The Use of Cover and Biofumigant Crops to Reduce Wireworm Populations in Potatoes

H. Blogg[1], B. Clunie[2], M. Cox[3], R. Griffith[4], D. Shailes[5], N. Taylor[6]

[1] Soil Association, [2] Harper Adams University, [3] Blackthorn Arable Ltd, [4] Produce Solutions, [5] Hutchinsons, [6] TC & N Taylor

1. Project Overview

This field lab aimed to explore the viability of different cover crops and cultivation timing on wireworm populations and the effect on following potato crops. Concerns around wireworm damage and its effect on growers' ability to grow crops has intensified in recent years, with a huge increase in the pest pressure seen across the country.

Processors are pushing towards more regenerative techniques in potato production. However, regenerative practices such as leaving stubble and providing green cover provide a food source for wireworm which leads to potato damage, yield losses and downgrading for a lower return. This can cause significant knock-on effects for growers and packers in the following seasons and damages growers economically. Huge crop losses mean that this is not sustainable for growers or packers and therefore alternative non-chemical control methods need to be explored.

In this field lab, we explored control methods by harnessing the chemical properties of mustards and buckwheat in rotations to ward off wireworm. The field lab group consists of potato growers, agronomists and researchers that undertook core sampling to identify how buckwheat and biofumigant crops affect juvenile populations, when compared with stubble. It is suggested that some species of cover crops have allelopathic effect on wireworm particularly in the juvenile stage.

1.1 Potential Benefits

It has been found that no-till systems increase the pressure of wireworm by providing a feed source (e.g. stubble, cover crops) during times where otherwise land would be fallow. Wireworm populations are reported to increase from zero tillage, which precludes cultivations, and min-till systems, which avoid the use of inversion cultivation (Lole, 2010). Inversion cultivation may reduce wireworm populations in a rotation by direct mortality of larvae, but other effects may be equally important such as reducing survival of pupae, adult beetles or juvenile larvae hatching in the preceding weeks. The effectiveness of cultivation will depend on the sensitivity of the life stages present, but this trial was designed to investigate the effect of different stubble management regimes on juvenile wireworms. It has been shown that neonate wireworms will die within five weeks in soil if deprived of actively growing plants (Sufyan, 2012) and we attempted to create this by including trial plots using cultivation and flame weeding, the latter because the host farm is an organic producer, and the herbicides used in conventional agriculture are not available for this method of farming.

Because of the risks of not cultivating, some farmers looking increase the use of regenerative techniques are cautious to do so, and organic farmers are left to rely on tillage for some control of the pest. However, whilst cultivation can reduce wireworm damage (Le Cointe et al., 2023), farmers have found that it does not achieve sufficient control of the pest.

Importantly, green manures and cover crops may increase wireworm risk as they keep soils warmer and provide a food source. However, some cover crops such as buckwheat are known to have allelopathic effects after incorporation into soils, meaning that during decomposition of the plant, chemicals are released which suppress weeds, pests and pathogens (Nikoukar & Rashed, 2022). Biofumigants such as hot mustard also contain naturally occurring compounds that may be toxic to soil pests and pathogens (Laznik *et al.*, 2014). It is known that wireworm are most vulnerable to these effects at the juvenile stage, so the particular focus of this field lab was to assess the degree that population levels of juveniles are reduced.

2. Trial Design

Replicated trials took place at a site on Taylor’s Organic Farm in Shropshire. The site was chosen based on severity of damage and sufficient soil moisture to undertake core sampling. The site has had hundreds of adult beetles caught previously, and pre-sampling was carried out to ensure that wireworm were present within the plots. Each treatment was 0.33ha, and there were five replications of each treatment. The site was previously rotated with oats in 2023, carrots in 2022, potatoes in 2021 and barley in each of 2020 and 2019. It was the 2021 potato harvest that raised concerns about the scale of wireworm infestation in the field. The rain delayed the 2023 oat harvest, resulting in late drilling of the trial plots.

The six treatments were as follows, each planted with a 6-metre drill:

- Control: Stubble - natural regeneration
- Bare stubble (weed burner), uncultivated
- Stubble, cultivated
- Common buckwheat (*Fagopyrum esculentum*), drilled at 40-50kg/ha
- Brown mustard, drilled
- Hot mustard mix, drilled with incorporation at appropriate time[1]

All seed was supplied by Hutchinsons Ltd.

Adult beetles were sampled on site for a 6-week period in Spring 2023, with pheromone traps placed out for each of *Agriotes lineatus*, *sputator* and *obscurus*. These were placed 20 metres into the field at the approximate location of the trial site and spaced evenly apart, with collections on a weekly basis.

For larval sampling, 10 core samples per plot were taken with a 10 cm corer with samples being sent to ADAS for wireworm counts via floatation methods.

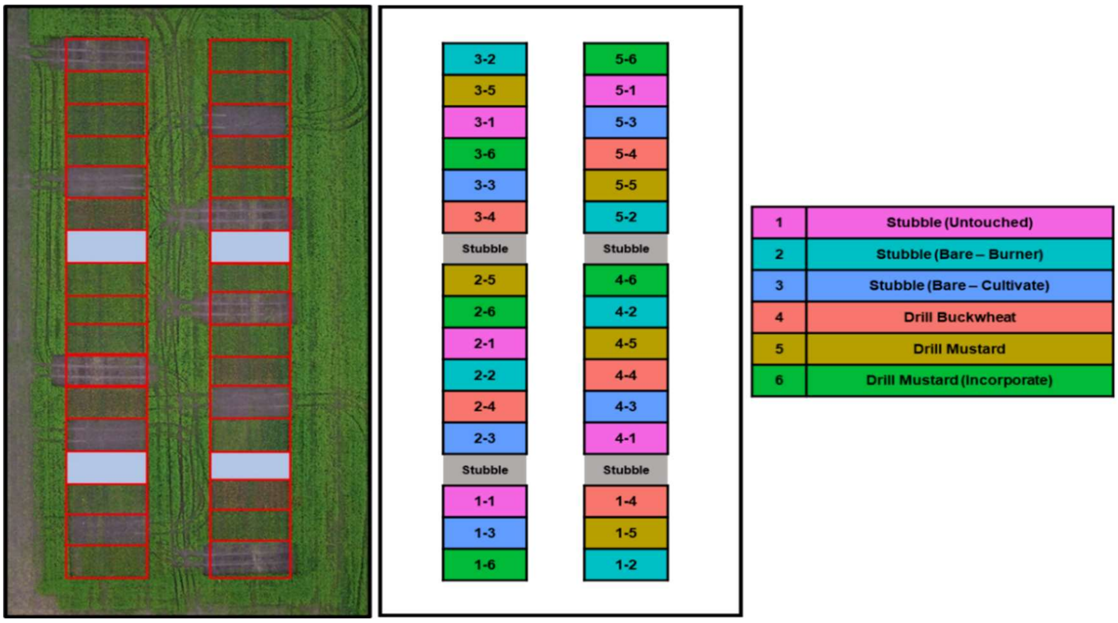

Fig. 1. Plot location and treatment allocation for the field trial, overlaid onto aerial photo of the field trial taken post-planting.

[1] Hot mustard mix ultimately not incorporated due to wet conditions – see results section for details

3.1 Project Timeline

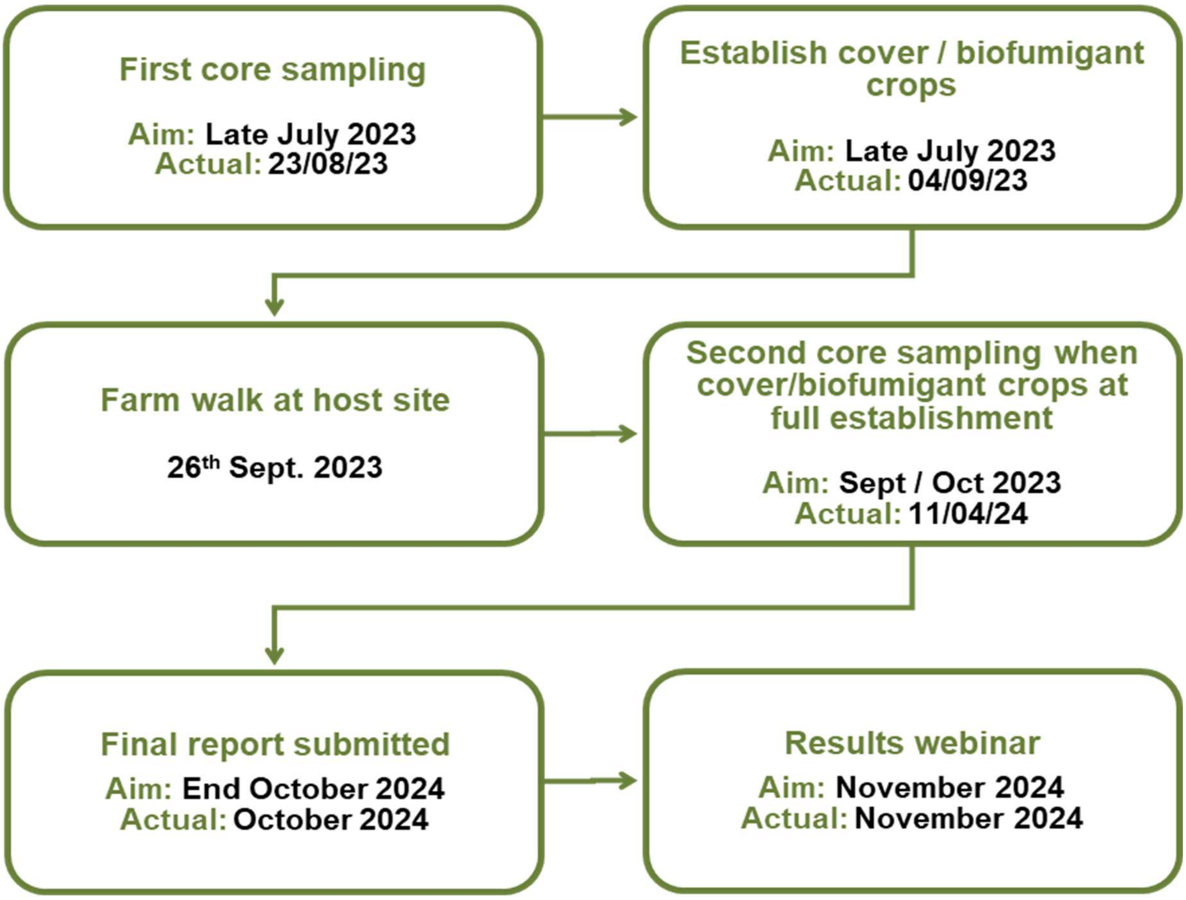

Fig. 2. Final Project timeline adjusted from initial plans (https://www.innovativefarmers.org/field-labs/the-use-of-cover-and-biofumigant-crops-to-reduce-wireworm-populations-in-potatoes/).

3. Results & Discussion

A negative binomial GLMM was fitted to examine the effects of Treatment, Sample Date, and their interaction on wireworm counts, with Block included as a random effect. Differences in wireworm counts across treatments can be seen in Figure 3 (a&b) for both pre-treatment (Autumn 2023) and post-treatment (Spring 2024) plot samples. The second mustard plots were not incorporated during the trial due to overly wet conditions negating any possible effect. This is denoted by 'Mustard(*)' in both figures. Though as both mustard treatments then yielded similar results, there is an element of credibility in the findings.

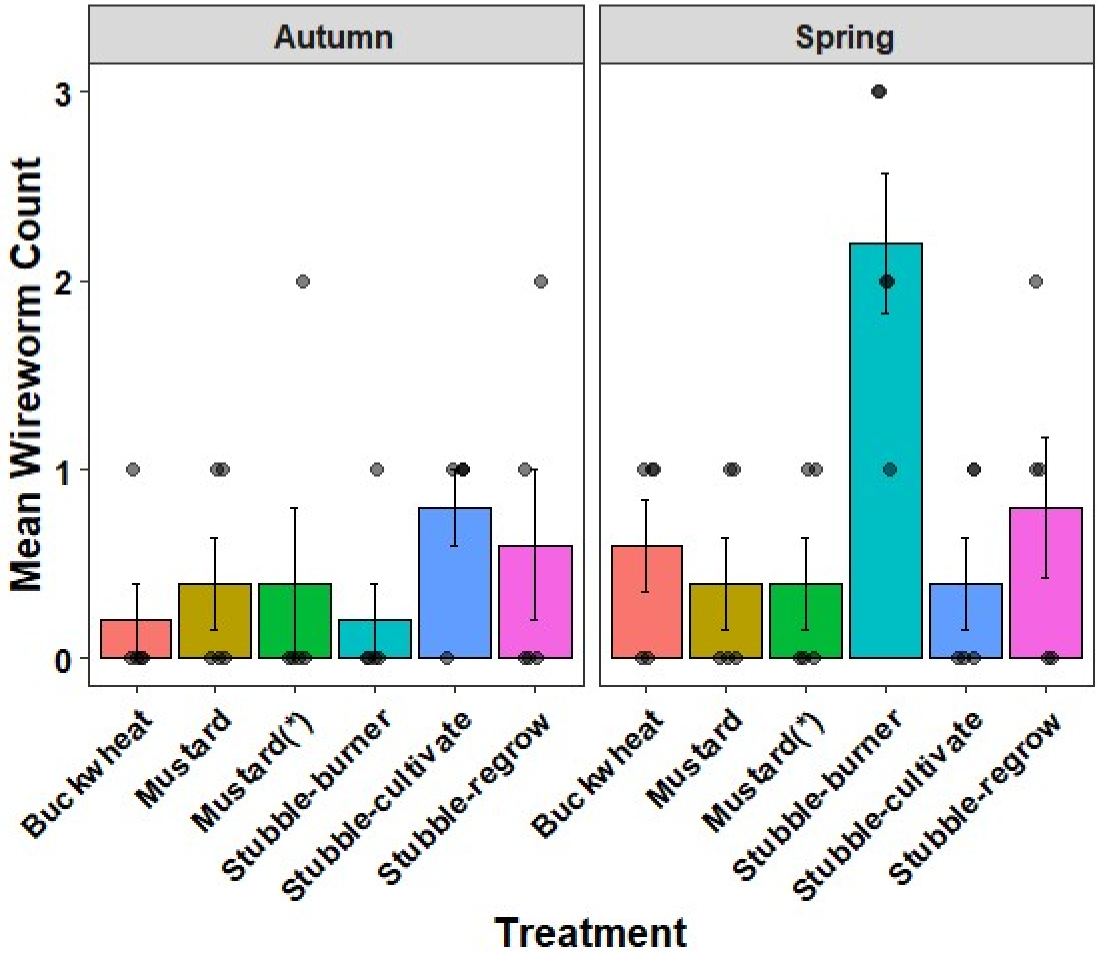

Fig. 3 (a & b). Mean wireworm counts across treatments for both Autumn pre-treatment (3a) and Spring post-treatment (3b) sampling. Error bars indicate SE and actual data overlaid as jittered points.

The treatments had a marginal, non-significant effect on wireworm counts (χ^2 (5) = 13.35, p = 0.0204). Neither Autumn nor Spring had a significant main effect (χ^2 (1) = 0.99, p = 0.3193). The change in numbers can be seen in Figure 4. The interaction between Treatment and Sample Date was not significant ($\chi^2(5)$ = 5.92, p = 0.3141). The random effect of Block accounted for some variation (σ^2 = 0.01707), suggesting some potential clustering of wireworm counts within blocks.

While the results suggest some potential differences between treatments and pre- and post-treatment sampling, the lack of strong statistical evidence indicates that these effects should be interpreted cautiously. The high variability in wireworm counts and the relatively small sample size may have limited the power to detect significant effects.

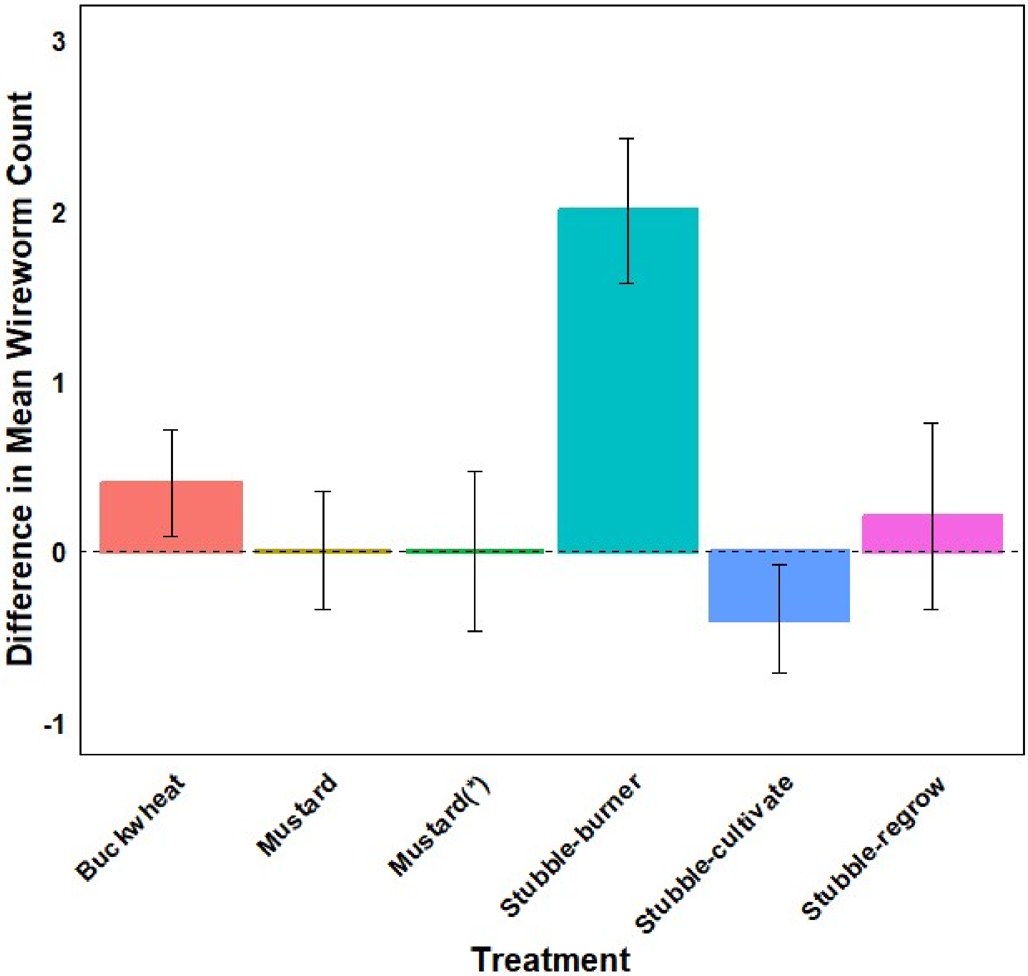

Fig. 4. Difference in mean wireworm counts between Autumn ’23 and Spring ’24. Error bars indicate SE.

The major limiting factor in this project was our ability to detect the presence of very small (juvenile) larvae in soil. At the time of sampling, juvenile larvae would be approximately 3-5mm and too small to be detected by using bait trapping or soil sifting. A mechanical extraction system was designed by Salt & Hollick (1944), adapted (Cockbill *et al.* 1945) and was used to identify population changes in soil by floatation. A similar system is used by ADAS (ADAS, 2005) to extract wireworms from soil samples and is currently the only method available, but the detection threshold is relatively high at 62,500 per hectare and was used in similar work (Lole 2010). Larvae caught during the trial can be seen in Figure 5 (a & b).

The cores used (20 x 10 cm, to a depth of 15 cm) meet this detection threshold with one larva found per 20 cores. If the results obtained here are extrapolated to represent this threshold, and wireworms caught are averaged across all treatments then in the autumn we have approximately 55,000 wireworm / ha and in the Spring approximately 100,000 / ha. Whilst wireworm populations are dynamic, with the number of damaging larvae present varying due to myriad factors, and early instar larvae dependent on success of that year’s oviposition within the site, fluctuations of that degree indicate the difficulties in detection using the method. As mentioned, the method was selected as the only indiscriminate method of detection available that ignores feeding state of the larvae but, as with other sampling methods, is dependent on soil conditions being appropriate for larval presence and is influenced by presence of plant material. That said, these suggested numbers are still representative of a population capable of significantly damaging a potato crop and, alongside more informal sampling at the start of the trial, likely a conservative estimate of the field's true population total.

5a

5b

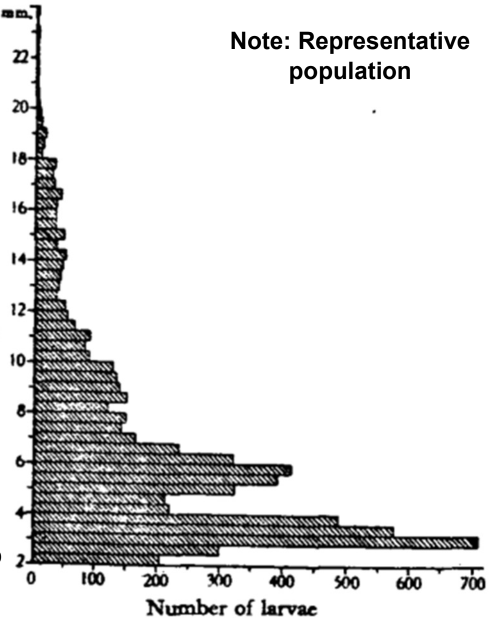

Fig. 5 (a & b). 5a – larvae collected from the trial and extracted by ADAS, demonstrating range in larval sizes from late (i) to early (ii) instars, and highlighting the difficulty in detection. Larvae are a mixture of both *Agriotes* and *Adrastus* spp. **5b** – historical data from Salt & Hollick (1944) indicating a typical population size range from a comprehensively sampled site, using similar soil extraction methods. Numbers typically peak a month or two after hatching.

We must accept that the results lack significant differences but there are some interesting observations, the most obvious one being the effect of flame weeding. The results could suggest that flame weeding was killing some predators of wireworms, most likely carabid or rove beetles although other predators such as stiletto fly larvae, Larger Elateridae (click beetles) have also been known to predate on juveniles (Furlan *et al.,* 2010). The apparent lack of effective control from buckwheat showed impaired development, but it is possible the larvae were already too large for this to happen. Until we have a better understanding of the stage in wireworm development when they are no longer highly susceptible to starvation or the effects of buckwheat, we can only guess at which point this occurs.

Other research work in Canada has shown that growing two crops of buckwheat or brown mustard a year for two years can dramatically reduce wireworm populations (Noronha *et al.,* 2023). This has been assumed to mean that it killed the larvae, but it may simply be an effect of reduced oviposition or egg survival depending on the exact timing of operations. In a UK context this approach may be feasible under land management conditions similar to those in the Sustainable Farming Incentive (SFI) scheme, introduced in 2022. Unfortunately, attempting to control pests with cover crops like these within a long-term rotation is often not a financially viable solution to farmers without these incentives. Doubly so due to the withdrawal of the scheme in its current guise, only three years after its implementation (DEFRA, 2025).

4. Conclusions

This trial suffered due to the extremely wet autumn and winter of 2023-24 and as a result of this, we were unable to carry out all the work at the intended timings or in the case of the biofumigation incorporation, not at all. The work on the trial was delayed by the wet harvest of the previous years' oats and this will have allowed juveniles to feed longer than usual thus reducing their susceptibility to starvation (Sufyan 2012). This ensured that all treatments in the trial were ultimately drilled too late in the year. As a result, the mustard was never likely to reach optimal growth stages for incorporation, further limited by overly wet soil conditions. The wet conditions may also have reduced the effects of cultivations on weeds and volunteers and mortality of juveniles.

Although there were few significant effects in this trial, most treatments did behave as expected except for the flame weeder. This raised questions about wireworm preferences for an area ostensibly free of any viable food source, hinting towards a possibility of a preferably warmer environment due to bare soil, or the presence of enough organic matter or previous plant material to reduce need for migration. Anecdotally, larvae were observed feeding on stubble during informal sampling prior to soil-coring, further cementing these organisms' ability to sustain themselves on minimal or nutritionally poor food sources.

Arable farming is rapidly adopting the use of cover cropping and reduced or zero tillage, but we have not yet managed to predict the longer-term effects of these changes although they are widely considered to increase click beetle populations. To enable these studies, we must develop improved techniques for detecting small larvae in soil from a known area of soil. While core sampling remains the accepted standard for determining population density of small larvae, this study has highlighted its limitations - particularly in detecting low populations and early-instar larvae. Even if they are found, the small size of juvenile larvae is at the lower limit of the extraction methods used. This was evidenced here where core sampling failed to detect early-instar larvae in areas where prior manual sampling had indicated a reasonable wireworm population.

To compound this drawback of the trial, the ground was far too wet for a potato crop in the field following treatments and so post-harvest assessment to quantify any wireworm presence or damage was impossible. The development of more sensitive detection methods, potentially drawing from techniques used in nematology or other areas of soil science, could significantly advance our understanding of treatment efficacy.

The unexpected results from flame-weeded plots warrant further investigation. The increased wireworm populations in these areas could either represent natural variation or indicate previously unknown ecological interactions, such as impacts on predator populations. Although our data is limited here, it does point towards the complexity of wireworm ecology and the need for a comprehensive understanding of soil ecosystem dynamics when implementing control measures.

At T C & N Taylor, Nick remains committed to organic growing techniques, and the implementation of any novel methods that can sustainably solve current pest problems. After the trial, Nick did grow buckwheat within the rotation but found it particularly susceptible to periods of cold weather, a possible barrier to wider UK adoption. TC & N Taylor's main focus is to overwinter areas with mustard to combat subterranean invertebrate pests and continue to have something in the ground year-round. If the benefit of field-scale implementation was better studied under various conditions, then uptake would be an option moving forward.

Planting potentially inconsistent crops and the costs incurred with incorporation of those, such as mustard, currently may not currently be economically viable for all growers.

5. References

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