Abstracts for the first workshop of the EWRN

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KEYNOTES

Keynote 1: Managing Wireworms in Potatoes: Understanding the Problem and Solutions

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Abstract:
The European potato industry faces a growing threat from wireworms. Their presence across the EU has significantly increased in recent years, severely impacting potato production. Damaged potatoes become unmarketable or must be used for alternative purposes, leading to substantial financial losses for growers and increased food waste. The problem extends beyond potatoes. Wireworms also damage sugar beet, beetroot, tomatoes, corn, cereals, sunflowers, winter cabbage, various fruits, and more. Evidence suggests that the presence of wireworms has been getting worse and more extensive in the last few years. Several factors contribute to this spread. They notably include climate change, the switch to more cover crops and less bare soil, and a reduction in farm populations for predation. But the most important is the loss of certain plant protection products. Many EU potato growing countries experience significant financial losses due to wireworms, with some estimates reaching millions of euros. In extreme cases, individual growers report up to 90% crop damage. The land where wireworms have been detected is often no longer suitable for potato growing. It means that growers have to make a switch to another crop as larvae can remain in the soil up to four years depending on the species. In some cases, the high risks associated with wireworms discourage potato planting. A coordinated approach to research on wireworm management is urgently needed. This research should facilitate further investigation and exchange of best practices to combat this growing threat.

Keywords: [potatoes, wireworms, potato production, growers, trade, plant protection, solutions, sustainability]

Keynote 2: Wireworms in Austria: a challenge for farmers, producers, and researchers

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Abstract:

- **Predominant known wireworm pest species in your country**: *Agriotes ustulatus* (83,46%), *A. sputator/ brevis* (13,54%), *A. obscurus* (0,33%), *A. lineatus* (0,07%), *Hemicrepidius niger* (1,03%), *H. hirtus* (0,75%), *Selatosomus aeneus* (0,14%), *Melanotus tenebrosus* (0,14%), *M. brunnipes* (0,07%). Percentages are based on 11126 wireworms collected from infested potato field between 2020 and 2023. The samples were taken from potato fields throughout Austria, but most of the samples came from the Weinviertel region in eastern Austria.
- **Major crops at risk of wireworm damage**: Potato, maize, oil pumpkin, onion, root and tuber vegetables, sugar beet, salad, sunflower, rapeseed
- **Research priority area in your country**: Regulatory measures and DSS
- **List of authorised products in your country**: Cypermethrin (Belem 0.8 MG, Columbo 8.8 MG, Cylem, Picador 1.6MG), Tefluthrin (Force Evo, Disastar Maxi), Lambda-Cyhalothrin (Karate 0.4GR), Spinosad (Spintor GR)
- Current wireworm research project(s): Wireworm-Control ("Practical and sustainable control of wireworms"), ELATMON ("Monitoring of click beetles in potatoes for the Austrian pest and disease warning system"), RIMPEST ("The effect of changing climate on potential Risks from IMportant insect PESTs on plant production in Austria and related adaptation options")
- Previous wireworms research project(s): ElatPro ("Spotting the needle in a haystack: Predicting wireworm activity in topsoil for integrated pest management in arable crops"), EIP-Agri ("Alternatives in wireworm control for potatoes")
- Research on monitoring and DSS models: ELATMON, ElatPro, RIMPEST
- Expectations of countries from a European network: Exchange on current research in the field of wireworm regulation to make efficient progress

Wireworms pose a significant challenge to potato production in Austria. With average wireworm pressure, around 10% of the volume of ware potatoes produced in Austria is lost to this pest. Based on volumes and prices from the past five years, this equates to an annual loss of 5.8 million €. In 2018, wireworm damage reached its peak, with an estimated 25% of damaged tubers being discarded. That year, for the first time, ware potato production in Austria was no longer able to guarantee its own market supply. Austria's potato farmers suffered an economic loss of 21.4 million € in 2018. These calculations do not even include the cost of unnecessary freight or additional labour for sorting.

Controlling wireworm in arable crops is currently only partially successful. The aim of current research is therefore to identify wireworm control measures that are both efficient and

environmentally friendly. Three research projects on wireworm control are currently being carried out in Austria. The projects aim to validate and improve the efficiency of available measures against wireworms by considering the biology of the pest during application.
In the “ELATMON” project ("Monitoring of click beetles in potatoes for the Austrian pest and disease warning system"), the flight phases of the most important pest species of the genus *Agriotes* in Austria are recorded and made available via the warning service website of the Austrian Chamber of Agriculture (warndienst.at).
The “Wireworm-Control” project ("Practical and sustainable control of wireworms") is investigating the implementation of soil cultivation to reduce the number of eggs laid by click beetles, decimate eggs and young larvae, and determine the expected efficiency of these measures. The timing of tillage is determined based on the activity phases of click beetle species that occur in the respective region of the trial sites. Furthermore, this project is investigating ways to optimize the use of insect-pathogenic fungi against *Agriotes* larvae, the impact of crop rotation on wireworm populations, and the use of attractant plants to reduce crop losses. The control measures are tested both alone and in combination at different locations in multi-year experiments. The implementation of the trials involves farmers, interest groups, and advisory organizations.
In the project “RIMPEST” data on annual wireworm damage levels in potatoes from north-eastern Austria were linked with corresponding weather data. The resulting model calculates the damage level in late summer/autumn based on soil temperatures during the previous months. The possibilities for using the model as decision support for farmers and for estimating future trends are currently being discussed.
Reducing the wireworm population can be achieved by implementing site-specific, multi-year strategies that combine several measures. However, despite extensive research, no definitive solutions against wireworms have been found yet. There is a need for research and exchange of knowledge at European and international level in order to jointly develop solutions against the pest.

Keywords: [wireworms, click beetles, species-specific, monitoring]

Funding information
“Monitoring of click beetles in potatoes for the Austrian pest and disease warning system" (ELATMON) is funded as part of the Austrian Rural Development Programme “Netzwerk Zukunftsraum Land” by the Austrian Federal Ministry of Agriculture, Forestry, Regions and Water Management, the Austrian federal provinces and the European Union.
“Practical and sustainable control of wireworms" (Wireworm-Control) is funded by the Austrian Federal Ministry of Agriculture, Forestry, Regions and Water Management and by the Austrian federal states.
“The effect of changing climate on potential Risks from IMportant insect PESTs on plant production in Austria and related adaptation options” (RIMPEST) is funded as a part of the Austrian Climate Research Program ACRP.

Keynote 3: Contribution of models to the assessment of risks associated with wireworm infestation and damage

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Abstract:
"All models are wrong but some are useful" (G. Box). In this presentation, I aim to show that research questions such as assessing the risk associated with wireworm infestation and the potential damage to crops can benefit from statistical and mathematical modelling. A wide variety of modelling approaches can be used.
The first use, certainly the most traditional, relies on regression models based on data that can reveal relationships between a response variable such as wireworm abundance (or occurrence) or crop damage and potential explanatory descriptors. Among the many studies that apply this approach, I will discuss the analysis of long-term survey data on maize fields in France, where we examined the relative influence of putative key explanatory variables on wireworm damage and derived a model for predicting damage risk [Poggi et al, 2018][1]. Depending on its generalisation capacity, such a model may form the cornerstone of a decision support system for the management of wireworm damage in maize crops.
Beyond correlative approaches, certain modelling frameworks allow latent variables to be considered and inferred, which is particularly relevant when dealing with quantities that are difficult - if not impossible - to access, such as populations of belowground pests. Hierarchical Bayesian modelling offers this possibility and also provides an appropriate framework for dealing with risk assessment, since the model results are expressed as probabilistic distributions (called *posteriors*). By way of illustration, I will present an original hierarchical Bayesian model that explicitly considers biological knowledge (including three biological processes: mortality, oviposition and vertical migration) and the uncertainty of field observations (stochastic observation model), rather than relying solely on statistical correlations, to predict the level of wireworm infestation [Roche et al., 2023][2].
Overall, the development of models that describe the mechanisms driving wireworm colonization, and subsequently elucidate the ecological processes operating at the landscape scale, remains an avenue for future research. In an initial attempt, we proposed a framework combining (i) a spatially explicit mechanistic model describing the population dynamics of the pest in the aerial and soil compartments involved throughout its life cycle, and (ii) spatio-temporal representations of various landscape contexts [Poggi et al, 2021][3]. Once parameterised, in particular on the basis of the knowledge available in the scientific literature, this model opens the way to exploring the spatio-temporal manipulation of land use (e.g. the arrangement of grassy landscape elements) for pest management.
All these examples are intended to contribute to the discussion on how to better assess the risks associated with wireworm infestation and the potential damage it can cause to crops, either by enriching the data to be analysed or by improving the integration of knowledge in order to better describe the mechanisms driving the wireworm infestation at plot or landscape scale.

Keywords: [risk assessment, regression model, hierarchical Bayesian model, mechanistic model, population dynamics, landscape ecology]

References:

[1] Poggi S. *et al.*, 2018. J Pest Sci, 91 (2), 585-599.
[2] Roche J. *et al.*, 2023. Smart Agricultural Technology, 4.
[3] Poggi S. *et al.*, 2021. Ecol Modelling, 440.

COUNTRY UPDATES

Updates on wireworm problems, research areas and knowledge gaps within Norway

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Context in Norway

Damage due to wireworms, the soil-dwelling larvae of click beetles, is on the rise in Norway. Damage in potato production has been observed at an alarming rate in recent years. There are however huge differences between fields. Potato is the main crop where wireworm damage is problematic in Norway, but wireworm damage is also observed in other crops, e.g. cereals. A common crop rotation is potato and cereals, which make wireworm pest management challenging. At present, effective pest control tools are missing, and alternative wireworm control methods are needed.

Predominant wireworm pest species

According to Ottesen [1], 69 click beetle species are found in Norway, but only a few of these are considered pests of agricultural crops. A Norwegian textbook list *Agriotes lineatus*, *A. obscurus*, *Agrypnus murinus* (syn. *Lacon murinus*) and *Selatosomus aeneus* (syn. *Corymbites aeneus*) as the most important pest species in Norway[2]. However, during our recently finished wireworm project (2019-2022), we found that the dominating species in Norwegian potato production were *Agriotes obscurus*, *Hypnoidus riparius* and *Hemicrepidius niger*. *Hemicrepidius niger* may act both as a predator (stable-isotope analysis, [3]) and as herbivore. In the field trials we have found larvae of *H. niger* in tunnels inside potatoes.

List of authorised products in your country

The pyrethroid deltamethrine (Decis) is the only registered plant protection product against wireworms in Norway.

Previous and current wireworm research projects

At the moment there are no ongoing wireworm projects in Norway. The wireworm project "Improved Monitoring and Control of wireworms in Norwegian Potato Production" (2019-2022, funded by) aimed at presenting a robust IPM system including monitoring- and biocontrol tools for wireworms in Norwegian potato production. In the project period the main potato growing regions were surveyed to map wireworm species. Adult click beetles were collected using both pheromone baited and non-baited Vernon Pitfall Traps™ (VPT), and wireworms were collected in field using bait traps with wheat and maize seeds (Csalomon®). The project had a broad approach also looking into potato cultivars susceptibility to wireworm damage, crop rotation, decision support system and alternative biocontrol method for direct control in field (ATTRACP®).

Research priority area in Norway

Due to minor focus on the wireworm problem in Norway until recently, there is a need for new knowledge. The newly finished wireworm project helped us on the way, but there are still knowledge gaps. We need more knowledge on seasonal population dynamics, the biology and ecology in general for the main wireworm pest species, particularly with regards to Norwegian conditions (cooler climate). How will agronomic practices contribute to population build up or decline, and what crop rotations should be implemented in infested areas. IPM in general.

Country expectations from a European network

Collaboration and knowledge sharing between countries, covering both research and extension efforts. Periodic meetings to share updates on scientific results. A "meeting place" contributing to initiation of consortiums for new project proposals regarding different aspects of wireworm research.

Major crop(s) at risk of wireworm damage

Primarily potato, but damage has also increasingly been observed in cereals and different vegetable crops.

Research on monitoring and DSS models

A Canadian wireworm risk rating system has been evaluated for Norwegian potato production, but was found not to work as well in Norway. The reason for this might be differences in wireworm population sizes and wireworm species composition and abundance.

[1] Ottesen PS (red.) (1993) Norske insektfamilier og deres artsantall. NINA Utredning 55, 1-40 (Revised internet version 1999 at http://www.entomologi.no/norskeinsekter/NorskeInsektfamilier/index.htm)

[2] Ramsfjell T, Fjelddalen J (eds.) (1962) Sjukdommer og skadedyr på jordbruksvekster. Bøndenes forlag, Norge, 196pp.

[3] Traugott, M., Schallhart, N., Kaufmann, R. and Juen, A. 2008. The feeding ecology of elaterid larvae in Central European arable land: new perspectives based on naturally occurring stable isotopes. Soil Biology and Biochemistry 40: 342–349.

Updates on wireworm problems, research areas and knowledge gaps within the Flemish Region of Belgium

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Abstract:

- **Predominant known wireworm pest species in your country**: *Agriotes lineatus* (>50%), *A. obscurus* and *A. sputator* (20-25% each). *Agriotes gallicus*, *A. acuminatus*, *A. pallidulus*, *A. sordidus*, *Hemicrepidius niger* and *Adrastus* sp. have been sporadically observed in surveys but are not believed to be agriculturally significant based on current knowledge of their biology and abundance in Flanders.
- **Major crop(s) at risk of wireworm damage**: potato, chicory, maize, sugar beet.
- **Research priority area in your country**: improved monitoring and molecular identification, user-friendly risk models and effective management strategies. Better IPM strategies for wireworm in potato are especially critical due to the crop's economic importance to the Flemish Region (€2 billion/year, 50% of arable farming by value).
- **List of authorised products in your country**: tefluthrin (Force/Force Evo, Soilguard, Teflix), cypermethrin (Sherpa, Langis), lambda-cyhalothrin (Karate), fosthiazate (Nemathorin – potato only). No products authorised for organic production.
- **Current wireworm research project(s) (if any):**
  - Ctrl-Elat: towards integrated management of wireworms in potato cultivation – submitted, decision around 01/05/2024.
    - 4 years, €810k budget
    - Cooperation between ILVO, Inagro and PCA (Centre for Applied Research and Extension in Potatoes).
    - Objectives: (1) Improved monitoring and molecular identification, (2) development of a more accurate and user-friendly risk model and associated web tool, (3) evaluation of management options (chemical, microbial and cultural).
- **Previous wireworms research project(s) (if any):**
  - IWT-Ritnaalden (2015-2019): monitoring in witloof chicory, maize and potato fields [Taning, 2016][1], damage threshold determination, risk modelling and evaluation of green manures and attract-and-kill approaches for control. Notable results: successful validation of a pheromone trap for *A. lineatus* (specificity ± 90%), but poorer results for *A. obscurus/sputator* (50-60% specificity). Trials with attract-and-kill and biofumigation management approaches showed highly variable results. A random forest prediction model for wireworm abundance was developed, with a predictive accuracy of approximately 70%. Analysis of variable importance revealed strong influence of soil type, pH, organic matter content and especially prior cereal/grass cultivation, but limited effects of tillage/no-till and green manures and no effect of grass strips in field margins. This model was implemented in an online application (https://app.inagro.be/agriorisk). Due to the availability of larger monitoring datasets, advances in machine learning and improved databases of agricultural plot properties and associated APIs, the Ctrl-Elat model will seek to develop a more accurate and much more user-friendly/automated successor.
  - ElatPro (2016-2019): ILVO participated in this European project through development of a rapid DNA extraction and LAMP protocol for molecular identification of *A. sputator* and *A. lineatus/obscurus* [Witters, 2018][2].
  - Mesurol-free maize (2020-2022): evaluation of available chemical and cultural management options of wireworms in maize. Major conclusions: wireworm problems are increasingly prevalent on plots without prior history of grassland use, available chemical controls show moderate and variable efficacy, monitoring using simple baited

traps (buried pots with germinating maize seeds as baits) is highly valuable to determine damage risk and guide management decisions.

- **Research on monitoring and DSS models (if any):** work on risk modelling in IWT-Ritnaalden led to a first risk model (https://app.inagro.be/agriorisk). A more accurate and user-friendly application with an updated underlying model will be developed in Ctrl-Elat, with particular focus on potato growers. Monitoring was conducted within IWT-Ritnaalden and will again be conducted during Ctrl-Elat.
- **Country expectations from a European network:** data sharing for risk and DSS model development and validation, exchange of best practices for monitoring and management

Keywords: [wireworms, monitoring, *Agriotes*, prediction models, IPM]

References:

[1] Taning, L., Witters, J., Berkvens, N., Temmerman, F., De Blauwer, V., Rutten , N., Vanhaeren, L., Van Ceulebroeck, C., & Casteels, H. (2016). Occurrence of wireworms in agricultural fields in Flanders, Belgium. Communications in Agricultural and Applied Biological Sciences, 81/3

[2] Witters, J., Verstraeten, J., Bonte, J., Temmerman, F., Vervisch, B., Wouters, S., Vanhaeren, L., De Win, J., De Jonghe, K., & Casteels, H. (2018). Identification of Agriotes spp. (Coleoptera: Elateridae) by loop-mediated isothermal amplification (LAMP). In *Identification of Agriotes spp. (Coleoptera: Elateridae)by loop-mediated isothermal amplification (LAMP)* (p. 158-158)

Management tools to reduce wireworm damage in potatoes in Canada.

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Abstract:

- **Predominant known wireworm pest species in your country**: *Agriotes sputator, A. obscurus, A. lineatus, Limonius califonicus, Selatosomus aeripennis destructor, Hypnoidus abbreviates.*
- **Major crop(s) at risk of wireworm damage**: Potatoes, Carrots, Corn/Maize, Small grain (wheat/barley), Soybean.
- **Research priority area in your country**: Developing control strategies, Pheromones for monitoring, Biocontrol.
- **List of authorised products in your country**: Broflanilide, Phorate, Clothianidin, Thiamathoxmin.
- Current wireworm research project(s) (if any): Biology, Semiochemical and Molecular tools, Biocontrol.
- Previous wireworms research project(s) (if any): Rotation crops, Field management, Wireworm movement, Monitoring strategies, Chemicals, Biocontrol agents, Click beetle biology.
- Research on monitoring and DSS models (if any): Pheromone identification.
- Country expectations from a European network: To develop research collaborations and exchange research findings on wireworm control.

Wireworms are of major concern to agriculture worldwide as damage by this pest can result in heavy economic losses for growers. The cryptic nature of the larvae, together with its wide host range and scarcity of efficacious insecticides makes controlling this pest exceedingly difficult. In Canada, ~20 economically important pest species have been identified causing damage to potatoes, carrots, corn, wheat, barley, peas etc. resulting in millions of dollars in economic loss. Prince Edward Island the smallest province in Canada, has a total land area of 1.4 million acres and farms represent about 42.5% of the total land area. Potatoes are the main economic crop followed by barley, oats, corn, soybeans, wheat, and vegetable crops such as carrots onions, turnips, and cabbage. Farms follow a three-year mandated crop rotation strategy. The first crop failure resulting from wireworm damage on the island was recorded in 2004; monitoring efforts demonstrated a continuous population increase and expansion. Tuber losses due to wireworms reached seven million in 2013. *Agriotes Sputator* was identified as the main species causing damage. Because of the lack of viable control options [Noronha *et. al.* 2013][1] we embarked on a research project from 2008 to 2010 to study the use of rotation crops, brown mustard (*Brassica Juncea var. Duchess*), buckwheat (*Fagopyrum esculentum* var. Mancan) and Alfalfa (*Medicago sativa* var. AC Brador); each crop grown for two years in a heavily infested fields prior to a potato crop, Barley (*Hordeum vulgare* var Chapais) was grown as the standard crop for comparison. The study was conducted in three different commercial farms. Results showed an 80% reduction in tuber damage and an increase in marketable tuber yield following the brown mustard and buckwheat crop when compared with alfalfa and barley crop [Noronha 2011][2]. In this trial two crop were planted per year for two years with the first crop plowed down as green manure before the second crop was planted. Subsequent studies showed that planting these crops one year prior to potatoes was sufficient to reduce tuber damage, eliminating the need for a second crop. Adoption of this strategy was slow until 2013 when a few growers planted these crops in their fields that were heavily infested with wireworms. The success of this strategy in these select fields together with increasing wireworm pressure and movement into new uninfected area, resulted in the widespread use of these rotation crops from 2016 onwards. As more farmers adopted this practice wireworm population and reported incidence of damage started to decrease in fields planted with these crops. From 2009-2022, we tracked click beetle populations in eighty-five fields across the island using pheromone traps to determine movement into new areas and the efficacy of control strategies. Results showed that during the initial years (2009-2016) population increase and infestation into new areas continued. Populations in 2016 doubled from 2012 levels and reached

record numbers. In the 2019 survey, a significant decrease in the population which observed, this downward trend continued into 2022. The planting of brown mustard or buckwheat in rotation with potatoes was the main strategy used to reduce populations over this time span. Our survey results showed a 50% decrease in click beetle numbers in 2022 in all regions of the province when compared to 2016 numbers, we also noted a decrease in numbers in newly infested fields. In another study a light trap, invented to capture both male and female beetles (NELT™), was used for 3 years to observe the effects of trapping and rotation crop on populations and tuber damage. Results showed a significant decrease in populations after the first year of planting of brown mustard and trapping females resulting in a significant decrease in damage to the potato crop after two years. Detailed research results will be presented and discussed.

Keywords: [Crop rotation, potato, click beetle monitoring, *Agriotes sputator*]

References:

[1] Noronha C, 2011. IOBC/WPRS Bull 66:467–471
[2] Noronha C. et. al. 2013. Pest Manag. Res. Rep. 2013: 3-6

Wireworm research in Canada: Pest species, past research, and future directions

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Abstract:
The loss of effective insecticides resulted in a resurgence in pest wireworms in North America since the 1990's. Our research program has focussed on wireworm and click beetle research since the mid-1990's, initially working on three introduced species (*Agriotes lineatus, A. obscurus*, and *A. sputator*) in coastal British Columbia and eastern Canada [Traugott et al. 2015][1], but since the mid-2000's also on many of the 20+ native pest species (*Limonius* spp., *Melanotus* spp., *Hypnoidus* spp., *Selatosomus destructor*, *Agriotes* spp.) that predominate on farmland in the Prairie provinces, Ontario, and Quebec. Over the years we, with many great collaborators, have conducted long-term, national surveys of pest species, developed new wireworm and beetle monitoring methods and field risk assessments, conducted studies on beetle and wireworm biology and behaviour (e.g. egg development, beetle movements across the landscape, wireworm and beetle response to insecticides, genetic composition), done lab and field studies with many different insecticides (leading to new registrations for potato and cereal crops in Canada and the USA), identified the sex pheromones of >10 click beetle species, and conducted studies on pheromone-based management tactics (mass trapping, mating disruption) [Vernon and van Herk 2022][2]. Most of this research is continuing. Now that effective insecticides are again available to growers in North America, anticipated future work with current and new collaborators will (hopefully) focus on developing non-chemical management tactics for wireworms and click beetles, and on developing improved, cost-effective and farmer-friendly identification, monitoring and risk forecasting tools [Rashed and van Herk 2024][3].

Keywords: [integrated pest management, *Agriotes*, *Limonius*, wireworm, click beetle]

References:

[1] Traugott M., *et al.* 2015. Ann. Rev. Entomol. 60: 313-334.
[2] Vernon RS, van Herk WG. 2022. Wireworms as pests of potato. In: Insect pests of potato: Global perspectives on biology and management. Academic Press, Elsevier, Amsterdam, pp 103–147.
[3] Rashed A, van Herk WG. 2024. Ann. Rev. Entomol. 69:1-20.

Updates on wireworm problems, research areas and knowledge gaps within Estonia

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Abstract:
Wireworms, the larval stage of click beetles, have emerged as significant pests in agricultural sectors worldwide. In Estonia *Agriotes obscurus* and *Agriotes lineatus* are identified as the predominant wireworm species posing a critical threat to major crops, including potatoes, maize, carrots, strawberries, and wheat. The biggest damages are observed in potatoes, especially in organic production and in maize. The sole authorized plant protection product for wireworm management in Estonia is Soil Guard (tefluthrin).
In our previous project spanning from 2020 to 2023, the focus was on employing alternative methods to control wireworm populations in potato fields. We evaluated the efficacy of treatments utilizing both biocontrol agents and chemical formulations. For biological control, we utilized the entomopathogenic fungus Attracap® (*Metarhizium brunneum*), along with three nematode-based products: Larvanem (*Heterorhabditis bacteriophora*), Entonem (*Steinernema feltiae*), and Capsanem (*Steinernema carpocapsae*). For comparison, chemical insecticides such as Columbo 0.8 MS (cypermethrin), Force Evo (tefluthrin), SoilGuard (tefluthrin), and the cyanamide-containing fertilizer Perlka® were used in the study.
Over a three-year field trial, the effectiveness of all tested plant protection products against wireworms was generally low and varied across the different years. Among the array of chemical insecticides evaluated, only Force Evo demonstrated the highest effectiveness rates although still limited to a maximum of 30% reduction in wireworm feeding damage on potato tubers throughout the whole trial period. In contrast, biological agents such as Attracap® and Larvanem, Entonem, and Capsanem showed promising potential in the initial year of trials, with reductions in damage reaching around 35% and 42%. In the following years, their effectiveness diminished. The low efficacy of the biological products could be attributed to exceptionally dry weather conditions, which were marked by low soil moisture and high temperatures. The limited effectiveness of these biological agents may be due to their origin in warmer regions. Continuous research and trials are crucial to find nematode and fungal strains better suited to our cooler climate, improving biological control solutions.
The effect of mechanical soil cultivation was assessed in frames of the same project. Repeated soil treatment with a pick-up rotor cultivator a year before the potato planting show promised results in diminishing wireworm populations and reduction of damaged potato tubers.
In tandem with field experiments, we utilized automated video tracking techniques combined with soil bioassay arenas. We observed that the fertilizer Perlka® was non-toxic to wireworms but exhibited a moderate repellent effect. In contrast, pyrethroids (tefluthrin and cypermethrin) failed to achieve wireworm mortality. Interestingly, tefluthrin also demonstrated repellent properties against wireworms. Surprisingly, wireworms showed minimal interest in feeding on Attracap®, despite repeated contact with the granules over short periods. These experiments provide valuable insights into the attractancy, repellency, and irritancy of control products, as well as the duration of wireworm feeding on chemically treated seeds and attract-and-kill granules. Moreover, they enable assessing toxic stress levels and the identification of behavioural resistance to insecticides, offering a rapid means of evaluating plant protection products before conducting labor-intensive and costly field trials.

Keywords: [elaterids, toxic stress, alternative wireworm control]

Wireworm research development in the Netherlands: update from a running public private partnership project

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Abstract:
In the Netherlands the main damaging wireworm species for agricultural crops are *Agriotes lineatus* and *A. obscurus* although other species are found as well. Damage can be qualitative to the produced yield (mainly potatoes) or quantitative (mainly maize). However there is an increase in report on wireworm damage in other crops. Authorised products to control wireworm include pyrethoids/pyrethrins, fosthiazate and *Metarhizium anisopliae* F52.
The Dutch and EU policy agendas and the agricultural sectors express a commitment to sustainability towards circular agriculture. This means less and more targeted use of pesticides, more green manure cultivation and less intensive soil cultivation. These measures may promote population growth of a number of soil pests, among which wireworm draws much attention. These are related to soil quality, or to land rental and land exchange with livestock farmers for arable farming and flower bulb cultivation. A future-proof approach to these soil pests requires new pest management concepts. Insufficient quantitative, recent and locally (Netherlands) relevant information is available about many soil pests. In the four-year public-private partnership project Grondige Aanpak Bodemplagen ("solid soil pest approach") a broad consortium, including advisory companies, growers associations, potato trade, potato industry and the government, together with research institutes focusses on development step on three main overarching aspects:

- An as adequate as possible insight in the pest status of a cultivation plot - which soil pests are present, in what numbers and under what circumstances do these numbers exceed a damage threshold?
- A toolbox with measures that can control a population of soil pests above a damage threshold to below this threshold
- The best and most recent knowledge on the biology, phenology and behaviour of soil pests at hand

Regarding the last aspect a state of art report has been put together, with all relevant information on biology, phenology and behaviour of wireworms (and others), to define current and future control possibilities [1]. This serves as a source of experimental ideas and suggestions, within the project and beyond.
With the project two years underway steps have been made to try and model the field situation. For this we kindly build upon the work done earlier in e.g. SIMAGRIO-W (D, AT) [2] and Agriorisk (B). To gain insight in the Dutch situation hundreds of farmers fields, with wireworm problems and similar field without problems, have been brought together in a dataset, and steps have been made to distinguish critical parameters that predict wireworm presence and damage. Next up is to use these parameters to predict the wireworm risk of a typical field.
Another critical aspect in gaining as good as possible insight in the situation in a typical field is adequate monitoring [3]. Many tools are available, but the risk of false negative results undermines the practical implementation so far. We have taken first steps to develop an algorithm that recognises wireworms. Ultimately this would help farmers to have ongoing insight in the field situation, if modelled with correlation parameters.
Control measures are as relevant as ever, but often need a different approach than in the past, and need to be integrated in an Integrate Crop Management (ICM) strategy, that not only includes the crop itself but also the crop rotation and the surroundings. For this we look at effects of different rotational cash and other crops, aspects of e.g. tillage and water management and timing of targeted control measures.
An ICM strategy, based on validated modelling of the field situation, proper monitoring tools to know or predict the field population together with quantitative insight in effects of agronomy and targeted control measures, should provide farmers with the best possible starting situation to grow crops with as little as possible wireworm damage.

Keywords: [Wireworm biology, field characterisation, population monitoreing, Integrated Crop Management]

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Implementing IPM for wireworm management in potatoes, recent experience in the U.K.

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Abstract:
Wireworms, the larvae of click beetles (Coleoptera: Elateridae) have become increasingly problematic in arable rotations over the last two decades and the term 'arable wireworm' is used to describe this situation[1]. Risk assessment in the UK relied heavily on the presence of grassland in the rotation or other permanent cropping situations, minimal tillage and south facing slopes were also implicated. The criteria used to identify fields at risk [2]. were found to be insufficient and bait trapping to detect larvae was known to be unreliable. Many crops suffered unexpectedly high levels of damage and when Mocap (ethoprophos) was withdrawn some potato growers found the challenge too great and stopped growing the crop.

The position in the UK is that we are now hearing many more reports of severe crop damage by wireworms, particularly in the South of England, rotations dominated by cereals are now considered high risk. Potatoes are damaged, also cereals, maize, vegetables such as lettuces, onions and brassica transplants. It is hard to quantify the extent of damage to potatoes in the UK as the only data available is from pre-packers and this is not publicly available. The author has discussed the situation with all sectors of the industry and has been told that some packhouses in the East of England can find between 14-21% of loads have wireworm damage. One packer indicated that 1500 t was rejected in one season recently. One repsonse by packers is to increase the tolerance slightly and to consider the loads from a field as a whole rather than pouncing on one load which is slightly out of specification. Damage is considered to be less of a problem in processing crops although not absent. This may be a combination of a higher tolerance to the damage and varieties which may be less attractive to the pest but some processing varieties have been found to suffer as much damage as the benchmark varieties Maris Peer and Marfona in recent Cupgra funded research.

Carrots are usually damaged less than potatoes, parsnips, linseed and spring beans are rarely if ever badly damaged. Although problems are less frequent in Scotland, they are increasing and growers now need advice on IPM (Dr Kerry Leslie, SAC, personal communication, May 1st 2024)

The genus responsible for most damage is Agriotes, with A.obscurus and A.lineatus found over most of the UK, A.sputator are common and often the dominant species in the South and East of the UK but rare, or absent in the North of the UK.Other species found in arable land and known to damage crops include members of the genera Athous, Ctenicera, and Selatosomus but these are much less common in arable soils at present. Species belonging to the genera Adrastus, Agrypnus, Hemicrepidius, Melanotus are either not pests, or not important and in some cases are known to predate on pest species.

Research is being carried out in the UK and insecticides are tested and compared in work carried out by the Potato Partnership (TPP), none are achieving anything near complete control.

A recent project funded by Innovative Farmers has investigated autumn management options in stubbles including buckwheat, mustard and cultivation, this will be published in 2024.

Another aspect of the recent work in the UK has been to understand the species involved and learn more about the critical parts of the life cycle, the Enigma 1 project at Fera has been critical in this respect, this summary or the project was provided by Dr Larissa Collins who leads the project. "We have DNA barcoded 10 species and confirmed that we can use DNA barcoding to identify larvae. We have had promising results from glasshouse cover crop studies. We are using monitoring data and data from life history studies at different temperatures to predict current and future geographical ranges of pest species."

Work at CUPGRA has been important over the last four years and started with a review into the pest, the Cupgra Wireworm Review [3] ,major outputs from this have included improvements in risk assessment, improving bait trapping and IPM strategies which have allowed growers to identify risk sites and adapt management strategies, confirming to growers that damage does start early and identification of species by sending samples for DNA barcoding in Austria. The DNA barcoding confirmed that some wireworm species found in arable soils were not considered to be crop pests. Recent work here has involved studies into variety susceptibilty which have recently failed to find a correlation between TGA and damage incidence, the work continues in 2024.

Other work in the UK at Rothamsted Research involves semiochemicals and this summary has been provided by Anusha Mohan Kumar, the PHD student working with Dr Jozsef Vuts and Dr Gareth Thomas. "Semiochemicals, which are naturally occurring chemicals that influence development and behaviour, offer a non-toxic and environmentally friendly alternative for managing soil pests. Like aboveground insects, soil-dwelling arthropods respond to these root chemicals, which diffuse in soil pores and act as cues for locating host plants more specifically than CO2, a general attractant. The primary goal of this Southwest Bio CASE PhD project, with Syngenta as industry collaborator, is to conduct foundational research for developing management strategies based on root-emitted volatiles to control wireworms, which are significant pests in agriculture."

Research work funded by Cupgra has included a review into the UK situation and a revised method of risk assessment including much needed revision of the UK advice for bait trapping. (Cox & Allison 2022). Recent work at Cupgra has been on potato variety susceptibility (Bishop et al. 2022, Cox, Collis & Tomlinson. 2023)
Another important part of our work is knowledge exchange (KE) to inform growers and agronomists of our findings and teach them the importance of the whole rotation. The author has presented technical updates to all sectors of the industry and Their feedback is also important and without this dialogue we would be unaware of a large problem caused by Athous species in Kent, the exact reason for this is unknown at present.

Other recent work in the UK has included:
A PhD by Dr Ben Clunie (2016-21) which focussed in particular on biological control of wireworm in potato crops.

Evaluation of Metarhizium brunneum- and Metarhizium-Derived VOCs as Dual-Active Biostimulants and Pest Repellents in a Wireworm-Infested Potato Field. (Wood et al. 2023)

B-Hive are investigating hyperspectral cameras to detect wireworms during soil cultivation.

Keywords: Wireworms, Agriotes spp, Risk assessment, Bait trapping, IPM, Glycoalkaloids.

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Updates on wireworm problems, research areas and knowledge gaps within Spain

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Abstract:

- **Predominant known wireworm pest species in your country**: In northern Spain (temperate-humid-temperate *Cfb*), the two species usually recorded are: *Agriotes sordidus* and *A. lineatus*, with *A. sordidus* being the predominant species on potato. In addition, in Spain-Southern Zone (Temperate-Dry-Subtropical *Csa*) [1], it is possible to find *A. obscurus*, *A. curtus and A. sputator* on sweet potato, cotton, maize and sugar beet [2,3].
- **Major crop(s) at risk of wireworm damage**: Economic damage is recorded in maize, sugar beet, sweet potato, cotton and potato; it is especially in potato and sweet potato where damage is significant and recurrent every year.
- **Research priority area in your country**: The priority research topics are focused on the evaluation of effective crop protection products to reduce the annual severity of damage. Other parameters taken into account in R&D studies are crop rotation and, above all, the timing and type of irrigation (drip or sprinkler irrigation). In Spanish potato breeding programmes, varietal susceptibility has not been a priority parameter of selection.
- **List of authorised products in your country**: There are 9 plant protection products authorised in Spain for potato. In addition, there are 4 other products registered for crops other than potato. See the list below.

Nº Registro	Name	Company	Formula	Crop
ES-00377	MACISTE	SIPCAM	LAMBDA CIHALOTRIN 0,4% [GR] P/P	Potato
20111	NATURALIS	CBC IBERIA	BEAUVERIA BASSIANA (CEPA ATCC 74040) 2.3% (2,3X10E7 ESPORAS VIABLES/ML) [OD] P/V	Potato
22004	NEMATHORIN 10 G	ISK	FOSTIAZATO 10% [GR] P/P	Potato
ES-00067	POINTER GEO	SIPCAM INAGRA	LAMBDA CIHALOTRIN 0,4% [GR] P/P	Potato
ES-01191	SOILGUARD 0.5 GR	SHARDA (España)	TEFLUTRIN 0,5% [GR] P/P	Potato
ES-00521	SPINTOR GR	SBM DEVELOPPEMENT	SPINOSAD 0,4% [GR] P/P	Potato
ES-00068	TRIKA LAMBDA 1	SIPCAM INAGRA	LAMBDA CIHALOTRIN 0,4% [GR] P/P	Potato
ES-01428	TRIKA LAMBDA 2	SIPCAM INAGRA	LAMBDA CIHALOTRIN 0,24% [GR] P/P	Potato
ES-01429	TRIKA LAMBDA 4	SIPCAM INAGRA	LAMBDA CIHALOTRIN 0,15% [GR] P/P	Potato
ES-01280	FUERZA	SHARDA (España)	TEFLUTRIN 0,5% [GR] P/P	Crops, NOT for potato
17502	LEBRON	ADAMA ESPAÑA	TEFLUTRIN 0,5% [GR] P/P	Crops, NOT for potato
25760	METEOR	DIACHEM	DELTAMETRIN 1,57% [SC] P/V	Crops, NOT for potato
ES-01151	SOILGUARD 1.5 GR	SHARDA (España)	TEFLUTRIN 1,5% [GR] P/P	Crops, NOT for potato

- **Current wireworm research project(s) (if any):** At the moment there are no projects funded by the Spanish Ministry, although there are projects funded in Spanish regional calls, in Andalusia (IFAPA) and in the Basque Country (NEIKER-BRTA).

- **Previous wireworms research project(s) (if any):** From 2006 to 2009, Control of wireworms in potatoes in the humid zone of northern Spain (La Rioja and Basque Country), co-funded by the Spanish Ministry.
- **Research on monitoring and DSS models (if any):** not known
- **Country expectations from a European network**: Currently in Spain, there is a lack of effective control measures to control the pest. Phytosanitary products as effective as those recently banned in the EU are not available. The incidence and severity recorded in the last 3 years has been extraordinarily high due to the very dry summers. It is essential to undertake a European project to share control strategies and validate them in different agro-climatic areas and different agricultural management.

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Wireworm issues, research areas and knowledge gaps in France todate

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Abstract:

- **General introduction:**Wireworms have long been recognised as major pests worldwide. At the beginning of the 20th century, when the use of chemicals was much less widespread, wireworms were considered the most damaging pests of arable crops. Wireworms are extremely polyphagous and feed on almost all crops (all cereals; all vegetables including onions, leeks and garlic; maize; potatoes; sweet potatoes). Some crops are less susceptible to wireworm damage in terms of yield due to agronomic characteristics (plant growth rate and density, tissue susceptibility, sowing and harvesting dates). This leads to the perception that some crops are specifically attacked when this is generally not the case. Damage is mainly attributed to the genus *Agriotes*, as shown by the bibliography, which is almost exclusively devoted to this genus. Very few studies have been carried out on the other genera of Elateridae, some of which are carnivorous, others detritivorous and many with unknown diets [Poggi et al., 2021].

- **Context in France:** In France, since the gradual withdrawal of broad-spectrum pesticides, 20 years ago, many crops are regularly damaged by wireworms leading to both yield losses and a deterioration in product quality, making potatoes, for example, unmarketable. Protecting potatoes against wireworms is particularly difficult because growers have few options (pyrethroids, spinosad, *Beauveria bassiana*) with limited persistence and efficacy. Since 2016 and the progressive ban of ethoprophos, the damage associated to wireworms in potato production has significantly increased, with annual economic cost often estimated between 2 to 5 million euros for the seed sector alone, depending on the environmental conditions of the reference year and with up to 15% of unmarketable production for the most affected areas (FN3PT data). On maize, ARVALIS estimated in 2022 that 22% of the surface area is exposed to a risk of wireworm damage. In the absence of protection against these pests, losses due to wireworms are estimated at 6% of national production. This threat, combined with a reduced availability of pesticides, has put farmers in a difficult situation and calls for research to develop sustainable alternative control strategies, both preventative and curative [Le Cointe et al., 2023].

- **Predominant wireworm pest species and research priorities in France**: Having a tool for accurate risk assessment based on the production context (e.g. crop, weather, climate, soil characteristics and landscape) and population monitoring would be a first major step forward. Between 2005 to 2014, more than 1200 maize fields across a vast geographical area stretching from the north-west to the south-west of France have been surveyed to map wireworm species and identify the main factors associated with wireworm abundance and the level of damage caused to crops. These survey data have been analysed. Soil characteristics (pH, organic matter content, soil texture) and summer rainfall were found to influence the abundance of wireworms in the soil while weather conditions before and after planting, crop rotation - including the presence of a meadow on the plot or in its immediate vicinity - were found to influence the level of damage. Such findings help us to understand the risks of infestation and damage, but it remains difficult to characterise them precisely for each field. During these field surveys, *Agriotes lineatus* was the most abundant species (42.5% of the larvae collected), followed by *Agriotes sordidus* (29.5%) and *Agriotes sputator* (20.4%). *Agriotes obscurus* was less frequent (6.7%). A similar dataset is being

acquired on potatoes, covering a total of 250 fields, starting in 2020 and these studies are still in process.

Prophylactic practices to reduce wireworm abundance (e.g. use of low-risk rotations, tillage) are being researched. Additionally, curative methods based on the use of natural enemies and on naturally derived insecticides are under development. The identification and quantification of naturally occuring *Metarhizium* strains, potentially pathogenic to wireworms, were carried out in some of the monitored maize fields. The same approach is applied in another project for entomopathogenic nematodes.

Finally, practices aimed at reducing crop damage by manipulating the behaviour of wireworms (e.g. the use of companion plants or organic fertilizers) are curently being developed. Given that their feeding phase accounts for 20-30% of their total development time, a promising and inexpensive control strategy could be to feed the wireworms to lure them away from crops during the host's susceptibility period [Thibord et al., 2017].

- **Major crop(s) at risk of wireworm damage**: potatoes, maize, carrots, lettuce, bulbs
- **Research priority area in your country**: Risk assessment, Decision support system, factors affecting wireworm population dynamics, biocontrol.
- **List of authorised products in your country**: pyrethroids (lamba-cyhalothrine), Spinosad, *Beauveria bassiana*
- **Current wireworm research project(s):** TaupiFAST (a national project under construction for all affected crops), TAUPIC (a national project on potatoes), LOTO (on maize), Opti-NEPs (on potatoes)
- **Previous wireworms research project(s) (if any):** SEMAE Taupinland, Ecophyto Startaup, CasDAR Taupins
- **Research on monitoring and DSS models (if any):** A hierarchical Bayesian model that explicitly accounts for biological knowledge and uncertainty in field observations has been developed to predict the level of wireworm infestation. The model was encapsulated as a software (R shiny application) to predict the risk of wireworm infestation in any field of interest, and can be used by farmers or agricultural advisors as a decision support system for the implementation of IPM strategies [Roche et al. 2022].
- **Country expectations from a European network:** Effective communication and collaboration between countries and research units, periodic sessions for researchers to share updates on research results. Building up a European project consortium

Keywords: [Risk assessment, biocontrol, companion plant]

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SIMAGRIO-W – A Decision Support System to predict Wireworm Activity of *Agriotes spp.* in Germany

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Abstract:

In Germany there are damages in potato, sugar beet (sometimes secondary pests such as rooks searching for wireworms) and other crops. Occurrences and damages are site-specific and variation throughout years is high.

In the past 15 years and currently we are part of several projects that include wireworm monitorings. Within these projects wireworms on field and semi-field sites were sampled from 2016 to 2024. The traps are flowerpots filled with vermiculite and germinated wheat that are dug in a depth of 10 cm underneath the soil surface. The wireworm numbers are recorded once or twice a week. On the field sites, the flowerpots migrate one meter per week to get a higher chance of catching wireworms due to the heterogenetic distribution within fields and to avoid false negative results due to catching away all individuals in this spot. Within the monitoring the species we found most were *Agriotes sputator* and *A. sordidus*.

The Decision support system (DSS) SIMAGRIO-W was developed, which calculates the activity of wireworms in upper soil layers. Soil temperature, calculated soil moisture, crop and soil type are the input parameters. The output can support a timely management of wireworms. If the activity threshold is higher than 30%, the risk of occurring wireworms is high and a management measure can be considered. When validating the DSS, it works well at the beginning of the season in spring and in fall. However, in the monitoring years, summer activity on various locations with different *Agriotes* spp. has been encountered. This activity during high soil temperature and low soil moisture is not displayed in the model. Adjustments in the algorithm did not have the desired effect until now. The biggest challenge is the lack of monitoring data under different environmental conditions to show further factors that might influence the wireworm activity.

Keywords: [decision support system, SIMAGRIO-W, wireworm activity, integrated crop management]

POSTER SESSION

Development of ATTRACAP®: A novel biological control using attract-and-kill to target *Agriotes* spp.

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Abstract:
Wireworms, the polyphagous, soil-dwelling larvae of click beetles (Coleoptera: Elateridae), are important insect pests of global significance and cause enormous yield losses in various cropping systems, e.g. potatoes. Biological control of wireworms with entomopathogenic fungi is a challenge, as these organisms are more difficult to handle and have a limited shelf life compared to synthetic pesticides (Brandl et al., 2017). So far, promising entomopathogenic fungi such as *Metarhizium brunneum* have been used in simple formulations, mostly on barley or rice grains. In the ATTRACT and ATTRACAP projects, we have developed novel mechanically stable beads that contain CO_2-emitting baker's yeast as an attractant, an isolate of *M. brunneum* Cb15-III as an active ingredient and a substrate as a nutrient source and drying aid (Hermann et al., 2021). The pellets marketed as ATTRACAP® can be used in innovative attract and kill strategies based on purely biological components. ATTRACAP® has been available to German farmers since 2016 in accordance with Article 53 of Regulation (EC) No. 1107/2009 for 120 days. The regular authorization process is in process. The product is designed for the control of *Agriotes* spp. in potato and asparagus crops.
ATTRACAP® granules are produced by encapsulating both the microorganisms and the substrate in alginate and dried using an innovative fluidized bed drying process. The attract and kill formulation allows a lower application dose of 30 kg/ha with an active ingredient of 1.2 x 10^{10} conidia/ha, making the product cost-efficient and environmentally friendly. The results of minimum 37 EPPO field trials with results from Germany, France, UK and Italy will be presented as well as insights into which external factors influence the efficiency and how new adapted formulations or applications techniques may further improve the system.
In summary, this novel CO_2-releasing granule is not only suitable for the cost-effective application of low doses of fungal biological control agents against wireworms into the soil, but this technology can also be transferred to other soil-dwelling pest species, such as *Pentastiridius leporinus*.

Keywords: [Wireworm control, Biocontrol, Entomopathogenic fungi]

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Horizontal and vertical movement of wireworms, *Agriotes sputator* (Coleoptera: Elateridae) through soil in Canada

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- **Predominant known wireworm pest species in your country**: *Agriotes sputator*, *A. obscurus*, *A. lineatus*, *Limonius califonicus*, *Selatosomus aeripennis destructor*, *Hypnoidus abbreviates.*
- **Major crop(s) at risk of wireworm damage**: Potatoes, Carrots, Corn/Maize, Small grain (wheat/barley), Turnips.
- **Research priority area in your country**: Developing control strategies, Pheromones for monitoring, Biocontrol.
- **List of authorised products in your country**: Broflanilide, Phorate, Clothianidin, Thiamathoxmim.
- Current wireworm research project(s) (if any): Biology, Semiochemical and Molecular tools, Biocontrol.
- Previous wireworms research project(s) (if any): Rotation crops, Field management, Wireworm movement, Monitoring strategies, Chemicals, Biocontrol agents, Click beetle biology.
- Research on monitoring and DSS models (if any): Pheromone identification.
- Country expectations from a European network: To develop research collaborations and exchange research findings on wireworm control.

The larvae of the click beetles (Coleoptera: Elateridae), wireworms, are identified as a major pest of potatoes and other vegetable crops worldwide. A steady increase in the population of an invasive species *Agriotes sputator* in Prince Edward Island (PEI), Canada, resulted in its spread into un-infested crop land. Severe winters conditions in Canada requires elaterid species to enter diapause during this unfavourable period. In Quebec, elaterid larvae were found to overwinter below the frost line during the winter months [Lafrance and Cartier 1964][1]. However, information on the timing of wireworm movement within the soil profile is required to ascertain the correct time for installing bait traps to monitor populations. We investigated the horizontal and vertical movement of the wireworms in the soil. Studies have shown that wireworms responded to soil moisture by moving lower down in the soil profile during the summer months [Lefrance 1968][2]. But there was a dearth of information on the wireworm's response to bait traps and time spent at a food source. Using 5cm diameter tubes, we studied the time required and distance traversed by a wireworm, through the top layers of the soil, towards a food source and time spent feeding. Results show that 15 and 20% of medium and large size wireworms respectively moved a distance 3.6m in 24 hours to find a food source. Results also show that if a food source is found some wireworms will feed for a short duration before moving in search of another food source. This information is critical for determining the time required from bait instillation to removal to obtain an accurate representation of the population. To study vertical movement, 5cm diameter tubes were used to take soil cores to a depth of 80cm. Wireworms 10/tube were placed at the top of the tube and the bottom was sealed with mesh cloth to prevent wireworms from escaping. Each tube was reinstalled into the same location where the core was collected. Once a month from November to June, tubes were removed and the number of wireworms at different depths was recorded. Results show that wireworms can move down to a depth of 80cm in the spoil profile. We found that the majority of wireworms spend the winter months at a depth just below the frost line until April when they begin to move up as the soil temperature rises. All wireworms were at the surface by end May - beginning of June.

Keywords: [Movement, soil, vertical, horizontal, bait]

References:

[1] Lafrance, J., 1968. Can Entomol 100,801-807. DOI: https://doi.org/10.4039/Ent100801-8
[2] Lafrance J and Cartier JJ, 1964. Phytoprot., 45:83-87.