	14/05/2022	0	100	0	**100**
14/06/2022	A		Cattle	376140	109589	Calves, heifers	Good	Ivomec Classic Injection for Cattle and Sheep	14/05/2022	0	40	0	**40**
24/06/2022	A		Cattle	377169	110104	Calves, heifers	Good	Ivomec Classic Injection for Cattle and Sheep	14/05/2022	20	160	0	**180**
26/06/2022	B		Cattle	377210	110139	Dairy Heifers	Good	-	-	0	0	0	**0**
02/07/2022	A	-	Cattle	378557	110401	Calves, heifers	Good	Ivomec Classic Injection for Cattle and Sheep	14/05/2022	0	240	20	**240**
01/07/2022	B	-	Cattle	378560	110404	Dairy Heifers	Excellent	-	-	0	20	0	**20**
26/07/2022	Individual Only	1224	Cattle	381854	111330	Calves, heifers	Good	Animec Pour-On	01/10/2020	0	0	0	**0**
26/07/2022	A	-	Cattle	381855	111331	Calves, heifers	Good	Ivomec Classic Injection for Cattle and Sheep	06/07/2022	0	20	0	**20**
26/07/2022	B	-	Cattle	381884	111354	Dairy Heifers	Good	-	-	0	0	0	**0**
13/08/2022	A	-	Cattle	384172	112336	Calves, heifers	Excellent	Endospec 10% SC	05/08/2022	0	0	0	**0**
13/08/2022	B	-	Cattle	384176	112338	-	-	-	-	0	0	0	**0**
25/08/2022	A	-	Cattle	384865	112739	Calves, heifers	Excellent	Endospec 10% SC	05/08/2022	0	20	0	**20**

Fig. 9. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

Anthelmintic treatments: once again the number of anthelmintic treatments in the 2022 grazing season was reduced below the levels used prior to the start of the project. Ivomec classic injection on 14/05/2022 – as discussed this was prompted by FECPAK^{G2} result of 360 EPG in batch of FGS. A further Ivomec classic injection was applied on 06/07/2022. This was followed by Endospec 10% SC on 05/08/2022. July and August treatments 2023 were applied for lungworm as opposed to GINs. The rotation of anthelmintic was driven by observations that ivermectin based treatments had limited efficacy at earlier points of the season.

Main improvements to parasite management throughout the project:

- Weighing platform introduced on farm. Regular liveweight measurements performed and now applying anthelmintic treatments according to animal weight.
- The participant farmer did not observe any obvious difference in the time it took to rear livestock to target weight in each grazing season, despite a reduction of at least two anthelmintic treatments per year.

Suggested future improvements for on farm parasite management:

- Improved rotation of anthelmintic agents required. Ivermectin is currently used regularly on farm and is also used for quarantine treatments. Suggested anthelmintic rotation to benzimidazole treatment in 2022 grazing season was successful.
- Avoid grazing youngstock on the same fields at the same time each year. However, this is challenging to alter in a dairy herd as youngstock grazed at out-farm.

Farm 2 – Trevor Somervile

Farm background

Beef, suckler cows and others (store dairy steers), mixed breeds mainly dairy, 200+ cattle, spring calving. Planned pasture rotation grazing system, 3-5 weeks, other cattle and silage/hay cuts.

Identified positive parasite management strategies on farm prior to project start:

- Anthelmintic treatments applied according to animal weight.
- Livestock are moved to fields with some parasite contamination post-treatment.
- Participant farmer has discussed topics such as anthelmintic resistance with vet.
- Regular FECs carried out with local vet.

Identified areas of improvement for parasite management strategies prior to project start:

- Anthelmintic treatments applied annually based largely on time of year.
- Lungworm vaccine not implemented on farm.
- Anthelmintic dosing equipment is never calibrated prior to application.
- Livestock brought onto farm without adequate parasite quarantine strategy.
- Anthelmintic resistance to group 3 anthelmintics (macrocyclic lactones) confirmed via previous QUB FECRT and drench check.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:

- Turn out without treatment.
- **Assess group pooled FEC every 2 weeks:**
  - FEC 0-100 eggs per gram (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-200 epg, don't treat, but re-sample group again 5-7 days later.
  - FEC >200 epg, treat whole group (TT).

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 2: TST – Treatment based on individual FEC

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turn out without treatment.
- **Assess individual FEC every 2 weeks:**
  - FEC <100 epg, don't treat, re-sample 2 weeks later.
  - FEC 100-200 epg, don't treat, but re-sample again 5-7 days later.
  - FEC >200 epg, apply treatment.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 3: TST – Treatment based on individual DLWG/weight targets

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turnout without treatment.
- **Assess ability to reach individualised targets by weighing every 2 weeks.**
  - Treat according to traditional farm weight targets, i.e. treat individuals not meeting desired target weight.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- Group pooled FEC every 2-3 weeks after turnout.
- Switch to a **TT** strategy if infection spike observed i.e. treat the whole group.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

2021 grazing season summary

- Tracked two batches of FGS cattle under rotational grazing across out-farms.
- A smaller batch of FGS calves and two SGS batches were also followed but not tracked in the same detail as Batch 1 and Batch 2.
- Batch 1 spent ~10 months housed before first grazing event; Batch 2 spent ~6 months housed before first grazing event.
- Batch 1 (n =35) were vaccinated with Huskvac lungworm vaccine and Batch 2 (n = 36) were not vaccinated with Huskvac.
- Batch 1 calves were weighed at four time-points (**Fig. 10** and **Fig. 11**) and Batch 2 were weighed at five time-points (**Fig. 12** and **Fig. 13**).
- 8 FECPAK ^{G2} submissions (**Fig. 14**) with FECs supplemented by multiple QUB visits (**Fig. 15 – Fig. 19**).
- Farmer applied one anthelmintic treatment to Batch 1 and two treatments to Batch 2 during the 2021 grazing season. Farmer stated they wanted to develop natural immunity in cattle. This appeared to have adverse effects from August onwards. Delay in anthelmintic treatment for too long resulted in gradual buildup of parasites on pasture.
- Fears of lungworm outbreaks prevented application of TST on farm. TT options were more applicable.
- The distribution of cattle on out-farms away from weighing facilities reduced ability to employ weight-based strategies.

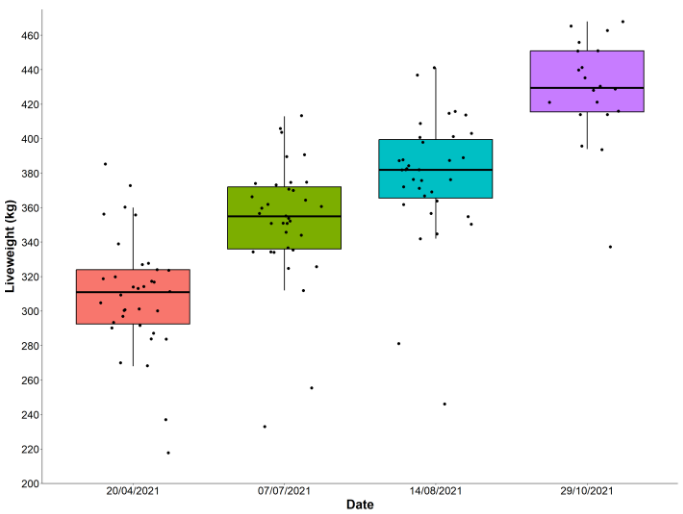


Fig. 10. Liveweight (kg) of Batch 1 FGS calves throughout the 2021 grazing season.

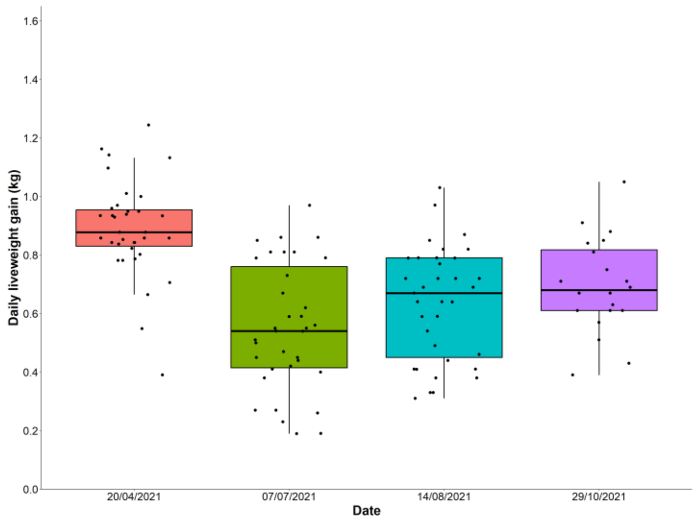


Fig. 11. Daily liveweight gain (kg) of Batch 1 FGS calves throughout the 2021 grazing season.

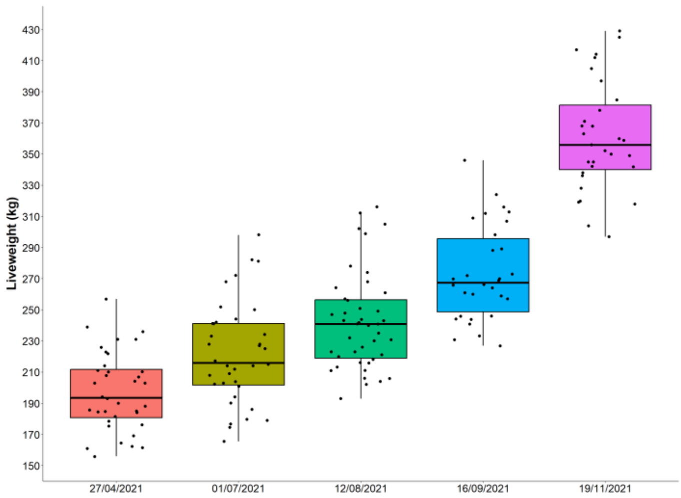


Fig. 12. Liveweight (kg) of Batch 2 FGS calves throughout the 2021 grazing season.

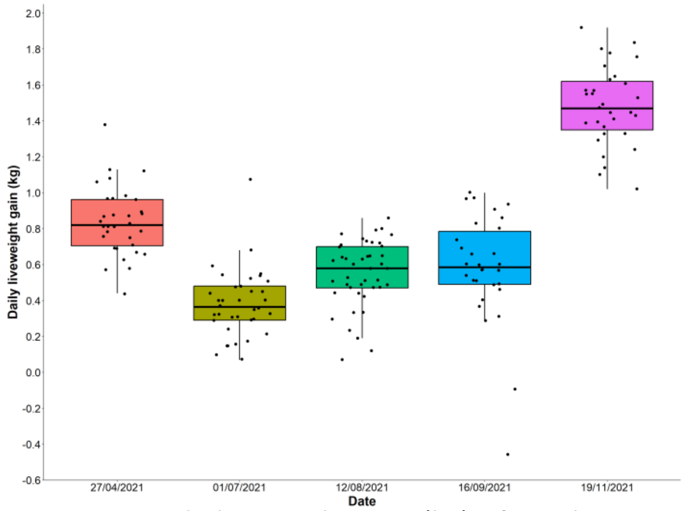


Fig. 13. Daily liveweight gain (kg) of Batch 2 FGS calves throughout the 2021 grazing season.

January	February	March	April	May	June	July	August	September	October
		1			2		5		

Received	Mob Name	Individual Name	Animal Name	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
10/03/2021	Blade calves March 2020 (Batch 1)		Cattle	-	Good	-	-	0	20	0	**20**
22/06/2021	Blade calves March 2020 (Batch 1)		Cattle	R1Y	Good	-	-	0	80	0	**80**
22/06/2021	Main batch own calves 2021		Cattle	Calves	Moderate	-	-	20	60	0	**80**
17/08/2021	Small calves (Batch 5)		Cattle	Calves	Poor	Cydectin 0.5% Pour-On for Cattle	12/08/2021	0	160	0	**160**
17/08/2021	Main batch own calves 2021 born (Batch 2)		Cattle	Calves	Moderate	Cydectin 0.5% Pour-On for Cattle	12/08/2021	0	140	0	**140**
21/08/2021	Blade calves March 2020 (Batch 1)		Cattle	Calves	Moderate	Bimectin Pour-On for Cattle	08/08/2021	0	0	0	**0**
21/08/2021	Blade calves March 2020 (Batch 1)		Cattle	Calves	Moderate	Bimectin Pour-On for Cattle	07/08/2021	0	20	0	**20**
21/08/2021	Main batch own calves 2021 born (Batch 2)		Cattle	Calves	Moderate	Cydectin 0.5% Pour-On for Cattle	05/08/2021	0	60	0	**60**

Fig. 14. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

The participant farmer contacted authors early in the project as they were keen to see how FECPAK^{G2} submissions compared with QUB FEC analysis. Dung samples were therefore collected by the authors on 03/06/2021 from Batch 1 and Batch 2 FGS calves (**Fig. 15.** and **Fig. 16.**). No lungworm larvae were detected at this sampling event.

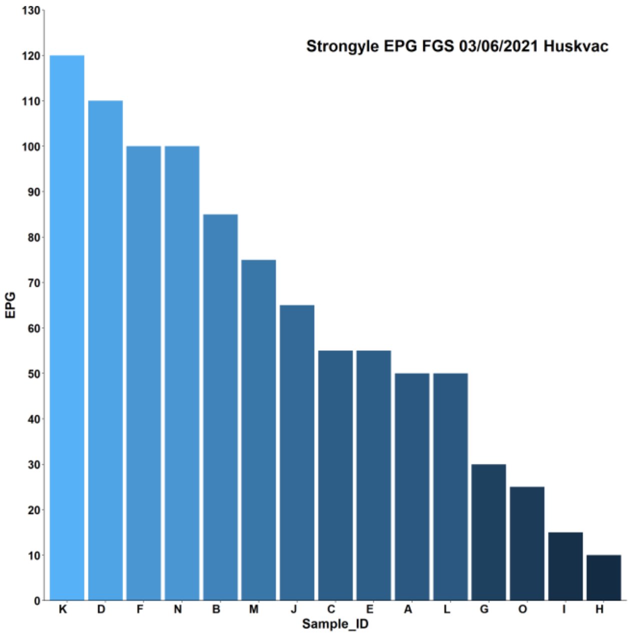


Fig. 15. Batch 1 FECs carried out by QUB on 03/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

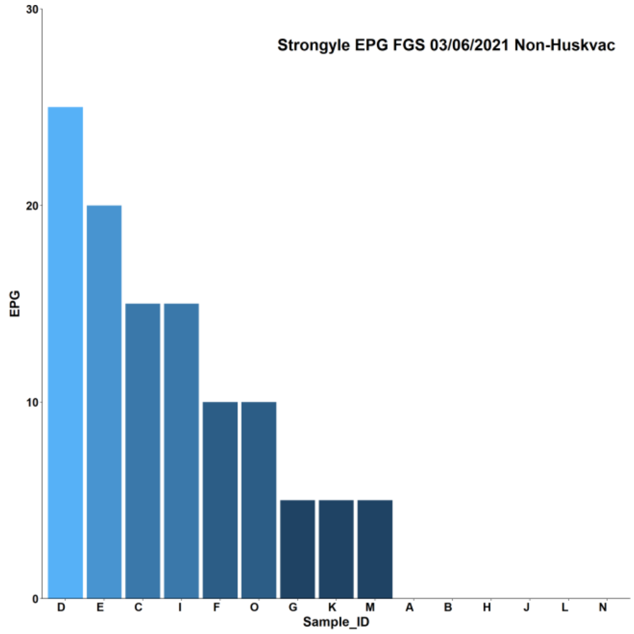


Fig. 16. Batch 2 FECs carried out by QUB on 03/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

The participant farmer contacted authors on 25/06/2021 to raise concerns about livestock condition including group wide coughing. Sample collection was arranged for 28/06/2021. Due to time constraints in the laboratory pooled samples (n = 15) were collected off pasture and analysed as five separate replicates.

- Batch 1 = average 35 strongyle EPG
- Batch 2 = average 45 strongyle EPG

No lungworm larvae observed in either batch.

The participant farmer contacted authors a further time on 29/07/2021 to raise concerns about coughing in both Batch 1 and Batch 2 of FGS calves. Sample collection was arranged for 02/08/2021. On this occasion individual dung samples were collected from each batch and analysed separately. On this occasion GIN counts were higher than previous assessments (**Fig. 17** and **Fig. 18**) and lungworm larvae were isolated in the dung from both Batch 1 (range: 0 – 31 L1 in 30 g dung) and Batch 2 (range: 0 – 121 L1 in 30 g dung) individuals.

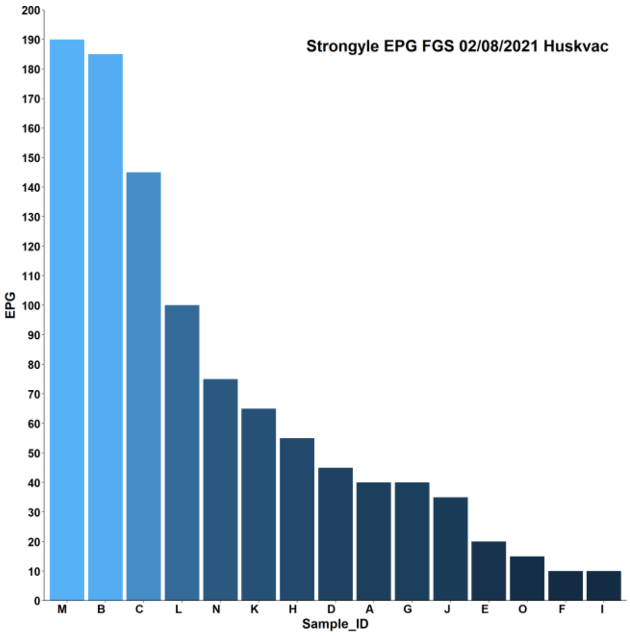


Fig. 17. Batch 1 FECs carried out by QUB on 02/08/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

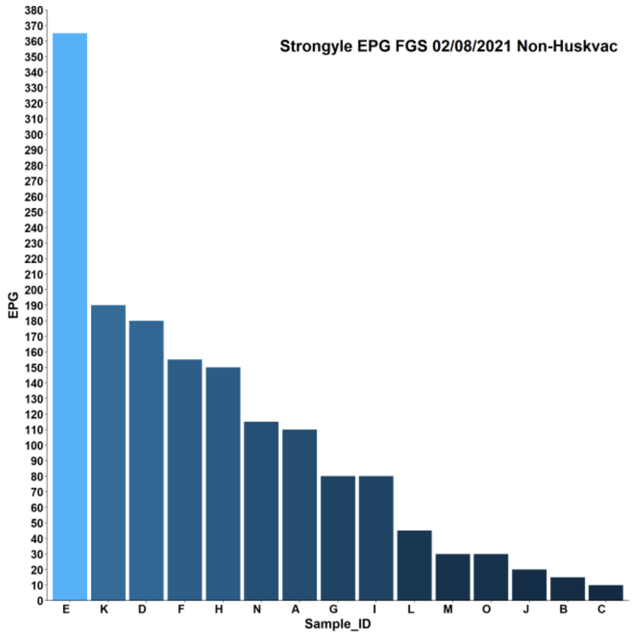


Fig. 18. Batch 2 FECs carried out by QUB on 02/08/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

The participant farmer contacted the authors on 26/08/2021 to report coughing in cattle, particularly non-vaccinated batches despite the application of cydectin only two weeks prior. The farmer had reported similar problems around the same time in 2020 during a previous QUB project. QUB therefore visited on 30/08/2021 to collect samples to assess lungworm levels. Due to lab workload, dung samples from 5 individuals were pooled (equal volumes, 15 individual samples total per batch) to check for lungworm and FECs. This led to a total of 7 faecal egg counts. For the lungworm check pooled samples were analysed in duplicate - 14 lungworm counts in total.

- Batch 1 = average of 13 strongyle EPG, 1 L1 lungworm in 30 g dung
- Batch 2 = average of 3 strongyle EPG, 0 L1 lungworm in 30 g dung

The participant farmer contacted the authors a further time on 18/10/2021 to enquire about the possibility of further FECs by QUB. Another batch of FGS were turned out for grazing at the start of September 2021 and vaccinated with Huskvac (Batch 3). The farmer wanted to test for the presence of lungworm and fluke in these individuals. Three batches of cattle were sampled on 21/10.2021. For Batch 1 five dung samples were collected for analysis as group size was now reduced to 14 individuals. For Batch 2, 15 individual dung samples were analysed. A total of 10 individual dung samples were also analysed for Batch 3, consisting of FGS calves turned out at start of September 2021 and vaccinated with Huskvac (**Fig. 19**). Batch 1 (range: 0 – 50 EPG). Batch 2 (range: 0 – 10 EPG). No lungworm L1 larvae were detected in either Batch 1 or 2. Vet suggested the residual coughing in these batches is likely due to the damage already done by pneumonia (Batch 2) and/or lungworm.

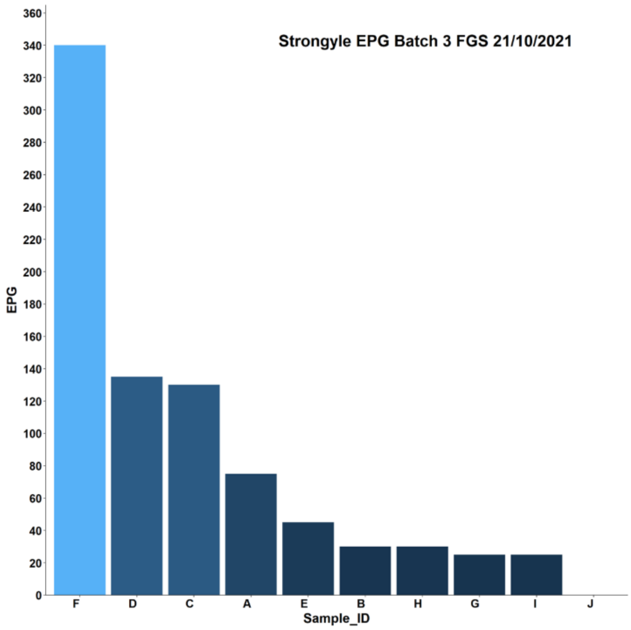


Fig. 19. Batch 3 FECs carried out by QUB on 21/10/2021. 10 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Anthelmintic treatments: Following the FECs analysed on 03/06/2021, the farmer made the decision to hold off with anthelmintic treatment to allow development of natural immunity and development of refugia on pasture. The farmer was keen to delay treatments as long as possible. The next batch of dung samples collected by QUB on 02/08/2021 showed increased strongyle counts and presence of lungworm in both batches (much lower in vaccinated batch). The farmer at this point applied the first anthelmintic treatment to each batch. Batch 1 = Ivomec pour on (14/08/2021), Batch 2 = Cydectin pour on (12/08/2021). Batch 1 only received one anthelmintic treatment at grazing in 2021. Batch 1 was then split into males and females on 06/10/2021 and the 21 bullocks were housed on 29/10/2021. Shortly after they received a Zanil dose followed by an Ivomec pour on around Christmas. The 14 heifers were housed in late November before receiving the same treatments. Batch 2 received a further anthelmintic treatment with Tramzole 2.5% on 16/09/2021 following vet advice as despite low FECs, coughing remained prevalent in this batch. Additional treatments of Dectomax were then applied to Batch 2 on 30/09/2021 and Tramazole 2.5% on 18/11/2021. Dectomax treatment driven by continued coughing and Tramazole provided as a housing dose.

The farmer suggested weight gains during 2021 were undesirable but attributed this to grass provision. Although it was commendable that the farmer decided to reduce anthelmintic treatments significantly in this first season, it may have been more beneficial to apply an anthelmintic treatment following the FECs carried out in June 2021. This would have reduced later pasture contamination hence reducing the issues observed from late August until housing.

2022 grazing season summary

- Tracked three batches of FGS calves:
    - Batch 1: 42 bull calves mixed breed
    - Batch 2: 33 Wagyu calves
    - Batch 3: 9 small calves (Wagyu)
- No batches were vaccinated using the Huskvac vaccine for lungworm in 2022 or 2023 due to practicalities and additional cost of sourcing/applying the vaccine.

- Batch 1 = five weighing time-points (**Fig. 20** and **Fig. 21**) and Batch 2 = five weighing time-points (**Fig. 22** and **Fig. 23**).
- An additional batch of suckler calves and cows born 2022 were recorded using FECPAK^{G2}.
- SGS batches (2021 FGS individuals) liveweight data. Pending.
- 22 FECPAK^{G2} submissions (**Fig. 24**) were supplemented by multiple QUB visits on 25/04/2022, 25/07/2022 and 13/10/2022.
- Each batch of FGS calves received four anthelmintic treatments in 2022, largely driven by outbreaks of lungworm on farm as opposed to GIN concerns.

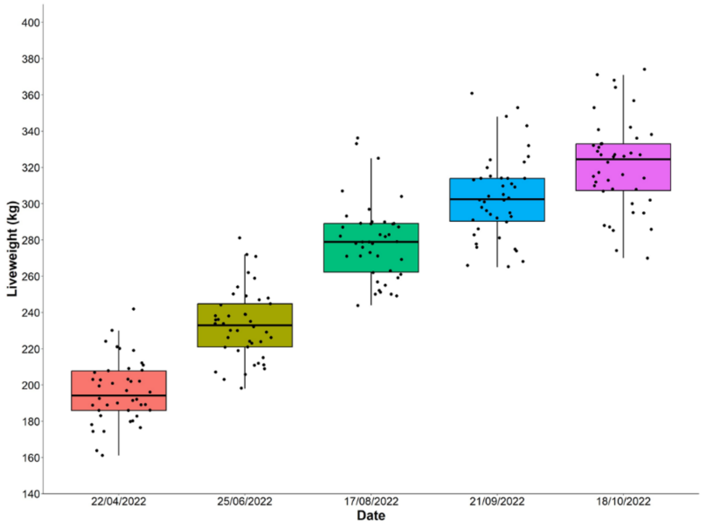


Fig. 20. Liveweight (kg) of Batch 1 FGS calves throughout the 2022 grazing season.

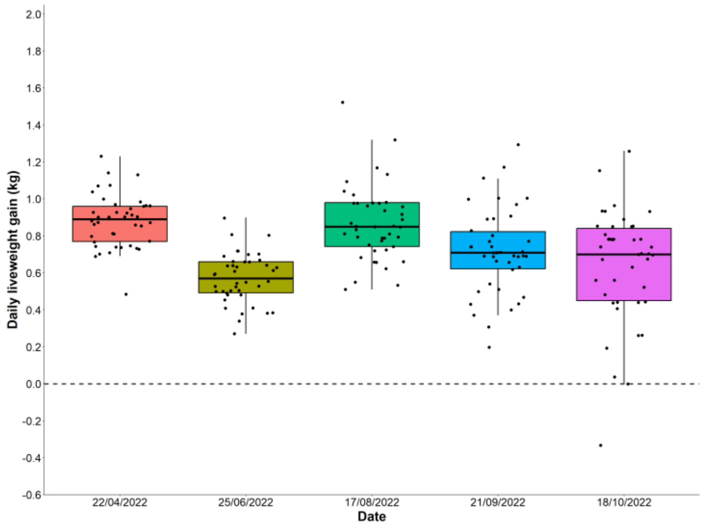


Fig. 21. Daily liveweight gain (kg) of Batch 1 FGS calves throughout the 2022 grazing season.

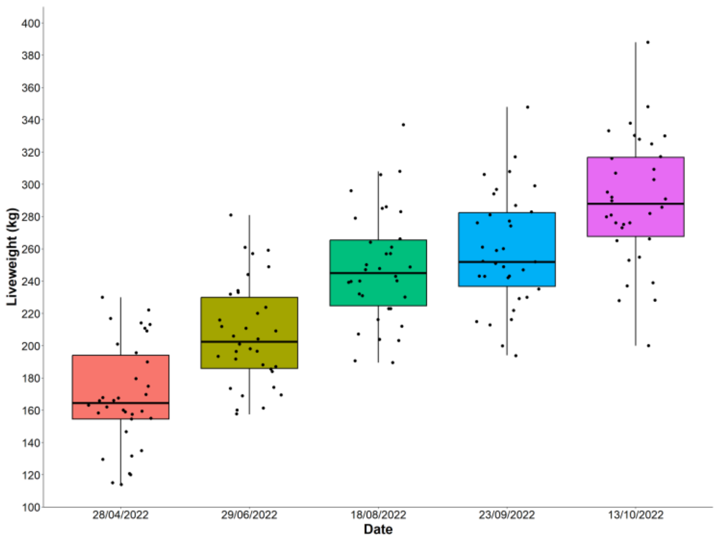


Fig. 22. Liveweight (kg) of Batch 2 FGS calves throughout the 2022 grazing season.

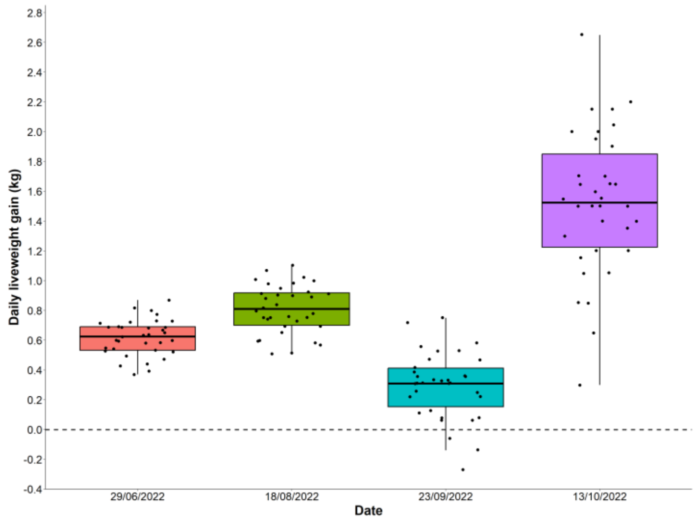


Fig. 23. Daily liveweight gain (kg) of Batch 2 FGS calves throughout the 2022 grazing season.

January	February	March	April	May	June	July	August	September	October
					3	5	11	3	

Sample Collected	Mob Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus FEC	Strongyle FEC	Strongyloides FEC	Total FEC
21/06/2022	42 calves 2021/2022	Cattle	377148	110086	Calves, bulls	Moderate	-	-	0	60	0	**60**
29/06/2022	33 Wagyu	Cattle	378083	110291	Calves	Good	-	-	40	60	0	**100**
29/06/2022	9 small calves 2022	Cattle	378084	110292	Calves	Moderate	-	-	100	140	0	**240**
12/07/2022	42 calves 2021/2022	Cattle	380139	110838	Calves	Good	Ivomec Classic Injection for Cattle and Sheep	25/062022	0	40	0	**40**
11/07/2022	12 Heifers woods	Cattle	380140	110839	R2Y Heifers	-	-	-	0	40	0	**40**
11/07/2022	16 BH 2022	Cattle	380141	110840	R2Y Steers	Good	-	-	0	20	0	**20**
20/07/2022	9 small calves 2022	Cattle	381566	111190	Calves	Moderate	Ivomec Classic Injection for Cattle and Sheep	29/06/2022	0	40	0	**40**
20/07/2022	33 Wagyu	Cattle	381567	111191	Calves	Good	Ivomec Classic Injection for Cattle and Sheep	-	20	40	0	**60**
16/08/2022	42 calves 2021/2022	Cattle	384125	112302	Calves	Good	-	-	0	200	0	**200**
16/08/2022	42 calves 2021/2022	Cattle	384126	112303	Calves	Good	-	-	0	160	0	**160**
16/08/2022	33 Wagyu	Cattle	384127	112304	Calves	Good	-	-	0	180	0	**180**
16/08/2022	33 Wagyu	Cattle	384128	112305	Calves	Good	-	-	0	140	0	**140**
23/08/2022	Suck calves 2022	Cattle	384729	112706	Calves	Good	-	-	20	140	0	**160**
23/08/2022	Suck cows	Cattle	384730	112707	Cows	-	-	-	0	0	0	**0**
24/08/2022	19 blade heifers feb 2021	Cattle	384731	112708	Heifers	Good	-	-	20	0	0	**20**
27/08/2022	33 Wagyu	Cattle	385064	112834	Calves	Good	Levamisole Injection	18/08/2022	0	20	0	**20**
27/08/2022	42 calves 2021/2022	Cattle	385065	112835	Calves	Good	Levamisole Injection	17/08/2022	0	0	0	**0**
27/08/2022	33 Wagyu	Cattle	385068	112838	Calves	Good	Levamisole Injection	18/08/2022	0	0	0	**0**
27/08/2022	42 calves 2021/2022	Cattle	385069	112839	Calves	Good	Levamisole Injection	17/08/2022	0	0	0	**0**
23/09/2022	42 calves 2021/2022	Cattle	387673	114106	Calves	Moderate	Levamisole Injection	17/08/2022	0	0	0	**0**
23/09/2022	33 Wagyu	Cattle	387674	114107	Calves	Moderate	Levamisole Injection	18/08/2022	0	0	0	**0**
23/09/2022	33 Wagyu	Cattle	387675	114108	Calves	Moderate	Levamisole Injection	18/08/2022	0	20	0	**20**

Fig. 24. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

First QUB FEC analysis of 2022 was arranged for 25/04/2022. Dung samples were collected by the authors from the Batch 3 calves from year one of the project. These calves were FGS, turned out at start of September 2021 and vaccinated with Huskvac. 15 individual dung samples were collected with 6 replicate analyses taken from the pooled samples. Replicate GIN FECs had a range of 0 – 85 EPG and an average of 26 EPG.

Second QUB FEC analysis of 2022 was arranged for 25/07/2022. The participant farmer contacted to request sampling due to the presence of coughing across batches turned out in 2022. Once again 15 individual dung samples were collected from each batch, pooled at the group level, and analysed using four replicate FEC analyses. Batch 1 GIN FECs had a range of 85 – 190 EPG and an average of 140 EPG. Batch 2 GIN FECs had a range of 90 – 110 EPG and an average of 101 EPG. Lungworm analyses were also performed on each pooled replicate with a range of 0 – 8 L1 lungworm per 30 g of dung.

The third QUB FEC analysis of 2022 was arranged for 13/10/2022. The participant farmer reported that Batch 2 had received Dectomax injection on 23/09/2022 but were still coughing considerably despite being on relatively 'clean' pasture. Lungworm counts on this batch showed L1 lungworm were still present in the dung with a range of 0 – 150+ L1 in a 60 g dung sample. This may have signified poor drug efficacy.

Anthelmintic treatments: All three batches were treated with Ivomec injection on 25/06/2022 for Batch 1 and 29/06/2022 for Batch 2 and Batch 3. The participant farmer decided to treat at this stage due to increased egg counts observed by FECPAK^{G2} submissions. The farmer also mentioned that the treatment was used as the batches were all moving to after grass and the farmer wanted to lower the burden to try and not dirty the after grass. Although this strategy may have reduced contamination on the new grazing fields, it will have increased anthelmintic resistant risk on these fields due to a lack of diluting anthelmintic susceptible refugia. The after grass was cut for silage in May and prior to that, no cattle had grazed the fields from November 2021. Refugia was likely to be at low levels – the authors made the farmer aware of the issues this may have introduced regarding anthelmintic resistance. Drug efficacy trials by FECPAK^{G2} following this treatment showed reduced drug efficacy (reduction of 60 EPG to 40 EPG for batch 1 calves 14 days post-treatment).

Following the FEC analyses on 25/07/2022 the farmer did not decide to apply anthelmintic treatment. On 16/08/2022 the farmer completed two FECPAK^{G2} submissions for Batch 1 and Batch 2. Batch 1 = 160 EPG and 200 EPG. Batch 2 = 140 EPG and 180 EPG. There was also an increase in coughing across the herd. The farmer therefore applied a levamisole-based injection on 17/08/2022 to Batch 1 and 18/08/2022 to Batch 2. Post-treatment FECPAK^{G2} submissions for each batch showed considerable reduction in GIN EPG. Levamisole had not been used on farm for 3 years prior to application. A batch of suckler calves and cows were also FECPAK^{G2} sampled on 23/08/2022 and calves were treated with levamisole-based injection due to FEC of 160 EPG.

SGS heifers (i.e. Huskvac FGS calves in 2021) were FECPAK^{G2} sampled on 24/08/2022 with an FEC of 20 EPG. They only received one anthelmintic treatment in 2022 as a result of normal farm routine.

Batch 1 experienced considerable coughing in late September and therefore received an additional levamisole-based injection on 21/09/2022. Although Batch 2 were not coughing as much, they still received a Dectomax injection on 23/09/2022. FECPAK^{G2} submissions for both batches were low. Batch 2 received an additional levamisole-based injection on 12/10/2022. Batch 1 and suckler calves received Dectomax on 18/10/2022. These were pre-housing treatments as part of normal farm routine.

Main improvements to parasite management throughout the project:

- The farmer integrated the Huskvac lungworm vaccine to two batches of cattle in the first year of the trial (2021 Batch 1 and Batch 3). The group in which the vaccine was applied only received one anthelmintic treatment throughout the grazing season. This was two treatments less than the batch that did not receive the vaccine. However, it is worth noting that the vaccinated calves were also a few months older than the non-vaccinated batch.
- The number of time livestock were weighed throughout the season increased compared to levels before the start of the project. This helped the farmer identify other factors that may be reducing cattle performance in combination with GINs due to the increased amount of animal handling.
- The farmer developed a better understanding of the theory of refugia based strategies for GIN management, however suggested practically applying these strategies in a rotational grazing system was difficult.
- Increase in the number of FECs being carried out on farm. Although FECs were performed by the farmer prior to the start of the project these were often irregular, and farmer suggested waiting times for vet response of results were unworkable.

Suggested future improvements for on farm parasite management:

- Despite applying treatments using a TT strategy based on group FECs, some anthelmintic treatments were still applied when they may not have been required. These additional treatments are largely aimed towards lungworm control as opposed to GINs. Improved lungworm diagnostics and timing of sample collections relative to treatment will help reduce these treatments further.

- Group 3 macrocyclic lactone anthelmintics were used very regularly on farm and there appears to be at least some reduction in drug efficacy to GINs given pre- and post-treatment egg count assessment. Rotation to a Group 2 levamisole-based treatment during the 2022 grazing proved to be much more effective at reducing GIN FECs.
- The farmer on occasion still employed a dose and move strategy when treating livestock i.e. providing treatment and then moving to clean pasture. This may promote the development of anthelmintic resistance on farm. The authors made the farmer aware of this during the project.
- TST was not carried out at any point during the project. This was due to the increased handling required. The farmer suggested they were still unsure of which parameters to use for treatment decision and were fearful of withholding treatment from high performance animals. For example, when applying anthelmintics based on liveweight it may be necessary to dose the high performing individuals a few weeks later when they fall behind. Future trials on farm using smaller batches of liveweight based TST may be feasible.

Farm 3 – Jayme Carvill

Farm background

Sheep and beef cattle enterprises. EIP project focused on sheep enterprise. Rotational grazing system with some hill pastures. Cattle and sheep share fields in rotation but co-grazing minimal. Average of two anthelmintic treatments for lambs, two anthelmintic treatments for ewes per season. Cattle traditionally receive three anthelmintic treatments per season.

Identified positive parasite management strategies on farm prior to project start:

- Lambs and ewes were receiving two anthelmintic treatments per grazing season.
- Individuals were dosed according to the heaviest individual in the batch.
- Dosing equipment was already calibrated 2-3x a year.
- Livestock were yarded for multiple days after quarantine before turnout onto pasture with moderate to high level contamination pasture.
- Farmer tracked FECs via vet throughout season, treating when egg counts were high.

Identified areas of improvement for parasite management strategies prior to project start:

- Dose and move onto 'clean' pasture was regularly applied throughout season.
- Treatment for *Nematodirus battus* was based on time of year and egg counts, with no use of forecasts e.g. SCOPS.
- Quarantine treatments consisted of Group 3 macrocyclic lactones only.
- The farmer had not heard of using refugia for parasite management.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 eggs per gram faeces (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-250 epg, don't treat, but re-sample group again 5 - 7 days later.
  - FEC >250 epg, treat whole group.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 2: TST – Treatment based on individual DLWG/weight targets

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess ability to reach individualised targets by weighing (lambs) every 2 weeks.**
  - Treat according to traditional farm weight targets, i.e. treat individuals not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- Adjust weight thresholds if pasture is heavily contaminated.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Group pooled (lambs) FEC every 2-3 weeks after turnout.
- Switch to a **TT** strategy if infection spike observed i.e. treat the whole group.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 3: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 epg, don't treat, re-sample 2 weeks later.
  - FEC >250 epg, treat whole group (**TT**).
  - FEC 100-250 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

2021 grazing season summary

- Tracked 1 batch of lambs and ewes.
- 11 FECPAK^{G2} submissions (**Fig. 25**) used alongside liveweight to investigate drops in DLWG (six liveweight time-points).
- QUB visit on 01/06/2021 to collect dung samples for FEC analysis (**Fig. 26**).
- Anthelmintic treatments for lambs maintained at two per grazing season.
- *Moniezia expansa* tapeworm cysts identified in samples alongside GINs.

January	February	March	April	May	June	July	August	September	October
	1		2	5		1	1	1	

Received	Mob Name	Individual Name	Animal Name	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	A		Sheep	-	Good	Flukiver	01/01/2021	0	140	0	**140**
27/04/2021	A		Sheep	-	Good	-	-	140	0	0	**140**
27/04/2021	B		Sheep	Ewes	-	-	-	0	70	0	**70**
07/05/2021	A		Sheep	Hoggets	-	-	-	0	105	0	**105**
07/05/2021	B		Sheep	Hoggets	Moderate	Cydectin TriclaMox	02/01/2021	0	175	0	**175**
21/05/2021	A		Sheep	Lambs	Moderate	-	-	245	245	0	**245**
21/05/2021	A		Sheep	Ewes	Good	-	-	0	35	0	**35**
21/05/2021	A		Cattle	Calves	Good	-	-	0	60	0	**60**
05/07/2021*	C		Sheep	Lambs	Moderate			35	175	0	**210**
02/08/2021	B		Sheep	Lambs	-	-	-	0	245	0	**245**
03/09/2021	A		Sheep	Lambs	-	-	-	0	0	0	**0**

Fig. 25. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

Lambs averaged 4.5 kg at turnout from housing post lambing (15/03/2021). Ewes averaged 78 kg. Lambs weighed again on 15/05/2021 now averaging 22 kg with an average daily gain of 0.29 kg across the flock. The lambs were weighed again mid-June, averaging 30.4 kg and an average daily gain of 0.25 kg. In early July average daily gain for lambs fell to 0.15 kg with lambs weaned on 8th July. Average daily gain increased again to 0.26 kg by mid-August with an average lamb liveweight of 38 kg in late August (target 46 kg).

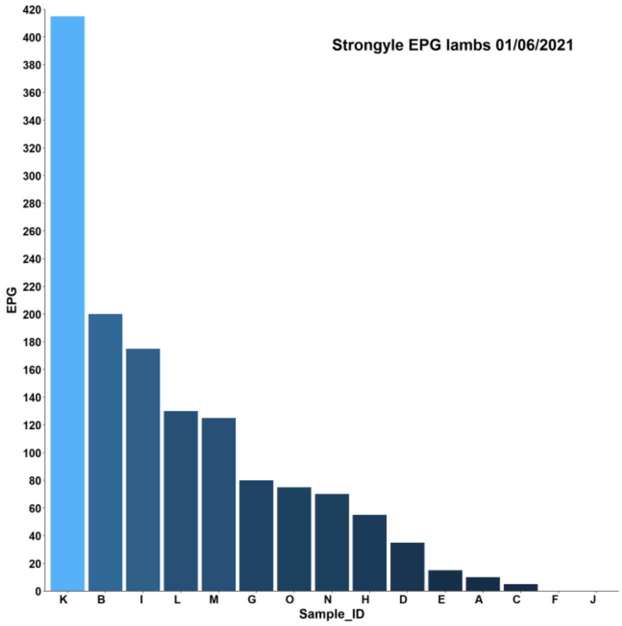


Fig. 26. Batch 1 FECs carried out by QUB on 01/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Zero *Nematodirus battus* eggs present. Low levels of *Moniezia expansa* cysts present in two samples (J and K).

Anthelmintic treatments: lambs received a cydectin drench on 08/07/2021. FECPAK^{G2} samples showed low FECs (210 EPG) but DLWG had dropped considerably to around 150 g/day. The farmer suggested this was probably due to drought conditions and lack of grass, but the farmer decided to apply an anthelmintic treatment despite of this. Lambs also received a mineral drench and the DLWG improved to 260 g/day. It is therefore difficult to determine if the increase in DLWG was a result of mineral application, strongyle worm removal or both. DLWG dropped again to 190 g/day which prompted an additional FECPAK^{G2} submission on 02/08/2021. According to the farmer grass growth was very patchy throughout the 2021 season and may be more of an influence on the DLWG than parasite presence. Information on second anthelmintic application in 2021. All ewes received a Cydectin TriclaMox treatment on 18/09/2021 for fluke and worms prior to tupping – following veterinary advice.

2022 grazing season summary

- Tracked 3 batches of lambs and ewes. All were managed the same way due to logistical difficulties.
- Farmer was experiencing intermittent connectivity issues with the FECPAK^{G2} system throughout the grazing. Zero submissions in 2022. Multiple QUB visits were therefore required on 11/04/2022, 23/05/2022, 28/06/2022 and 15/09/2022 to collect dung samples for FEC analysis (**Fig. 27** and **Fig 28, Table 1 - 3**).
- Liveweight data in 2022 consisted of six weighing timepoints.
- Anthelmintic treatments were maintained at same level as first year of the project with the addition of a Vecoxan coccidia treatment as a preventative measure based on high oocysts counts early in the season of 2021.

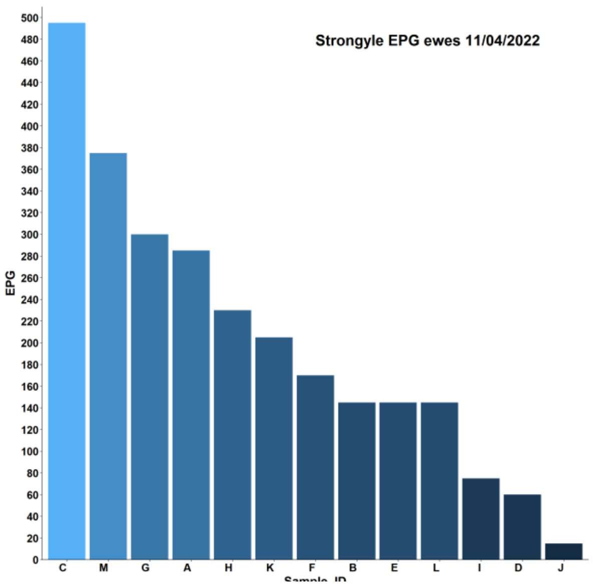


Fig. 27. Batch 1 FECs carried out by QUB on 11/04/2022. 13 individual ewe dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

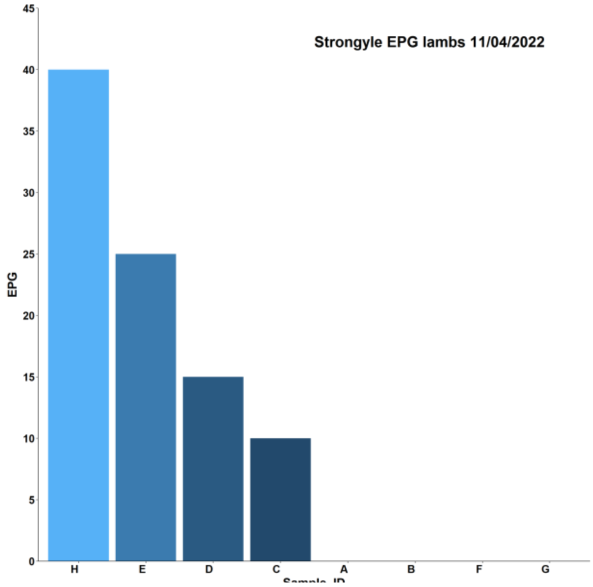


Fig. 28. Batch 1 FECs carried out by QUB on 11/04/2022. 8 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Low levels of *Nematodirus battus* eggs were detected in both ewe and lamb individual samples (range: 0 – 10 EPG). Lambs presented with high coccidia counts (range: 5040 – 100080 oocysts per gram (OPG) dung) in April 2022. Dung samples were not sporulated, so it was not possible to ascertain whether the coccidia oocysts present consisted of pathogenic *Eimeria* spp., however given the results the farmer decided to treat the lambs on farm with Vecoxan.

Table 1. FECs carried out by QUB on 23/05/2022. 15 individual dung samples collected from each batch, pooled and then analysed using three replicate Mini-FLOTAC analyses to assess the presence of strongyle (GIN) eggs.

Sample ID	Strongyle EPG	*Nematodirus battus* EPG
Dry hoggets pooled replicate 1	290	0
Dry hoggets pooled replicate 2	400	0
Dry hoggets pooled replicate 3	175	0
Average	**288**	**0**
Hogget lambs pooled replicate 1	1095	765
Hogget lambs pooled replicate 2	1150	670
Hogget lambs pooled replicate 3	845	515
Average	**1030**	**650**
Ewe lambs pooled replicate 1	115	25
Ewe lambs pooled replicate 2	370	70
Ewe lambs pooled replicate 3	335	60
Average	**273**	**52**

Table 2. FECs carried out by QUB on 23/06/2022. 15 individual dung samples collected from each batch, pooled and then analysed using three replicate Mini-FLOTAC analyses to assess the presence of strongyle (GIN) eggs.

Sample ID	Strongyle EPG	*Nematodirus battus* EPG
Light lambs pooled replicate 1	45	35
Light lambs pooled replicate 2	120	95
Light lambs pooled replicate 3	110	130
Average	**92**	**87**
Hogget lambs pooled replicate 1	145	0
Hogget lambs pooled replicate 2	105	0
Hogget lambs pooled replicate 3	70	0
Average	**107**	**0**
Ewe lambs pooled replicate 1	465	0
Ewe lambs pooled replicate 2	1325	0
Ewe lambs pooled replicate 3	220	0
Average	**670**	**0**
Heavy lambs pooled replicate 1	225	150
Heavy lambs pooled replicate 2	25	55
Heavy lambs pooled replicate 3	75	20
Average	**108**	**75**

Table 3. FECs carried out by QUB on 15/08/2022. 15 individual dung samples collected from each batch, pooled and then analysed using three replicate Mini-FLOTAC analyses to assess the presence of strongyle (GIN) eggs.

Sample ID	Strongyle EPG	*Nematodirus battus* EPG
Hoggets pooled replicate 1	135	0
Hoggets pooled replicate 2	90	0
Hoggets pooled replicate 3	80	0
Average	**102**	**0**
Ewes pooled replicate 1	60	0
Ewes pooled replicate 2	45	0
Ewes pooled replicate 3	60	0
Average	**55**	**0**
Ewe lambs pooled replicate 1	590	5
Ewe lambs pooled replicate 2	430	15
Ewe lambs pooled replicate 3	540	5
Average	**520**	**8**
Tup lambs pooled replicate 1	215	0
Tup lambs pooled replicate 2	310	0
Tup lambs pooled replicate 3	315	0
Average	**280**	**0**

Lambs were weighed on six occasions throughout the grazing season. At lambing average lamb weight on 16/03/2022 was 4.5 kg. On the 14/05/2022 average lamb liveweight was 21 kg with a DLWG of 0.28 kg. On 13/06/2022 prior to weaning, lamb liveweight was 31 kg with a DLWG of 0.33 kg. Following weaning, lamb liveweight averaged 34 kg on 02/07/2022 with

DLWG reducing to 0.16 kg. Average lamb liveweight on 06/08/2022 was 42 kg with a DLWG of 0.22 kg. The final liveweight measurement of remaining lambs on 10/09/2022 averaged 49 kg with a DLWG of 0.2 kg. At this point replacement ewe lambs were moved to winter grazing and remaining lambs were fed meal for slaughter.

Anthelmintic treatments: lambs were treated with Vecoxan for coccidia burdens at the end of April 2022. After this treatment coccidia burdens remained low at proceeding timepoints likely due to the development of natural immunity. Ewe lambs received a white drench of Albacert on 17/05/2022 to treat for *Nematodirus battus*. Hogget lambs also received a white drench (Albacert) on 28/05/2022 again targeted at *Nematodirus battus*. Dry hoggets (**Table 1**) last received an anthelmintic treatment in September 2021 (cydectin). An anthelmintic treatment of cydectin was provided to all lambs on 04/07/2022 at weaning. Anthelmintic treatments were at this point applied on the basis of TT due to poor DLWG. At this point in the season lambs were culled every 10 days. A Chanaverm anthelmintic treatment was also applied to the flock on 20/08/2022 due to widespread coughing. The vet suggested anthelmintic treatment, but this did not resolve the coughing – may have thus been microplasma as opposed to *Dictyocaulus filaria*. The small number of slaughter lambs remaining on farm towards the end of the grazing season were dosed with levafas diamond on 10/09/2022 according to veterinary advice due to poor DLWG. Replacement ewe lambs were treated with Cydectin Triclamox on 20/09/2022 pre-tupping. Veterinary advice on this farm was to continue with multiple anthelmintic treatments, often without FECs to confirm egg counts.

Main improvements to parasite management throughout the project:

- The number of annual anthelmintic treatments for lambs was low prior to the start of the trial and this trend was maintained throughout the project.
- Anthelmintic treatment of ewes at lambing was removed.
- Treatments were provided on a targeted basis rather than based on time of year using a combination of FECPAK^{G2} submissions (2021 only)/QUB FECs alongside assessment of liveweight gains. Going forward the farmer plans to continue sending dung samples to the vet.
- Mobile crush purchased on the project enabled liveweight measurements in the field.

Suggested future improvements for on farm parasite management:

- Targeted selective treatments (TST) were not employed during the project due to the excess handling required, particularly when animals were grazing hill pastures. Going forward, the famer suggested they may try to use DLWG as a treatment parameter.
- Pre-tupping anthelmintic treatments are still applied to ewes however this is the only treatment they receive each year (Cydectin TriclaMox). Due largely to handling issues and desire to not disturb animals for treatment during tupping if it was required.
- Early season assessments of coccidia levels are required to ensure levels do not get too high.
- Beef cattle are also purchased and grazed on farm. Staggered grazing at present, there may be options to co-graze in the future.
- Integration of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.

Farm 4 – Martin Craig

Farm background

Sheep and beef cattle. EIP TST project focused on sheep enterprise. Ewes traditionally receive one anthelmintic treatment per year, lambs receive up to four anthelmintic treatments. An additional 120-180 SGS+ cattle present on farm at any stage with batches of 50-60 on a rotational grazing system. Low numbers of FGS cattle are also bought in and co-grazed with sheep. Carried out one pasture-based drug efficacy trial and one full FECRT in 2021.

Identified positive parasite management strategies on farm prior to project start:

- Ewes receive one anthelmintic treatment per grazing season.
- Anthelmintic treatment dose calculated based on weighing heaviest individual.
- Calibration of dosing equipment annually. However, every time would be more beneficial.

Identified areas of improvement for parasite management strategies prior to project start:

- Lambs receive four anthelmintic treatments per grazing season.
- Anthelmintic treatments applied based on an annual routine/pre-set interval.
- Dose and move strategy employed, with lambs moved onto low level contamination pastures post treatment.
- Nematodirus spp. treatment using parafend same date each year/by weather judgement – no use of prediction forecasts.
- Quarantine treatments using Group 3 anthelmintics (macrocyclic lactones), no yarding post-treatment and then placed onto low contamination pastures.

2021 grazing season summary

- Tracking two batches of ewes and lambs in 2021 – Batch 1 and Batch 2.
- Lambs weaned and formed one large batch on 20/07/2021.
- 25 FECPAK^{G2} system (**Fig. 29**) used alongside liveweight to investigate drops in DLWG. Liveweight data stored on Datamars system (data not shown here).
- QUB visits on 09/06/2021, 29/06/2021 to collect dung samples for FEC analysis (**Fig. 30 – Fig. 35**).
- Anthelmintic treatments maintained at four per season for lambs. However at least one treatment (Noromectin) was applied for GINs when it may not have been required.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:

- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 eggs per gram faeces (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-250 epg, don't treat, but re-sample group again 5 - 7 days later.
  - FEC >250 epg, treat whole group.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 2: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 epg, don't treat, re-sample 2 weeks later.
  - FEC >250 epg, treat whole group (**TT**).
  - FEC 100-250 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 3: TST – Treatment based on individual FEC

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turn out without treatment.
- **Assess individual FECs (lambs) every 2 weeks:**
  - FEC 0-250 epg, don't treat, re-sample 2 weeks later.
  - FEC >250 epg, apply treatment.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Switch to a **TT** strategy if infection spike observed i.e. dose the whole group.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

January	February	March	April	May	June	July	August	September	October
	1	4	2	4	2	4	8		

ɜved	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	yard		Cattle	295092	92696		Excellent	Endofluke 10%	30/10/2021	0	40	0	**40**
03/03/2021	Individual Only	10	Cattle	297781	92875	R1Y Heifers	-	taurador	02/11/2020	0	40	0	**40**
04/03/2021	eft Side Heifer Hous	Test	Cattle	298268	92915	-	Excellent	-	-	0	40	0	**40**
15/03/2021	Ewe Lambs	Test	Sheep	301282	93194	Lambs, ewes	Excellent	Endofluke	10/03/2021	0	0	0	**0**
17/03/2021	Individual Only	10	Sheep	301678	93260	Ewes	Moderate	-	-	0	70	0	**70**
22/04/2021	Sheep Mob 1		Sheep	312682	94271	Lambs	Excellent	-	-	35	0	0	**35**
28/04/2021	Sheep Mob 1		Sheep	313311	94396	Lambs	Excellent	-	-	35	0	0	**35**
07/05/2021	Sheep Mob 1		Sheep	314422	94745	Lambs	Excellent	-	-	175	350	0	**525**
11/05/2021	Sheep Mob 2		Sheep	314845	94850	Lambs	Excellent	-	-	35	0	0	**35**
20/05/2021	Sheep Mob 1		Sheep	316399	95198	Lambs	Excellent	-	-	385	420	0	**805**
20/05/2021	Sheep Mob 2		Sheep	316400	95199	Lambs	Excellent	-	-	70	0	0	**70**
09/06/2021	Sheep Mob 1		Sheep	317914	95904	Lambs	Excellent	Noromectin Drench	18/05/2021	245	490	0	**735**
11/06/2021	Sheep Mob 2		Sheep	318077	95980	Lambs	Excellent	Tramazole SC 2.5%	18/05/2021	315	315	0	**630**
21/07/2021	Sheep Mob 1		Sheep	322662	97736	Lambs	Excellent	Noromectin Drench	15/06/2021	70	105	0	**175**
23/07/2021	Sheep Mob 3		Sheep	323073	97893	Lambs	Excellent	Noromectin Drench	15/06/2021	105	455	0	**560**
23/07/2021	Sheep Mob 4		Sheep	323088	97896	Lambs	Excellent	Noromectin Drench	15/06/2021	0	140	0	**140**
29/07/2021	Individual Only		Sheep	323673	98187	Lambs	Poor	Noromectin Drench	16/06/2021	0	1050	0	**1050**
13/08/2021	Sheep Mob 3 and 4		Sheep	325899	98995	Lambs	Good	Noromectin Drench	20/07/2021	0	0	0	**0**
13/08/2021	Sheep Mob 1 and 2		Sheep	325914	99002	Lambs	Good	Noromectin Drench	28/07/2021	0	0	0	**0**
16/08/2021	Sheep Mob 3 and 4		Sheep	326035	99052	Lambs	Excellent	Noromectin Drench	20/07/2021	0	0	0	**0**
16/08/2021	Sheep Mob 1 and 2		Sheep	326060	99054	Lambs	Good	Noromectin Drench	28/07/2021	0	35	0	**35**
23/08/2021	Sheep Mob 1 and 2		Sheep	326911	99397	Lambs	Excellent	Noromectin Drench	20/07/2021	0	0	0	**0**
23/08/2021	Sheep Mob 1 and 2		Sheep	326946	99401	Lambs	Excellent	Noromectin Drench	20/07/2021	0	0	0	**0**
27/08/2021	Individual Only		Sheep	327707	99654	Lambs	Good	Noromectin Drench	20/07/2021	105	0	0	**105**
27/08/2021	Individual Only		Sheep	327718	99658	Lambs	Good	Noromectin Drench	20/07/2021	0	0	0	**0**

Fig. 29. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

Batch 1 *Nematodirus battus* FECs from 09/06/2021 range: 0 – 705 EPG with an average of 142 EPG. Batch 2 *N. battus* FECs from 09/06/2021 range: 0 – 245 EPG with an average of 127 EPG.

At this stage it was decided to examine drug efficacy on farm. Dung samples were collected off pasture on each occasion so the same individual animal may not have been tested. FECs collected on 09/06/2021 (**Fig. 30** and **Fig. 31**) were considered pre-treatment FECs with post-treatment FECs collected 29/06/2021 (**Fig. 32** and **Fig. 33**). Both batches were treated with Noromectin drench on 15/06/2021 according to the heaviest individual in the group. The dosing gun was calibrated prior to treatments. All treatments were applied by the farmer.

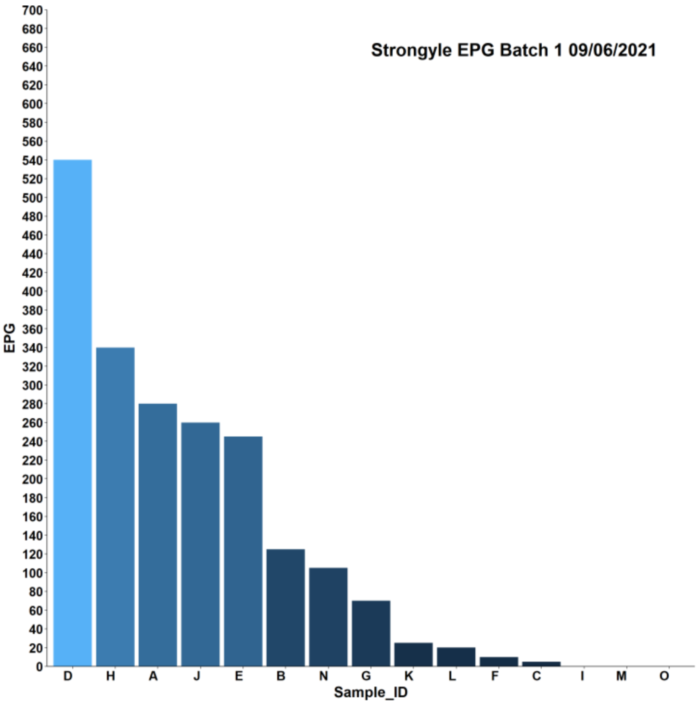


Fig. 30. Batch 1 pre-treatment FECs carried out by QUB on 09/06/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

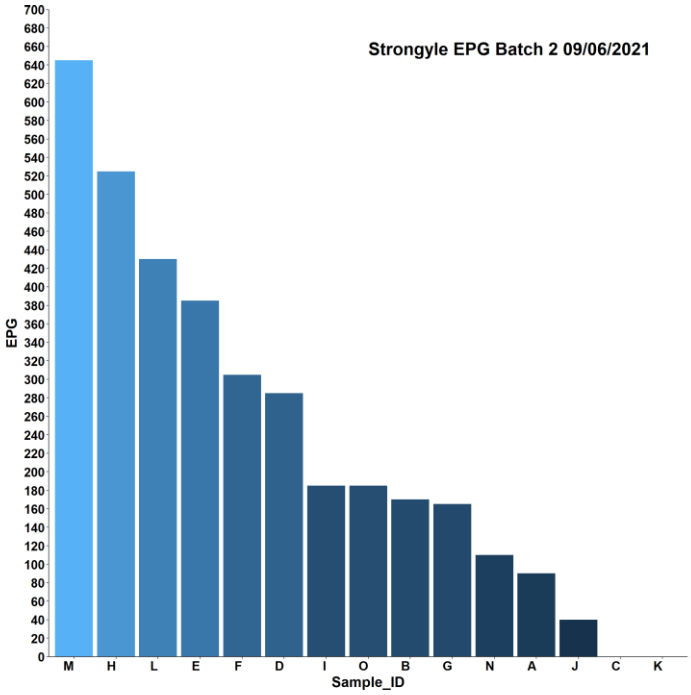


Fig. 31. Batch 2 pre-treatment FECs carried out by QUB on 09/06/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

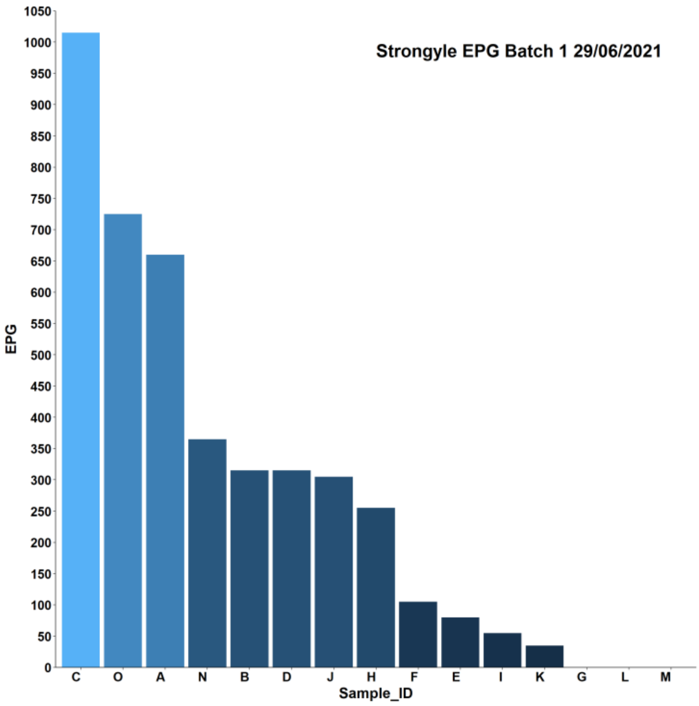


Fig. 32. Batch 1 post-treatment FECs carried out by QUB on 29/06/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were not tied.

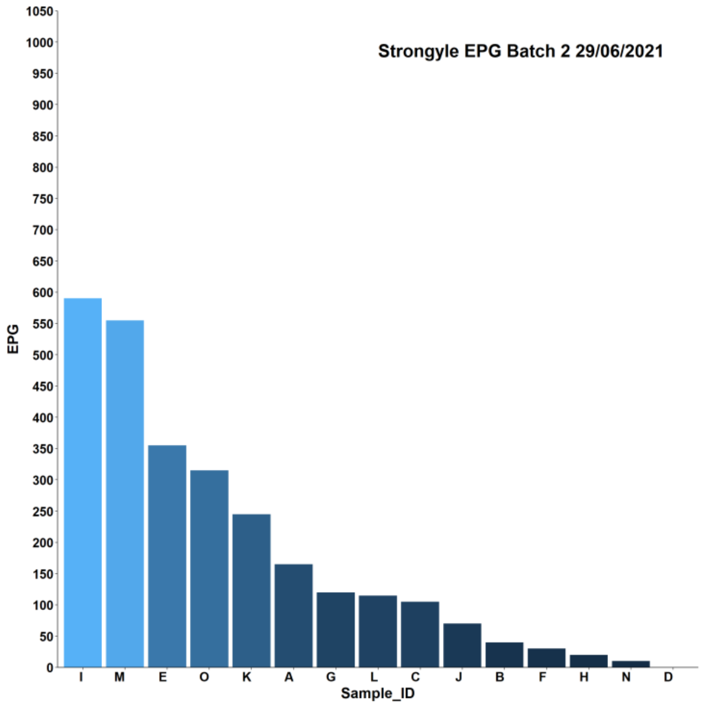


Fig. 33. Batch 2 pre-treatment FECs carried out by QUB on 29/06/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were not tied.

Batch 1 FECs increased post-treatment whilst Batch 2 observed a 22.30% reduction (95% CI: -57.46 to 61.66). Suggesting that drug efficacy of ivermectin was reduced on farm. *Nematodirus battus* counts in each batch reduced to zero for post-treatment for all individuals (n = 30) suggesting that ivermectin was still active against this parasite species. This also confirmed that the drug application was correct.

As the season progressed and following multiple FECPAK^{G2} submissions the farmer took the decision to apply another anthelmintic treatment of noromectin drench on 20/07/2021. At this point QUB carried out a full faecal egg count reduction test (FECRT) on Batch 1 – using tied individuals. Dung samples collected off yard (with tag recorded) for 19 individuals on 20/07/2021. Anthelmintic application applied according to individual weight. It was possible to collect post-treatment samples from 16 individuals in Batch 1 on 03/08/2021 – FECRT analysis below includes only those 16 individuals (**Fig. 34** and **Fig. 35**).

In hindsight the farmer realized that this treatment may not have been required given low average FECs. The farmer acknowledged that this second treatment in July was likely unwarranted and admitted this would make them think twice before applying a treatment at a similar EPG level in the future given additional cost for minimal benefit.

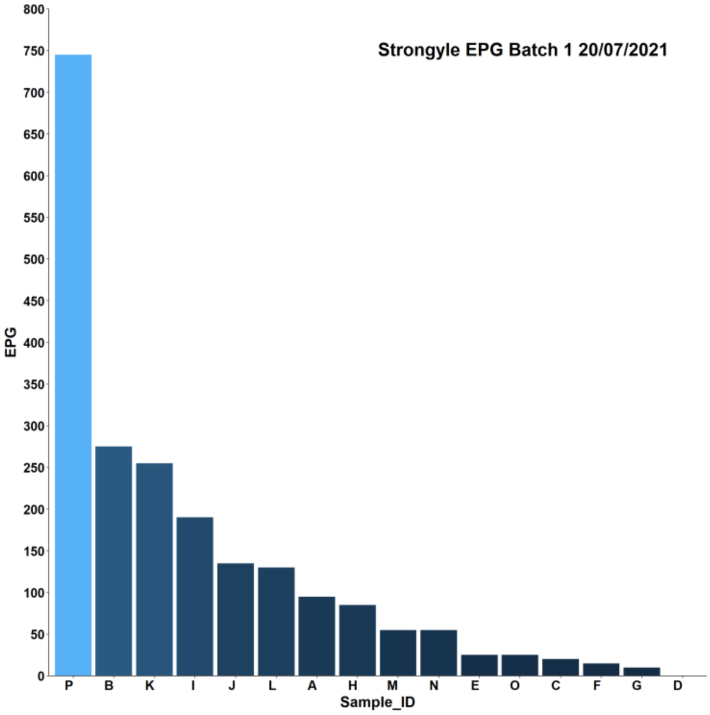


Fig. 34. Batch 1 pre-treatment FECs carried out by QUB on 20/07/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were tied.

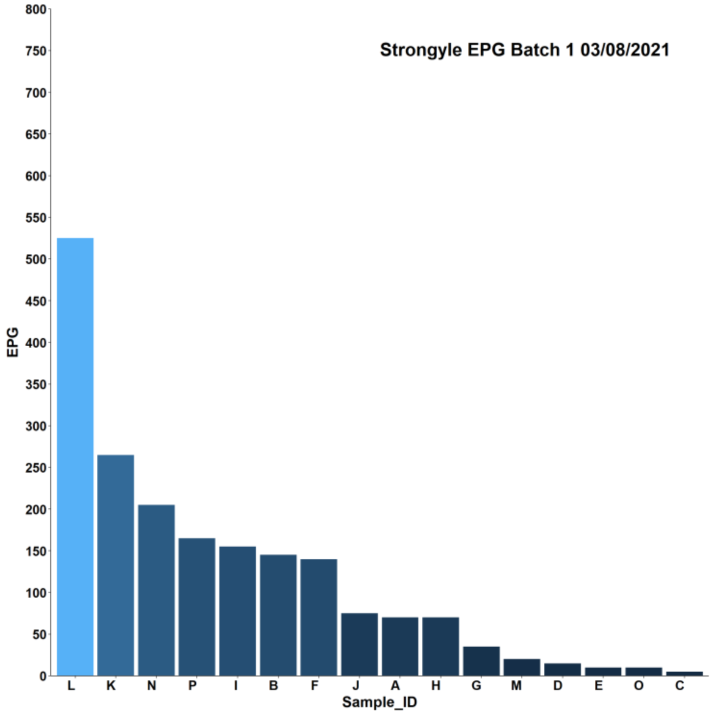


Fig. 35. Batch 1 post-treatment FECs carried out by QUB on 03/08/2022. 15 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were tied.

On this occasion Batch 1 FECs decreased post-treatment with an observed 9.69% reduction (95% CI: -125.47 to 63.83). Once again suggesting that drug efficacy of ivermectin was reduced on farm. *Nematodirus battus* counts remained at zero for pre- and post-treatment counts.

Anthelmintic treatments: Farmer carried out a FECPAK^{G2} submission on 18/05/2021 and identified that Batch 1 had a strongyle EPG of 420 and *Nematodirus battus* EPG of 385, whilst Batch 2 had a strongyle EPG of 0 and a *Nematodirus battus* EPG of 70. The farmer made the decision to apply treatment on the basis of TT employing Tramazole for Batch 2, solely to treat for *N. battus* and Noromectin oral drench for Batch 1 to treat both strongyles and *N. battus*.

The farmer applied a noromectin treatment on 15/06/2021 to Batch 1 and Batch 2. A drug efficacy trial (described above) identified reduced ivermectin drug efficacy. At a further anthelmintic treatment with noromectin drench on 20/07/2021, QUB completed a full FECRT to assess the presence of anthelmintic resistance in Batch 1. FEC reduction post-treatment was <10%.

As the season progressed the farmer noted that on multiple FECPAK^{G2} submissions FECs were at zero EPG or at very low levels. However, due to liveweight not increasing the farmer applied a Zolvix treatment to all lambs on 23/08/2021. Once again, the farmer agreed that this treatment was likely unnecessary given the low FECs and it was inferred that poor liveweight gain was likely the result of grass provision rather than worm burdens.

Cattle anthelmintic treatments for FSGs normally consist of Noramectin and Dectomax. Closamectin used in 2020 for cattle treatments. SSGs traditionally receive an anthelmintic treatment at the end of May, graze for 7/8 weeks, heaviest then taken out and fed meal to a weight of 570 kg. FGS cattle were dosed with Taurador pour-on on 25/05/2021 and 30/07/2021. A new batch of cattle on farm were quarantined using Taurador pour-on on 18/06/2021. However, FECs were only tracked at the start of the grazing season.

2022 grazing season summary

- Tracking four batches of ewes and lambs in 2022 – Batch 1, Batch 2, Batch 3 and Batch 4.
- Batch 1 and 2 were formed on 18/04/2022. Batch 3 on 25/04/2022. Approx. 65 ewes in each batch with Batch 3 consisting of 50% 1st time lambers. Batch 1 and Batch 2 consisted of 112 and 100 lambs, respectively. Batch 3 consisted of 70 lambs. Batch 4 was 1st time lambers in a smaller batch.
- Batch 2 and Batch 3 were combined at weaning on 19/07/2022 to form a batch of 170 lambs renamed Batch 2.
- The farmer was interested in integrating co-grazing with cattle into the system. Sheep in Batch 1 were therefore grazed with 10 SGS beef cattle and 7 FGS cattle until 04/10/2022.
- The farmer also decided to integrate co-grazing for the 2023 grazing season with cattle now grazed alongside three sheep batches.
- Liveweight of lambs was only recorded at weaning in 2022 (data not shown). The farmer suggested this was due to the increased labour associated with regular weighing and therefore decided to select alternative parameters to determine performance i.e. scouring + FECPAK^{G2}.
- 22 FECPAK^{G2} submissions in the 2022 grazing season (**Fig. 36**) and QUB visit on 05/04/2022 to sample ewes in Batch 1 and Batch 2 (**Fig. 37** and **Fig. 38**).
- Detailed records of pasture grazing rotations maintained by farmer.

January	February	March	April	May	June	July	August	September	October
			4	3	5	7		2	1

Sample Collected	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus FEC	Strongyle FEC	Strongyloides FEC	Total FEC
26/04/2022	A		Sheep	366632	107637	Lambs	Good	-	-	0	0	0	**0**
26/04/2022	B		Sheep	366634	107639	Lambs	Good	-	-	0	70	0	**70**
27/04/2022	Individual Only		Sheep	366976	107676	Lambs	Moderate	N/A	-	0	0	0	**0**
28/04/2022	Sheep Mob 2		Sheep	367405	107719	Lambs	Good	N/A	-	0	0	0	**0**
05/05/2022	Sheep Mob 1		Sheep		107958	Lambs	Good	N/A	N/A	0	0	0	**0**
10/05/2022	Sheep Mob 2		Sheep		108180	Lambs	Good	N/A	N/A	455	175	0	**630**
31/05/2022	Sheep Mob 1		Sheep		109072	Lambs	Good	Noromectin Drench	11/05/2022	210	455	0	**665**
06/06/2022	Sheep Mob 3		Sheep	375338	109211	Lambs	Moderate	Noromectin Drench	10/05/2022	70	175	0	**245**
06/06/2022	Sheep Mob 2		Sheep	375340	109213	Lambs	Good	Noromectin Drench	11/05/2022	70	1365	0	**1435**
20/06/2022	Sheep Mob 1		Sheep	376888	109980	Lambs	Good	Levafas Diamond	06/06/2022	0	420	0	**420**
21/06/2022	Sheep Mob 3		Sheep	378071	110281	Lambs	Good	Levafas Diamond	07/06/2022	35	245	0	**280**
22/06/2022	Sheep Mob 2		Sheep	378072	110282	Lambs	Excellent	Noromectin Drench	11/05/2022	0	70	0	**70**
08/07/2022	FGS		Cattle	379536	110689	-	Moderate	taurador	07/06/2022	0	0	0	**0**
08/07/2022	SGS		Cattle	379537	110690	-	Good	taurador	07/06/2022	0	0	0	**0**
08/07/2022	Sheep Mob 2		Sheep	379539	110692	Lambs	Excellent	Levafas Diamond	07/06/2022	0	245	0	**245**
08/07/2022	Sheep Mob 1		Sheep	379540	110693	Lambs	Excellent	Levafas Diamond	06/06/2022	35	105	0	**140**
27/07/2022	Dirty Lambs		Sheep	382003	111426	Lambs	Moderate	Levafas Diamond	06/06/2022	140	350	0	**490**
27/07/2022	Sheep Mob 2		Sheep	382004	111427	Lambs	Good	Levafas Diamond	07/06/2022	105	35	0	**140**
27/07/2022	Sheep Mob 1		Sheep	382005	111428	Lambs	Excellent	Levafas Diamond	06/06/2022	35	175	0	**210**
13/09/2022	Sheep Mob 2		Sheep	386596	113635	Lambs	Good	Levafas Diamond	09/08/2022	140	245	0	**385**
13/09/2022	Sheep Mob 2		Sheep	386597	113636	Lambs	Good	Levafas Diamond	09/08/2022	105	175	0	**280**
05/10/2022	Sheep Mob 1		Sheep	388773	114565	Lambs	Good	Levafas Diamond	16/08/2022	0	0	0	**0**

Fig. 36. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

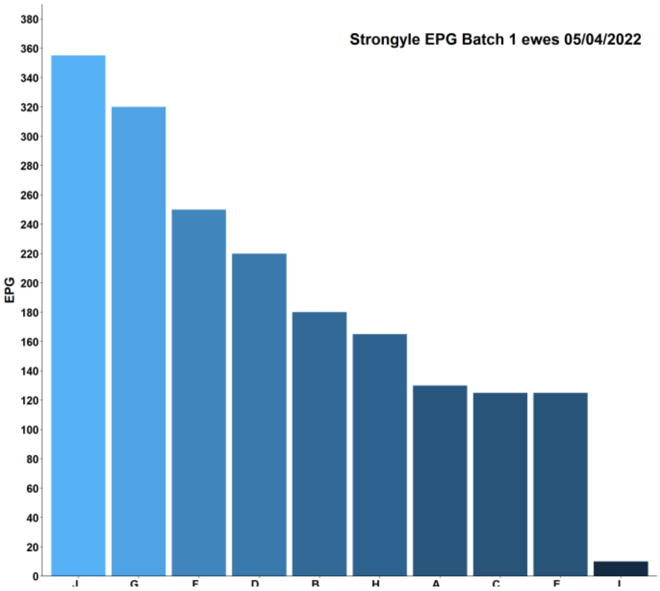


Fig. 37. Batch 1 ewe FECs carried out by QUB on 05/04/2022. 10 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were tied.

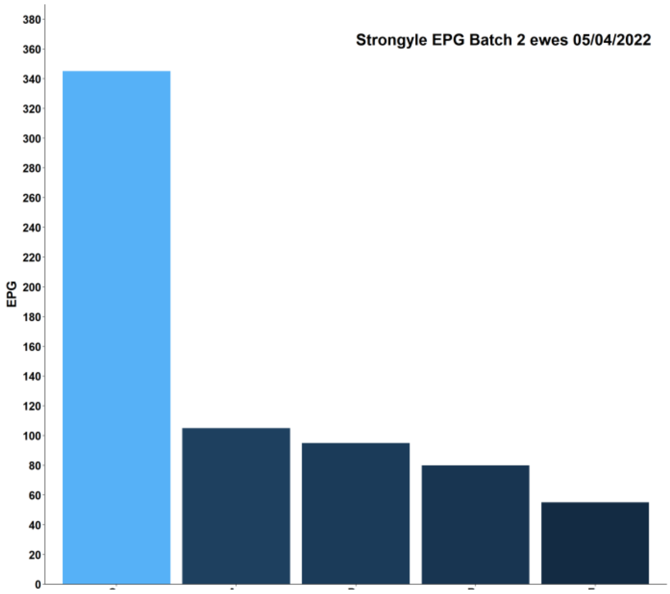


Fig. 38. Batch 2 ewe FECs carried out by QUB on 05/04/2022. 10 individual lamb dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Samples were tied.

Anthelmintic treatments:

- **Batch 1** = Noromectin drench on 11/05/2022 for *N. battus*, Levafas Diamond on 06/06/2022 for *N. battus*. Levafas Diamond on 16/08/2022 for GINs.
- **Batch 2** = Noromectin drench on 11/05/2022 for *N. battus*, Levafas Diamond on 07/06/2022 for *N. battus*.
- **Batch 3** = Noromectin drench on 10/05/2022 for *N. battus*, Levafas Diamond on 07/06/2022 for *N. battus*.
- **Combined Batch 2 (Batch 2 and Batch 3 merged)** = Levafas diamond on 09/08/2022, Zolvix break dose on 13/09/2022.

Batch 1 co-grazing with cattle received three TT anthelmintic treatments in 2022 – two of which were only targeted at *N. battus*. Batch 2 (merged) received four TT anthelmintic treatments in 2022 two of which were only targeted at *N. battus.* A Zolvix break dose in September 2022 was also applied to Batch 2. Between these points TST was applied to Batch 2.

Targeted Selective Treatments (TST) were carried out in Batch 3 lambs using scouring as the decision parameter. This group was FEC sampled on 29/06/2022 with some nematodirus present. Scouring lambs in this batch were therefore selectively treated. Around 20 lambs were treated with Levafas Diamond at this point with all showing an improvement in condition. All other lambs in this batch plus the other two batches were not scouring and FEC results showed no *N. battus*. Lambs did not receive an anthelmintic treatment until FEC results increased or scouring was observed.

From 08/07/2022 onwards only lambs that were scouring were dosed with Levafas Diamond. Lambs were assessed and treated accordingly on a weekly basis. This was completed by observing animals in the field or when stock was being moved under grazing rotation. Individuals were then isolated and treated as required. Individuals were moved to new fields every 7-10 days throughout the grazing season. No scouring lambs were observed in Batch 1 and thus did not receive any anthelmintic treatments during this period. However, on 16/08/2022 all lambs in both batches i.e. Batch 1 and the combined Batch 2 were dosed with Levafas Diamond as the number of scouring lambs was rising sharply and weight gain in Batch 1 had slowed.

Cattle did not show high FECs, however rate of coughing was increasing so received Taurador pour-on on 26/07/2022. FECPAK^{G2} submissions for cattle in 2022 were more regular than the 2021 grazing season.

Main improvements to parasite management throughout the project:

- Anthelmintic treatments were provided on a targeted basis during the 2021 and 2022 grazing season.
- Anthelmintic treatments in 2021 were largely performed on the basis of TT. However, in 2022 the farmer opted for a combination of TT and TST, applying anthelmintic treatments to individual animals on the basis of scouring and associated group level FECPAK^{G2} submissions.
- Anthelmintic rotations were introduced during the project due to overreliance on Group 3 (macrocyclic lactones) agents.
- Group 4 Zolvix anthelmintic treatments were provided as a break dose in 2021 and 2022. However, the 2021 application was poorly timed as FECs were low and anthelmintic treatment did not improve group liveweights suggesting other factors may have contributed to reduced condition.
- The participant farmer suggested regular FECPAK^{G2} submissions had provided the confidence to integrate the changes on farm.

Suggested future improvements for on farm parasite management:

- Ivermectin appears to have low drug efficacy on farm for GINs at present. In 2022 the farmer switched to using ivermectin only for the treatment of *N. battus*. The farmer also plans to further integrate Group 2 and Group 5 anthelmintics.
- Integration of regular weighing of sheep throughout the grazing season would provide further information on performance and could be integrated as a parameter for TST (in discussions with developers of the SmartWorm App).
- Assessment of the benefits of co-grazing at different ratios of cattle relative to sheep, taking care of risks associated with liver fluke.
- Integration of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.

Farm 5 – Oliver McKenna

Farm background

Beef cattle enterprise. Suckler cows and stores, mixed breed, 50-99, split calving between autumn and spring. Grazing rotation system with movement determined by grass availablity, return < 3 weeks, rotation with other cattle.

Identified positive parasite management strategies on farm prior to project start:

- Weighing platform available on farm with individuals weighed and treated accordingly.
- Regular FECs are carried out in association with local vet.

Identified areas of improvement for parasite management strategies prior to project start:

- FGS and SGS batches each receive three anthelmintic treatments throughout the grazing season.
- Lungworm vaccine (Huskvac) not applied.
- Regular application of dose and move strategy with cattle moved onto 'clean' pasture post treatment to reduce reinfection rate.
- Unsure of applying targeted approaches at the beginning of the project and initially unwilling to change from a pre-set treatment plan.
- FECRT with vet confirmed Group 3 ML anthelmintic resistance prior to the start of the project.

2021 grazing season summary

- Tracked three batches of cattle. Batch 1: weanling heifers (n = 8) 2020 spring born. Batch 2: SGS calves (n = 14) nine 2020 spring born and five 2019 autumn born. Batch 3: dams and calves (n = 38) 19 of each.
- 20 FECPAK^{G2} submissions (**Fig. 39**) were completed by the farmer in 2021. FECs were often performed on an individual animal basis. Supplementary QUB FECs completed on 08/06/2021 (**Fig. 40** and **Fig. 41**) and 23/09/2021 (**Fig. 42** and **Fig. 43**). Liver and rumen fluke diagnostics performed on 23/09/2021. Low numbers of rumen fluke eggs detected; no liver fluke eggs detected.
- FEC based TT applied during the grazing season.
- Regular dung samples were sent by post to QUB for lungworm analysis.
- Anthelmintic treatments were reduced and delayed – but applied treatments when coughing heard in batches.

TT/TST options provided

Option 1: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turnout without treatment.
- **Assess group pooled FEC every 2 weeks:**
  - FEC 0–100 epg, don't treat, re-sample 2 weeks later.
  - FEC >200 epg, treat whole group (**TT**).
  - FEC 100-200 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 2: TST – Treatment based on individual DLWG/weight targets

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:

- Turnout without treatment.
- **Assess ability to reach individualised targets by weighing every 2 weeks.**
  - Treat according to traditional farm weight targets, i.e. treat individuals not meeting desired target weight.

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- Group pooled FEC every 2-3 weeks after turnout.
- Switch to a **TT** strategy if infection spike observed i.e. treat the whole group.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 3: TT – Treatment based on group pooled FEC

Benefits of strategy:

- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:

- Turn out without treatment.
- **Assess group pooled FEC every 2 weeks:**
  - FEC 0-100 eggs per gram (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-200 epg, don't treat, but re-sample group again 5-7 days later.
  - FEC >200 epg, treat whole group (TT).

Possible risks:

- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:

- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

January	February	March	April	May	June	July	August	September	October
	1		2	5	5		3	4	

Received	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	Individual Only	1031	Cattle	295093	92697	Cows	Moderate	-	-	0	0	0	**0**
19/04/2021	Individual Only	477	Cattle	311533	94149	Cows	Moderate	-	-	0	0	0	**0**
23/04/2021	14 heifers	-	Cattle	312753	94321	Heifers	Good	-	-	0	80	0	**80**
08/05/2021	14 heifers		Cattle	314465	94776	Heifers	-	-	-	0	0	0	**0**
08/05/2021	Autumn 2020 heifers		Cattle	314466	94777	Heifers	-	-	-	0	0	0	**0**
08/05/2021	Individual Only		Cattle	314467	94778	-	-	-	-	0	0	0	**0**
24/05/2021	Individual Only		Cattle	316622	95332	-	-	-	-	0	0	0	**0**
24/05/2021	8 heifers		Cattle	316623	95333	-	-	-	-	0	80	0	**80**
28/06/2021	Individual Only	1133	Cattle	319526	96640	-	-	-	-	0	40	0	**40**
28/06/2021	Individual Only	1119	Cattle	319527	96641	-	-	-	-	0	100	0	**100**
28/06/2021	Individual Only	1152	Cattle	319528	96642	-	-	-	-	0	60	0	**60**
30/06/2021	Individual Only	1153	Cattle	319967	96835	-	-	-	-	0	80	0	**80**
30/06/2021	Individual Only	1151	Cattle	319968	96836	-	-	-	-	0	0	0	**0**
03/08/2021	Individual Only	1174	Cattle	324119	98390	Calves	-	-	-	0	20	0	**20**
03/08/2021	Individual Only	845	Cattle	324120	98391	Cows	-	-	-	0	20	0	**20**
03/08/2021	Individual Only	1171	Cattle	324121	98392	Calves	-	-	-	0	0	0	**0**
04/09/2021	Individual Only	1128	Cattle	328557	99953	-	-	Dectomax 10mg/ml Solution	29/06/2021	0	260	0	**260**
04/09/2021	Individual Only	1110	Cattle	328558	99954	-	-	Dectomax 10mg/ml Solution	29/06/2021	0	0	20	**0**
04/09/2021	Individual Only	1116	Cattle	328559	99955	-	-	Dectomax 10mg/ml Solution	29/06/2021	0	0	0	**0**
04/09/2021	Individual Only	1136	Cattle	328566	99962	-	-	Dectomax 10mg/ml Solution	29/06/2021	0	20	0	**20**

Fig. 39. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

The participant farmer contacted authors on 03/08/2021 stating that coughing had been heard in multiple batches of cattle. Farmer proposed collecting a set of individual dung samples from coughing individuals. Three individual samples were analysed on the FECPAK^{G2} yielding GIN counts of 20, 20 and 0 strongyle EPG. Four dung samples were also sent by first class post to QUB for lungworm diagnostics – samples arrived 05/08/2021. Samples were negative for lungworm L1. On 17/08/2021 farmer was vaccinating spring born calves (with dams) for pneumonia and applied Dectomax injection at the same handling timepoint. Calves at this stage were still 6-8 weeks from weaning. Anthelmintic treatment applied to reduce future handling.

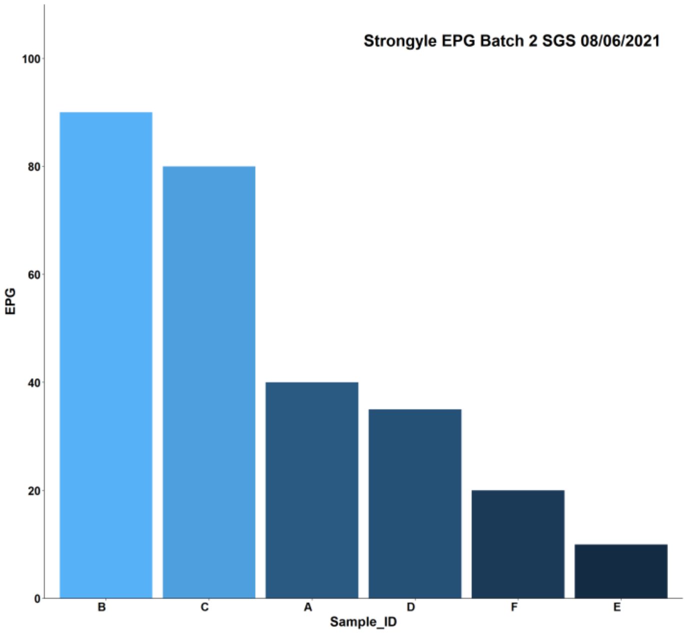


Fig. 40. Batch 2 SGS calves FECs carried out by QUB on 08/06/2021. 6 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

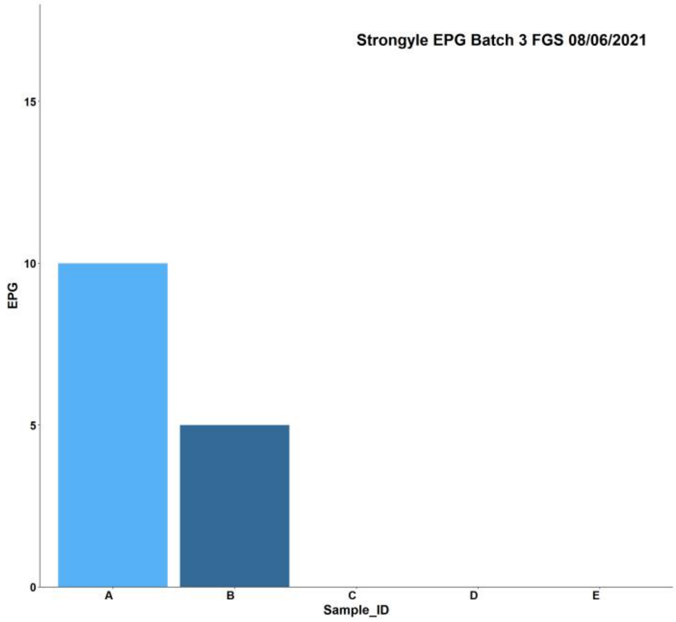


Fig. 41. Batch 3 FGS calves FECs carried out by QUB on 08/06/2021. 5 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

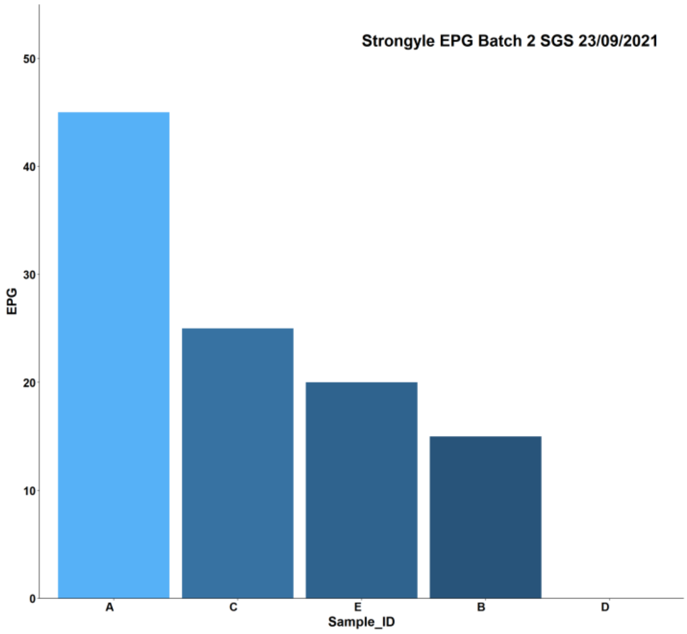


Fig. 42. Batch 2 SGS calves FECs carried out by QUB on 23/09/2021. 5 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

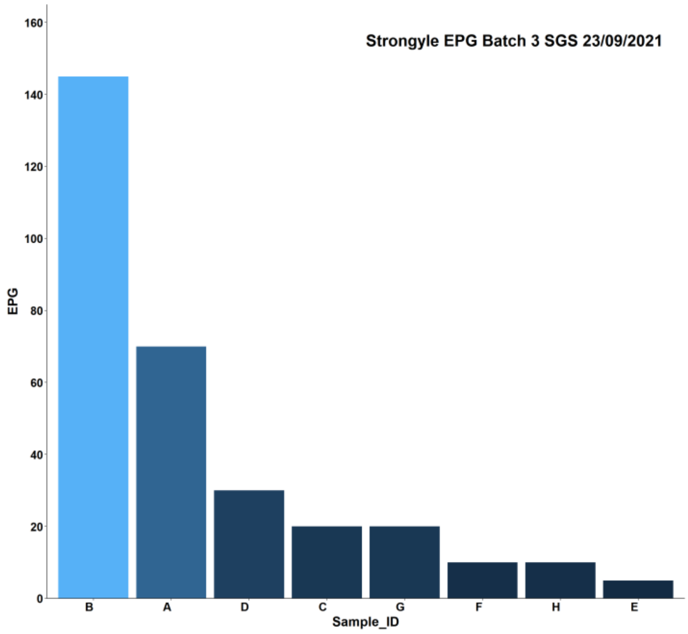


Fig. 43. Batch 3 cows and calves FECs carried out by QUB on 23/09/2021. 6 individual dung samples from cows and 2 dung samples from calves (G and H). Analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Batch 2 cattle received a Dectomax injection on 29/06/2021 following the observation of coughing in the group and a couple of animals showing poor condition (poor body form and dry hair). Five individual FECPAK^{G2} samples collected the day prior to anthelmintic application. Samples submitted on 28/06/2021 and 30/06/2021 - average of 56 strongyle EPG.

2022 grazing season summary

- Tracked three batches of cattle. FGS batch and two SGS batches (FGS in 2021).
- 18 FECPAK^{G2} submissions (**Fig. 44**) by farmer and supplemented by QUB FECs on 25/04/2022 (**Fig. 45** and **Fig. 46**). Additional dung samples were sent to QUB by post for lungworm and fluke analysis.
- Increased regularity of weighing (**Table 4** and **Table 5**). Liveweight gains of many individuals documented to be below target weight at multiple points in the season.

January	February	March	April	May	June	July	August	September	October
					3		9	3	3

Sample Collected	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
10/06/2022	Individual Only	845	Cattle	375905	109432	-	-	-	-	0	0	0	**0**
10/06/2022	Individual Only	1212	Cattle	375908	109435	-	-	-	-	0	0	0	**0**
10/06/2022	Individual Only	1205	Cattle	375909	109436	-	-	-	-	0	20	0	**20**
05/08/2022	Individual Only	1214	Cattle	382825	111865	-	-	-	-	0	0	0	**0**
05/08/2022	Individual Only	1216	Cattle	382826	111866	-	-	-	-	0	0	0	**0**
05/08/2022	Individual Only	1203	Cattle	382827	111867	-	-	-	-	0	140	0	**140**
05/08/2022	Individual Only	1207	Cattle	382866	111899	-	-	-	-	0	60	0	**60**
05/08/2022	Individual Only	1206	Cattle	382867	111900	-	-	-	-	0	20	0	**20**
05/08/2022	Individual Only	941	Cattle	382868	111901	-	-	-	-	0	0	0	**0**
23/08/2022	Individual Only	unknown (11 heifers)	Cattle	384598	112595	-	-	-	-	20	300	0	**320**
23/08/2022	Individual Only	1175	Cattle	384599	112596	-	-	-	-	0	100	0	**100**
23/08/2022	Individual Only	1179	Cattle	384600	112597	-	-	-	-	0	0	0	**0**
06/09/2022	Individual Only	1167	Cattle	385942	113330	-	-	-	-	0	200	0	**200**
06/09/2022	Individual Only	1171	Cattle	385943	113331	-	-	-	-	0	100	0	**100**
06/09/2022	Individual Only	1165	Cattle	385944	113332	-	-	-	-	0	0	0	**0**
06/10/2022	Individual Only	1025	Cattle	388904	114600	-	-	-	-	0	20	0	**20**
06/10/2022	Individual Only	1209	Cattle	388905	114601	-	-	-	-	0	80	0	**80**
06/10/2022	Individual Only	1211	Cattle	388906	114602	-	-	-	-	0	280	0	**280**

Fig. 44. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

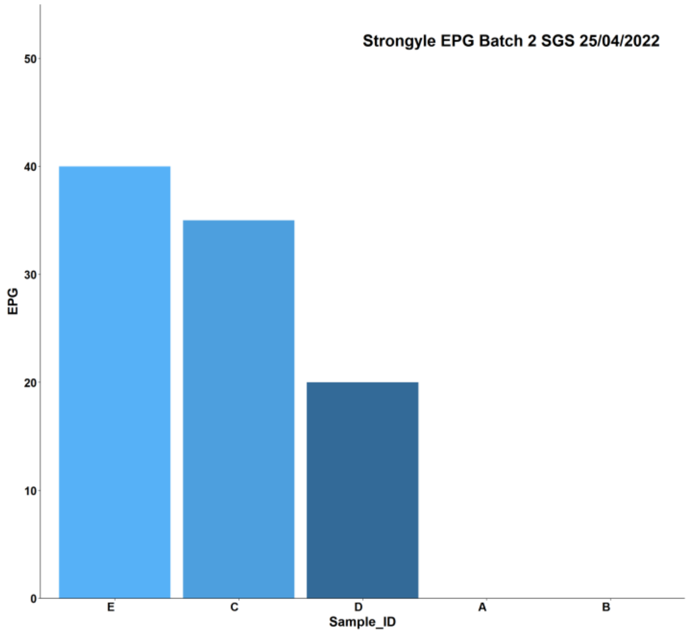


Fig. 45. Batch 2 heifers SGS FECs carried out by QUB on 25/04/2022. 5 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

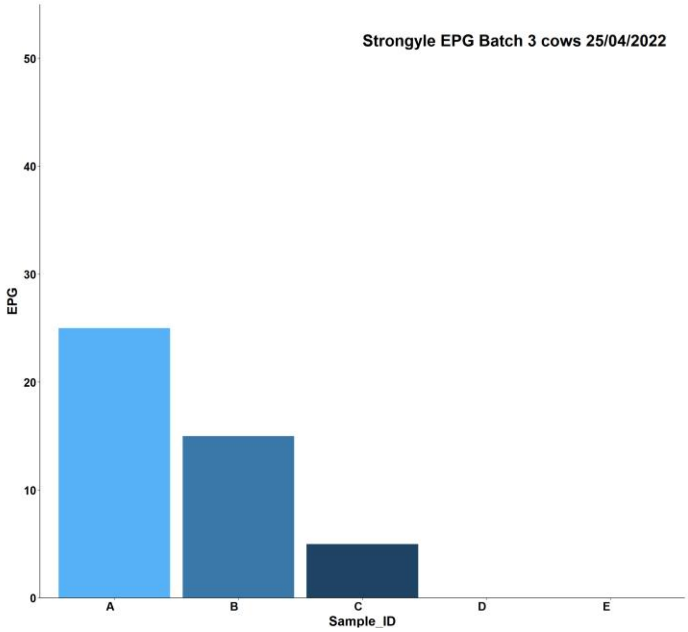


Fig. 46. Batch 3 cows FECs carried out by QUB on 25/04/2022. 5 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

The participant farmer contacted authors on 18/10/2022 stating that coughing had been heard in multiple batches of cattle. Eight dung samples were sent by first class post to QUB for lungworm diagnostics – samples arrived 27/10/2022. Only one sample, a spring born 2022 bull calf, was positive for low numbers of lungworm L1.

The farmer also contacted authors on 27/03/20223 to request FEC analysis of fluke and strongyles. Four dung samples sent by first class post to QUB – samples arrived 29/03/2023 (3 cows, 1 year old heifer). Strongyle counts ranged from 0 – 15 EPG. Low levels of rumen fluke eggs were detected; no liver fluke eggs detected.

Table 4. Liveweight measurements for Batch 2 heifers SGS in 2022 i.e. the original FGS spring born calves from 2021 grazing season (Batch 1).

	04/05/2022		**06/09/2022**	
Individual ID	**Liveweight (kg)**	**DLWG (kg/day)**	**Liveweight (kg)**	**DLWG (kg/day)**
1157	504	0.57	582	0.62
1161	373	0.63	438	0.52
1162	430	0.89	479	0.39
1165	439	0.93	510	0.57
1166	405	0.7	435	0.24
1167	428	0.35	506	0.62
1171	424	0.35	506	0.66
1173	430	0.67	534	0.83

Table 5. Liveweight measurements for Batch 3 heifers SGS in 2022 i.e. autumn born calves from 2021 grazing season.

	29/08/2022	
Individual ID	**Liveweight (kg)**	**DLWG (kg/day)**
1175	405	0.66
1192	388	0.92
1182	414	0.69
1178	420	0.79
1180	372	0.35
1187	418	0.74
1190	422	1.06
1179	418	0.51
1186	421	0.67
1191	371	0.65
1176	495	0.94

Anthelmintic treatments:

Twenty spring born calves (FGS) treated with Panacur on 14/06/2022 due to widespread coughing among calves. FGS calves were treated with Ovidrench on 05/08/2022 due to lungworm concerns. SGS batch 1 (batch of 11 heifers) – an individual FECPAK^{G2} submission showed egg count of 320 EPG in mid-August combined with group wide coughing. A subsequent fenbendazole oral drench applied. SGS batch 2 (8 spring 2021 born heifers) - an individual FECPAK^{G2} submission showed an egg count of 200 EPG in early September, coughing group wide. Levamisole treatment QUADROSOL 10% injectable or Anthelminticide 15% applied on 06/09/2022. Farmer noted difference in drug application rate - QUADROSOL 10% had dosage of 1 ml/20 kg, Anthelminticide 15% had a dosage of 1.2 ml/20 kg. Seven of the FGS heifer calves received a panacur anthelmintic treatment on 11/10/2022 pre-housing. The 13 FGS bull calves received Anthelminticide on 24/10/2022. These calves were dosed based on lungworm fears at housing. Farmer suggested that group coughing may also be attributed to by pneumonia. SGS batch 1 (batch of 11 heifers) – received Endospec SC on 03/11/2022. The first six autumn calving cows also received this anthelmintic treatment. Twenty autumn 2022 calves (n = 22) were treated with Anthelminticide on 19/12/2022 due to widespread coughing in the group at this stage. Adult cows received Bimectin plus on 07/01/2023 for the treatment of liver fluke. Meanwhile, heifers (SGS, FGS batch from 2022) received Bimectin plus on 23/02/2023. Farmer noted that the heifer batches were not thriving early in 2023 and thus received an additional Endospec anthelmintic treatment after the Bimectin plus.

Main improvements to parasite management throughout the project:

- Regular liveweight measurements and continued dosing animals to weight.
- Reduced anthelmintic treatments by two events per individual per year.
- Integration of regular individual FECs and lungworm assessments.
- Anthelmintic rotations introduced in 2022 rotating between ivermectin, levamisole and benzimidazole based anthelmintic treatment.

Suggested future improvements for on farm parasite management:

- Combination fluke and worm anthelmintic treatments are applied in the house early in the year prior to grazing despite the application of a pre-house treatment. Fluke only anthelmintic treatments at this time point may prove more beneficial.
- Despite applying treatments using a TT strategy based on group FECs, some anthelmintic treatments were still applied when they may not have been required. These additional treatments are largely aimed towards lungworm control as opposed to GINs. Improved lungworm diagnostics and timing of sample collections relative to treatment will help reduce these treatments further.
- TST was not carried out at any point during the project. Future trials on-farm using smaller batches focusing on liveweight based TST may be feasible.
- Integration of lungworm vaccine into parasite management.
- Calf rearing enterprise started (cattle brought onto farm at three weeks of age). Farmer advised on how to quarantine effectively for older stock bought in that may contain parasites.

Farm 6 – John Martin

Farm background

Sheep enterprise. Grazing another dairy calves from another farm from 2021 onwards as the farmer was keen to get away from an all-sheep enterprise from a parasite perspective. EIP project focused on parasite management in sheep. Short overwinter housing period ~6 weeks. Split lambing period with first lambing in early January before turn out onto Redstart forage crop. Second lambing period in mid-March with turnout quickly after, spread out across farm in small groups and amalgamated as grass grows. January born lambs normally replacements. 650 ewes + lambs in 2021. Ewes and lambs split into 10-12 batches of smaller numbers. Complex rotational grazing system.

Identified positive parasite management strategies on farm prior to project start:

- Ewe anthelmintic treatment was reduced to one per season prior to project start.
- Some TT/TST practices already established on farm prior to project start including TT based on flock level drops in liveweight gain or high pooled FECs. Treatment of a proportion of the flock on the basis of DLWG was also trialled during the 2020 grazing season. The farmer was already aware of the concept of refugia.
- Regular FECs carried out in association with local vet.
- Each animal already treated according to liveweight.
- Calibration of dosing equipment performed at each treatment event, replacing equipment as required.
- Lambs moved to moderate pasture contamination post treatment with lambs treated and put back onto same pasture for a few days before rotation.
- Good nematodirus vigilance including use of SCOPS forecast.
- Always quarantine with a Group 4 + flukicide and yard for a few days, turning out onto moderately contaminated pastures post-quarantine.

Identified areas of improvement for parasite management strategies prior to project start:

- Lambs traditionally receive more than four treatments per grazing season.
- Group 1 anthelmintic resistance confirmed previously by drench check.

2021 grazing season summary

- Tracked one batch of lambs in detail. The second TST batch was sampled more irregularly.
- 19 FECPAK^{G2} submissions (**Fig. 47**) with QUB FECs completed on 20/04/2021, 02/06/2021, 25/06/2021, 09/07/2021 and 26/07/2021 (**Fig. 48** – **Fig. 53**). **Table 6** - **Table 11** show levels of additional parasite species detected. FECs remained high throughout grazing season.
- Zolvix ‘break dose’ applied mid-August. Zolvix drug efficacy checked pre- and post-treatment using tied samples. Rectal dung samples collected by farmer. 16 pre- and post-treatment dung samples collected from individuals by farmer on 25/06/2021 and 09/07/2021.

- TST applied on two separate occasions based on FECPAK and dag score or DLWG. For example, in June 2021 lambs were thriving but *Nematodirus battus* remained at 35 EPG. Farmer took decision to apply TST, only treating individuals that were scouring.
- Liveweight measurements at multiple time points (**Fig. 54**).
- Anthelmintic treatments maintained at four per season.
- Mortality of some January born lambs with suspected *Nematodirus battus* when treatment withheld. Lambs grazed previous years pasture for two weeks before going onto Redstart in early February. Possible that some *Nematodirus battus* L3 survived overwinter as conditions would not have allowed L3 hatching from developed eggs already on pasture.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 eggs per gram faeces (epg), don't treat, re-sample 2 weeks later.
  - FEC 100-250 epg, don't treat, but re-sample group again 5 - 7 days later.
  - FEC >250 epg, treat whole group.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 2: TST – Treatment based on individual DLWG/weight targets

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess ability to reach individualised targets by weighing (lambs) every 2 weeks.**
  - Treat according to traditional farm weight targets, i.e. treat individuals not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- Adjust weight thresholds if pasture is heavily contaminated.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Group pooled (lambs) FEC every 2-3 weeks after turnout.
- Switch to a **TT** strategy if infection spike observed i.e. treat the whole group.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

Option 3: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC (lambs) every 2 weeks:**
  - FEC 0-100 epg, don't treat, re-sample 2 weeks later.
  - FEC >250 epg, treat whole group (**TT**).
  - FEC 100-250 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Nematodirus infections.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Use of Nematodirus SCOPS forecast. Apply white (BZ) drench if required.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for fluke testing.

January	February	March	April	May	June	July	August	September	October
	1	1		4	6	3	2	2	

Recieved	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	Testing		Sheep	295094	92698	Ewes	-	-	-	0	0	0	**0**
08/03/2021	Testing		Sheep	299012	92981	Lambs	Moderate	-	-	35	0	0	**0**
04/05/2021	january 21 lambs		Sheep	313975	94613	Lambs	Good	Ovidrench S&C 2.5%	16/04/2021	35	105	0	**140**
04/05/2021	2021 TST trial mob 1		Sheep	313976	94614	Lambs	Good	Ovidrench S&C 2.5%	14/04/2021	0	0	0	**0**
05/05/2021	2021 TST trial mob 1		Sheep	314229	94630	Lambs	Good	Tolracol	01/05/2021	0	0	0	**0**
24/05/2021	january 21 lambs		Sheep	316592	95303	Lambs, rams	Moderate	Noromectin Drench	05/05/2021	175	315	0	**490**
13/06/2021	2021 TST trial mob 1		Sheep	318172	96039	Lambs	Good	Tramazole SC 2.5%	31/05/2021	0	245	0	**245**
17/06/2021	2021 first weaned March lambs		Sheep	318611	96218	Lambs	Excellent	Tramazole SC 2.5%	07/06/2021	35	35	0	**70**
21/06/2021	january 21 lambs		Sheep	318928	96325	Lambs, rams	Moderate	Noromectin Drench	05/05/2021	245	280	0	**525**
21/06/2021	2021 TST trial mob 1		Sheep	318971	96361	Lambs	Good	Tramazole SC 2.5%	31/05/2021	140	280	0	**420**
25/06/2021	Own ewes lambs		Sheep	319400	96587	Lambs	-	Tramazole SC 2.5%	31/05/2021	70	525	0	**595**
28/06/2021	january 21 lambs		Sheep	319531	96645	Lambs, rams	Good	Noromectin Drench	20/06/2021	0	0	0	**0**
08/07/2021	january 21 lambs		Sheep	321171	97218	Lambs, rams	Good	Noromectin Drench	20/06/2021	0	105	0	**105**
19/07/2021	2021 ewe lamb replacements		Sheep	322519	97666	Lambs, ewes	Good	Noromectin Drench	06/05/2021	70	1400	0	**1470**
19/07/2021	2021 weaned ewe lambs		Sheep	322520	97667	Lambs, ewes	Good	Zolvix	30/06/2021	0	0	0	**0**
22/08/2021	2021 finishing ewe lambs including TST group		Sheep	326881	99366	Lambs, ewes	Good	Zolvix	25/06/2021	0	140	0	**140**
22/08/2021	2021 ewe lamb replacements		Sheep	326882	99367	Lambs, ewes	Good	Zolvix	25/06/2021	0	70	0	**70**
13/09/2021	2021 breeding ewe lambs to sell		Sheep	330564	100371	Lambs, ewes	Moderate	Levacide Low Volume 7.5%	13/08/2021	35	735	0	**770**
13/09/2021	2021 March ram lambs		Sheep	330565	100372	Lambs, rams	Moderate	Levacide Low Volume 7.5%	16/08/2021	70	595	0	**665**

Fig. 47. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

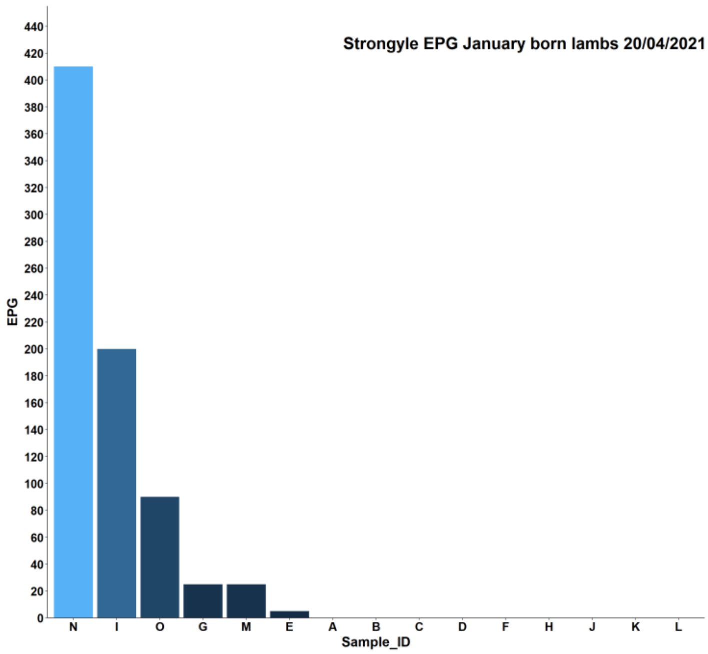


Fig. 48. January born lamb FECs carried out by QUB on 20/04/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

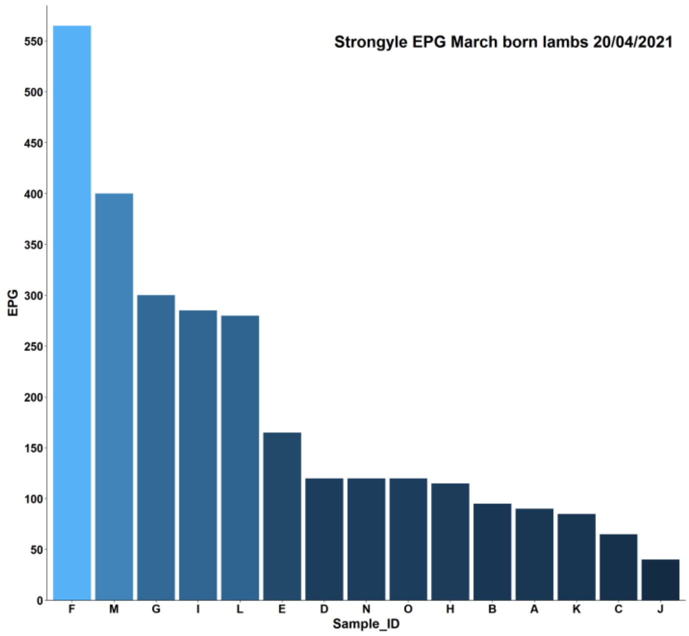


Fig. 49. March born lamb FECs carried out by QUB on 20/04/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 6. Additional parasite species and Eimeria oocysts per gram (OPG) isolated from January born lamb dung samples collected 20/04/2021.

Individual ID	*Nematodirus battus* EPG	*Trichuris ovis* EPG	*Strongyloides papillosus* EPG	Eimeria OPG
A	10	10	5	110
B	0	30	0	1225
C	0	25	15	230
D	0	20	15	335
E	0	0	0	90
F	0	5	0	335
G	5	0	0	3790
H	0	0	0	65
I	0	0	0	5
J	0	5	0	1100
K	0	0	0	110
L	0	0	0	550
M	25	10	15	80
N	0	0	0	0
O	0	0	0	130

Table 7. Additional parasite species and Eimeria oocysts per gram (OPG) isolated from March born lamb dung samples collected 20/04/2021.

Individual ID	*Nematodirus battus* EPG	*Trichuris ovis* EPG	*Strongyloides papillosus* EPG	Eimeria OPG
A	5	0	0	5
B	0	0	0	10
C	0	10	0	0
D	0	0	0	0
E	0	0	0	15
F	0	0	0	20
G	0	0	0	0
H	0	0	0	0
I	0	0	5	0
J	0	0	0	0
K	0	0	0	0
L	0	0	0	20
M	0	0	0	20
N	0	0	0	25565
O	0	20	0	55

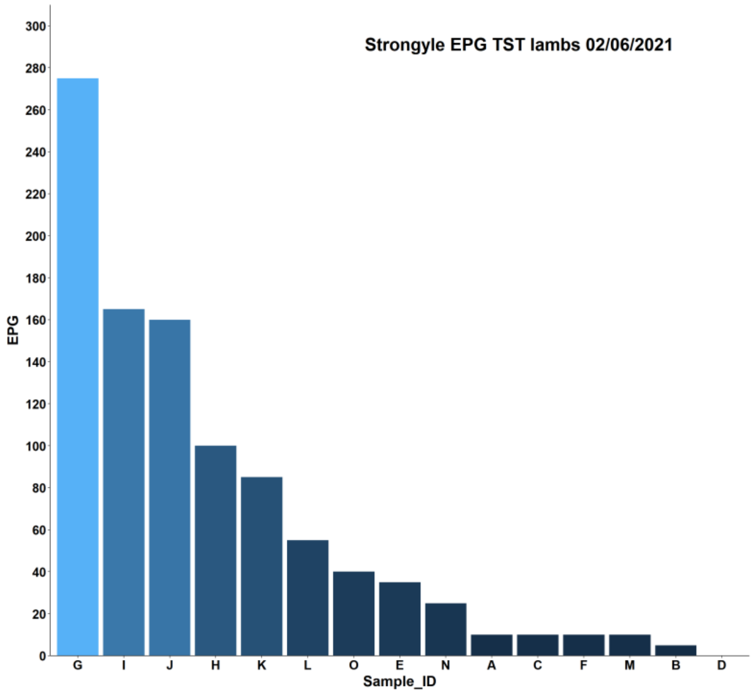


Fig. 50. March born lambs pre-TST application FECs carried out by QUB on 02/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 8. Additional parasite species from pre-TST lambs, dung samples collected 02/06/2021.

Individual ID	*Nematodirus battus* EPG
A	35
B	25
C	0
D	0
E	0
F	5
G	0
H	0
I	0
J	0
K	0
L	0
M	10
N	0
O	405

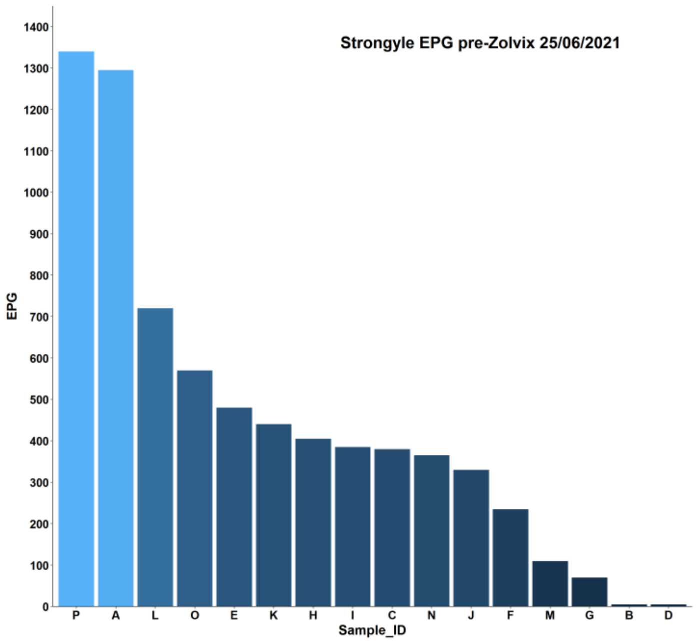


Fig. 51. FECs of March born TST lambs pre-Zolvix 'break dose' anthelmintic treatment on 25/06/2021. 16 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 9. *Nematodirus battus* EPG from pre-Zolvix treated lambs, dung samples collected 25/06/2021.

Individual ID	*Nematodirus battus* EPG
A	40
B	425
C	0
D	50
E	20
F	125
G	210
H	115
I	110
J	500
K	25
L	360
M	0
N	405
O	5

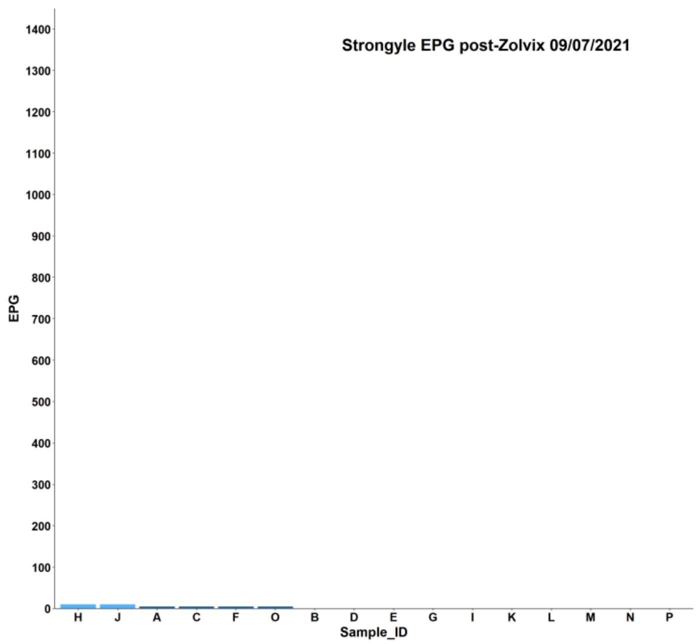


Fig. 52. FECs of March born TST lambs post-Zolvix 'break dose' anthelmintic treatment. Dung samples collected 09/07/2021. 16 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs. Y-*axis scale retained for visualisation of EPG reduction.*

Table 10. *Nematodirus battus* EPG following Zolvix treatment. Dung samples collected 09/07/2021.

Individual ID	*Nematodirus battus* EPG
A	0
B	0
C	0
D	0
E	0
F	0
G	0
H	0
I	0
J	0
K	0
L	0
M	0
N	0
O	0

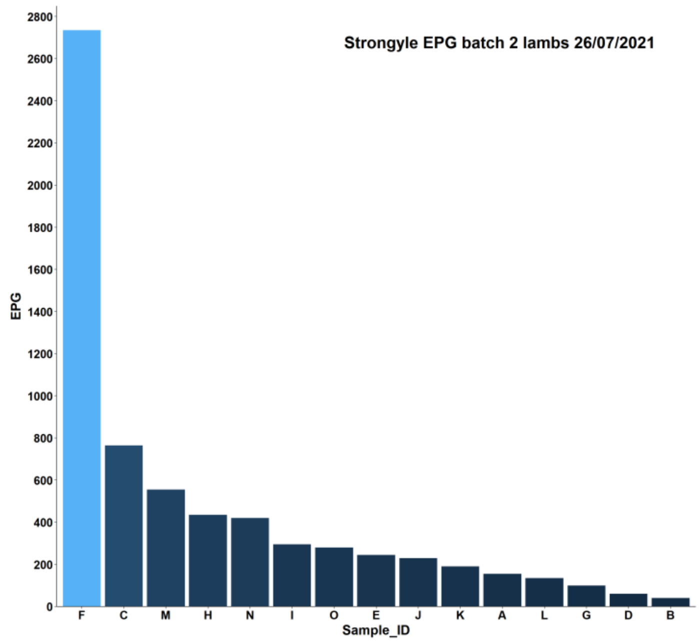


Fig. 53. FECs of March born TST lambs batch 2, dung samples collected 26/07/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 11. *Nematodirus battus* EPG batch 2 TST lambs, dung samples collected 26/07/2021.

Individual ID	*Nematodirus battus* EPG
A	5
B	0
C	15
D	5
E	0
F	20
G	10
H	0
I	0
J	35
K	0
L	0
M	0
N	0
O	5

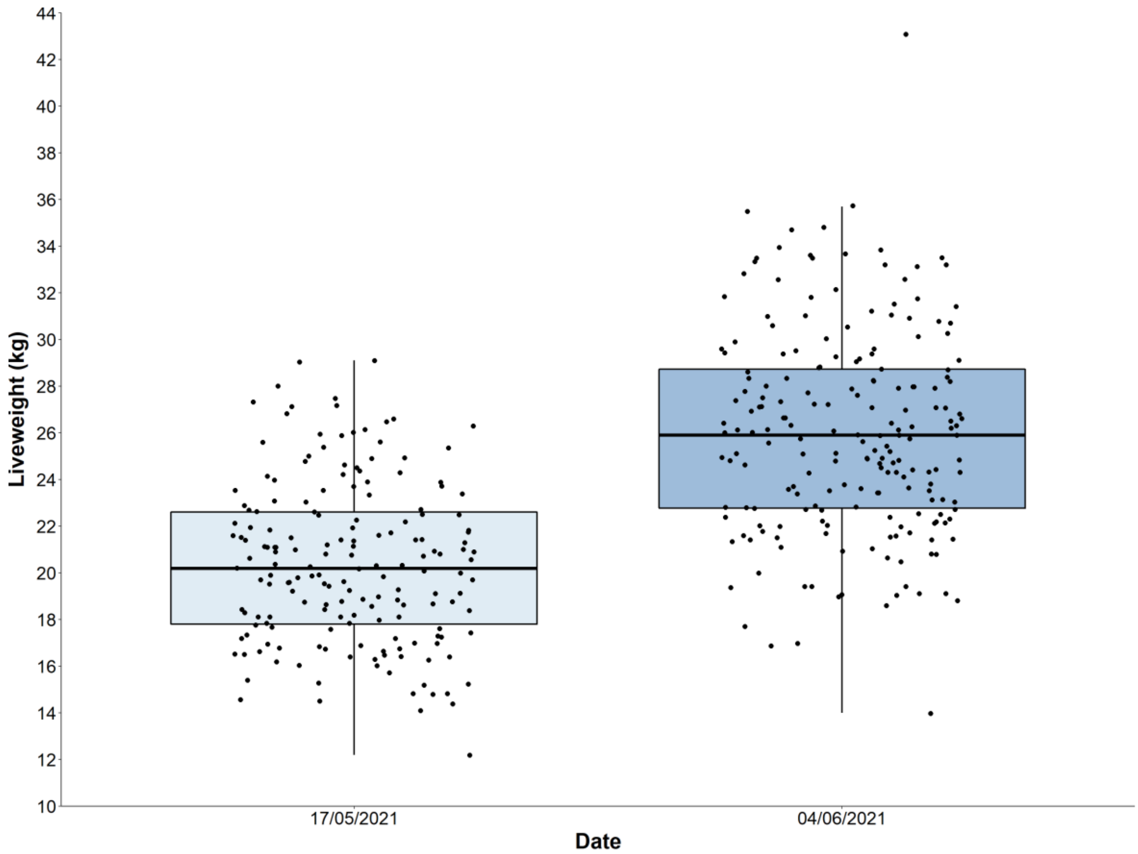


Fig. 54. Liveweight (kg) of Batch 1 TST lambs at two timepoints during 2021 grazing season.

Anthelmintic treatments:

Tracked March born lambs (Batch 1) received an ovidrench S&C 2.5% anthelmintic treatment for *Nematodirus battus* on 14/04/2021, tolracol on 01/05/2021 for the treatment of coccidiosis and a tramazole dose for *Nematodirus battus* on 31/05/2021. January born lambs received an ovidrench S&C 2.5% anthelmintic treatment for *Nematodirus battus* on 16/04/2021, a noromectin drench on 05/05/2021 and 20/06/2021. All lambs on farm received a 'break dose' of Zolvix between 25/06/2021 and 30/06/2021. Breeding ewe lambs to sell and March ram lambs were treated with levacide low volume 7.5% on 13/08/2021 and 16/08/2021, respectively.

2022 grazing season summary

- Multiple groups of lambs and ewes were tracked.
- 11 FECPAK^{G2} submissions (**Fig. 55**). Reduction in FECPAK^{G2} use due to the time required to collect and analyse the results – multiple gatherings of lambs.
- QUB FECs were completed on 01/04/2021 in a batch of January born lambs (**Fig. 56**) and a batch of ewes that lambed in March (**Fig. 57**). **Table 12** and **Table 13** show levels of additional parasite species detected.
- Anthelmintic treatment of ewes at lambing removed. However, in 2023 the farmer decided to reintroduce targeted treatments of ewes, treating only twin or triplet ewes.
- Anthelmintic treatments provided on a targeted basis using liveweight with treatment applied to lambs growing <200 g/day. This was reduced to those <180 g/day as the season progressed as all liveweight gains reduced due to weather and feed quality.
- SmartWorm App tested on 09/09/2022 for selection of individuals requiring anthelmintic treatment.
- Hosted Business Development Group meeting in July focusing on TST. Video webinar on TT/TST provided by Dr Christopher McFarland for the event.
- Challenging year from a grass growth perspective with extra feed required. Growth rates of lambs slower than average. There was not an unusually high number of lambs still on farm in December, however, the farmer supplied additional meal at 100 g/day throughout September, October and November.
- Zolvix anthelmintic treatment implemented as a 'break dose' in June.
- At the start of the 2023 grazing season a coccidiosis outbreak resulted in 10 lambs dying. Lambs were all March born and from the same batch which had grazed a particularly muddy field grazed by lambs in the previous grazing season. Samples were sent to VSD for analysis. Lambs were treated for Nematodirus the week prior to death. After 3-5 died treatment with Tolracol 50 mg/ml but some still died. Previous two years switched back to decox in feed mix for coccidiosis treatment.

January	February	March	April	May	June	July	August	September	October	November	December
				2		2	6				1

Sample Collected	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus FEC	Strongyle FEC	Strongyloides FEC	Total FEC
23/05/2022	2022 January lambs		Sheep	369391	108068	Lambs	Good	Tramazole SC 2.5%	06/04/2022	490	210	0	**700**
23/05/2022	2022 January lambs		Sheep	373421	108705	Lambs	Good	Tramazole SC 2.5%	04/05/2022	0	175	0	**175**
04/07/2022	2022 January lambs		Sheep	378609	110432	Lambs	-	Cydectin 0.1% Drench	20/06/2022	0	455	0	**455**
07/07/2022	2022 March lambs		Sheep	379518	110674	Lambs	Good	Zolvix	25/06/2022	0	0	0	**0**
01/08/2022	2022 finishing lambs	-	Sheep	382402	111694	Lambs	Good	Zolvix	04/07/2022	0	35	0	**35**
13/08/2022	2022 finishing lambs	-	Sheep	383916	112184	Lambs	-	Zolvix	04/07/2022	0	175	0	**175**
08/08/2022	2022 finishing lambs	-	Sheep	383917	112185	Lambs	Good	Zolvix	04/07/2022	0	175	0	**175**
15/08/2022	2022 finishing lambs	-	Sheep	384695	112684	Lambs	Good	Zolvix	04/07/2022	0	455	35	**455**
24/08/2022	2022 finishing lambs	-	Sheep	384699	112686	Lambs	Good	Zolvix	04/07/2022	0	420	0	**420**
17/08/2022	2022 med lambs	-	Sheep	384700	112687	Lambs	Good	Zolvix	04/07/2022	0	420	0	**420**
03/12/2022	2023 Jan lambing ewes		Sheep	394879	117526	Mixed age, ewes	Good	Endofluke	03/12/2022	0	350	0	**350**

Fig. 55. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

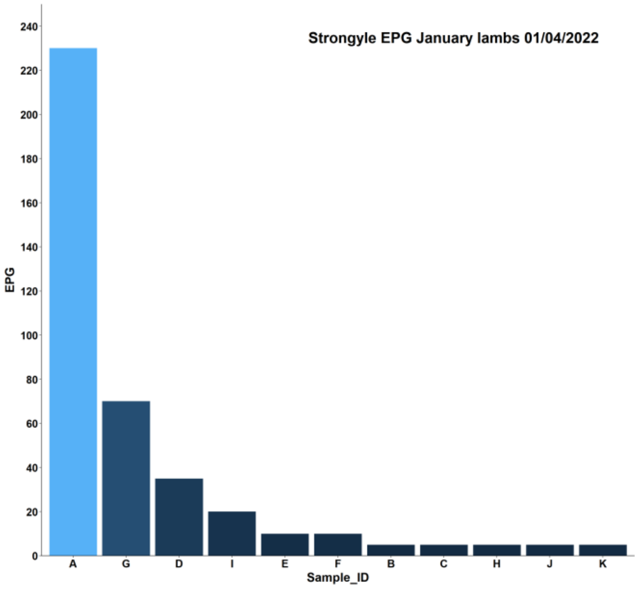


Fig. 56. FECs of January born lambs, dung samples collected 01/04/2022. 11 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 12. *Nematodirus battus* EPG and Eimeria OPG for January born lambs, dung samples collected 01/04/2022. Eimeria oocysts not speciated.

Individual ID	*Nematodirus battus* EPG	Eimeria OPG
A	5	11220
B	0	8640
C	5	20820
D	5	60
E	15	10740
F	0	28800
G	35	1860
H	5	11160
I	0	0
J	0	1140
K	10	2040

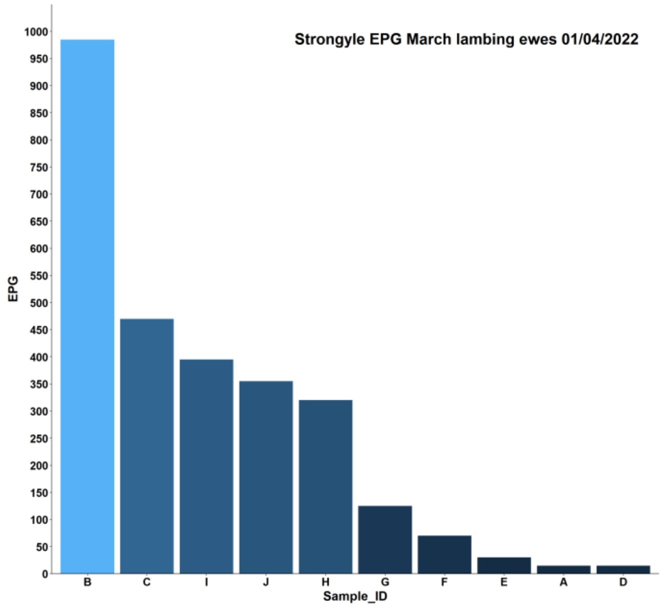


Fig. 57. FECs of March lambing ewes, dung samples collected 01/04/2022. 10 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Table 13. *Nematodirus battus* EPG for March lambing ewes, dung samples collected 01/04/2022.

Individual ID	*Nematodirus battus* EPG
A	0
B	0
C	0
D	0
E	0
F	0
G	0
H	0
I	0
J	0

Lambs weighed every 3-4 weeks. Small and medium lambs refers to those <34 kg whilst lambs >34 kg considered 'heavy lambs'.

Anthelmintic treatments: January born lambs received three group 1 anthelmintic treatments (tramazole SC 2.5%) for *Nematodirus battus* in mid-March, on 06/04/2022 and 04/05/2022. March born lambs received two group 1 anthelmintic treatments for *Nematodirus battus* in April and May. January born lambs received a cydectin dose on 20/06/2022. March born lambs received Zolvix break dose on 25/06/2022 and had not received any anthelmintic treatments prior to this. All finishing lambs (January born) received a Zolvix anthelmintic treatment on 04/07/2022. The SmartWorm App was tested on 09/09/2022 for selection of individuals requiring treatment. Individuals below a threshold of 0.66 received Startect anthelmintic treatment. Using the SmartWorm App the farmer left 29% of lambs untreated, when running approximately 460 lambs over the weighbridge. However, the farmer noted that subsequently about half of those untreated on the 09/09/2022 required anthelmintic treatment two weeks later as liveweight gains slowed and overall condition reduced. Some March born lambs remaining on farm received a further cydectin treatment in October 2022. Any anthelmintic treatments not applied for Nematodirus control were provided on a liveweight basis or through visual cues e.g. scouring.

Main improvements to parasite management throughout the project:

- Anthelmintic treatments were provided on a targeted basis in both 2021 and 2022 grazing season. This involved TST using DLWG alongside visual observations and group level FECs to inform treatment decision.
- Anthelmintic treatments were delayed and reduced at certain times of year due to improved information on species presence from FECPAK^{G2} system.
- Group 4 Zolvix anthelmintic treatments provided as a break dose in 2021 and 2022.
- On multiple occasions throughout the project the farmer utilised pre- and post-anthelmintic treatment FECPAK^{G2} submissions to examine drug efficacy for multiple drug classes.

Suggested future improvements for on farm parasite management:

- The farmer plans to integrate the SmartWorm App into future TST strategies.
- Assess benefits of co-grazing sheep and cattle on farm to reduce sheep parasites, taking care of risks associated with liver fluke.
- Continued use of Group 4 or Group 5 anthelmintics for quarantine with appropriate post-treatment strategies.

Farm 7 – Albert O'Neil

Farm background

Dairy enterprise. Cows and heifer replacements totaling approximately 100-200 individuals. Multiple calving periods in autumn, winter and spring. Rotational grazing system on basis of grass availability returning to same fields in < 3 weeks. Youngstock have pre-defined fields that are only used by FGS calves every year. Sheep from another farm graze fields for six weeks over the winter period.

Identified positive parasite management strategies on farm prior to project start:

- Movement of livestock onto fields with some parasite contamination following anthelmintic treatments.

Identified areas of improvement for parasite management strategies prior to project start:

- Anthelmintic treatments for FGS calves reliant on the use of long-acting agents e.g. Cydectin LA, with limited opportunity for development of natural immunity in the first grazing season.
- SGS cattle require more than three anthelmintic treatments at grazing. This may be prompted by reduced immunity development in the first grazing season.
- The farmer was not aware of the Huskvac lungworm vaccine.
- No weighing facilities were available on the farm. This resulted in the estimation of group weight and dosing of individuals to that weight. Subsequently, weighing equipment was purchased as part of the project.
- FECs were only employed for sick or scouring animals, not at group level decisions.

2021 grazing season summary

- Followed two batches of FGS calves:
    - **Batch 1:** Turnout on 13/04/2021. 30 individuals. Treated with Cydectin LA at turnout.
    - **Batch 2** = Turnout 21/04/2021. 30 individuals. No treatment at turnout.

- At the start of the project the farmer opted to use a mixed approach of FEC and liveweight data for targeting anthelmintic treatments.
- Calves were weighed every four weeks with the new weighing system integrated on farm –six weighing time-points for Batch 1 and five time-points for Batch 2 (**Fig. 58** - **Fig. 61**). However, farmer noted disagreements with farm workers on the cost benefits of increased effort required for liveweight monitoring compared to routine anthelmintic treatments.
- 7 FECPAK^{G2} submissions (**Fig. 62**) with QUB FECs completed on 08/06/2021 and 11/08/2021 (**Fig. 63 – Fig. 65**). First three FECPAK^{G2} submissions completed by farmer before opting to outsource FECPAK^{G2} analyses to local merchants due to time constraints.
- Due to weather conditions at the start of the 2021 grazing season the farmer took the decision to rehouse cattle for a short period in May before turning back out again.

TT/TST options provided

Option 1: TT – Treatment based on group pooled FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.
- Reduced handling.

Suggested actions:
- Turn out without treatment.
- **Assess group pooled FEC every 2 weeks:**
    - FEC 0-100 eggs per gram (epg), don't treat, re-sample 2 weeks later.
    - FEC 100-200 epg, don't treat, but re-sample group again 5-7 days later.
    - FEC >200 epg, treat whole group (TT).

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 2: TST – Treatment based on individual FEC

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turn out without treatment.
- **Assess individual FEC every 2 weeks:**
    - FEC <100 epg, don't treat, re-sample 2 weeks later.
    - FEC 100-200 epg, don't treat, but re-sample again 5-7 days later.
    - FEC >200 epg, apply treatment.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

Option 3: TT + TST – Treatment based on group pooled FECs and DLWG

Benefits of strategy:
- Promote development of parasite refugia on pasture.
- Reduce total number of anthelmintic treatments.
- Promote development of GIN immunity.

Suggested actions:
- Turnout without treatment.
- **Assess group pooled FEC every 2 weeks:**
    - FEC 0-100 epg, don't treat, re-sample 2 weeks later.
    - FEC >200 epg, treat whole group (**TT**).
    - FEC 100-200 epg, apply **TST** on basis of individual DLWG i.e. treat those not meeting desired target weight.

Possible risks:
- Increased GIN prevalence and increased pasture contamination levels.
- Those not treated will be exposed to lungworm.
- Some condition loss.
- Liver fluke infections.

Reducing risks:
- Consider contamination levels of pastures based on grazing history.
- More frequent FEC sampling or lower epg thresholds if pasture was heavily grazed last year.
- Weigh individuals every 4 weeks or sooner.
- Regular visual monitoring of whole group.
- QUB collect regular pooled faecal samples for lungworm and fluke testing.
- Treat whole group if lungworm larvae observed in faeces or coughing observed.

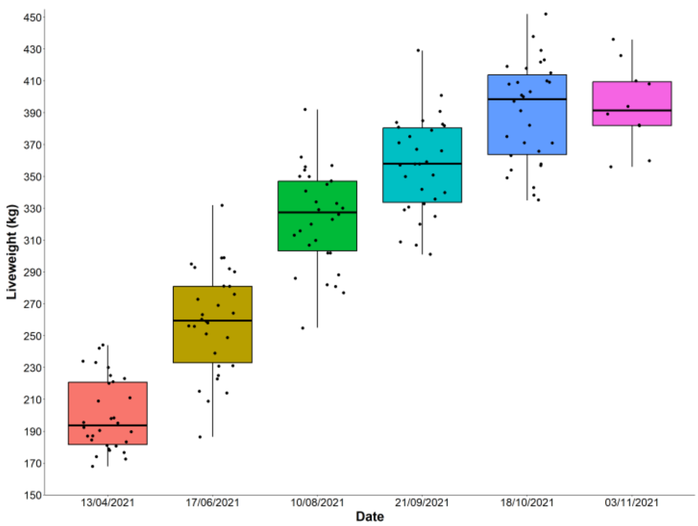


Fig. 58. Liveweight (kg) of Batch 1 FGS calves throughout the 2021 grazing season.

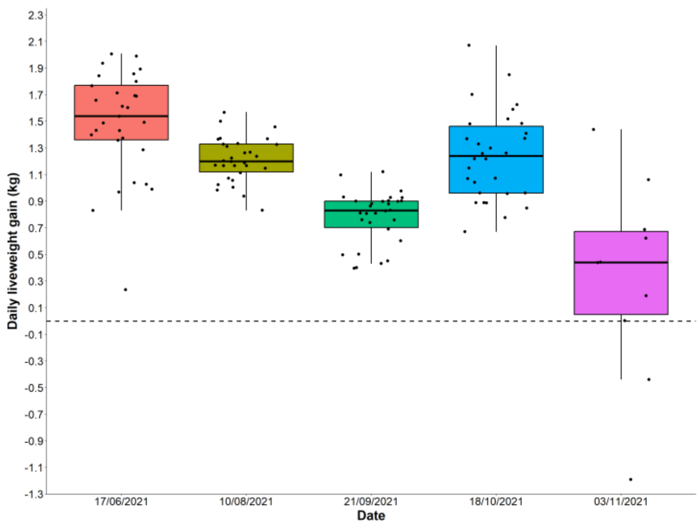
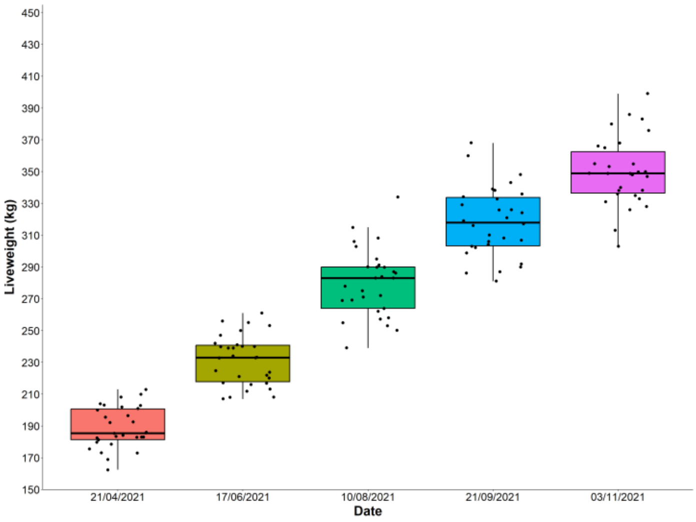


Fig. 59. Daily liveweight gain (kg) of Batch 1 FGS calves throughout the 2021 grazing season.



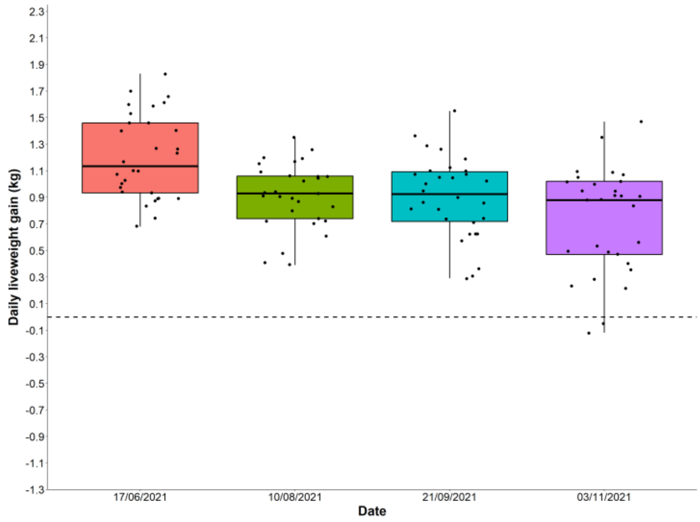


Fig. 60. Liveweight (kg) of Batch 2 FGS calves throughout the 2021 grazing season.

Fig. 61. Daily liveweight gain (kg) of Batch 2 FGS calves throughout the 2021 grazing season.

January	February	March	April	May	June	July	August	September	October
	1						2	2	2

Recieved	Mob Name	Individual Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
24/02/2021	left hand pen in calf heifers		Cattle	295095	92699	Dairy Heifers	-	-	-	0	0	0	**0**
06/08/2021	non treatment batch		Cattle	324987	98623	Dairy Heifers	Good	-	-	0	120	0	**120**
06/08/2021	non treatment batch		Cattle	324988	98624	Dairy Heifers	Good	-	-	0	40	0	**40**
21/09/2021	Untreated batch					Heifer cows	Good			0	20	0	**20**
21/09/2021	Cydectin LA batch					Heifer cows	Good			0	20	0	**20**
25/10/2021	Untreated batch					Heifer cows	Good			0	0	0	**0**
25/10/2021	Cydectin LA batch					Heifer cows	Good			0	60	0	**60**

Fig. 62. FECPAK^{G2} submissions by the farmer throughout the 2021 grazing season.

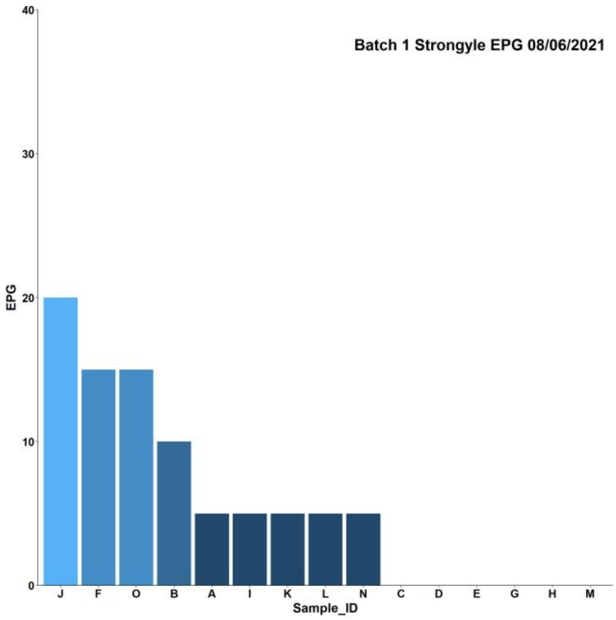


Fig. 63. Batch 1 FGS FECs carried out by QUB on 08/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

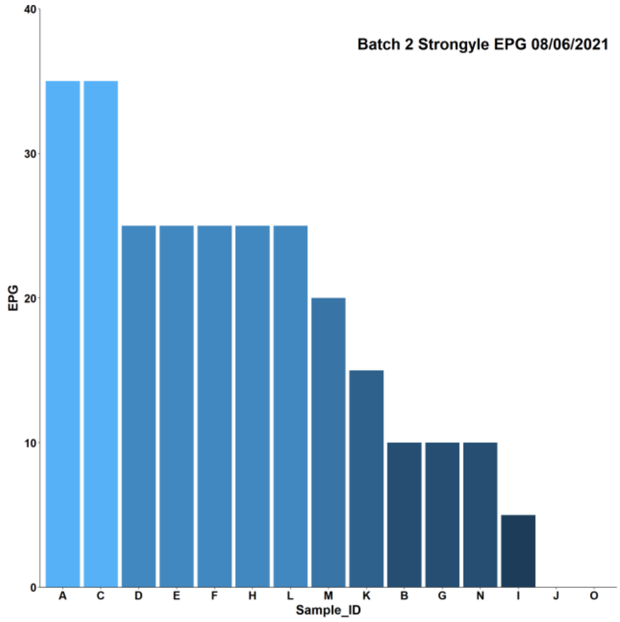


Fig. 64. Batch 2 FGS FECs carried out by QUB on 08/06/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

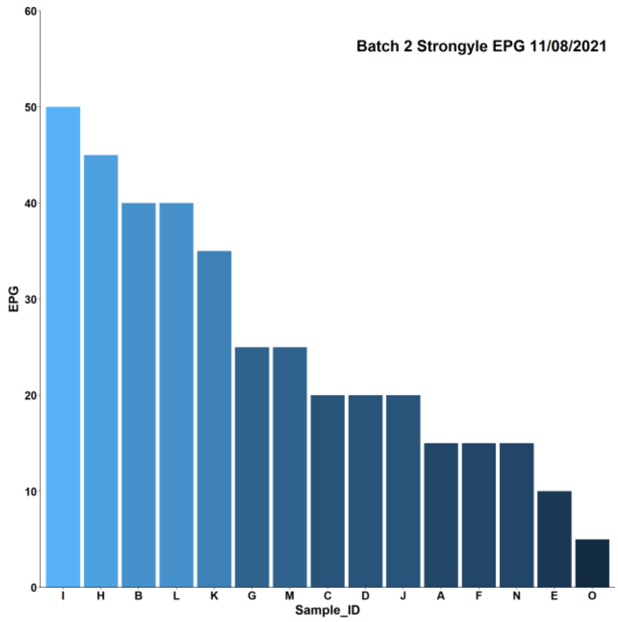


Fig. 65. Batch 2 FGS FECs carried out by QUB on 11/08/2021. 15 individual dung samples analysed using the Mini-FLOTAC method to assess the presence of strongyle (GIN) eggs.

Anthelmintic treatments: Batch 2 calves received an ivomec pour on anthelmintic treatment on 10/08/2021 at weighing. This batch observed decreased DLWG compared to the long-acting treatment batch. Batch 1 and 2 received a pour on cydectin triclamox treatment on 21/09/2022 for fluke and worms. Ten individuals from Batch 1 were housed on 18/10/2021 and at this point received another pour on cydectin triclamox treatment. The other 20 individuals in this batch were at this point sent to another farm for contract rearing for 10 months due to space limitations. Batch 2 individuals were retained on farm for observation in 2022 and housed on 24/10/2021. Batch 2 also received a cydectin triclamox treatment on 29/10/2021. Both batches were treated due to widespread coughing, despite anthelmintic treatments only a few weeks prior. However, Batch 2 FEC was at 0 EPG on 25/10/2021.

2022 grazing season summary

- Two batches of FGS calves and three batches of SGS calves (FGS from 2021) were tracked.
- The farmer noted that some SGS individuals were behind at the start of 2022 but caught up again quickly.
- All FGS and SGS calves received the Huskvac lungworm vaccine in 2022.
- The farmer implemented the vaccine for a second time at the start of the 2023 grazing season to FGS calves.
- 22 FECPAK^{G2} submissions (**Fig. 66**) were completed at a local merchant.
- Weight data only available for SGS cattle in 2022 (**Fig. 67** and **Fig. 68**) due to labour constraints.

January	February	March	April	May	June	July	August	September	October
				5	5	12			

Recieved	Mob Name	Animal Name	SampleID	LabID	Stock Class	Stock Condition	Drench	Last Treated	Nematodirus	Strongyle	Strongyloides	TOTAL EPG
25/05/2022	Halls Batch	Cattle	374275	108881	Calves	Good	-	-	0	0	0	**0**
25/05/2022	Below Brocky Calves	Cattle	374276	108881	Calves	Good	Never been treated	-	40	0	0	**40**
26/05/2022	Coolermoney Heifers	Cattle	374287	108892	Heifers	Good	-	-	0	0	0	**0**
26/05/2022	Middle Brae	Cattle	374288	108892	Heifers	Good	-	-	0	40	0	**40**
24/05/2022	Hendersons	Cattle	374289	108892	Heifers	Good	-	-	0	20	0	**20**
24/06/2022	Middle Brae	Cattle	377191	110124	Calves	Good	-	-	40	20	0	**60**
24/06/2022	Hendersons	Cattle	377192	110124	Heifers	Good	-	-	0	0	0	**0**
24/06/2022	Relff Grounds	Cattle	377193	110125	Heifers	Good	-	-	0	0	0	**0**
24/06/2022	Calves at Halls	Cattle	377194	110125	Calves	Good	-	-	0	0	0	**0**
24/06/2022	Big Heifers Halls	Cattle	377195	110125	Heifers	Good	-	-	0	0	0	**0**
07/07/2022	Claves down the road	Cattle	379190	110618	Calves	Good	Never been treated	-	0	20	0	**20**
14/07/2022	A	Cattle	380568	110871	Heifers	Good	-	-	0	0	0	**0**
14/07/2022	Big Heifers Halls	Cattle	380578	110873	Heifers	Good	-	-	0	60	0	**60**
14/07/2022	Calves Middle Bray	Cattle	380579	110873	Heifers	Good	-	-	0	0	0	**0**
14/07/2022	Big Moss	Cattle	380580	110873	Heifers	Good	-	-	0	0	0	**0**
14/07/2022	Calves at Halls	Cattle	380581	110874	Calves	Good	-	-	0	0	0	**0**
14/07/2022	Hendersons	Cattle	380582	110874	Calves	Good	-	-	0	0	0	**0**
26/07/2022	Animal 5899	Cattle	381846	111328	Cows	Good	-	-	0	0	0	**0**
26/07/2022	Animal 7372	Cattle	381847	111328	Cows	Good	-	-	0	20	0	**20**
26/07/2022	Animal 7191	Cattle	381848	111328	Cows	Good	-	-	0	0	0	**0**
26/07/2022	Animal 7157	Cattle	381849	111328	Cows	Good	-	-	0	0	0	**0**
26/07/2022	Individual Only	Cattle	381850	111328	Cows	Good	-	-	0	0	0	**0**

Fig. 66. FECPAK^{G2} submissions by the farmer throughout the 2022 grazing season.

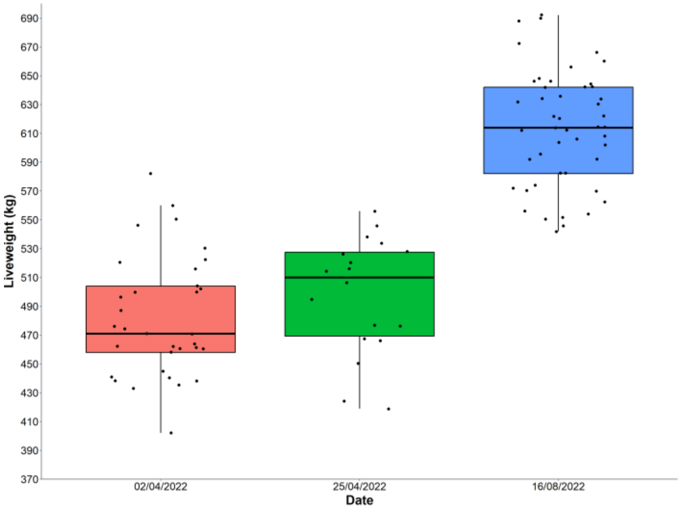


Fig. 67. Liveweight (kg) of Batch 2 SGS calves throughout the 2022 grazing season.

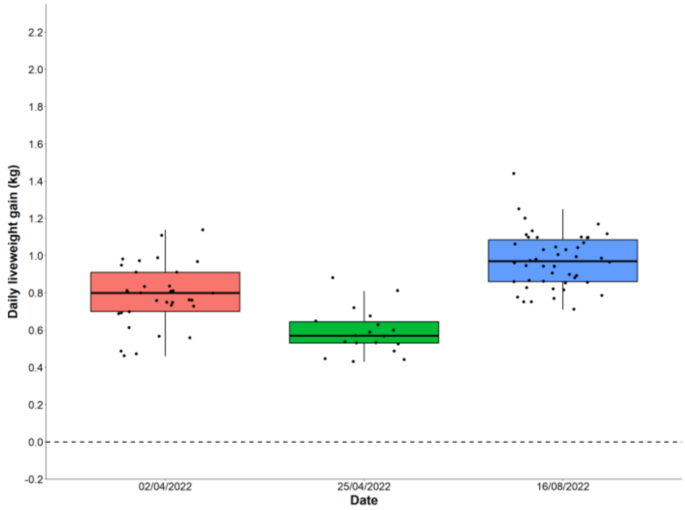


Fig. 68. Daily liveweight gain (kg) of Batch 2 SGS calves throughout the 2022 grazing season.

Anthelmintic treatments: 2022 FGS calves and heifers received the first and second huskvac vaccine doses on 01/04/2022 and 03/05/2022, respectively. A batch of smaller SGS cattle received ivomec pour on 20/07/2022. Whilst the FGS calves received their first anthelmintic treatment (ivomec pour on) on 29/07/2022. As these calves were grazed on another farm during the 2022 grazing season it was not possible to obtain weight data for anthelmintic application. Although FECs were low in this batch the decision was taken to treat the batch due to logistical issues with handling and fears of larval build up on pasture. All SGS heifers received a cydectin triclamox pour on 16/08/2022 or 18/08/2022. Anthelmintic treatment was applied due to fears around calving which ran between August and September. This was the only treatment the SGS heifers received in 2022. This was a considerable reduction compared to pre-project levels for SGS cattle which included anthelmintic treatment at turnout followed by treatments ever 6 weeks throughout the grazing season. The FGS cattle received a further ivomec pour on treatment on 22/09/2022 due to lungworm fears.

Main improvements to parasite management during project:

- Anthelmintic treatments on farm were traditionally carried out according to time of year – at turnout and then every six weeks thereafter. Targeted treatments applied throughout 2021 and 2022 grazing season leading to a reduction in the number of anthelmintic treatments given to both first and second grazing season cattle.
- Huskvac lungworm vaccine introduced to annual farm management for first grazing season cattle.
- The weighing platform purchased during the project has enabled the tracking of liveweight and improved accuracy of treatment application.

Suggested future improvements for on farm parasite management:

- The participant farmer has planned to reseed some fields with multi species swards in 2023 to help counter unreliable weather conditions i.e. both increased rainfall and drought. Farmer suggested this may also have additional benefits for livestock health and parasite development.

- The farmer is committed to nature friendly farming moving forward and at the centre of this is the continued surveillance of anthelmintic drug use.
- Continue with rotation of anthelmintic rotation throughout the grazing season. Anthelmintic treatments in 2022 seen application of macrocyclic lactone based anthelmintics at multiple time points i.e. ivomec pour on and also cydectin triclamox for fluke control.

4. **Assess the feasibility and practicality of undertaking targeted, selective treatment of anthelmintics on farms in Northern Ireland**

Cattle:

- Farms stocking cattle found TT easier to implement than TST simply due to the increased handling requirements often requiring a team of people for safe movements.
- Lungworm in cattle was a stumbling block to TT/TST approaches based on the farms surveyed. It may be at high-risk periods of the year a TT approach should be employed in favour of TST to allow treatment of all individuals. The decision to treat in this case would be based on the detection of lungworm L1 in faeces.
- All cattle farmers on the project suggested that they would consider using a lungworm vaccine or have already applied it throughout the project. However, all noted that the vaccine was difficult to obtain, and more information was required on optimal timing of vaccine application. Better education of veterinarians on the use of the vaccine was also noted as an important factor for uptake.

Sheep:

- The size of flock or herd must be an important consideration when determining the feasibility of TT/TST strategies on farm given the increased time and labour requirements.
- Lambs are easier to handle for TT/TST after weaning.
- Farmers raised fears that withholding treatments of best performing individuals at one timepoint, particularly in lambs, could set them back to the worst performing individuals after a 2-week interval. Additional costs associated.
- Treatment of lambs for *Nematodirus battus* on a prophylactic basis should be retained given the associated acute risks. However, the timing of these treatments should be determined by considering a number of factors including grazing history, FECs and parasite forecasts such as the *N. battus* SCOPS forecast.
- Outbreaks of coccidiosis should also be monitored, particularly in the early stages of the grazing season.

Parameter selection:

- TST approaches using individual FEC based methods appear only feasible on smaller farm enterprises or when used in a focused manner in smaller groups due to the associated costs.
- Farmer 3 commented that Farmer's eye was the most useful parameter for determining treatment requirement on their farm. Suggested this may be easier to achieve in a small batch of cattle compared to much larger batches of sheep.
- Using DLWG as a measurement in the case of lambs require 30-40 individuals to run through the crush before making a decision on a treatment threshold. These individuals likely all receive an anthelmintic dose.

General recommendations:

- Discussions with farmers suggested that we need to improve online resources for topics such as refugia and TT/TST. All agreed that the farm walks and seminars provided have improved their understanding of parasite management theory but practically employing management, particularly in a rotational grazing system provides difficult.
- Farmers also highlighted major obstacles that prevented applying TT or TST strategies included the variability in climate and year to year changes. In 2021 and 2022 grass growth seemed to be a particularly important factor that reduced liveweight gains later in the grazing season. Despite low FECs some farmers applied anthelmintic treatments in the hope this would improve liveweight gain however this was often unsuccessful.
- TT/TST appears feasible in NI but this will rely on a strong underlying infrastructure. For example all farmers agreed that the FECPAK^{G2} was beneficial when making on farm decisions. Reassurance factor. If not parasites prompts further investigation into what the issues could be. However, farmer impressions of the actual system varied from farm to farm. Many suggested that the system was still time consuming when considering the collection, sedimentation and reading steps. Some farmers also had continuous issues with connectivity throughout the project prompting multiple QUB visits in the absence of reliable connection. A hybrid setup such as that proposed by Fane Valley stores that provide FECPAK^{G2} support may prove more attractive for most farmers. One farm in the project decided to only use Fane Valley for FECPAK^{G2} submissions during the 2022 grazing season.
- Initial startup to the project appeared key to build confidence to go forward. Farmers reported that it was good to have additional support in the background.
- When we consider overall reductions in the number of anthelmintic treatments it is important to note the variability in the time it takes individual animals to make culling target weight. For example, high performing individuals may only receive a single anthelmintic treatment, whilst slower growing individuals could receive multiple anthelmintic treatments in a grazing season. This will ultimately be determined by complex interactions of multiple variables including parasites, non-parasite diseases, genetics, feed quality etc.
- Multiple levels need to be onboard with fundamental changes including researchers, veterinarians, drug merchants and the farmers themselves. Without this some farms may carry out TT/TST strategies very well, others not so, guided by the advice the farmer is provided with.
- Testing of drug efficacy to all available drug classes on farm should be a key priority when establishing TT/TST strategies.
- Complication of combining batches as the season progresses, particularly in sheep, mean that very good anthelmintic treatment records for each individual animal are required.
- Measures should be taken to ensure that farms are maintaining equipment that is calibrated and functioning accurately. For example weighing equipment and dosing equipment.

Final interview questions overview

Parasite epidemiology and control

1. *Do you have a better understanding of how anthelmintics work from your time involved with this project?*

   All farmers agreed that their knowledge of anthelmintics had improved throughout the duration of the project. All noted that they now thought more carefully about applying an anthelmintic treatment without at least carrying out some further investigations e.g. liveweight measurements and/or FECs.

2. *Do you have a better understanding of the term refugia from your time involved with this project?*

   All farmers agreed that their knowledge of refugia had increased throughout the duration of the project, aided by online seminars. However, most suggested that they could understand the theory behind the use of refugia on farm but applying grazing management whilst thinking about refugia maintenance, particularly in a rotational grazing system, was difficult to achieve. Some suggested that they didn't think farmers at the wider scale knew about refugia – "can see weeds, can't see worms".

3. *Do you have a better understanding of what anthelmintic resistance is and what measures can be taken to slow development from your time involved with this project?*

   Some of the farmers gained a better understanding of anthelmintic efficacy on their farm. Sheep and cattle farms on occasion showed reduced efficacy of macrocyclic lactone-based treatments which sometimes prompted a rotation to different anthelmintic classes. Two of the three sheep farms introduced Zolvix treatments as 'break doses' later in the grazing season to counter the suspected build-up of anthelmintic resistant GINs. Some farmers also noted they were more aware of the wider scale issue of anthelmintic resistance throughout the farming industry.

4. *Do you understand what anthelmintic rotation means?*

   All farmers were aware of what anthelmintic rotation was with some integrating this strategy throughout the project. One farmer did suggest that drug merchants still pushed the same drug class multiple times – "it worked last year so why change it". Most farmers showed some concern about a lack of future anthelmintic treatment options with no new drugs coming to market. One farmer noted they were going to implement combination treatments at certain points in the season to combat the presence of anthelmintic resistant parasites.

TT/TST strategies

1. *Do you have a better understanding of what Targeted Treatment (TT) and Targeted Selective Treatment (TST) mean from your time involved with this project?*

   All farmers were more aware of the theory behind TT and TST strategies. Some suggested they were not aware of the difference before the start of the project. This was improved by online seminars and advice from the authors. Application desire for TT/TST strategies varied between the farms. The requirements for improved online resources detailing

TT/TST options was noted. TT strategies were preferred over TST strategies on most farms due to the increased labour associated with TST.

2. *Do you feel confident enough to develop and tailor your own TT/TST strategies on farm going forward?*

   A varied response. Some farmers said they were confident to integrate their own TT/TST strategies in the future. Some farms also applied TST strategies without additional advice from the authors. However other farmers suggested they would not be confident integrating TST strategies on farm without the option for advice on ideas from the authors or a veterinarian.

3. *Do you think the use of the FECPAK^{G2} system improved your decision-making process when deciding to apply anthelmintic treatments?*

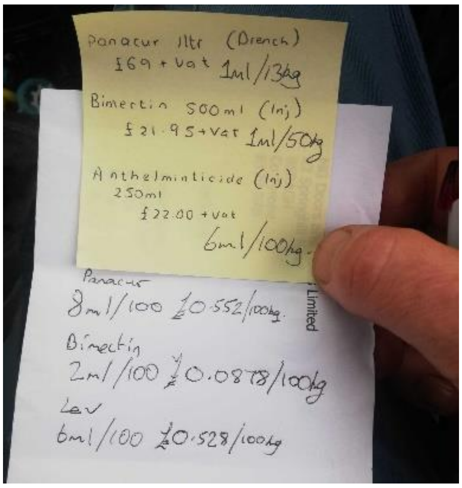
   A varied response. Some farmers completed FECPAK^{G2} submissions regularly throughout the grazing season to guide anthelmintic treatment applications on a TT basis. Some farmers suggested that they would often question if they made a mistake with sample preparation if the result came back as a zero value for strongyles at certain points in the season. On one farm the FECPAK^{G2} was only used in the 2021 grazing season. The farmer then opted to complete all FECPAK^{G2} submissions at a local merchant due to the extra time requirements associated with sample analysis. On a second farm, technical difficulties in the 2022 grazing season with the FECPAK^{G2} system, despite guidance from Techion, led to regular QUB FECs to advise the farmer. Some farmers suggested the option of a FECPAK^{G2} system at a local merchant was perhaps more appealing if wait times were short due to the time required to both collect and analyse their own samples. One farmer noted that they also believed FECPAK^{G2} systems could be a useful addition to business development groups (BDGs) to allow sharing of resources and advice. The current inability to detect lungworm on the FECPAK^{G2} system was noted as a limitation by all cattle farmers on the project.

4. *Do you think the use of the existing or weighing equipment purchased during the project has improved your decision-making process when deciding to apply anthelmintic treatments?*

   New systems or mobile weighing systems. An increase in the number of liveweight timepoints relative to pre-project assessments was observed. Some farmers suggested the use of liveweight measurements prompted further investigations into herd or flock health when parasite burdens were perceived as low. Most commented that liveweight measurements were more difficult to collect at certain times of the year for example pre-weaning in sheep and when cows and calves graze together.

5. *Can you give an example of obstacles that prevented you from applying TT or TST strategies during the project?*

Cattle lungworm mid-season. Increased labour – one farmer noted that automated in-field weighing systems would be much more beneficial for tracking cattle weights to reduce overall stress of handling for both the farmer and the cattle. Group size, particularly pre-weaning in lambs. DLWG drops associated with grass quality and provision – difficult to separate from worm burdens. Some farmers also suggested that fears of reduced productivity were an obstacle for TT/TST application. For example, not treating high performing individuals and then waiting two weeks for next assessment at which point considerable losses may have occurred. This was deemed particularly concerning on sheep farms with high lamb turnover. Similarly, some farmers were concerned that reducing anthelmintic treatments earlier in the season would ultimately lead to more parasites on the grass later in the grazing season. One farmer also suggested that it was difficult to justify the additional work required when it is often cheaper and quicker to apply blanket anthelmintic treatments – effects of anthelmintic resistance often not obvious. The difference in cost between different drug classes was also noted with ivermectin based drugs often working out much cheaper to apply. One farmer also noted that improved information on timing anthelmintic treatments relative to lungworm vaccine was required to improve vaccine efficacy.



6. *Can you foresee any obstacles in the future that will prevent you from applying TT/TST strategies on your farm?*

Many listed the same obstacles they face now. However, some noted that the increased variability in climatic conditions year to year may make decisions more difficult. One farmer noted that improved veterinarian education on parasite epidemiology was required noting that they were often risk averse and advised anthelmintic treatment without further investigation.

7. *Do you think that lungworm outbreaks limit the ability to apply TT/TST strategies on your farm?*

All cattle farms suggested this was a considerable source of hesitation with TST strategies mid-grazing season. Risk outweighed the benefits, and a TT strategy was preferable once coughing occurred. Noted that current lungworm diagnostics must also be improved.

8. *How feasible and practical do you think it would be to apply TT/TST strategies on all farms in NI?*

TT/TST strategies must be flexible enough to allow tailoring to the variability in farm structure. For example, TT/TST strategies must be flexible enough for application at different farm enterprise sizes accounting for availability of weighing equipment, cost of regular FECs, workforce available, stocking densities, available grazing fields etc. Improved online resources are required including resources on parasite lifecycles and timing on pastures in a rotational system. Assessment of anthelmintic resistance status for each drug class available for stock class is recommended.

9. *Do you think that the TT/TST options given at the start of the project were useful/easy to follow/too constrained? How could these options be refined in the future?*

   Provided confidence to make changes when risks outlined. Difficult to get away from traditional time of year anthelmintic treatments. Options on some farms required further tailoring throughout the project to deal with arising issues.

10. *What additional support from researchers/veterinarians is required to make TT/TST strategies a success?*

    Knowledge exchange events between farmers to allow feedback on TT/TST strategies that worked on a particular farm structure. Improved support from farm vets on rotation of anthelmintic treatment drug classes. One farmer suggested better resources to track both genetic breeding and anthelmintic treatment requirements may provide a platform for targeting female replacements that need less treatments, breeding resilience.

11. *Would you feel confident enough to describe and help other farmers implement TT/TST strategies on their own farms?*

    Some farmers suggested they would be confident to describe what practices they had integrated on farm at knowledge exchange events. One farmer noted that they believed BDGs were the best place to discuss these strategies. However, some suggested they would be concerned about the risks associated with providing advice.

12. *Do you think that improved information on topics such as TT/TST/refugia generation/anthelmintic resistance are required?*

    More detailed information on how the strategies would vary depending on farm structure. Initial and continued costs of introducing TT/TST strategies most also be made available. Information sources must be obtainable from multiple sources not just online e.g. newspaper articles, handbooks etc.

13. *What methods do you think would be most impactful for teaching others about TT/TST strategies?*

    A varied response. Some found the online seminars and on-farm walks useful for knowledge exchange. One farmer believed that previous on-farm walks were sometimes overcomplicated. Most farmers believed learning from what other farmers were doing was the best way of assessing feasibility of TT/TST strategies on their farm. One farmer stated that BDGs were a good place to discuss these issues with a smaller group of farmers compared to farm walks etc. The smaller group was also perceived to be less intimidating for presenting ideas or advice.

14. *What parameters are most useful for deciding when to apply anthelmintics?*

    A varied response. One cattle farm relied on a combination of liveweight measurements and group FECs for TT. Three cattle farms believed that although regular liveweight measurements were useful, the increased labour for moving cattle, particularly when located across out farms or under a rotational grazing system, outweighed the benefits.

On these farms treatments were applied on a TT basis using group FECs. On one sheep farm a combination of group FECs and DLWG measurements were employed for a combination of TT and TST strategies in lambs throughout the grazing season. On a second sheep farm anthelmintic treatments were applied to lambs on a TT basis in year one of the project (2021) using group pooled FECs. However, in the second grazing season (2022) the farmer employed visual observations of scouring for the application of anthelmintic treatments employing TST alongside regular group level FECs. The farmer then reverted to a TT strategy when widespread scouring was observed across the flock. On the third sheep farm visual observations alongside FECs and DLWG measurements were employed to decide when to apply TT.

Future parasite strategies

1. *Do you think making anthelmintics prescription only in NI would change how you perceive diagnostic results e.g. on some cases FECPAK EPG was low but still dosed just in case.*

   All farmers suggested they thought the change to prescription anthelmintics would not have a beneficial effect. For example, some suggested that FECs should not be the only parameter considered when prescribing the treatments as body condition, liveweight etc. must also be examined. One farmer noted laboratory or collection errors may result on the withholding of anthelmintics which could impact animal health. Furthermore, another farmer suggested changing to prescription based may also promote stockpiling of anthelmintics prior to changes in legislation which may in the short term promote inadequate drug applications e.g. incorrect storage and expiry dates.

2. *Do you think it is feasible to manage fields for both parasite refugia and grass cover at the same time? What factors make this difficult?*

   All farmers suggested this was difficult to achieve, particularly when grass growth is variable throughout the season and interannually. Some farmers suggested the feasibility of achieving reliable refugia development was dependent on a combination of stocking density and the number of grazing fields available – sometimes fields predicted to have high parasite contamination need to be grazed.

3. *What measures do you plan to take to reduce the likelihood of introducing anthelmintic resistant parasites to your farm through purchased livestock?*

   All farmers suggested they would continue with the strategies they had initiated during the project such as increased frequency of FECs and liveweight measurements. Integrate more appropriate quarantine treatments with pre- and post-treatment FECs to check on efficacy. One farmer suggested they would also aim to reduce the number of different farms livestock were purchased from to reduce the likelihood of introducing anthelmintic resistant parasites.

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