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Evaluation of GF-120™ (Naturalyte) for control of *Psila rosae* in carrot in Prince Edward Island

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ABSTRACT

Carrot rust fly, *Psila rosae* F., (Diptera: Anthomyiidae) is a significant pest in Prince Edward Island causing losses of up to 25% to carrot producers. Organic producers have limited means to control this pest and conventional producers are concerned about the development of resistance to currently available pesticides. An alternative insecticide treatment is required for carrot growers to remain competitive. GF-120™ (Naturalyte) is a spinosad (0.02%) product using an 'attract and kill' approach. Currently registered for use on tree fruits, it holds promise for control of other pests. Three replicates of three treatments (control – no spray, GF-120™ and Matador®) were applied in a Latin square design on a carrot planting located on PEI. Eight applications of GF-120™ were required throughout the season compared with 3 applications of Matador®. Damage in the GF-120™ plots was not significantly different from damage observed in the control plot and both were significantly higher than damage in the Matador® plot. A comparison of the costs of the control methods highlighted that as a spray application requiring multiple sprays, GF-120™ does not provide an economically feasible alternative to the currently available insecticide spray.

RÉSUMÉ

La mouche de la carotte, *Psila rosae* F., (ordre des Diptères, famille des Anthomyiidae) est un ravageur important présent dans l'Île-du-Prince-Édouard, qui cause des pertes pouvant aller jusqu'à 25 % pour les producteurs de carottes. Les producteurs biologiques disposent de moyens limités pour lutter contre ce ravageur, et les producteurs classiques sont inquiets de l'acquisition d'une résistance aux pesticides actuellement disponibles. Les producteurs de carottes ont besoin d'un traitement insecticide de rechange pour demeurer concurrentiels. L'insecticide GF-120MC (Naturalyte) renferme du spinosad (0,02 %) et est utilisé selon une technique de piégeage meurtrier. À l'heure actuelle, ce produit est homologué pour une utilisation sur les arbres fruitiers et semble prometteur pour lutter contre d'autres ravageurs. Trois traitements faits en trois exemplaires (témoin – sans pulvérisation, GF-120MC et Matador®) ont été appliqués selon un plan en carré latin sur une culture de carottes située à l'Île-du-Prince-Édouard. Huit applications de GF-120MC ont été requises tout au long de la saison, comparativement à trois applications de Matador®. Les dommages observés dans les parcelles traitées avec le GF-120MC n'étaient pas significativement différents de ceux observés dans les parcelles témoins, et les deux présentaient des dommages significativement plus importants que ceux constatés dans les parcelles traitées avec le Matador®. La comparaison du coût des méthodes montre que le GF-120MC, utilisé en pulvérisation nécessitant plusieurs applications, n'offre pas une solution de rechange rentable aux insecticides pulvérisés actuellement disponibles.

INTRODUCTION

The farm gate value of carrots for PEI is approximately $3.3 million dollars annually (Stats Can 2012). *Psila rosea* F. (Diptera: Anthomyiidae), carrot rust fly, is an important pest in Prince Edward Island, adversely impacting production and reducing farm incomes. Crop management strategies to control this pest are necessary for the continued economic

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health of this farm sector in PEI. Currently, organic growers have no registered product for the control or suppression of *Psila rosae* (PRRP 2004; Burgess and Leclerc 2016) and can lose up to 25% of their crop to this pest. For conventional producers, there are regional concerns that currently registered insecticides targeting this pest may not be effective due to the development of resistance (Niemczyk and Harris 1962). Therefore, it is critically important that alternative and effective insecticide treatments be identified for carrot growing regions across Canada.

Psila rosae is conventionally managed using pesticides, applied once yellow sticky trap catches reach 0.1 flies/trap/day for fresh market carrots and 0.2 flies/trap/day for processing carrots (Burgess and Leclerc 2016). Some pesticide applications have limits with respect to the frequency of use and re-entry periods (e.g. cypermethrin and lambda-cyhalothrin). Resistance to pesticides (e.g., aldrin) was documented in the early 1960s (Niemczyk and Harris 1962) and recent concerns have been raised about pesticides such as diazinon. Despite judicious use, application of diazinon may yield no significant benefit in certain years (Judd et al. 1985). Use of diazinon is also questionable due to its negative effects on the environment and concerns for human health (Muehleisen and Ostrom 2003).

GF-120™ (Naturalyte, Dow Chemical) is a product that is registered for use in tree fruit production and uses an 'attract and kill' approach. It is a sugar-based bait containing a low dose of spinosad (0.02% w/w). Benefits of the product include the very low volume applied to the crop (1.5 L/ha) and that it will break down leaving no residue on the crop (OEHHA 2016). GF-120™ was shown to have no effect on honey bees in field applications (Rendon et al. 2000) with minimal or no effect on non-target beneficial insects (Burns et al. 2001; Vargas et al. 2001; Michaud 2003). In 2002, GF-120™ bait was used in apple against apple maggot. The solution was a GF-120™: water, 1:1.5 (vol:vol) ratio applied at 2.4 L/ha using a spray gun achieving a droplet size of 4-6 mm. Weekly application of GF-120™ for six weeks reduced percentage of apples infested with apple maggot by 67% (Pelz et al. 2005). Similar control was obtained for blueberry maggot during the same study, demonstrating that GF-120™ when used in apple or blueberry under Michigan field conditions has potential to control these pests.

GF-120™ is only registered for use in apple, blueberry, cherry and walnut production crops (Dow Chemical Company 2017), so only a few studies in vegetables have been done to date. With the promising results on Diptera from tree fruit studies, a likely target in vegetable production is other dipteran pests such as *Psila rosae*. A study conducted in Denmark on *Psila rosae* showed GF-120™ to be as effective as Fastac® 50 (a pyrethroid) when applied at a rate of 1.0 L/ha and diluted 1:5 with water (Paaske 2010). When GF-120™ was diluted 1:10 and applied at either the 1.0 L/ha or 1.5 L/ha rate, carrots showed significantly more damage (20% and 30%, Fastac® and GF-120™, respectively). The untreated control had 40% damage, indicating that use of GF-120™ or a conventional pesticide suppressed the population and subsequent damage by approximately 20%. In that study, GF-120™ was applied 4 times during the study while Fastac® was applied 6 times during the season. At this frequency of application and with the benefit being equal for GF-120™ and Fastac®, the economic benefit was not clear owing to the higher cost of GF-120™ when compared with Fastac® (Paaske 2010). Rainfall during the study period was low (5—10 mm) which allowed GF-120™ to be applied and remain effective for longer intervals. In areas with sufficient rainfall to wash the product off the foliage, the number of applications required could be significantly greater. Another challenge of using the product includes the low volume, which can lead to difficulty in achieving adequate distribution within the crop, and modifying commercial equipment to produce the effective droplet size.

The objectives of this study were to evaluate the efficacy of GF-120™ against *Psila rosae* on Prince Edward Island and determine if use of the product is cost effective in comparison with a conventional insecticide application.

MATERIALS AND METHODS

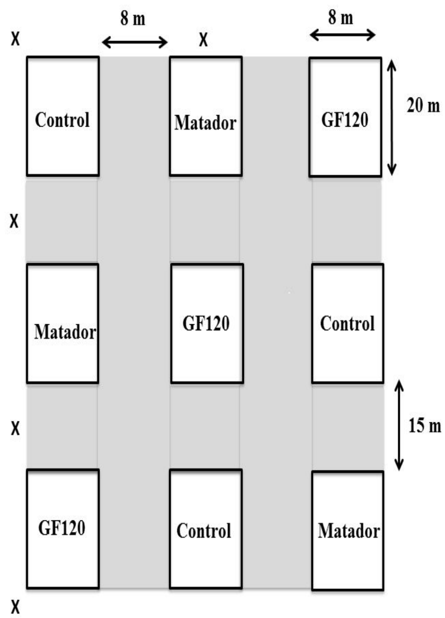
Field site and plot layout

The field site for this carrot planting was located in Warren Grove, Prince Edward Island (46.286124, -63.226173). A large area measuring 200 x 200 m was seeded with Sugar Snax carrots on 30 May 2015. Nine plots (8 m wide x 20 m deep), arranged in a 3 x 3 grid within the large plot, were marked off on 15 June 2015 (Figure 1). Between each row and between each plot within a row were buffer zones, areas planted with carrots but not receiving any treatment. Between each row this zone was 15 m deep. Between the plots within each row, these measured 8 m wide x 20 m deep. These buffer zones served to reduce contamination of the treatment plots. The width of 8 m represents 7 beds of carrots.

Treatments and droplet size

Treatments were control (no spray), GF-120™ applied at a rate of 7.5 L/hectare, and Matador® 120 EC (lambda-cyhalothrin, Syngenta Canada) applied at a rate of 83

Figure 1. Schematic (not to scale) showing layout of the field site used to evaluate GF-120™ against *Psila rosae* in Warren Grove, PEI in 2015. Shaded area represents the buffer zones created between treatment plots to prevent contamination. 'X' denotes placement of yellow sticky traps to monitor *Psila rosae*.



mL/hectare. Treatments were assigned to the plots in a Latin square design. Treatments were applied when trap captures exceeded threshold (see *Monitoring* below). GF-120™ was applied every 7 days until trap captures returned to 0, with additional sprays occurring following a rain event. Matador® was applied only once/generation when trap captures exceeded threshold.

The recommended droplet size for effective use of GF-120™ is 4—6 mm diameter (Paaske 2010). To achieve this droplet size, GF-120™ was applied using a CO_2 backpack sprayer with 30 psi of pressure. Two different types of nozzle were used: a hollow cone nozzle (Teejet AITXA8002), and a flat fan nozzle (Teejet AI11002vs). The hollow cone nozzles broke after the first 2 sprays and the flat fan nozzles were used for the remaining spray applications. Before each spray, the sprayer was calibrated to ensure correct droplet size. Delivery of the required volume was achieved by walking the length of the plot over the central bed of carrots. This resulted in the recommended application rate of 1.5 L of GF-120™ in 6.0 L of water (1:4 ratio), for a total volume of 7.5 L/hectare. GF-120™ was applied once traps reached threshold and then every 7 — 10 days, or if a rain event was sufficient to wash the product from the foliage.

Matador® was applied by the grower using standard boom sprayers at 60 psi at a rate of 83 mL/hectare in 370.6 L/hectare of water. Matador® is applied only once when traps reach threshold.

Monitoring

To determine the *Psila rosae* populations present in the field early in the season, five yellow sticky traps measuring 15 cm x 22.5 cm were positioned at a 45° angle (Collier and Finch 1990) with the sticky side facing the soil. Traps were attached to 60 mm (diameter) dowel using 12-gauge wire such that the lower edge of the trap was approximately 10 cm above the canopy with traps spaced ~30 m apart and placed along the perimeter of the plot area (see Figure 1). These were monitored twice each week and captures were used to calculate the number of *Psila rosae*/trap/day. Additionally, one sticky trap was placed within each treatment plot at planting to monitor population development over the course of the growing season. A threshold of 0.1 flies/trap/day in the original five traps was used to determine when treatments were applied.

Damage Assessment

When the carrots reached maturity on 20 October, a sample of 100 carrots per plot were taken for assessment. Five spots within each plot (near the trap and near each corner) were selected and 20 carrots from each spots (a total of 100 carrots per plot) were harvested for assessment. As this sample size represented a very small percentage of the total carrots in the plot, a second harvest occurred on 6 November. One meter long strips, taken from 5 of the 7 beds within the plots, had all carrots within the row harvested and assessed in the lab. Damage was assessed as the presence or absence of such typical signs as rusty coloured tunnels on the surface of the carrot.

Data Analysis

Mean percent damage was compared between treatments using ANOVA from the stats package in R (R Core Team 2015). For the first harvest on 20 October, the model was Percent Damaged Carrots (20 Oct) = Treatment + Row + Column. Row and Column were included in the model to represent the Latin Square Design (Perry et al. 1980). The second harvest on 6 November was run using the same model with an added variable of Replicate:Sample to reflect the fact that the sub-samples were nested within replicate. Percent damage was evaluated for homogeneity of variance prior to analysis using Bartlett's test, then examined for normality of residuals using Shapiro-Wilk's test after running the model without transformation to determine if transformation was required. As a result, percentages were transformed using asin(x) prior to final analysis to ensure normality. The cost of application for the treatments on a per hectare basis was calculated using label rates and the current cost for GF-120™ and Matador®.

RESULTS

Psila rosae populations exceeded threshold in this location three times during the growing season. When this occurred, GF-120™ and Matador® were applied. In total, there were three applications of Matador® (Figure 2, panel C) compared with 8 applications of GF-120™ due to rain events (Figure 2, panel B). Percent *Psila rosae* damaged carrots was highest in the control (no spray) plots and lowest in the Matador® plots (Table 1 and Figure 3). For the first harvest, there was no statistical difference between treatments (Table 1). Damage from the second harvest did show significant differences, likely due to the larger sample size, with Matador® producing the lowest percentage of damaged carrots. GF-120™ plots showed no significant difference from the control or Matador® with respect to percent damage (Figure 3). The use of GF-120™ under conditions with higher than typical rain events cost $619 per hectare (Table 2). This compares with Matador® applied 3 times in this trial costing $44 per hectare. Had GF-120™ been applied at the same frequency as Matador®, the cost would still be higher at $232 per hectare.

DISCUSSION

GF-120™ did not provide control of *Psila rosae* populations in Prince Edward Island. There was no reduction in flies/trap from one generation to the next (Figure 2), nor any significant reduction in percent damaged carrots at harvest (Figure 3). Use of GF-120™ in tree fruits has shown effective suppression against apple maggot (Reekie et al. 2010) and showed promise as a perimeter spray against blueberry maggot in organic systems. Sciarappa et al. (2008) found GF-120™ to be more effective than PyGanic and Agroneem for control of blueberry maggot in organic production of highbush blueberry in New Jersey. In contrast with carrot, tree fruits and highbush blueberries have a larger canopy and greater foliage area to hold the droplets. Carrots have more finely divided foliage which may result in the droplets not remaining at their optimum size following application. Particularly during the first application, where plants would have been at the 4th true-leaf stage, the canopy would have been thin and much of the product would have landed on the soil surface. Subsequent applications would have occurred when the canopy was larger however the finely divided leaf structure likely wouldn't have supported the droplets, thereby reducing their attraction in the field.

Figure 2. *Psila rosae* per trap per day over the 2015 growing season in control (A), GF-120™ (B) and Matador® (C) plots in Warren Grove, PEI. Arrows indicate application of control products.

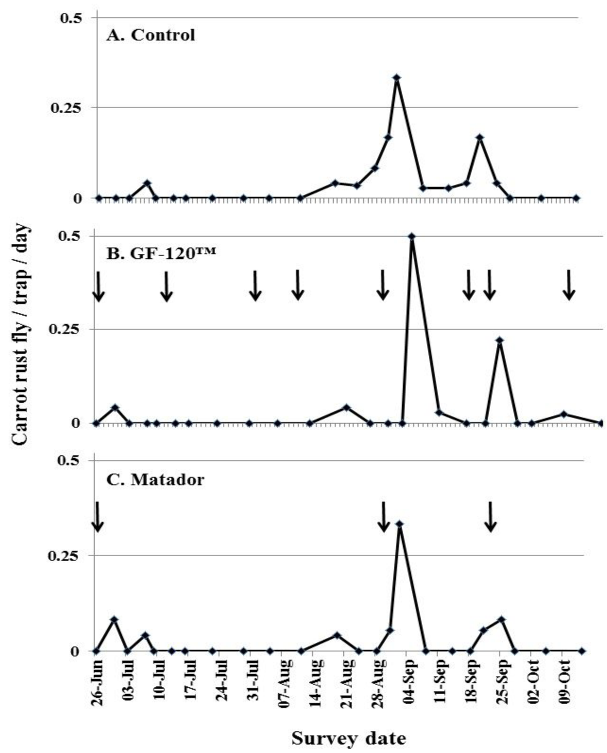


Table 1. ANOVA table for analysis of *Psila rosae* damage from plots treated with GF-120™, Matador® or a no-spray control located in Warren Grove, PEI during 2015.

Harvest date	Variable	F_{df}, *P*
20 October	Treatment	$3.18_{2,2}$ 0.24
	Row	$10.65_{2,2}$, 0.08
	Column	$4.15_{2,2}$, 0.19
6 November	Treatment	$7.33_{2,26}$, 0.003
	Column	$6.58_{2,26}$, 0.005
	Rep: Sample	$0.018_{12,26}$, 0.001

In contrast with the findings by Reekie et al. (2010) and Sciarappa et al. (2008), Prokopy et al. (2004) found that the use of GF-120™ as a border spray was ineffective to control melon flies. Field trials in 2005—2006 on cherry in British Columbia, Canada, found potential phytotoxicity from GF-120™. Further study into this observation demonstrated that necrotic lesions will appear on treated foliage within

Figure 3. Mean (± SE) percentage of carrots damaged by *Psila rosae* in control, GF-120™ and Matador® plots in Warren Grove, PEI in 2015. Letters above bars between treatments within harvest date denote significant differences at α = 0.05.

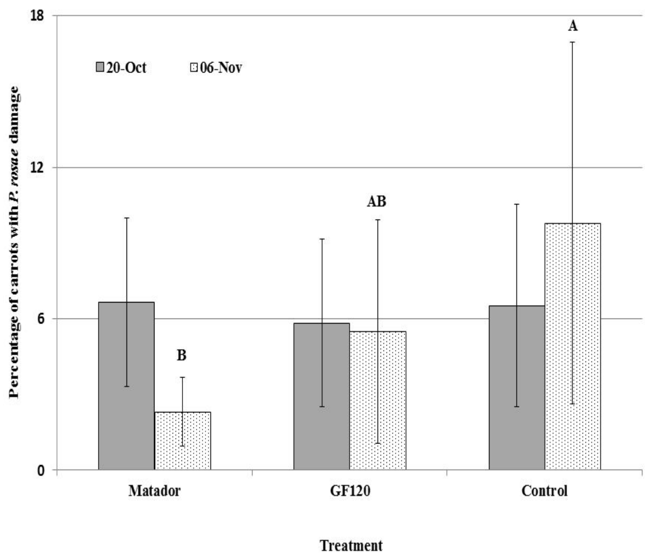


Table 2: Economic comparison of control products for *Psila rosae* control on PEI during 2015 field season.

Product	Cost/unit	Application rate	Applications/season	Total cost/ha
GF-120™	$190 / 3.68 L	1.5 L / ha	8	$619.56
Matador®	$680 / 3.78 L	0.083 L / ha	3	$44.79

24 hours of application with leaf drop to follow repeated applications (DeLury et al. 2009). Increased damage was found with increased dose used on the lower leaf surface, but not on the upper leaf surface. The study recommended that GF-120™ should be applied at doses of <20% to the lower leaf surface to minimize leaf phytotoxicity. In 2006, Mangan et al. (2006) showed that GF-120™ can be diluted up to 4 times in water without loss of efficacy, but knock-down effects are reduced after 10 days of exposure to UV radiation in the field. Variation in efficacy of GF-120™ resulted in a study of the droplet size and longevity under field conditions. Gazit et al. (2013) found larger droplets to retain their toxicity longer in the field, while smaller droplets were susceptible to UV radiation losing 50% of their toxicity in 6 days. These conflicting results suggest that GF-120™ needs to be examined more closely before recommendations on use can be made.

Based on the results from this study, use of GF-120™ for suppression of *Psila rosae* populations is not recommended. GF-120™ provided no significant control over the no-spray control and was not economical when applied multiple times. In areas such as the lower mainland of British Columbia or Vancouver Island, where rain events are more common than in Nova Scotia or PEI, use of GF-120™ would be even less economical for the producer. For organic growers with no control options, use of GF-120™ could have potential if applied in an alternate manner, i.e., bait station. Further work into this means of applying the product should be investigated.

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