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Differentiating between click beetle and carrot weevil damage in Nova Scotia

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ABSTRACT

Carrot weevil, *Listronotus oregonensis*, is a pest of carrot throughout Eastern Canada. Modified Boivin traps are used to monitor carrot weevil populations in Nova Scotia, but we have observed that click beetles, *Agriotes* spp., are often found in large numbers within these traps. In addition, damage to carrot roots caused by carrot weevil larvae and wireworms (*Agriotes* larvae) are similar and may be confused by growers. It was unknown if *Listronotus oregonensis* would avoid traps occupied by click beetles thereby affecting monitoring efforts. Further, even though both wireworm and carrot weevil can co-occur in a field, it was unknown which damage was caused by which pest, potentially overestimating the actual impact from either species. Therefore, we conducted laboratory studies to determine: (1) whether occupancy of modified Boivin traps by click beetles affects the tendency of carrot weevils to move into those traps; and (2) how damage to carrot roots inflicted by carrot weevil larvae differs from that of wireworm. Laboratory experiments found that even when as many as 90 click beetles occupied a Boivin trap with carrot bait, carrot weevil adults were as likely to move into that trap as a control trap with only carrot bait. Our second laboratory study demonstrated that whereas carrot weevil larvae tend to produce a continuous furrow around the carrot root when feeding, wireworm damage tends to be more variable, ranging from a few small entry holes, to large irregular excavations. Correctly attributing feeding damage to the right insect will allow growers to accurately identify and quantify their pest populations.

RÉSUMÉ

Le charançon de la carotte (*Listronotus oregonensis*) est un ravageur de la carotte présent dans tout l'est du Canada. Des pièges de Boivin modifiés sont utilisés pour surveiller les populations de charançon de la carotte en Nouvelle-Écosse, mais un grand nombre de taupins (*Agriotes* spp.) est souvent trouvé dans ces pièges. De plus, les dommages infligés aux racines de la carotte par les larves du charançon de la carotte sont semblables à ceux infligés par les larves de taupin (*Agriotes* spp.) et peuvent être confondus par les producteurs. On ignorait si le Listronotus oregonensis évite les pièges déjà occupés par des taupins, comportement qui aurait une incidence sur l'efficacité des activités de surveillance. De plus, des taupins peuvent être présents en même temps que le charançon de la carotte dans un champ, de sorte qu'il est impossible de déterminer la part des dommages attribuable à chaque ravageur, ce qui peut mener à une surestimation des répercussions réelles de chacun. Nous avons donc effectué des études en laboratoire pour déterminer: (1) si la présence de taupins dans les pièges de Boivin modifiés a une incidence sur la tendance du charançon de la carotte d'entrer dans ces pièges et (2) les différences entre les dommages infligés aux carottes par le charançon de la carotte et ceux infligés par les taupins. Nos expériences en laboratoire ont montré que la probabilité que les adultes du charançon de la carotte entrent dans un piège de Boivin contenant 90 taupins et un appât de carotte est aussi élevée que la probabilité qu'ils entrent dans un piège témoin contenant uniquement un appât de carotte. Notre deuxième étude en laboratoire a révélé que la larve du charançon de la carotte produit généralement en s'alimentant un sillon continu autour de la racine, alors que les dommages causés par larves de taupin sont généralement plus variables, allant de quelques petits trous d'entrée à de grands creux irréguliers. Les producteurs pourront ainsi déterminer correctement le ravageur responsable des dommages observés et pourront ainsi bien quantifier les populations de ravageurs.

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INTRODUCTION

Carrot, *Daucus carota* var. *sativa* (Apiaceae), is an important crop in Canada. Canadian carrot production in 2015 was 324,468 metric tonnes, covered 7,662 ha of land, and generated a farm gate value of $107 million (Statistics Canada 2015). Carrot weevil, *Listronotus oregonensis* Le Conte (Coleoptera: Curculionidae), can be found from Nova Scotia to Manitoba in Canada (LeBlanc and Boivin 1993). Carrot weevil larvae feed on carrot as well as parsley and other umbelliferous plants (Chittenden 1909). Reports of damage caused by this pest in North America include 90% yield loss in Iowa (Harris 1926), 50-90% in southern Illinois (Chandler 1926), and 40% in Quebec (Martel et al. 1982). At present, two techniques are widely used by carrot growers to monitor populations of carrot weevil adults; carrot root sections placed vertically in the soil, or the wooden plate trap baited with a section of carrot root (Boivin 1985). The Modified Boivin trap, hereafter called Boivin trap (Ghidiu and VanVranken 1995) is based on the plate trap but found to attract more carrot weevils.

Larvae of the click beetle, *Agriotes sputator* Linnaeus (Coleoptera: Elateridae), also known as wireworms, are believed to have been introduced to North America in the 1920s through nursery stock from Europe (Sasscer 1924). Wireworms are a serious pest of several crops such as potato, corn, wheat, oat, barley, and carrot. In carrots, wireworms damage the root by feeding, thus making the carrot unmarketable and susceptible to fungal growth (Vernon et al. 2001, Agriculture and Agri-Food Canada 2012). We have observed that from mid-May to mid-June, Boivin traps are often occupied by click beetles that are also attracted to the carrot bait. Most often the number of click beetles in Boivin traps is low or in the range of 30-50, but sometimes we have found as many as 75 to 90 click beetles in a single Boivin trap. This raises a question: does the presence of click beetles in a Boivin trap affect the ability of that trap to attract carrot weevils? Interference could result in carrot weevil populations being significantly under-estimated.

Damage on carrot in Nova Scotia has often been attributed to carrot weevil, even in fields where wireworm is suspected to occur. We are not aware of any studies that directly compare carrot weevil and wireworm damage in carrot. Side-by-side comparisons of the damage caused by each of these insects would be useful to help growers identify which pest is in their fields. Carrot weevil larvae feed on the root in a manner described as a line of feeding, sometimes black in color (from secondary fungal infection), within the upper third of the carrot (Boivin 1988). Wireworm damage has been described on a number of different root vegetables or tuber crops, and in general has been described as circular entry holes (Vernon and van Herk 2013). The ability to correctly distinguish carrot weevil from wire worm damage would allow growers to optimize management against the correct pest.

In this paper, we describe two studies. The first experiment determined whether or not the tendency of carrot weevil adults to enter a Boivin trap was affected by the presence of click beetles in that trap. We predicted traps that had high occupancy of click beetles would be less attractive to carrot weevils. The second study directly compared damage to carrot roots caused by carrot weevil larvae vs. wireworms, which we expected to have clearly distinguishable characteristics.

MATERIALS AND METHODS

Insect collection and maintenance

Adult click beetles and carrot weevils were collected for laboratory experiments from carrot fields in Debert and Glenholme, Colchester County, Nova Scotia, over several days in mid-May to early-June using Boivin traps. Boivin traps were 26 cm long x 9.5 cm wide x 4.5 cm high with a semicircular groove along its length (Figure 1, Ghidiu and VanVrankan 1995). A carrot root section was placed in the trap to attract adult carrot weevils. Carrot root sections were replaced twice per week. Insects were removed from traps and placed in plastic boxes. Before being used in experiments, carrot weevils were held in clear glass 500 ml Mason jars lined with filter paper containing a carrot section. Jars were covered with a wire mesh and a Kimwipe™ to maintain humidity. Mason jars were stored in a growth chamber at 22 ± 2° C, 16 h light : 8 h dark photoperiod and 65 ± 5% RH. Every third day the carrots, filter paper, and Kimwipe™ were replaced. Click beetles were held in a plastic container measuring 37 cm x 24 cm x 14 cm with a 5 cm x 10 cm mesh-covered hole in the lid. Soil from the carrot field was placed in the container and click beetles were provided with carrot slices as food. Insects were not starved before the experiment. Male and female carrot weevils were sexed while mating.

Influence of click beetles on carrot weevil trapping

Experiments were carried out on a bench-top in the laboratory at ambient temperature and humidity (approx. 21-22ºC and 78% RH). The bioassay arena consisted of clear plastic containers (57 cm x 28 cm x 10 cm) lined with paper towel. A series of choice tests were done where an

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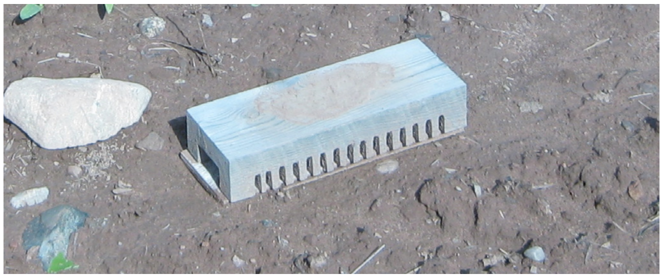
Figure 1. A modified Boivin trap.



adult carrot weevil was introduced into the bioassay arena and given the option of choosing a Boivin trap baited with carrot, or a baited trap containing click beetles. First, a Boivin trap containing a store-bought carrot root section (~25 cm) was placed at one end of the plastic container. During an experimental session, 3 bioassay arenas, each with 1 weevil, were tested simultaneously. In 2015, experiments were done between 30 June and 14 July with 0 (control), 10, or 30 click beetles. Prior to introduction of the carrot weevil adult, click beetles were introduced into the arena. After 30 minutes, when all the click beetles had moved into the trap, a second trap with a carrot root section was placed in the other end of the container. A male or female weevil was then placed in the center of the arena, and the movement of the weevil into a trap was observed. The time required for a weevil to make a choice varied from 1 to 10 minutes. Once the weevil had made its choice, it was removed, the paper towel was replaced, traps (still containing the carrot, or both carrot and click beetles) were switched in the container to the opposite end, and a new weevil was introduced. The experiment was repeated with twenty replications (weevils) for each click beetle number per sex. A given weevil may have been used in more than one bioassay when availability of weevils was low (i.e., some weevils were used more than once in a day), but an individual weevil was never used more than once within a given treatment. For example, a weevil may have been used in bioassays with 0 click beetles, and again in a bioassay with 30 click beetles, but the weevil was never used more than once within a series of tests for 0 or 30 click beetles. Bioassays were run twice each day. In 2016, the experiments were done between 19 May and 16 June using the same methods, but with 0 (control), 50, or 90 click beetles as treatments.

Chi-square analysis was conducted using Minitab, version 17 (Minitab 2016), for each treatment scenario. Males and females were tested separately to evaluate if reproductive status affects response to click beetle occupied traps. For each comparison, we tested the null hypothesis that presence of click beetles (independent variable) in a Boivin trap does not influence the tendency of carrot weevils (dependent variable) to move into that trap.

Damage caused by carrot weevil vs. click beetle

Carrot weevils were collected and maintained in glass jars with carrot as described above. Once carrots showed evidence of oviposition punctures, carrots were taken and dissected for eggs. Collected eggs were used for the experiment.

Unsexed wireworms, approximately 1.5 cm in length (3rd instar) were obtained from a laboratory colony maintained by Dr. Christine Noronha (Agriculture and Agri-Food Canada, Charlottetown, Prince Edward Island). Wireworms were maintained in soil with whole potato tubers in a plastic box (37 cm x 24 cm x 14 cm), with a lid containing a 5 cm x 10 cm hole covered in fine mesh, and placed in the growth chamber at 22 ± 2°C, 16 h light : 8 h dark photoperiod and 65 ± 5% RH, until used for the experiment.

Carrot plants, *Daucus carota*,(var. Cupar), were grown from seed individually in 15 cm-diameter pots containing sandy loam soil collected from a carrot field in Debert (the same field site from which carrot weevils were collected). Plants were grown in a greenhouse at 35±5°C and 16 h light : 8 h dark photoperiod. When carrot plants reached the 7-8 true-leaf stages (~48 days after planting) they were used for the experiment.

Carrots with oviposition punctures were removed from weevil rearing jars and dissected to reveal carrot weevil eggs, which were removed using a camel-hair brush. Two carrot weevil eggs were then placed at the base of the leaf petiole of each potted carrot plant. Twenty replicate carrot plants were each treated with carrot weevil eggs in this manner. For another 20 carrot plants, one wireworm was placed at the base of the petiole. Carrot plants were then placed in a growth chamber at 22 ± 2°C, 16 h light : 8 h dark photoperiod, and 65 ± 5% RH, and watered on alternate days. Carrots were uprooted at 110 days post-germination, meaning carrots were exposed to wireworm or carrot weevil larvae for 62 days, and examined under a dissecting microscope. Each carrot was photographed and its injury described. Damage caused by carrot weevil larvae was measured for length, width, and depth of the furrow in the carrot. Wireworm-inflicted damage to carrots was sufficiently different that only the depth of a tunnel or irregular excavation could be measured. Damage was also evaluated as location on the carrot: the upper, middle, or bottom third of the root. For carrot weevil larvae, a continuous furrow was measured as a

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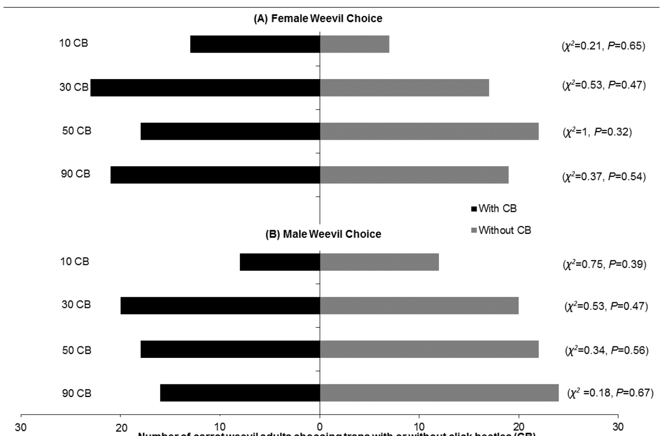
single unit of feeding. For wireworm, a single unit of feeding could range from a small entry hole to an irregular excavation. If a carrot from a wireworm treatment had two entry holes and an irregular excavation, the carrot was recorded as having three feeding injury sites.

A two-sample t-test was carried out (Minitab 2016) to test for differences between depth of the tunnel or furrow from carrot weevil larvae and wireworm. As our data did not meet the requirements for Chi-square analysis, we used descriptive statistics to characterize and compare feeding by wireworms and carrot weevils.

RESULTS

Carrot weevil movement into Boivin traps was not affected by the presence of click beetles in the trap (Figure 2). There was no significant difference in the response of male and female weevils with respect to their movement into traps (10 click beetles (CB): $\chi^2 = 0.19$, $P = 0.66$; 30 CB: $\chi^2 = 0.37$, $P = 0.54$; 50 CB: $\chi^2 = 0.34$, $P = 0.55$; 90 CB: $\chi^2 = 0.10$, $P = 0.74$).

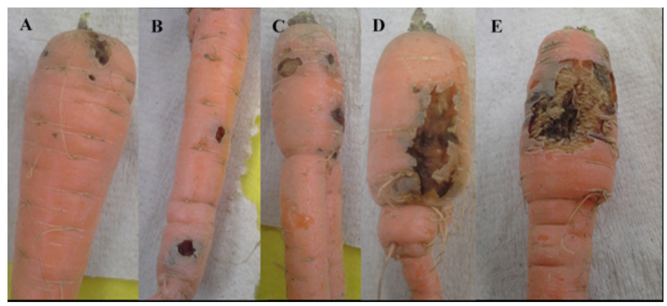
Figure 2. Percentage of carrot weevil adults (*Listronotus oregonensis*), females and males, selecting Boivin traps baited with carrot and occupied by 10, 30, 50 or 90 click beetles (with CB) in two-choice bioassays over a control trap containing only the carrot bait.



Carrot weevil larvae fed by circumnavigating the carrot and forming a furrow in the upper third of the carrot root (Figure 3). Wireworms did not form furrows when feeding but instead produced small holes, such as a tunnel into the carrot, or irregular excavations over the carrot surface (Figure 4A-E). Unlike damage caused by carrot weevil larvae, which was rather consistent across replicates, wireworm damage tended to vary considerably across replicates. Whereas carrots infested with carrot weevil larvae had only one furrow per carrot, a given wireworm

Figure 3. Damage to carrot from a single carrot weevil larva on carrots taken from laboratory damage experiment.

Figure 4. Damage to carrot roots from wireworms used in the laboratory damage experiment. Panels A-C show characteristic feeding holes and panels D and E show irregular excavations.



tended to feed from multiple locations within the same carrot. Furrows in carrot caused by carrot weevil larvae had an average length of 5.1 ± 0.7 cm, an average width of 0.8 ± 0.05 cm and an average depth of 0.9 ± 0.3 mm; $n = 10$.

Damage from both carrot weevil larvae (10 furrows in 10 replicates) and wireworm (14 tunnels/irregular excavations in eight replicates) was heavily concentrated in the upper third of the carrot, with little or no damage to other parts of the carrot root. The two-sample t-test found that the depth of the injury from carrot weevil larvae (0.9 ± 0.3 mm) to be significantly less than that from wireworm (3.2 ± 0.6 mm); $t = -3.30$, $P = 0.005$. Even though there were initially twenty plants per treatment, only ten plants were damaged by carrot weevil larvae, and only eight by wireworm feeding. We did not recover any carrot weevil larvae at the time of carrot harvest, but did recover seven wireworms.

DISCUSSION

We, and growers we have worked with in Nova Scotia, have noticed that Boivin traps set out for carrot weevil monitoring are often occupied by click beetles. The number of click beetles varies, but it is not uncommon to find as many as 75 to 90 click beetles in a single trap. This number of click beetles physically occupies significant space within

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trap and, by feeding on the carrot bait they might interfere with the cues that attract carrot weevils. Our laboratory experiment found the presence of as many as 90 click beetles in a trap to not affect the choice of carrot weevils.

Surprisingly, we were unable to find any studies that specifically examined the impact of by-catch on the efficacy of insect monitoring traps. There have been studies on improving trapping efficiency to reduce by-catch (Seldon and Beggs 2010), but these studies did not report the impact of by-catch on trapping of the target insect. Sweeney et al. (1990) reported that cumulative spruce budworm moth, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae), catches reduced efficiency of sticky traps, and that maintenance of traps every two days resulted in significantly higher numbers of moths than non-maintained traps.

In the field in Nova Scotia, we have noticed peak occupancy of Boivin traps by click beetles occurred over 2-3 weeks (between mid-May and mid-June). We have also observed that carrot weevil adults are present in the field well beyond this period, being active up to the end of June and into July. Therefore, there is a relatively short period where there is potential interference of click beetles in carrot weevil traps. Our results, and the fact that there may be minimal temporal overlap of carrot weevil and click beetle adults in the field suggests there is little concern of occupancy of Boivin traps by click beetles interfering with carrot weevil monitoring.

Accurate identification of the pest causing damage ensures the appropriate management strategies are applied. Efforts to manage an insect that has been erroneously identified can result in monetary loss, wasted time, and environmental pollution. Falsely identifying carrot weevil damage as wireworm damage, or vice versa, could lead to pesticide applications to control a pest not responsible for the observed damage. Our findings in a controlled laboratory experiment agree with field observations of Boivin (1988), who reported that 95% of carrot weevil damage occurs in the upper third of the carrot. Female carrot weevils oviposit on the leaf petiole and the hatching larvae then feed on the top third of the carrot (Boivin 1988). Similar to our findings, Vernon and van Herk (2013) reported that wireworm damage on potatoes appears as holes, as they burrow into the tuber, and they are often present partially or wholly inside potatoes. While click beetle and carrot weevil larvae readily feed on the carrot root, the characteristics of each type of feeding are distinct enough that assignment of damage to the correct species is possible.

Our results suggest that modified Boivin traps should effectively monitor carrot weevil populations even in fields where the click beetle population is large and where click beetle occupancy of Boivin traps is significant. Use of these traps and knowledge of the characteristics of feeding damage will help to properly quantify and identify carrot weevil damage in Nova Scotia carrot fields.

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