Canadian Agri-Science Cluster for Horticulture 3

Update to Industry

Final Report – 2018 - 2023

Activity title: Integrated management of the pepper weevil, an invasive pest of greenhouse pepper crops in Canada

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***Bruce Power and Nordion**, producers of Cobalt-60 isotopes required for weevil irradiation.*
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Activity Objectives:

1) Develop improved rearing methods for the pepper weevil.
2) Evaluate reduced-risk conventional and biopesticides for the management of the pepper weevil.
3) Evaluate non-target impacts of management products on beneficial insects used in greenhouse pepper biological control.
4) Establish the efficacy of parasitoid *Jaliscoa hunteri* for the management of the pepper weevil. Establish and compare the efficacy of rearing methods for *J. hunteri* production. Explore alternate crop delivery methods for *J. hunteri*.
5) Conduct laboratory and greenhouse trials investigating the potential of the Sterile Insect Technique (SIT) for managing the pepper weevil.

Research Progress & Results:

The pepper weevil is an important pest of pepper crops across North America which can incur yield losses of up to 100% when infestation levels are high. While it has a historically sporadic occurrence in Canada, its recurrence in pepper growing regions represents a potentially large threat to crop productivity. Given the considerable difficulty of managing this pest through conventional agents, this research set out to assess a broad diversity of tools or techniques which could potentially be used in cases of future pest outbreaks. We first focused on producing robust but highly contained colonies of this pest, needed for assessment of various control strategies. For instance, we developed apparatuses and substrates (either plant or artificial diet) that greatly improved rearing efficiency of the pepper weevil as well as its parasitoid *Jaliscoa hunteri* (Félix Longpré, AAFC London, Objective 1). We next completed in 2020, an ambitious on evaluation of 16 reduced-risk, microbial and conventional active compounds for control of pepper weevil (Objective 2). Through both laboratory evaluations, we found that few agents actually controlled pepper weevil, however products such as kaolin clay, mineral oil and thiamethoxam did provide good levels of suppression. Following this research, we have subsequently produced a summary of the non-target impacts of the most effective products tested (Objective 3), that will facilitate successful integrated management of this an other pepper pests.

Among the tools assessed for pepper weevil control in this project was the chalcid parasitoid wasp *Jaliscoa hunteri* (Objective 4) which attacks pepper weevil larvae ensconced within buds and pepper fruit. Through a series of controlled environment and commercial greenhouse trials, we demonstrated that this wasp can reduce the number of pepper weevil offspring by up to 61% within a single generation. We also showed that this wasp is highly attracted to the volatiles emitted by pepper weevil infested fruit (Serena Leo, AAFC Harrow) and by identifying these compounds (Tim McDowell AAFC London) we could elucidate the chemical signature of pepper weevil infested peppers. In future, this could lead to developing artificial parasitoid lures or even sensors that are specifically calibrated to detect weevils in a crop. As a consequence, are currently exploring sensor development through a collaboration with Dr. Arezoo Emadi in the Department of Engineering at the University of Windsor.

In addition to such cutting edge tools that this research has contributed to developing, we have also explored a relatively novel strategy of the Sterile Insect Technique (SIT) for pepper weevil management (Objective 5). In 2021, we successfully developed an effective irradiation and dosimetry protocol in collaboration with Bruce and Nordion Inc. which was used to study irradiation effects on weevils. Our results show that a high percentage of male (100%) and female (85%) pepper weevils irradiated as late-stage pupae at 90 Gy failed to produce offspring, while weevils receiving a lower dose were significantly less sterile. The lifespan of irradiated weevils was generally short (median of 14 day survival) compared to unirradiated weevils (median 80 days) though this may be sufficiently long for developing an effective SIT system targeting this pest. Together with subsequent research assessing the quality of sterilized males including their flight ability, sperm production and mating competitiveness, this study lays the groundwork for development of a new tool for pepper weevil suppression that could be applied to both field and greenhouse pepper crops on an area-wide scale.

Taken as a whole, the multiple effective and sustainable pest management tools identified through this project has resulted in a wealth of new knowledge that renders the Canadian greenhouse industry more resilient in the face of future threats posed by destructive pests such as the pepper weevil.

Key Message(s):

- We have now developed highly efficient methods for mass production of pepper weevil and its biological control agent *Jaliscoa hunteri* (Obj 1).
- We have elucidated the efficacy of multiple conventional, reduced risk and microbial insecticides for control of the pepper weevil on greenhouse pepper crops (Obj 2).
- We have provided evidence of the considerable potential for parasitoid *Jaliscoa hunteri* to suppress populations of the pepper weevil, not only in laboratory but also in commercial greenhouse settings (Obj 4).
    - We have also identified some of the chemical cues that may help guide this parasitoid to its pepper weevil host, information that may help develop recruitment strategies for such natural enemies in agricultural systems and facilitate biosensor development.
- Finally this research represents the first time the Sterile Insect Technique has been studied in Canada for control of a greenhouse pest species, which sets the stage for similar research targeting other pest species. Taken together, these developments will render the Canadian greenhouse sector more resilient in the face of costly invasive pest species such as the pepper weevil.

Overall benefit to industry:

Through this research project we have significantly innovated in three key areas:

A. Assessment of parasitoid *J. hunteri* for its biocontrol potential of pepper weevil (Objectives 1 and 4):

1. We have developed ornamental pepper rearing arenas to effectively test parasitism rates and weevil control rates.
2. We have developed an effective mass rearing method for *J. hunteri* based on novel 3D printed apparatuses. These 3D printed apparatuses were designed and generated so that they greatly reduce the amount of time and space required to rear *J. hunteri*. Relative to previous standard methods, these novel apparatuses reduce handling time by about 70% while also increasing parasitoid production by a factor of 7 fold.
3. We also developed another apparatus that greatly accelerates the process of separating male pepper weevils from females, which is key for an SIT strategy and supports the goals outlined in Objective 5.
4. This is critically relevant to biocontrol industry to facilitate the mass rearing of this parasitoid wasp.
5. We have elucidated the attractants that guide parasitoid recruitment to pepper weevil hosts through a series of Y-tube assays.

Key message and benefits to industry: Through our research, we have discovered that the parasitoid wasp *J. hunteri* can significantly reduce the incidence of pepper weevil emergence from pepper fruit and buds, especially when these occur in small sized fruit due to restricted parasitoid access (Objective 4). We have also showed that these wasps can effectively be recruited to plants infested with larval pepper weevil but not those with adult pepper weevil, suggesting there is a specific volatile interaction between parasitoids and their weevil hosts at the larval stage. This information could help support development of parasitoid recruitment technologies based on pheromone or volatile cues that improve wasp attraction to hosts in commercial greenhouse settings. In collaboration with Koppert, this information can be disseminated to growers interested in applying this technology.

Another innovation generated through this project was a parasitoid wasp rapid rearing apparatus which greatly reduces the amount of time and ease of mass rearing this natural enemy (Objective 1). Through future discussion with OIPC we will determine a possible mechanism for the commercialization of such an apparatus, which could be used by growers to produce their own natural enemies of the pepper weevil.

B. Pepper weevil product testing (Objectives 1, 2 and 3)

1. In this study, a series of insecticides covering a broad-spectrum of insecticidal modes of action were assessed for their potential in managing the pepper weevil under laboratory and greenhouse conditions. To accomplish this, laboratory mini-spray tower and greenhouse cage trials were conducted that evaluated the efficacy of 16 conventional, reduced-risk, and microbial insecticides. In laboratory trials, adult weevils were sprayed with insecticides, placed on treated leaves within a cup cage, and were monitored for their survival over 10 days. Of the 16 insecticides tested, 8 provided greater than 60% weevil control, a threshold considered necessary for including products in further greenhouse testing. In greenhouse trials, adult weevil mortality, bud and foliar damage, bud and fruit abortion, and subsequent weevil offspring emergence were measured following each of three weekly insecticide applications. The most efficacious insecticides included kaolin clay and mineral oil, which performed as well as the thiamethoxam-positive control, and incurred 70 and 55% of adult weevil mortality, respectively. Additionally, kaolin clay and mineral oil reduced offspring weevil emergence by 59 and 54%, respectively, compared with untreated controls. The publication and magazine coverage associated with these findings are available at the following links: https://academic.oup.com/jee/article/113/4/1903/5837496 and Pepper weevil studies bring new products to light - Greenhouse Canada
2. In addition to this targeted testing, we have also generated a list of non-target effects of control products based on data available from multiple sources.

Key message and benefits to industry: This study has served to identify useful new control products for pepper weevil integrated management, which should accelerate their availability for use in Canadian greenhouse and field pepper crops.

C. The Sterile Insect Technique – In collaboration with the University of Guelph, Bruce Power and Nordion Inc, we have conducted research needed for the development of a novel pepper weevil management approach based on the sterile insect technique (SIT). To this end we:

1. Identified the minimum dose required to fully irradiate both male and female pepper weevils. At this dose, a sufficient number of weevils survived the treatment to possibly be effective op an optimized pepper weevil irradiation protocol
2. We assessed the fitness of sterile individuals by measuring their longevity, flight ability, the production of sperm by irradiated males and the probability of successful mating between sterile and non-irradiated weevils. We have also evaluated a number of strategies for mass rearing pepper weevil such as through use of artificial diets, which is a critical factor for development of a pepper weevil SIT system. (Felix)

Key message and benefits to industry: Overall the research we conducted on the SIT informed us of the radiation dose and of the environmental parameters we could adjust to produce sterile pepper weevils of a quality high enough to use in a field or greenhouse pest management program. This information will be useful not only for a potential future application for pepper weevil control, but may also help devise SIT systems for other important greenhouse pests. Given the complete compatibility of this strategy with other IPM elements, such a tool could represent a highly effective and sustainable future pest management approach.

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