2019 Pest Management Research Report (PMRR) 2019 Growing Season

2019 Rapport de recherches sur la lutte dirigée (RRLD) pour la saison 2019

Canada

English

2019 PEST MANAGEMENT RESEARCH REPORT

Prepared by: Pest Management Centre, Agriculture and Agri-Food Canada
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The Official Title of the Report

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[1] This is the 20th year that the Report has been issued a volume number. It is based on the number of years that it has been published. See history on page iii.

This annual report is designed to encourage and facilitate the rapid dissemination of pest management research results, particularly of field trials, amongst researchers, the pest management industry, university and government agencies, and others concerned with the development, registration and use of effective pest management strategies. The use of alternative and integrated pest management products is seen by the ECIPM as an integral part in the formulation of sound pest management strategies. If in doubt about the registration status of a particular product, consult the Pest Management Regulatory Agency, Health Canada, at 1-800-267-6315.

This year there were 23 reports. Agriculture and Agri-Food Canada is indebted to the researchers from provincial and federal departments, universities, and industry who submitted reports, for without their involvement there would be no report. Special thanks are also extended to the section editors for reviewing the scientific content and merit of each report.

Suggestions for improving this publication are always welcome.

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Procedures for the 2020 Annual PMR Report will be sent in fall, 2020. They will also be available from Stefan Bussmann.

Pest Management Research Report History

1961 - The National Committee on Pesticide Use in Agriculture (NCPUA) was formed by its parent body, the National Coordinating Committee of Agricultural Services. It had three main duties: to define problems in crop and animal protection and to coordinate and stimulate research on pesticides; to establish principles for drafting local recommendations for pesticide use; and to summarize and make available current information on pesticides.

1962 - The first meeting of the NCPUA was held, and recommended the Committee should provide an annual compilation of summaries of research reports and pertinent data on crop and animal protection involving pesticides. The first volume of the Pesticide Research Report was published in 1962.

1970 - The NCPUA became the Canada Committee on Pesticide Use in Agriculture (CCPUA).

1978 - Name was changed to the Expert Committee of Pesticide Use in Canada (ECPUA).

1990 - The scope of the Report was changed to include pest management methods and therefore the name of the document was changed to the Pest Management Research Report (PMRR). The committee name was the Expert Committee on Pest Management (1990-1993) and the Expert Committee on Integrated Pest Management since 1994.

2006 - The Expert Committee on Integrated Pest Management was disbanded due to lack of funding.

2007 - Agriculture and Agri-Food Canada agreed temporarily to take over responsibility for funding and compilation of the Pest Management Research Report until an organisation willing to assume permanent responsibility was found.

The publication of the report for the growing season 2019 has been assigned a volume number for the 20th year. Although there was a name change since it was first published, the purpose and format of the publication remains the same. Therefore, based on the first year of publication of this document, the volume number will be 58.

An individual report will be cited as follows:
Author(s). 2019. Title. 2019 Pest Management Research Report - 2019 Growing Season. Agriculture and AgriFood Canada. April 2020. Report No. x. Vol. 58: pp-pp.

Français

Rapport de recherches sur la lutte dirigée - 2019

Préparé par: Centre de la lutte antiparasitaire, Agriculture et Agroalimentaire Canada
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Titre officiel du document
2019 Rapport de recherches sur la lutte dirigée - pour la saison 2019. Compilé par Agriculture et Agroalimentaire Canada, 960 avenue Carling, Ed. 57, Ottawa ON K1A 0C6, Canada
Avril 2020 volume 58[1]. 69 pp. 23 rapports.
Publié sur Internet à http://phytopath.ca/publication/pmrr/

[1]Ce numéro est basé sur le nombre d'année que le rapport a été publié. Voir l'histoire en page iv.

La compilation du rapport annuel vise à faciliter la diffusion des résultats de la recherche dans le domaine de la lutte antiparasitaire, en particulier les études sur la terrain, parmi les chercheurs, l'industrie, les universités, les organismes gouvernementaux et tous ceux qui s'intéressent à la mise au point, à l'homologation et à l'emploi de stratégies antiparasitaires efficaces. L'utilisation de produits de lutte intégrée ou de solutions de rechange est perçue par Le Comité d'experts sur la lutte intégrée (CELI) comme faisant partie intégrante d'une stratégie judicieuse en lutte antiparasitaire. En cas de doute au sujet du statut d'enregistrement d'un produit donné, veuillez consulter Santé Canada, Agence de réglementation de la lutte antiparasitaire à 1-800-267-6315.

Cette année, nous avons donc reçu 23 rapports. Les membres du Comité d'experts sur la lutte intégrée tiennent à remercier chaleureusement les chercheurs des ministères provinciaux et fédéraux, des universités et du secteur privé sans oublier les rédacteurs, qui ont fait la révision scientifique de chacun des rapports et en ont assuré la qualité.

Vos suggestions en vue de l'amélioration de cette publication sont toujours très appréciées.

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Des procédures pour le rapport annuel de 2020 seront distribuées à l'automne 2020. Elles seront aussi disponibles via Stefan Bussmann.

Historique du Rapport de recherche sur la lutte dirigée

Le Comité national sur l'emploi des antiparasitaires en agriculture (CNEAA) a été formé en 1961 par le Comité national de coordination des services agricoles. Il s'acquittait d'un triple mandat: cerner les problèmes touchant la protection des cultures et des animaux et coordonner et stimuler la recherche sur les pesticides; établir des principes pour l'élaboration de recommandations de portée locale sur l'utilisation des pesticides; synthétiser et diffuser l'information courante sur les pesticides.

À la première réunion du CNEAA, en 1962, il a été recommandé que celui-ci produise un recueil annuel des sommaires des rapports de recherche et des données pertinentes sur la protection des cultures et des animaux impliquant l'emploi de pesticides. C'est à la suite de cette recommandation qu'a été publié, la même année, le premier volume du Rapport de recherche sur les pesticides.

En 1970, le CNEAA est devenu le Comité canadien de l'emploi des pesticides en agriculture. Huit ans plus tard, on lui a donné le nom de Comité d'experts de l'emploi des pesticides en agriculture. En 1990, on a ajouté les méthodes de lutte antiparasitaire aux sujets traités dans le rapport, qui est devenu le *Rapport de recherche sur la lutte dirigée*. Par la suite, le nom du comité a changé deux fois: Comité d'experts de la lutte antiparasitaire de 1990 à 1993 puis, en 1994, Comité d'experts de la lutte antiparasitaire intégrée.

En 2000, on a commencé à attribuer un numéro de volume au rapport annuel. Même si ce dernier a changé de titre depuis sa création, sa vocation et son format demeurent les mêmes. Ainsi, si l'on se reporte à la première année de publication, le rapport portant sur la saison de croissance de 2009 correspond au volume 48.

En 2006, le Comité d'experts de la lutte antiparasitaire intégrée a été dissous en raison du manque de financement.

En 2007, Agriculture et Agroalimentaire Canada assume temporairement la responsabilité du financement et de la compilation du Rapport de recherche sur la lutte dirigée jusqu'à ce qu'une organisation désireuse d'assumer la responsabilité pour ce rapport sur une base permanente soit déterminée.

La publication du rapport pour la saison de culture 2019 a reçu un numéro de volume pour la 20e année. Bien qu'il y ait eu un changement de nom depuis sa première publication, l'objectif et le format de la publication restent les mêmes. Par conséquent, sur la base de la première année de publication de ce document, le numéro de volume sera 58.

Modèle de référence:
Nom de l'auteur ou des auteurs. 2019. Titre. 2019 Rapport de recherche sur la lutte dirigée. Agriculture et Agroalimentaire Canada. Avril, 2020. Rapport n^{o} x. vol. 58: pp-pp.

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2019 PMR REPORT # 01 SECTION B: VEGETABLES and SPECIAL CROPS – Insect pests

CROP: Garlic (*Allium sativum* L.), cv. Music
PEST: Leek Moth (*Acrolepiopsis assectella* (Zeller))

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TITLE: SURVEY OF LEEK MOTH POPULATIONS IN VARIOUS COUNTIES IN SOUTHWESTERN ONTARIO, 2019

MATERIALS: DELTA 1 Pheromone trap, lure #40AS009.

METHODS: DELTA 1 pheromone traps with a leek moth (*Acrolepiopsis assectella*) lure #40AS009 were set up in 15 locations in 10 counties in Southwestern Ontario from April 4 to May 16, 2019. Counties surveyed include Brant, Chatham-Kent, Essex, Grey, Huron, Lambton, Oxford, Perth, Renfrew, and Wellington. Traps were hung on wooden stakes approximately 40 cm above the ground. All fields included in the survey were garlic with the exception of a leek field in Perth county. Pheromone lures were changed every two weeks during the duration of the study. Sticky cards were changed weekly. Traps with specimens were counted using a dissecting scope and identified visually without extracting genitalia. Average moths/trap/week were recorded if the field site had more than one trap per field. Traps were left in several fields after garlic harvest to capture the third flight of the season. In the leek field, the traps were left until August 29.

RESULTS: As outlined in Figure 1.

CONCLUSIONS: Leek moth were detected at 12 locations surveyed during the 2019 field season while no leek moths were observed at three field sites in Chatham-Kent, Essex and Lambton counties (Figure 1). A spike of 40 leek moths was observed at a single location in Grey county on July 12 which was the same week a spike of 38 moths was observed in the same field on July 14 in 2018. Physical damage of plants was only observed at this site (garlic) and at the Perth site (leek). Leek moth counts were below an average of 15 moths/card/week in the majority of the locations. Several of the fields monitored in 2018 were also monitored in 2019. With no conventional insecticides applied, the number of captured leek moths doubled in 2019 compared to 2018 at a site in Renfrew county (Figure 2). However, exclusion nets at this field site have shown to be quite effective at eliminating leek moth damage. At a field site in Huron county, two conventional insecticide applications were applied after the second peak in June 2018 (Figure 3). Traps counts in 2019 at this location suggest that the level of leek moths present are much lower there than they were in 2018.

ACKNOWLEDGEMENTS: Thank you to Hannah Fraser, Cora Loucks, Dennis Van Dyk, Amanda Tracey, Josh Mosiondz, Victoria Snyder, Emily Pennington and Owen Hebb for their help throughout the growing season.

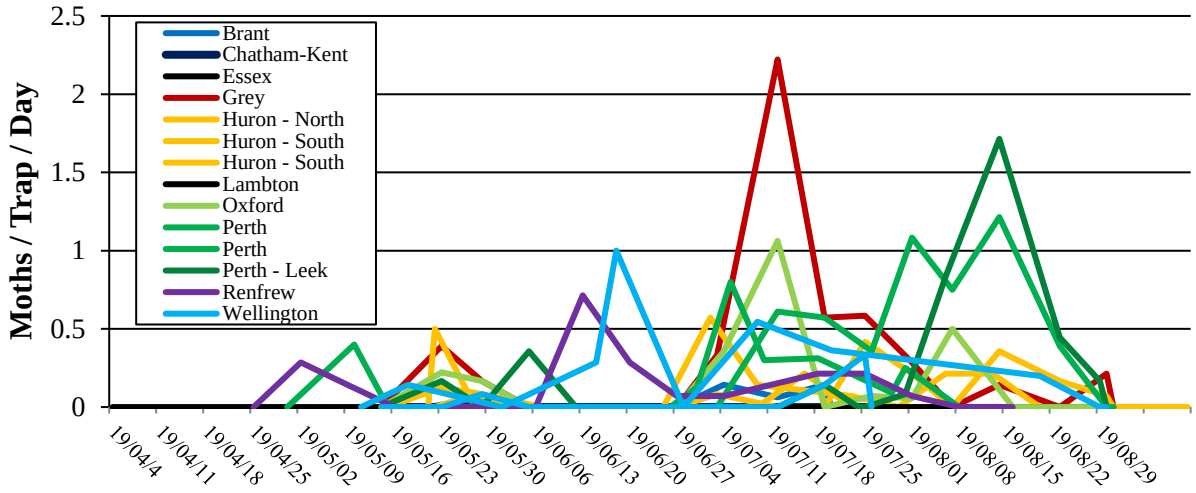

Figure 1. Average number of leek moths per sticky trap per day at 14 garlic fields and one leek field within the surveyed counties of Brant, Chatham-Kent, Essex, Grey, Huron, Lambton, Oxford, Perth, Renfrew, and Wellington.

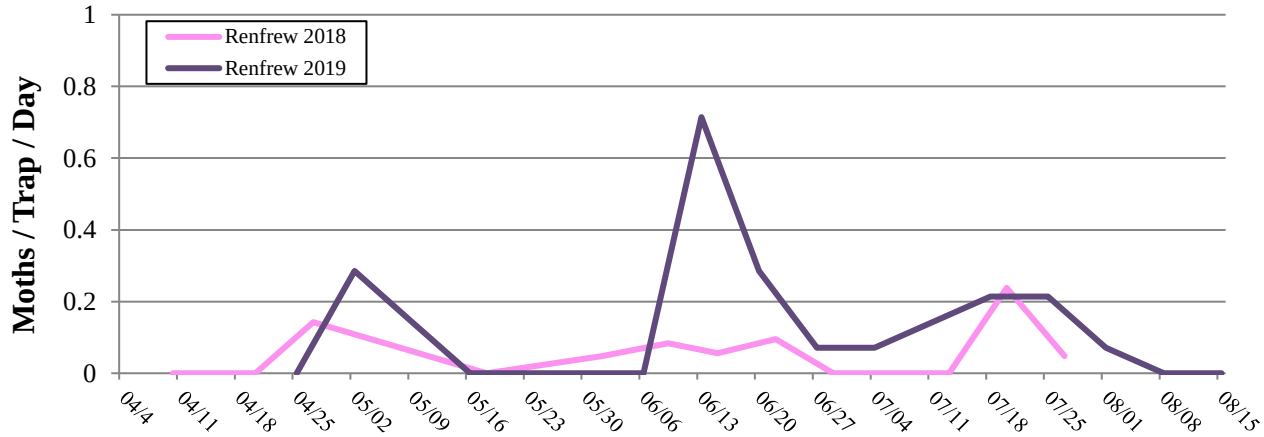

Figure 2. Leek moth counts at a field site in Renfrew county in 2019 (purple) and 2018 (pink).

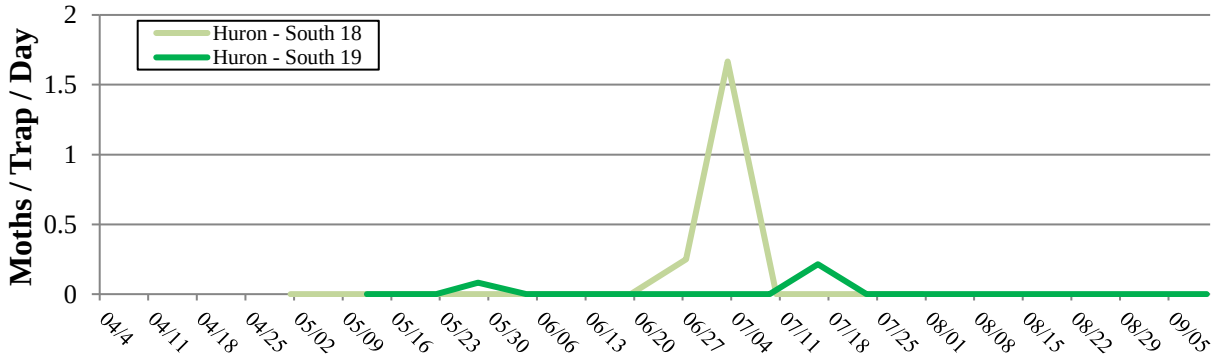

Figure 3. Leek moth counts at a field site in Huron county in 2018 (light green) and 2019 (dark green).

2019 PMR REPORT #02 SECTION B: VEGETABLES and SPECIAL CROPS – Insect pests

CROP: Yellow cooking onions (*Allium cepa* L.), cv. Trekker
PESTS: Onion maggot, (*Delia antiqua* (Meigen))
Seed corn maggot, (*Delia platura* (Meigen))

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TITLE: EVALUATION OF INSECTICIDE TRAY DRENCHES AND SEED TREATMENTS FOR CONTROL OF MAGGOTS IN YELLOW COOKING ONIONS, 2019

MATERIALS: PRO-GRO (thiram 50% + carboxin 30%), GOVERNOR 75 SP (cyromazine 75%), SEPRESTO 75WS (clothianidin 56.25% + imidacloprid 18.75%), PYRINEX 480 EC (chlorpyrifos 480 g/L), VERIMARK (cyantraniliprole 200 g/L), DELEGATE WG 400 (spinetoram 25%)

METHODS: Various insecticide tray drenches and commercial seed treatments for yellow cooking onion transplants, cv. Trekker, were evaluated in a field trial conducted on organic soil (pH ≈ 6.8, organic matter ≈ 67.3%) naturally infested with *Delia antiqua* and *D. platura* pupae near the Muck Crops Research Station, Holland Marsh, Ontario. On 11 March, onions were seeded, 3 seeds/cell, into 288-cell trays filled with soilless mix (Grower Mix, ASB Greenworld Ltd., Mount Elgin, ON). Seed treatments were: GOVERNOR at 6.6 g/100 g seed and SEPRESTO at 0.21 g/1000 seeds. An undrenched check consisting of onions grown from untreated check seed (PRO-GRO only) was also included. On 8 May, trays of onions grown from the check seed were drenched using 500 mL solution/tray of the following treatments: PYRINEX at 1.6 mL/tray, VERIMARK at 4.32 mL/tray and DELEGATE at 3.75 g/tray. A randomized complete block design with four replicates per treatment was use. Each experimental unit consisted of four rows, spaced 40 cm apart, 7 m in length. Onions were transplanted into the field on 16 May using a mechanical transplanter. Two randomly chosen 2 m sections and a 2.32 m yield section of row were staked out in each replicate. On 27 May, plants within the 2 m sections were counted and numbers recorded to determine initial stands. Beginning on 18 June, plants within the 2 m sections were examined for onion maggot losses or damage caused by other pests on a weekly basis. Damaged plants were removed, and the cause recorded. Final destructive assessments of the remaining plants within the assigned 2 m sections were conducted on 2 July (three weeks after the first generation peak), and on 8 August after onions were lodged (to assess total season damage). On 23 August, yield samples from the 2.32 m yield section of row were harvested and on 24 October samples were graded for size to determine yield. Data were analyzed using the General Analysis of Variance function of the Linear Models section of Statistix V.10. Means separation was obtained using Fisher's Protected LSD Test at P = 0.05 level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: Significant differences in the percentage of onions lost due to maggot damage from the first generation and for the total season were observed among the treatments (Table 1). Onion

transplants treated with VERIMARK, DELEGATE, or GOVERNOR had fewer losses from first generation maggot damage compared to onions treated with PYRINEX, SEPRESTO or the untreated check. Over the total season, all insecticide treatments resulted in fewer losses compared to untreated onions. At harvest, there were more onion bulbs per meter from onion transplants treated with VERIMARK, DELEGATE or PYRINEX 480 EC than from the SEPRESTO seed treatment or untreated onions (Table 1). No significant differences in size distribution or the percent marketable were found among treatments; however, onion transplants treated with DELEGATE, VERIMARK, PYRINEX or GOVENOR had higher yields (56 to 46 t/ha) than untreated transplants (Table 2).

ACKNOWLEDGEMENT: Funding was provided by the Plant Production Systems of the Ontario Agri-Food Innovation Alliance.

Table 1. Onion losses caused by maggot damage for transplanted onions, cv. Trekker, treated with insecticide seed treatments or tray drenches and grown near the Muck Crops Research Station, Holland Marsh, Ontario, 2019.

Treatment	Rate/tray[1]	Method of Application	% Onions Lost from Maggot Damage		Onions/m
			1st Gen[2]	Total Season[3]	
VERIMARK	4.32 mL	500 mL solution/tray	2.2 a[4]	1.1 a	23.2 a
DELEGATE	3.75 g	500 mL solution/tray	6.0 a	0.5 a	24.0 a
GOVERNOR	–	6.6 g/100 g seed	9.0 a	8.9 a	19.6 ab
PYRINEX	1.6 mL	500 mL solution/tray	19.5 b	14.4 a	24.4 a
SEPRESTO	–	0.21 g/1000 seeds	22.2 b	11.7 a	18.0 bc
Check	–	--	30.8 b	37.3 b	14.2 c

[1] Trays were drenched on 8 May, 66 days after seeding and 8 days before transplanting (16 May).
[2] Onions in the 2 m staked out section were removed and assessed for maggot damage on 2 July.
[3] Final assessment was conducted on 8 August after the 2nd generation peak and when onions were lodged.
[4] Numbers in a column followed by the same letter are not significantly different at P = 0.05, Fisher's Protected LSD Test.

Table 2. Yield and size distribution for transplanted onions, cv. Trekker, treated with insecticide seed treatments or tray drenches and grown near the Muck Crops Research Station, Holland Marsh, Ontario, 2019.

Treatment	Rates[1]	Yield (t/ha)	% Mkb	Size Distribution (%)[2]		
				Jumbo (>76 mm)	Can No. 1 (45-76 mm)	Cull[3] (<45 mm)
DELEGATE	3.75 g/tray	55.3 a[4]	98.5 ns[5]	3.1 ns	95.4 ns	1.5 ns
VERIMARK	4.32 mL/tray	55.8 a	97.0	4.5	92.5	3.0
PYRINEX	1.6 mL/tray	50.5 ab	95.7	1.0	94.6	4.3
GOVERNOR	6.6 g/100 g seed	46.2 ab	95.0	7.9	87.0	5.0
SEPRESTO	0.21 g/1000 seeds	40.3 bc	97.4	5.6	91.8	2.6
Check	--	26.8 c	93.9	0.0	93.9	6.1

[1] Insecticide drenches were applied using 500 mL water per tray.
[2] Percentage was determined using weight.

[3] The cull category also includes unmarketable onions due to maggot damage.
[4] Numbers in a column followed by the same letter are not significantly different at P = 0.05, Fisher's Protected LSD test.
[5] ns = no significant differences at P = 0.05, Fisher's Protected LSD Test

2019 PMR REPORT #03 SECTION B: VEGETABLES AND SPECIAL CROPS – Insect pests

CROP: Rutabaga (*Brassica napus* var. *napobrassica* L.), cv. Laurentian
PESTS: Cabbage maggot (*Delia radicum* (L.))

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TITLE: FIELD EVALUATIONS OF INSECTICIDES TO CONTROL EARLY AND LATE CABBAGE MAGGOT IN RUTABAGA, 2019

MATERIALS: PYRINEX (chlorpyrifos 480 g/L), DELEGATE (spinetoram 25%), ENTRUST (spinosad 240 g/L), MINECTO PRO (abamectin 28.5 g/L, cyantraniliprole 135 g/L), VERIMARK (cyantraniliprole 200 g/L)

METHODS: Two trials were conducted in a commercial field near Exeter, Ontario to evaluate insecticides for cabbage maggot control in rutabagas: an early cabbage maggot trial targeting the first generation and a late cabbage maggot trial targeting the third generation. Rutabagas, cv. Laurentian, were direct seeded at a rate of 6.5 seeds/m (6 inch in-row spacing) on 21 June 2019 for both trials. The early cabbage maggot insecticide trial was setup in a randomized complete block design (RCBD) with four replicates and eight treatments. Each experimental unit consisted of two rows, 76 cm apart and 4.5 m in length. Insecticides were applied either at seeding or at rutabaga emergence. The applications at seeding (S) included VERIMARK at 1.97 L/ha and MINECTO PRO at 0.67 L/ha and were applied on 25 June 2019. Emergence (E) treatments included VERIMARK at 1.97 L/ha, MINECTO PRO at 0.67 L/ha, DELEGATE at 0.20 L/ha, ENTRUST at 0.36 L/ha and PYRINEX at 2.75 L/ha and were applied on 16 July 2019. A second application (P) of PYRINEX was made on 30 July 2019. All treatments were applied as directed banded applications to the soil surface using a hand boom CO_2 sprayer with a TeeJet XR80035 nozzle and a spray volume of 500 L/ha of water. An UNTREATED check was also included as a treatment. Twenty rutabagas from each plot were hand-harvested on 20 August 2019 and assessed for cabbage maggot damage to the taproot to determine the percent damage. The late trial was setup in a RCDB with four replicates and six treatments. Each experimental unit consisted of two rows, 76 cm apart and 5 m in length. The treatments included VERIMARK, MINECTO PRO, DELEGATE, ENTRUST and PYRINEX along with an UNTREATED check. Treatments were applied on 20 August 2019 and 10 September 2019 to coincide with third generation cabbage maggot emergence and egg-laying based on degree day calculations. Treatments were applied in a directed banded application over the row using a hand boom CO_2 sprayer with a TeeJet XR80035 nozzle and a spray volume of 1000 L/ha of water. A harvest sample of twenty rutabagas were taken on 3 October 2019 and assessed for percentage and severity of cabbage maggot damage. Cabbage maggot damage was rated on a scale developed by Dosdall et al. (1994) where 0 = no root damage, 1 = small feeding channels on the root comprising less than 10% of the root surface area, 2 = 11-25%, 3 = 26-50%, 4 = 51-75%, and 5 = 76-100% of the taproot surface area damaged. The damage severity index (DSI) was determined using the following equation:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of rutabagas in each class})]}{(\text{total no. of rutabagas per sample})\ (\text{no. of classes} - 1)} \times 100$$

Percent damage was calculated by the number of rutabagas that had any cabbage maggot damage/total number of rutabagas multiplied by 100. According to the rating scale used anything rated a 2 and higher is considered a cull; percent culls was calculated by the number of rutabagas in category 2+/total number of rutabagas multiplied by 100. All data were analyzed using the Randomized Complete Block Design ANOVA in the Analysis of Variance section of Statistix V.10. Means separation was obtained using Tukey's test with $P = 0.05$ level of significance.
The monthly air temperature averages were: May 10.2°C, June 15.8°C, July 20.3°C, August 19.2°C and September 16.6°C. Monthly rainfall averages were: May 69.9 mm, June 70.9 mm, July 74.1 mm, August 10.8 mm and September 319.1 mm.

RESULTS: Data are presented in Tables 1 and 2.

CONCLUSION: For the early cabbage maggot trial, all treatments had numerically less damage compared to the UNTREATED check but none of the treatments were statistically significant different from the check. For the late cabbage maggot trial, all insecticide treatments had significantly lower percent cabbage maggot damage compared to the UNTREATED check. Rutabagas treated with MINECTO PRO, VERIMARK, DELEGATE and PYRINEX had significantly lower cabbage maggot damage severity compared to the UNTREATED check. Rutabagas treated with MINECTO PRO and VERIMARK had significantly lower percent culls compared to the UNTREATED check.
Currently, VERIMARK is registered for cabbage maggot control as a soil application only and PYRINEX is registered for soil and post planting applications in rutabagas in Ontario. These results highlight some potential products and use patterns that may provide some efficacy against cabbage maggot in rutabagas.

REFERENCES:
Dosdall, L. M., Herbut, M. J., & Cowle, N. T. (1994). Susceptibilities of species and cultivars of canola and mustard to infestation by root maggots (*Delia* spp.) (Diptera: Anthomyiidae). The Canadian Entomologist, 126(2), 251-260.

Table 1. Percent of cabbage maggot damage on rutabagas at harvest following insecticide application at seeding or rutabaga emergence in the early cabbage maggot insecticide trial, 2019.

Treatment	Application Timing[1]	Cabbage Maggot Damage (%)
PYRINEX	E, P	23.1 ns[2]
VERIMARK	S	25.0
MINECTO PRO	E	26.9
VERIMARK	E	37.5
MINECTO PRO	S	40.0
ENTRUST	E	42.5
DELEGATE	E	42.5
UNTREATED	-	50.0

[1] Insecticides either applied at seeding (S), at rutabaga emergence (E), or 28 days after seeding (P)
[2] ns indicates that no significant differences were found among the treatments at $P = 0.05$, Tukey's test

Table 2. Percent of cabbage maggot damage and damage severity index on rutabagas at harvest after insecticide application from the late cabbage maggot insecticide trial, 2019.

Treatment	Cabbage Maggot Damage (%)	DSI[2]	Percent Culls (%)
MINECTO PRO	21.3 a[1]	6.9 a	5.0 a
VERIMARK	27.5 a	9.1 a	6.3 a
DELEGATE	25.0 a	10.3 a	11.3 ab
PYRINEX	26.3 a	11.3 a	11.3 ab
ENTRUST	26.3 a	12.5 ab	15.0 ab
UNTREATED	43.8 b	22.2 b	25.0 b

[1] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's test

[2] DSI was calculated using the following equation:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of rutabagas in each class})]}{(\text{total no. of rutabagas per assessed})\ (\text{no. of classes} - 1)} \times 100$$

2019 PMR REPORT # 04 **SECTION C: POTATOES – Insect Pests**

CROP: Potato (*Solanum tuberosum* L.), cv. Kennebec
PEST: Colorado potato beetle (CPB), *Leptinotarsa decemlineata* Say

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TITLE: CANADA WIDE EVALUATION OF THE SUSCEPTABILITY OF COLORADO POTATO BEETLE LARVAE TO SIX REGISTERED INSECTICIDES, 2018

MATERIALS: ACTARA 240SC (thiamethoxam 21.6%), TITAN (clothianidin 48%), ENTRUST SC (spinosad 22.5%), DELEGATE WG (spinetoram 25%), VERIMARK (cyantraniliprole 18.7%), CORAGEN (chlorantraniliprole 18.4%).

METHODS: Adult Colorado potato beetle (CPB) adults were collected in 2018 with standardized collection kits from six different Canadian provinces (PE, NB, QC, ON, MB, AB) and mailed to either the Fredericton Research and Development Centre (FRDC; NB) or the London Research and Development Centre (LoRDC; ON) for insecticide susceptibility testing. An insecticide naive laboratory population (PL-189) of CPB maintained at the LoRDC was used to calculate the concentration of each insecticide required to kill 90% of larvae (LC_{90}) and these diagnostic concentrations (DC) were used for subsequent testing with the field collected CPB. Populations were maintained in growth cabinets at 25C, 50% RH at 16:8 L:D conditions and second instar larvae (L2) were used for feeding assays to assess susceptibility. To test susceptibility 43 mm leaf disks of *S. tuberosum* v. Kennebec were cut from 4 week old plants. Disks were dipped in one insecticide DC solution and allowed to completely dry before feeding assays began. Control leaf disks were dipped in reverse osmosis water. After drying, leaves were transferred to 47 mm microbial dishes lined with filter paper. Five L2 larvae from the same population were placed on each disk and allowed to feed for 48 hours in the case of Titan, Actara, Entrust, Delegate and 72 hours for Coragen and Verimark. Mortality was assessed by probing each individual with a small paintbrush. An individual was deemed dead if it was unable to right itself or move forward one step when probed. Two control disks, each with 5 L2 individuals, were run alongside each trial and used to adjust percent mortality using Abbott's formula. At least 60 L2 individuals were tested for susceptibility for each insecticide per population (360 larvae per population plus controls). Populations were classified as: susceptible to a particular insecticide if they had >70% mortality; reduced susceptibility with mortality <70% and >30% mortality; and resistant if mortality was <30% to the insecticide DC being tested.

RESULTS: As outlined in Figure 1.

CONCLUSIONS: Across Canada in 2018 resistance to the six insecticides screened in our study varied

both within and between provinces. Overall, 18/204 (9%) of population-insecticide combinations showed resistance to at least one insecticide (5 in MB, 1 in NB, 4 in ON, and 5 in QC). Sixty-six population-insecticide combinations (32%) showed reduced susceptibility (3 in AB, 14 in MB, 8 in NB, 17 in ON, 10 in PE, and 14 in QC). The remaining 120 combinations were susceptible to the given insecticide. Manitoba showed the highest levels of overall resistance. Four populations were resistant to Titan, 1 to Actara (both neonicotinoids), 2 populations were resistant to Delegate and 1 to Entrust (both spinosyns). Of the resistant populations detected in Quebec, 4 were resistant to Entrust while 1 was resistant to Actara. Resistant populations in Ontario were found with Titan (2 populations), Entrust (1 population) and Delegate (1 population). The lone resistant population in New Brunswick was tested against Entrust. The effectiveness of each insecticide varied by province, for example Titan appeared to be effective at controlling populations of CPB in PE, NB, QC and AB, but was far less so in MB and ON.
Our data demonstrates that in most regions of the country CPB populations no longer remain susceptible to all insecticide classes applied by growers. Moving forward we will look at these trends across multiple years, as well as incorporate surveys completed by growers to correlate frequency and rotation of insecticide application with CPB insecticide resistance over time.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Canadian Horticultural Council through the Canadian AgriScience Horticulture Cluster 3. We thank Sydney Boyachek, Taylor Gervais, Abbie Bechard, Chanelle Barel-Rutherford for technical assistance, and project partners and growers in each region for beetle collections.

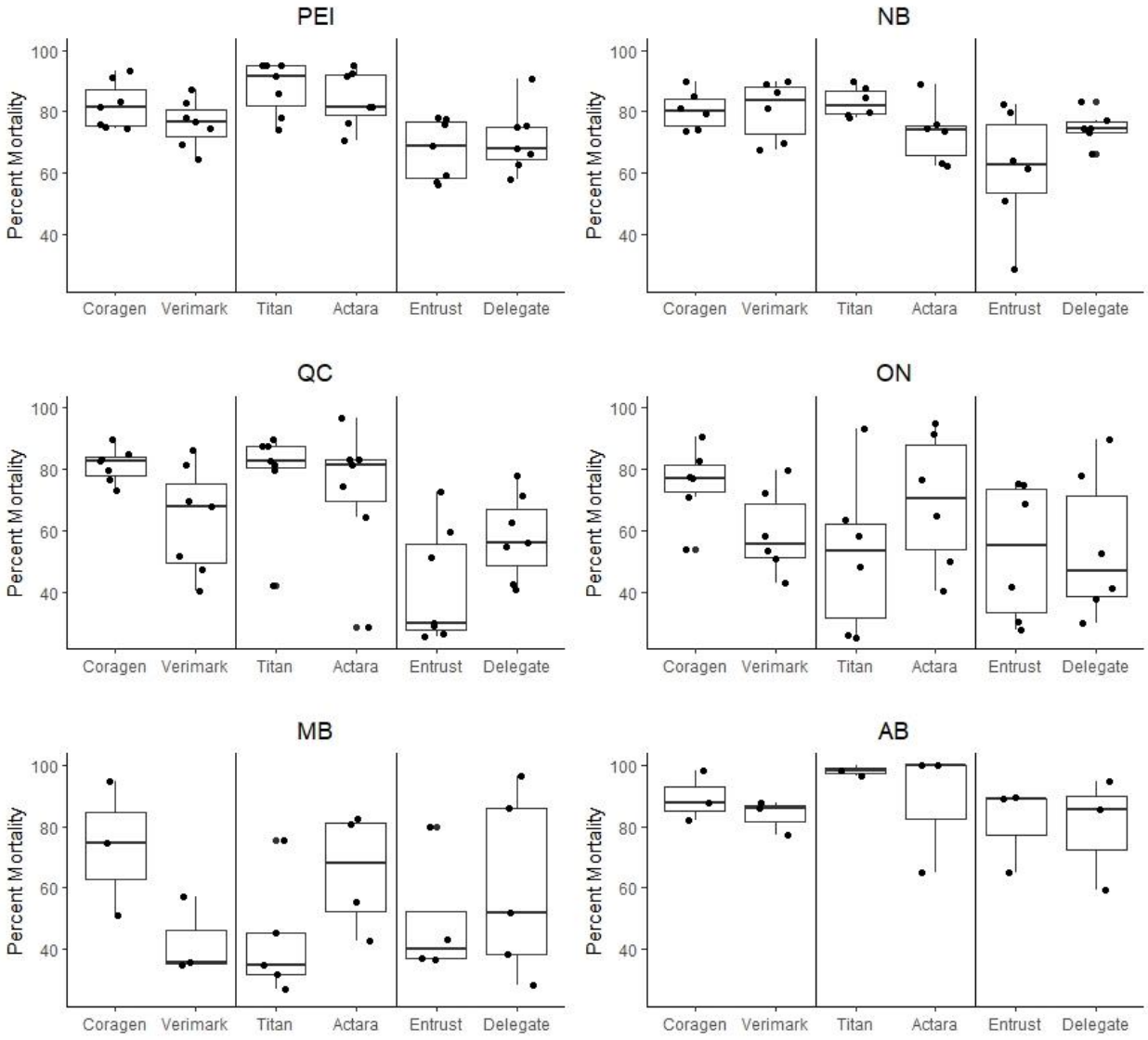

Figure 1. Percent mortality of second instar Colorado potato beetle larvae from populations collected in six provinces that were tested with six insecticides representing 3 chemical classes. Box plots represent median and quartile ranges, with dots indicating actual data points. Coragen and Verimark are anthranilic diamides, Titan and Actara are neonicotinoids, and Entrust and Delegate are spinosyns.

2020 PMR REPORT # 05 **SECTION E: CEREALS, FORAGE CROPS AND OILSEEDS –Insect Pests**

CROP: Cereal crops: wheat
PEST: Orange wheat blossom midge, *Sitodiplosis mosellana*

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TITLE: **THE POTENTIAL OF A HAIRY-GLUMED (HG) TRAIT TO REDUCE WHEAT MIDGE INFESTATION ON "HAIRY" WHEAT (2019)**

MATERIALS: *Triticum aestivum* cv CDC Teal, CDC Teal NIL w/ Hairy Glumes and cv Roblin.

METHODS: Currently, *Sm*1 is the only resistance gene against the orange-blossom wheat midge, *Sitodiplosis mosellana* (Cecidomyiidae) and this resistance must be protected. Mechanical resistance to egg-laying, such as trichomes (hairs) on the glumes of the wheat heads, might help reduce the number of eggs laid on *Sm*1 midge-tolerant plants. We evaluated the presence of trichomes on the glumes of wheat heads for their potential to reduce the number of wheat midge offspring in a series of replicated bioassays. Two Near-Isogenic lines (NILs) of CDC Teal, one with hairy glumes and the cv without hairy glumes. These were selected to evaluate the effect of trichomes on wheat glumes in reducing wheat midge larvae on wheat heads through reduced oviposition. The midge-susceptible cultivar AC Roblin, with no hairy-glumes, was used as a check.

Choice experiments were conducted in the laboratory with hairy and non-hairy CDC Teal wheat to determine the effect of hairy glumes on wheat midge oviposition. In the fall wheat midge 3rd instar larvae were placed in 5 inch plastic pots containing soil collected from the Saskatoon Research Farm. Larvae were covered with 1 cm of soil, the surface of the soil was moistened, and the pots were covered with a plastic lid. Pots were left on the laboratory bench at room temperature for four weeks prior to being placed in a cold room at 5°C. Pots with midge larvae were removed from cold storage after eight months, the soil was wetted to start development of midge larvae into pupae and pots were kept at room temperature for three weeks until wheat midge adults emerged.

Three cultivars of *Triticum aestivum* (CDC Teal hairy, CDC Teal not-hairy, and cultivar Roblin as a check) were assessed. Five pots of each cultivar with three seeds/pot were planted weekly and placed in the greenhouse. Wheat plants were grown until spikes emerged from the boot (Zadok's stage 50) at which time they were used in the bioassay. Two pots of each experimental variety for a total of six pots were placed in a BugDorm cage (60x60x120cm) along with emerging wheat midge (see above). Each wheat plant had approximately the same number of heads as the others in the bioassay. The experiment was replicated six times. In total, 78 heads of CDC Teal Not-Hairy, 71 heads of CDC Teal Hairy and 81 heads of Roblin were challenged with wheat midge. The experiments were conducted in a growth chamber set to 19°C; photo period 19L:5D; and relative humidity at 50-70%. Lights located above the cage were set to simulate dawn and dusk conditions to encourage oviposition. After midge adults had died the plants were removed from the cage (3-7 days after initial exposure). Wheat heads were enclosed in crossing bags to prevent desiccation of maturing larvae. Larvae were left to develop for three weeks after which the heads were removed and dissected. The number of larvae on each head of all three cultivars were counted.

A one-way ANOVA followed by a Tukey post-hoc test with the R statistical software was conducted to determine the effect of variety on the average number of midge larvae per head.

RESULTS: More wheat midge 3rd instar larvae were found on Non-hairy CDC Teal than on CDC Teal Hairy and Roblin wheat (Fig. 1). The number of times a wheat midge female chose a head of each variety (Fig 2.) indicates a preference for oviposition on the non-hairy Teal compared to the Hairy Teal and Roblin wheat heads drives the increased number of wheat midge larvae found on the Non-hairy CDC Teal. The difference in midge larvae among heads was significantly different ($F= 5.45$, $DF=2$, $P=0.0049$) with

approximately twice as many larvae per head on CDC Teal non-hairy (x=1.8 ± 4.1SE) significantly different from CDC Teal Hairy (x=0.4 ± 0.2SE, t=2.9, P=0.0089) and Roblin (x=0.6 ± 0.2SE, t=02.69, P=0.02). The average number of larvae per head between CDC Teal Hairy and Roblin were not significantly different (t=-0.377, P=0.925).

Figure 1. Total number of wheat midge larvae collected per wheat variety.

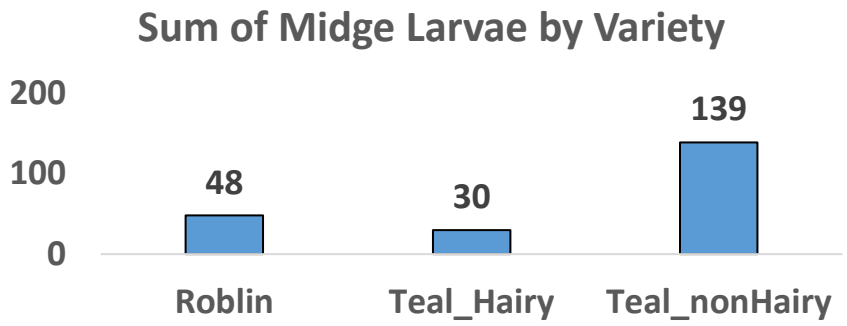
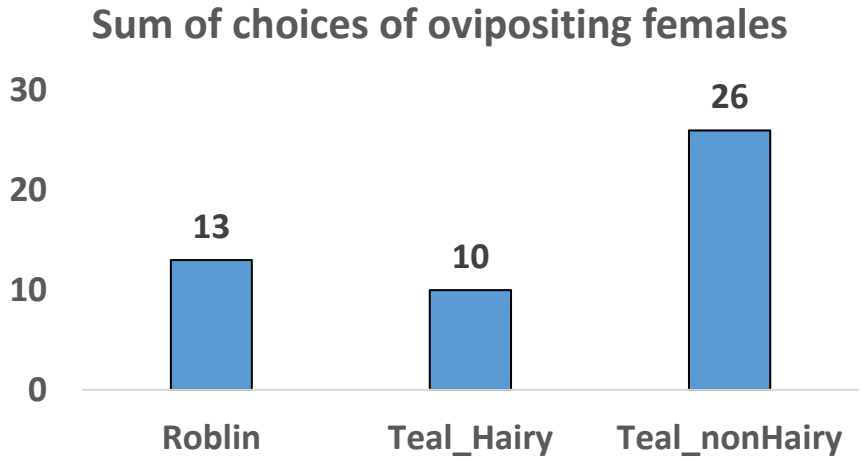


Figure 2. The number of times a wheat midge female chose to oviposit on a head of each variety of wheat.



CONCLUSIONS: The hairy-glumed trait on the CDC Teal Hairy NIL significantly reduced the number of ovipositions by wheat midge females and the number of larvae attacking kernels compared to the Non-Hairy CDC Teal NIL. This trait shows promise as a way to reduce the number of wheat midge eggs laid per head. The Roblin variety is included as a non-hairy check and is not a highly-attractive wheat variety to wheat midge. The low number of ovipositions and midge larvae recorded at approximately the same level as the CDC Teal Hairy variety is interesting. Future work will investigate how the hairy-glumed trait performs in bioassays under a no-choice scenario.

2020 PMR REPORT # 06 **SECTION E: CEREALS, FORAGE CROPS AND OILSEEDS –Insect Pests**

CROP: Cereal crops: wheat
PEST: Cereal aphids: specifically the English grain aphid, *Sitobion avenae* and Bird cherry-Oat aphid, *Rhopalosiphum padi*

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TITLE: ESTABLISHMENT OF CEREAL APHID SPECIES ON HAIRY-GLUMED WHEAT (2019)

MATERIALS: Two near isogenic lines (NIL) of wheat *Triticum aestivum*, of the cultivar CDC Teal (CDC Teal hairy NIL, CDC Teal not-hairy NIL

METHODS: Two near isogenic lines of wheat *Triticum aestivum*, of the cultivar CDC Teal (CDC Teal hairy NIL, CDC Teal non-hairy NIL), were assessed for resistance to settling of alate (winged)-fundatrix cereal aphids, Birdcherry-oat aphids (BCO), *Rhopalosiphum padi* and English grain aphids (EGA), *Sitobion avenae* (Hemiptera: Aphidoidea). CDC Teal hairy was selected because it has trichomes (hairs) on its glumes which were evaluated for their potential to deter alate (winged) cereal aphids from settling on wheat heads. Higher densities of trichomes can dissuade aphids settling on leaves (Aly et al. 2018). The CDC Teal non-hairy has glabrous glumes like most modern wheat varieties.
Pots of each cultivar with three seeds/pot were planted weekly and placed in the greenhouse. Wheat plants were grown until anthesis was complete and seed started to fill (Zadoks stage 70) at which time they were used in the bioassay. Pots of each experimental variety were placed into two BugDorm cages (60x60x120cm) to get as close as possible to having a balanced number of heads of each type in each cage for a total of 30 Hairy CDC Teal heads and 24 CDC Teal non-hairy heads. 25 alate EGA were placed between the pots on the floor of each cage in a Petri-dish. The aphids were given one week with plants to establish. One of the pots of non-hairy wheat died during the experiment and six experimental heads were lost (n=30 Hairy Teal heads, n=18 non-Hairy Teal heads).
A second experiment evaluated alate BCO against the CDC Teal Hairy and non-hairy plants. One pot of each experimental variety for a total of two pots per cage were placed into three BugDorm cages (60x60x120cm) along with 2 alate BCO per number of heads in each cage. Wheat plants were balanced per cage so that an equal number of wheat heads was available per cage (Cage 1, ten heads of each = 40 aphids, Cage 2, six heads of each = 24 aphids, Cage 3, eight heads of each = 32 aphids). Aphids were introduced to cages on Petrie dishes placed between the two pots. All experiments were conducted in a growth chamber set to 19°C; photo period 19L:5D; and relative humidity at 50-70%.
The number of aphids settling and on three locations on a tiller (head, stem and leaves) was recorded at the end of each experiment as the response variable. Two-way ANOVAs (factors: Wheat NIL and Location on plant) were run in R for each experiment to assess the effect of locations on the wheat plants and the two lines of wheat, Hairy and non-hairy CDC Teal. The most important comparison though, was the settling of aphids on the heads of each line and these mean number of aphids were assessed with a one-way ANOVA in R when applicable. α=0.05 was used in all tests.

RESULTS: In experiment one, alate English grain aphids (EGA), *Sitobion avenae*, chose to establish more frequently on non-hairy CDC Teal than the hairy CDC Teal (Fig. 1). The interaction between location and wheat lines was significant and driven by the few EGA settling on the leaves of either plant. More aphids were found on heads of non-hairy Teal than on heads and stems of Hairy Teal than on non-hairy Teal (Fig. 1, Table 1) and the location on the plant and the hairy-ness of the heads affected the settling of EGA (Fig. 1 Table1). The main point of the experiment was to evaluate if the hairy-glumes on the heads prevented

settling and there were significantly more aphids on non-hairy heads of CDC Teal than Hairy Heads (F=6.057, DF=1, P=0.0177, one-way ANOVA).

Figure 1. Average number (±SE) of winged English Grain Aphids on three locations (Head, stem and leaf) of two near-isogenic lines of wheat, CDC Teal Hairy with the hairy-glumed trait and CDC Teal non-hairy with glabrous glumes.

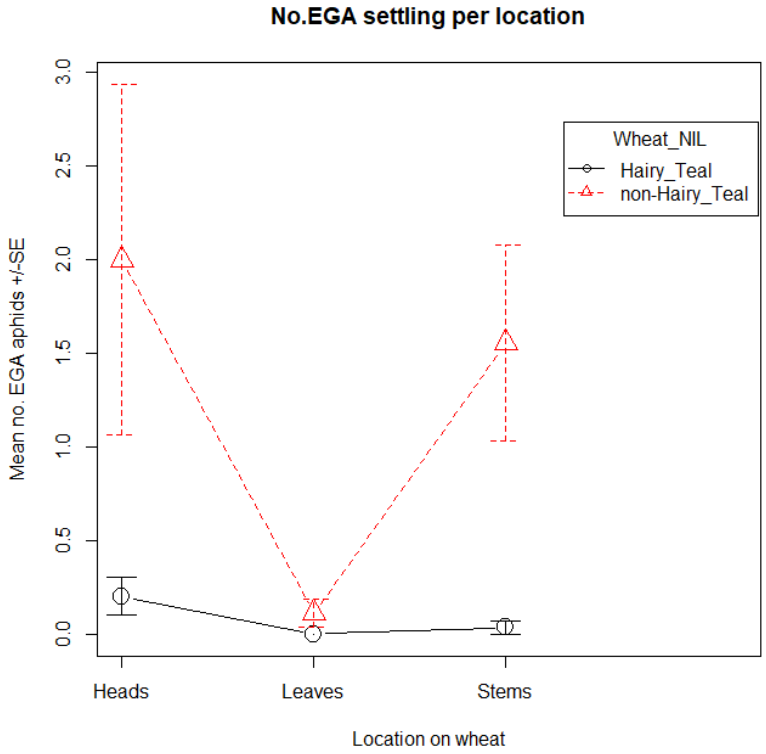

Table 1. Two-way ANOVA table for the Number of English Grain Aphids settling on various locations on Hairy and non-Hairy CDC Teal Wheat Near Isogenic Lines (NILs). Bold denotes significant P values at α=0.05

Factors/ No. English Grain aphids	Sum Sq	DF	F value	P value
Wheat Near Isogenic Line	17.35	1	3.288	0.0403
Location on plant	44.20	2	16.769	0.0000719
Location: Wheat NIL	18.45	2	3.498	0.0330
Residuals	363.99	138		

Figure 2. Average number (±SE) of winged BirdCherry-oat Aphids on three locations (Head, stem and leaf) of two near-isogenic lines of wheat, CDC Teal Hairy with the hairy-glumed trait and CDC Teal non-hairy with glabrous glumes.

In experiment 2, Birdcherry-oat aphids did not settle at all on wheat heads, either hairy or non-hairy (Fig. 2) and they preferred to settle on the stems and flag leaves of the non-hairy CDC Teal plants (Table 2: Location) more than on the hairy CDC Teal plants (Fig. 2, Table 2 Wheat NIL). The interaction between location and wheat lines was not significant (Table 2).

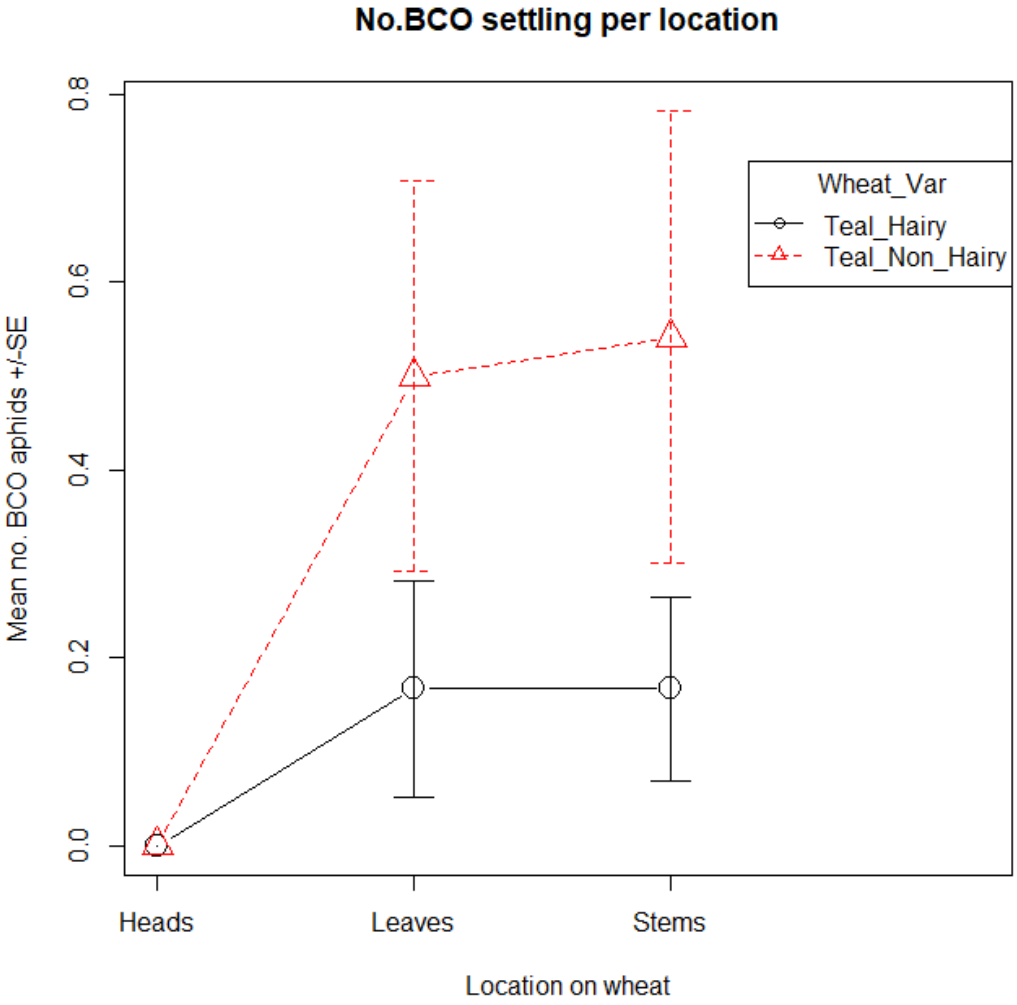

Table 2. Two-way ANOVA table for the Number of BirdCherry-Oat Aphids settling on various locations on Hairy and non-Hairy CDC Teal Wheat Near Isogenic Lines (NILs). Bold denotes significant P values at α=0.05

Factors/ No. English Grain aphids	Sum Sq	DF	F value	P value
Wheat Near Isogenic Line	2.007	2	4.036	**0.0465**
Location on plant	3.792	1	3.812	**0.0245**
Location: Wheat NIL	1.014	2	1.019	0.364
Residuals	68.625	138		

CONCLUSION:

English grain aphids typically prefer to settle and establish feeding on heads (Chongrattanameteekul et al. 1991) while bird-cherry oat aphids typically prefer to settle and establish feeding and colonies on stems and leaves ((Dean, 1974; Leather & Lehti, 1982) of wheat. Hairy glumes reduced the settling of EGA on heads and should be tested under no-choice conditions in the future. Birdcherry-oat aphids did not settle on the heads of either experimental wheat line, so this experiment failed to test the hairy-glumed trait. Birdcherry-oat aphids do infest wheat heads on occasion so the trait might still be useful to dissuade their settling on wheat heads. With the increase in settling on non-hairy stems and leaves, it is possible that alate BCO initially preferred to land on the non-hairy glumed heads and then moved down to their preferred feeding locations on the stems and leaves. Close behavioural observations of settling behavior are warranted for future experiments. In this second experiment, the average number per plant of any BCO aphids settling was low (Fig. 2) as was the EGA settling rate in experiment 1, so in future experiments, more than two aphids per tiller are recommended to begin the bioassay.

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2019 PMR REPORT #07 SECTION H: PEST MANAGEMENT METHODS-BIOLOGICAL CONTROL

CROP: Broccoli, *Brassica oleracea* L. var. italic
PEST: Large Yellow Underwing, *Noctua pronuba* (Linnaeus, 1758) (Lepidoptera: Noctuidae)

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TITLE: EVALUATION OF *BEAUVERIA BASSIANA* ISOLATES AND ENTOMOPATHOGENIC NEMATODES FOR CONTROL OF *NOCTUA PRUNUBA* LARVAE

MATERIALS: *Beauveria bassiana* isolates (ISH-189, ISH-190, ISH-252, OK-372, and OK-373) BOTANIGARD ® 22WP, *B. bassiana* strain GHA, LARVANEM, *Heterorhabditis bacteriophora* CAPSANEM, *Steinernema carpocapsae* ENTONEM, *Steinernema feltiae*

METHODS: Efficacy of five isolates of *Beauveria bassiana* (ISH-189, ISH-190, and ISH-252 from the coastal area of BC, and OK-372 and OK-373 from the Okanagan region of BC) and three entomopathogenic nematodes (EPNs) (*Heterorhabditis bacteriophora*, *Steinernema carpocapsae*, and *S. feltiae* purchased from Koppert Biological Systems) were tested against second instar larvae of *Noctua pronuba* (Lepidoptera: Noctuidae) at four temperatures (15°C, 17°C, 20°C, and 25°C). Bioassays were performed at the Institute for Sustainable Horticulture (ISH) research laboratory at Kwantlen Polytechnic University (KPU). Cutworm eggs were obtained from Eco-care Technologies Inc. in March 2019 and were reared at 15°C in insect rearing facilities. Larvae were fed artificial diet (McNeil's diet) with the addition of bok choy leaves grown at the ISH greenhouse. Fourteen-day-old cultures of *B. bassiana* were harvested and spore suspensions of 4.0×10^8 spores/ml were prepared in reverse osmosis (RO) water with 0.1% Tween-20. BotaniGard® 22WP and 0.1% Tween-20 served as positive and negative controls, respectively. Broccoli leaf discs (7 mm in diameter) were immersed in the *B. bassiana* suspensions for one minute and then transferred to paper towel to dry. Each leaf disc was set into a 1 oz plastic Solo cup and one larva was transferred into each cup. One trial was conducted, with twelve cups for each *B. bassiana* isolate at three temperatures (15, 17, and 20°C) for a total of 252 larvae. Larvae were monitored daily for mortality. Nematode suspensions were prepared in RO water. The number of nematodes was quantified with light microscopy using a nematode counting dish. Based on the label information, nematodes were mixed in suspension at 3000 EPNs/ml RO water. Filter paper was set into the bottom of each 1 oz Solo cup and 300 µL of the nematode suspension was applied, resulting in an application of approximately 68 EPNs/cm2 (900 EPNs per cup). One larva and a 5 mm plug of artificial diet were transferred to each cup and RO water served as the negative control. Cups were sealed with lids and maintained at four temperatures (15°C, 17°C, 20°C, and 25°C) in dark rooms. Two trials were conducted, with 7 and 12 larvae per treatment, for a total of 228 larvae tested. Larvae were assessed daily for mortality. The lethal time for 50% larval mortality (LT_{50}) and lower and upper fiducial confidence limits (LCL, UCL) were calculated in "R" (version 1.2.1335) using the ecotox package. Abbott's Correction was applied to data if the mortality in the control treatment was between 5 and 20%. If the control mortality was greater than 20% the data was excluded from the analysis.

RESULTS: The results are summarized in Tables 1 and 2.

CONCLUSIONS: The results indicate that larval mortality caused by *B. bassiana* isolates and nematodes declined with decreasing temperature. Biocontrol agents need to target *N. pronuba* larvae in the fall when larvae are small and temperatures are low. *Beauveria bassiana* isolate ISH-190 showed the greatest efficacy, followed by ISH-252 at 15°C. At 17 °C, both ISH-190 and ISH-252 killed half the treated larvae 8 to 9 days

after treatment. At 20°C ISH-252 was the most virulent isolate, killing half the larvae after 4.5 days. Nematode species, *S. carpocapsae,* followed by *S. feltiae* caused the highest mortality at all temperatures tested. Future studies would benefit from tests of combinations of these pathogens at low temperatures to determine their potential for integration into pest management strategies.

ACKNOWLDGEMENTS: We would like to thank the Industrial Research Assistance Program for financial support of this project, Dr. Tom Lowery to provide Okanagan isolates, Eco-Care Techologies for supplying *N. pronuba* eggs, and G. Aruda, A. Huang for their technical assistance with this project.

Table 1. Lethal time, in days, required to kill 50% (LT_{50}) of 2nd instar *Noctua pronuba* larvae and lower and upper fiducial confidence limits (LCL, UCL) when exposed to three *Beauveria bassiana* isolates from the Fraser Valley held at the Institute for Sustainable Horticulture (ISH), two from the Okanagan (OK), and commercial product BotaniGard® at temperature of 15, 17, and 20°C.

Isolates	Temperature (°C)	LT_{50}	LCL	UCL
ISH-189	15	15.3	11.4	63.2
ISH-190		11.0	9.3	16.2
ISH-252		>14	-	-
OK-372		>14	-	-
OK-373		>14	-	-
BotaniGard®		15.3	11.4	63.2
ISH-189	17	14.8	9.9	77.4
ISH-190		8.7	7.7	10.1
ISH-252		8.3	7.4	9.1
OK-372		16.6	13.1	-
OK-373		>14	-	-
BotaniGard®		>14	-	-
ISH-189	20	8.9	7.5	9.9
ISH-190		9.5	7.8	13.7
ISH-252		4.5	3.6	5.2
OK-372		>14	-	-
OK-373		>14	-	-
BotaniGard®		8.8	6.9	14.8

Table 2. Lethal time, in days, required to kill 50% (LT_{50}) of 2nd instar *Noctua pronuba* larvae and lower and upper fiducial confidence limits (LCL, UCL) when exposed to commercially reared entomopathogenic nematodes - *Heterorhabditis bacteriophora* (HB), *Steinernema carpocapsae* (SC), and *S. feltiae* (SF) at temperature of 15, 17, 20, and 25°C.

Nematode	Temperature (°C)	LT_{50} (days)	LCL	UCL
HB	15	11.7	10.8	13.9
SC		6.1	4.4	7.9
SF		7.3	6.5	8.2
HB	17	9.3	8.4	13.4
SC		3.8	2.2	5.4
SF		5.6	4.6	7.5
HB	20	6.7	4.9	7.4
SC		2.1	1.7	2.4
SF		2.0	0.9	2.5
HB	25*	5.8	4.9	7.2
SC		1.8	0.7	2.2
SF		2.9	2.3	3.4

*****$LT_{50,}$ LCL, and UCL estimates for 25°C is based on results from a single trial. Mortality in the second trial was >20% in the control treatment at 25°C.

2019 PMR REPORT # 08 **SECTION H: PEST MANAGEMENT METHODS – BIOLOGICAL CONTROL**

CROP: Onion (*Allium cepa* L.)
PEST: Onion Maggot (*Delia antiqua* (L.))

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TITLE: **SECOND YEAR FIELD DEMONSTRATION OF THE STERILE FLY RELEASE TECHNOLOGY FOR ONION MAGGOT MANAGEMENT IN ONION SET AND COOKING ONION PRODUCTION IN ONTARIO**

MATERIALS: Sterilized/irradiated *Delia antiqua* pupae.

METHODS: Two field sites near Exeter and Scotland, Ontario were sown with onions in the spring of 2019. At the Exeter field site, a field comprised of Grandby sandy-loam approximately 3.0 ha (7.4 ac) in size was seeded with onion sets on 22 May at a high density of ~20 million seeds / ha (~8 million seeds / ac) with no soil application of chlorpyrifos. At the Exeter site, the field used for onion sets the previous year (2018), was less than 300 m from the release field in 2019 (**Figure 1**). At the second site near Scotland, Ontario, two fields approximately 3.0 km apart were transplanted at an average density of ~345,000 plants / ha (140,000 plants / ac). At the first field where sterile flies were to be released, the field comprised of Camilla sandy-loam was approximately 8.3 ha (20.6 ac) in size and planted on 12 May. The control field, comprised of Grandby loamy-sand was approximately 3.3 ha (8.1 ac) in size and was planted one week after the release field (**Figure 2**). There were no other major onion fields within a 20 km radius from either the Exeter or Scotland field sites. Onion flies were produced by Phytodata, and then sterilized and released according to the protocol developed by Phytodata, using the Sterile Insect Technology (SIT). The *Delia antiqua* pupae were irradiated by Nordion and then shipped to Exeter and Scotland, ON, and kept alive until release following protocols developed by Phytodata Inc. Four onion maggot sticky traps consisting of three stakes with blue sticky cards clipped above the crop canopy were placed on each side of every field (**Figure 2B**). Cards were monitored weekly for natural onion maggot populations as well as for the displacement of sterile / pink flies throughout the growing season. Fly releases at the Exeter and Scotland sites began on 8 May and continued weekly until 11 September. At this site, flies were released on the north-west corner of the release field at least 30 m from the closest sticky card trap at the west side of the field. Damage plots measuring 15 x 15 cm capturing approximately 40 plants were set up a short distance away from the sticky traps at the flag leaf stage at each of the four sites around the onion set field near Exeter. The Exeter field was harvested 25 September. At the Scotland release field, flies were released on the southern site of the field also 30 m from the closest sticky card trap. Damage plots were created by counting out 25 plants on four rows for a total of 100 plants / plot. The number of plants were counted weekly until 22 August. In addition, 50 onions were harvested every week starting 24 July and commencing 22 August to monitor for maggot damage (**Figure 2C**). The control field was harvested 22 August and the release field was harvested 25 August.

RESULTS: At the Exeter field site, there was no control field monitored in 2019. Sticky card counts throughout the season indicated that the release field had a higher fertile fly pressure than the control field in 2018 (**Figure 4**). An average of 10.7 flies/trap/week were counted during the first peak 22 May and

14.4 flies/trap/week during the second peak 25 June (**Table 1; Figure 4**). At the Scotland field site, an average of 26.3 flies/trap/week were observed 12 June at the control field and 25.4 flies/trap/week were observed 27 June at the release field. Fly counts remained low relative to these peaks after 4 July (**Table 3; Figure 5**). At both field sites, pink flies were found at every trap at the release field but most were quantified throughout the season at the closest trap relative to where the sterile flies were released. No pink flies were found on any of the sticky cards at the control field at the Scotland location. Destructive sampling did not find any onion maggot larvae throughout the season (**Tables 1 & 3**).

CONCLUSION: Onion maggot (*Delia antiqua*) management has relied heavily on group 1B organophosphates, specifically chlorpyrifos insecticides which are at risk of becoming obsolete due to insect resistance or pesticide re-evaluations in the future. The prospect of insecticide resistance and potential restrictions of use illustrate the importance of alternative management strategies for this insect. Sterile Insect Technology (SIT) in Québec has proven to eliminate the application of soil and foliar chlorpyrifos insecticides in most fields while maintaining onion yields comparable to pesticide-based programs. Onion acreage in Québec using SIT has grown from 140 ha in 2011 to 825 ha in 2019. Work in Québec has shown that the release rates of sterile flies could be decreased by up to 90% within 5 years of repeated use due to the reduction of wild populations while also decreasing the cost of the sterile fly program itself. The first year of this trial in 2018 showed a population reduction of over 50% of fertile onion maggot flies at the release field within a single year at the Exeter field site, however in the second year fly populations were higher at this field site. This may be due to the close proximity of the 2019 site to the 2018 site (**Figure 1**). At the Scotland field site it is unknown whether the wild onion maggot population was equal between the two sites. A continuation of this program is required to observe the long-term effects of a sterile fly release on the onion maggot population to determine the overall effectiveness of reducing the need of chemical control options.

Table 1. Sterile fly release dates, plant stage, trap counts and damage plot levels at the Exeter release field site.

	Release Quantity ('000)	Plant Stage[1]	Fertile Flies	Pink Flies	Damage Plots
19/05/08	17	pre	--	--	--
19/05/15	17	loop	0.9	0.0	--
19/05/22	42	flag	10.7	0.0	--
19/05/28	57	flag	4.0	0.0	--
19/06/04	60	1LS	3.0	1.3	--
19/06/11	106	1LS	0.5	0.2	32
19/06/18	113	2LS	8.8	2.5	35
19/06/25	113	3LS	14.4	2.3	36
19/07/02	96	4LS	4.3	0.8	32
19/07/09	88	4LS	4.7	0.0	32
19/07/16	63	5LS	0.5	0.1	33
19/07/23	35	5LS	2.8	0.0	33
19/07/30	29	5LS	5.5	0.0	33
19/08/06	39	5LS	3.6	0.3	33
19/08/13	37	5LS	1.3	0.0	--
19/08/20	25	5LS	2.8	0.0	--
19/08/27	21	post	1.2	0.1	--
19/09/03	26	post	0.8	0.0	--
19/09/10	22	post	2.4	1.8	--

[1] Plant stage where pre = pre-emergence, loop = loop stage, flag = flag leaf stage, LS = leaf stage and post = after pulling/harvest
-- = Data points not taken

Table 2. Insecticide applications from seeding to harvest at the Exeter field site.

Date	Field	Trade Name	Common Name	Rate / Acre
19/06/13	Release	Mako	Cypermethrin	71 mL
19/07/18	Release	Matador	Lambda-cyhalothrin	76 mL

Table 3. Sterile fly release dates, plant stage, trap counts and damage plot levels at the Scotland field control and release field sites.

		Release Field				Control Field			
Date	Release Quantity ('000)	Plant Stage[1]	Fertile Flies	Pink Flies	Damage Plots	Plant Stage[1]	Fertile Flies	Pink Flies	Damage Plots
19/05/08	15								
19/05/15	15								
19/05/22	38	pre	--	--	--	pre	--	--	--
19/05/29	51	3LS	6.0	0.0	100	3LS	7.5	0.0	100
19/06/05	60	4LS	4.8	0.0	100	4LS	5.2	0.0	100
19/06/12	87	5LS	6.9	0.0	100	5LS	26.3	0.0	100
19/06/20	102	6LS	21.8	0.0	100	6LS	18.8	0.0	100
19/06/27	102	7LS	25.4	0.0	100	7LS	12.2	0.0	100
19/07/04	87	7LS	2.1	0.9	100	8LS	2.1	0.0	100
19/07/11	79	--	--	--	--	--	--	--	--
19/07/19	57	8LS	3.9	1.7	100	8LS	2.2	0.0	100
19/07/24	32	9LS	4.0	0.1	100	9LS	3.2	0.0	100
19/08/01	26	9LS	2.3	0.8	100	9LS	2.2	0.0	100
19/08/07	35	10LS	2.9	1.3	99	10LS	0.9	0.0	99.5
19/08/14	34	--	--	--	--	--	--	--	--
19/08/22	23	post	7.9	0.0	93	post	0.0	0.0	88.8
19/08/29	19								
19/09/05	24								
19/09/12	20								

[1] Plant stage where pre = pre-emergence, loop = loop stage, flag = flag leaf stage, LS = leaf stage and post = after pulling/harvest
-- = Data points not taken

Table 4. Insecticide applications from seeding to harvest at the Scotland field sites.

Date	Field	Trade Name	Common Name	Rate / Acre
19/05/09	Release	Lorsban 15G	Chlorpyrifos	6.3 kg
19/05/17	Control	Lorsban 15G	Chlorpyrifos	6.3 kg
19/07/25	Control + Release	Delegate WG	Spinetoram	136 g
19/08/05	Control + Release	Delegate WG	Spinetoram	136 g

Figure 1. The 2019 field site (**A**) near Exeter was seeded approximately 300 m from the 2018 field where sterile flies were release during the 2018 field season.

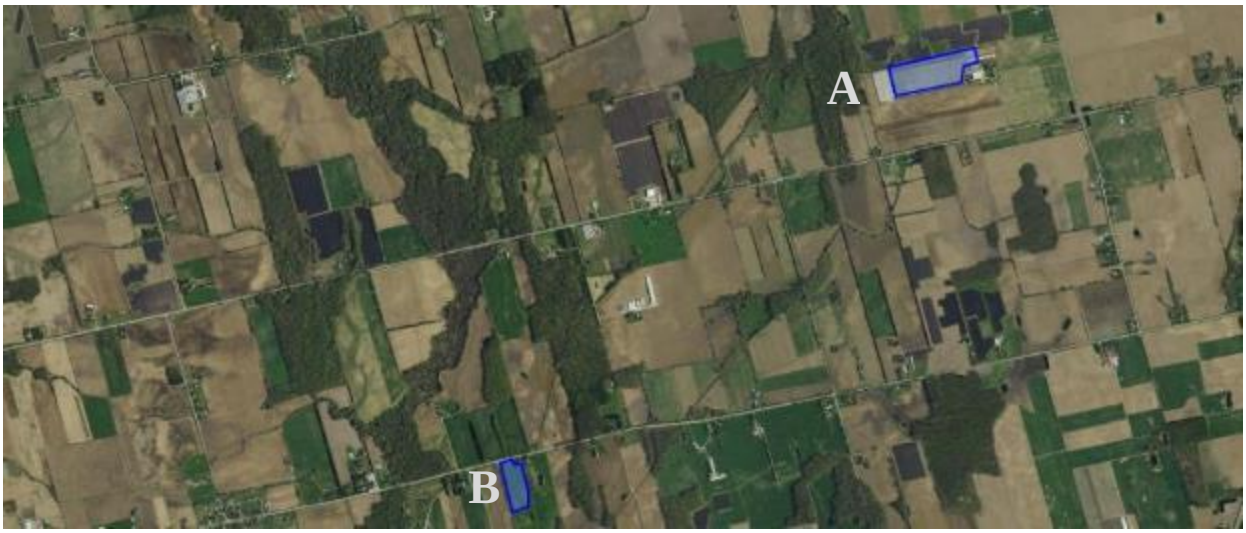

Figure 2. The field sites near Scotland had a release field (**A**) was approximately 8.3 ha (20.6 ac) in size and a control field (**B**) approximately 3.3 ha (8.1 ac) in size and was situated 3.0 km from the release field.

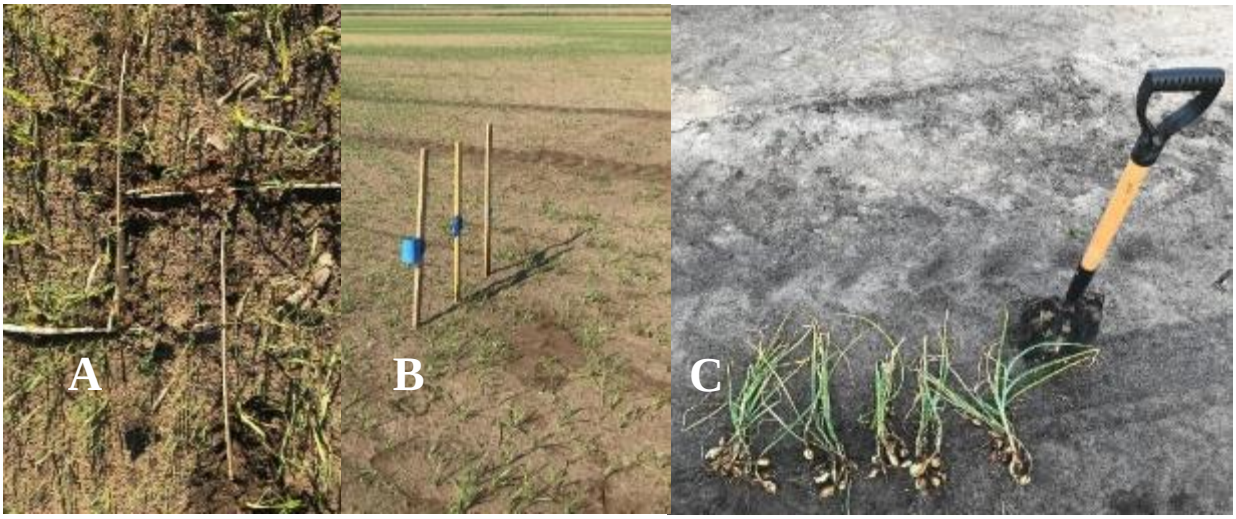

Figure 3. Damage plots (**A**), sticky cards (**B**) and destructive sampling (**C**) conducted on various dates outlined in **Table 1**.

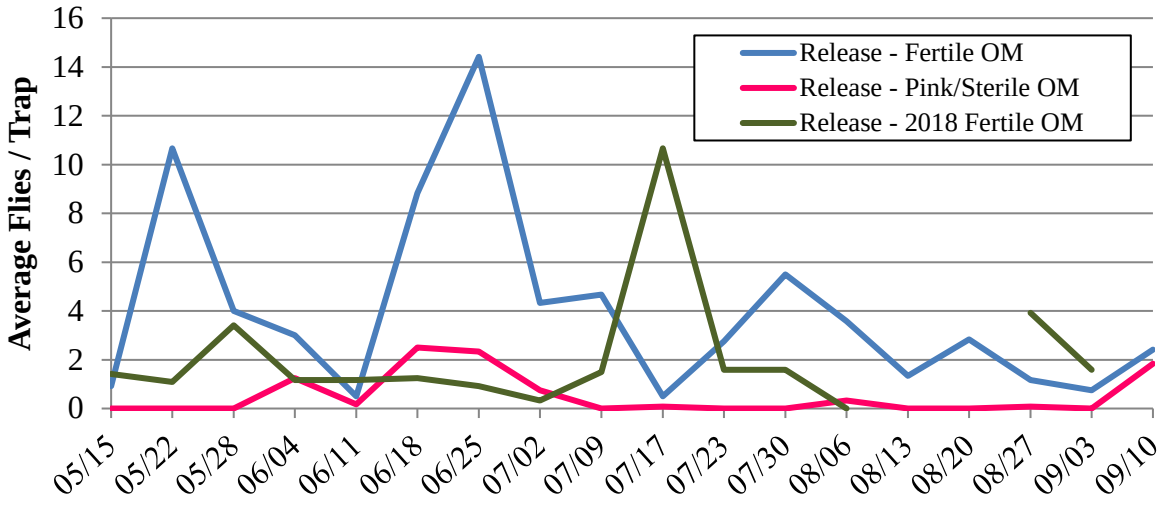

Figure 4. Average flies per sticky trap per week at the field site near Exeter. Fertile fly counts (blue) were higher than the peak counts in 2018 (green). Sterile pink flies were found in relatively low numbers at the release field (pink).

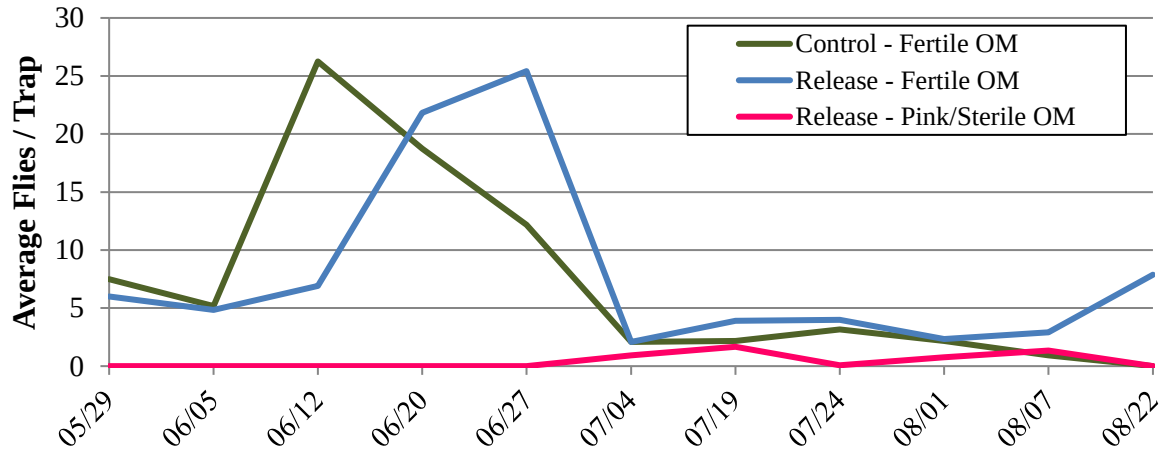

Figure 5. Average flies per sticky trap per week at the field sites near Scotland. Fertile fly counts at the control field (green) peaked earlier than the peak fly counts at the release field 3 km away (blue). Sterile pink flies were found in relatively low numbers at the release field throughout the season (pink).

ACKNOWLEDGEMENT: Funding for this project was provided by Pesticide Risk Reduction Program through the Pest Management Centre. Thank you to Hannah Fraser, Cora Loucks, Dennis Van Dyk, Josh Mosiondz, Emily Pennington, Victoria Snyder and Owen Hebb for their help throughout the growing season.

2019 PMR REPRT #09 **SECTION H: PEST MANAGEMENT METHODS-BIOLOGICAL CONTROL**

CROP: Turfgrass
PEST: European Chafer, *Amphimallon majale* classified as *Rhizotrogus majalis* prior to Montreuil 2000 (Razoumowsky, 1789) (Coleoptera: Scarabaeidae)

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TITLE: EFFICACY COMPARISON OF *BEAUVERIA BASSIANA* ISOLATES FOR THE CONTROL OF EUROPEAN CHAFER, *AMPHIMALLON MAJALE*

MATERIALS: *Beauveria bassiana* isolates (ISH-190, ISH-252, ISH-171, ISH-272, OK-372, and OK-373), BOTANIGARD ® 22WP (*B. bassiana* strain GHA)

METHODS: The assay was conducted at the Institute for Sustainable Horticulture (ISH) research laboratory at Kwantlen Polytechnic University (KPU), Langley campus, BC in July 2019. Second instar European Chafer were collected from Fraser Heights, Surrey, BC. The larvae were individually placed in 2 oz. plastic Solo® cups containing soil and turf roots and maintained at 15°C in an insect rearing room in the dark. The species of the collected larvae was confirmed based on raster pattern using a dissecting microscope. Three isolates of *Beauveria bassiana* (ISH-190, ISH-252, and ISH-272) from the coastal area of BC, two isolates (OK-372 and OK-373) from the Okanagan region of BC, and one tropical isolate (ISH-171) were considered as treatments. Each isolate was sub-cultured on Potato Dextrose Agar (PDA) media in Petri dishes and kept in the dark at 25 ± 1°C and RH 70 ± 5 %. Two weeks later, conidial stock suspensions of *B. bassiana* isolates were prepared using conidia harvested from the sub-cultures suspended in 0.1% Tween-20. BotaniGard ® 22WP, a commercially available conidia wettable powder product, was used as the positive control treatment. Conidial suspensions of the isolates, and BotaniGard were adjusted to a concentration of 4×10^8 conidia/ml using a Neubauer hemocytometer and viability counts. Ten microliters of each suspension were directly applied to the dorsal body surface of each second instar European Chafer. Ten microliters of a 0.1% Tween-20 solution (without fungal conidia) was applied as the negative control treatment. Each treatment had four replicates consisting of three larvae per replicate. The exposed larvae were individually placed in 2 oz. Solo® cups containing 10 grams of sandy loam soil, and incubated at 20 ± 1°Cat dark in a completely randomized design. The cups were assessed daily for two weeks or until death and sporulation. Probit analysis was used to estimate LT_{50} values of the isolates with 95% confidence limit (CL) (LdP Line, Finney, 1971). Correction for mortality in treatments was calculated using Abbott's formula (1925). Mortality and sporulation were analyzed separately using one-way ANOVA and means compared with Tukey's honestly significant difference (HSD) test (SPSS, Version 24, 2016).

RESULTS: The results are summarized in Figures 1, 2, and 3.

CONCLUSIONS: Percent mortality and sporulation, and lethal time were the indicators calculated. LT_{50} values describe the virulence of the isolates against the treated larvae, where lower numbers indicate the isolates have the potential to kill the larvae faster than the other isolates applied. On the 8th day post exposure, OK-372, OK-373, and BotaniGard, caused 90% corrected mortality of second-instar European Chafer at a concentration of 4×10^8 conidia/ml, and were the most efficacious isolates in comparison to the other isolates. However, ISH-252 had statistically similar efficacy to the listed isolates and caused 50% larval mortality (corrected) on day eight and 78% on day 12 (Figure 1). The highest sporulation rate observed for BotaniGard (42%) on day eight post exposure while, OK-373 showed the highest sporulation rate (50%) 12 days after exposure. However, sporulation rates for OK-372 and BotaniGard were statistically close to OK-373 (Figure 2). Table 1 shows that both OK-372 and Botanigard killed 50% of treated larvae three days' post exposure, while OK-373 and ISH-252 took about six and nine days, respectively. Overall, it may be said isolates OK-372, OK-373, and ISH-252 were able to control European Chafer at 20°C according to the laboratory conditions, however, OK-372 was the most efficacious isolate to control European Chafer in comparison to other isolates. Further experiments are needed to investigate the isolates efficacy in the field condition.

ACKNOWLDGEMENTS: We thank Canadian Parks and Recreation Association for providing financial support and Dr. Tom Lowery to provide Okanagan isolates.

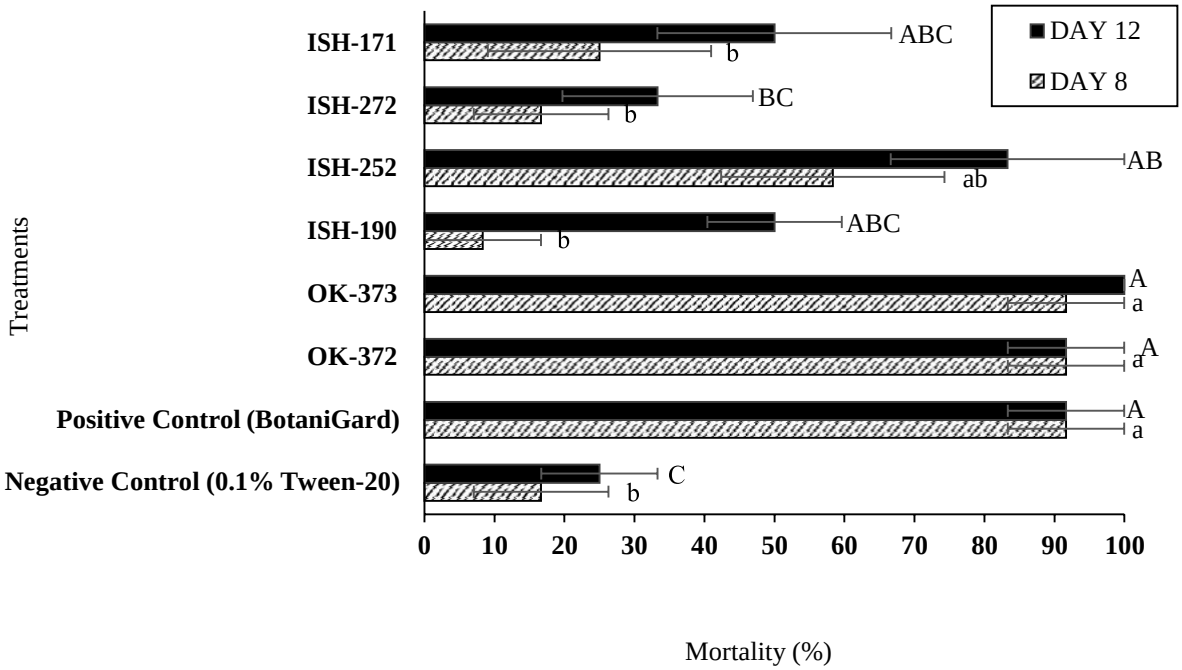

Figure 1. Mortality (%) (Non-corrected) of second instar European Chafer, *A. majale*, exposed to *B. bassiana* isolates at 4×10^8 conidia/ml of concentration via direct contact 8 and 12 days' post exposure at 20 °C. Values followed by different letters in mortality bars (lower case letters for mortality on day 8 and upper case letters for mortality on day 12) are significantly different according to Tukey's test (0.05)

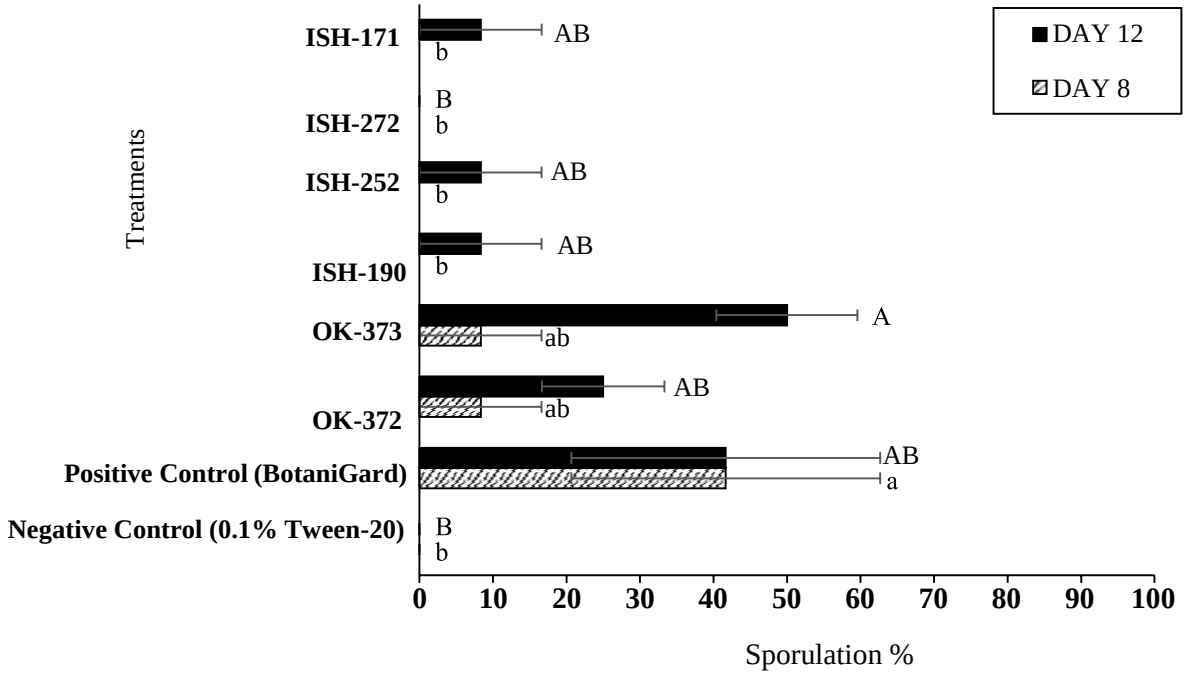

Figure 2. Sporulation (%) of second instar European Chafer, *A. majale*, exposed to *B. bassiana* isolates at 4×10^8 conidia/ml of concentration via direct contact toxicity 8 and 12 days' post exposure at 20 °C. Values followed by different letters in bars (lower case letters for mortality on day 8 and upper case letters for mortality on day 12) are significantly different according to Tukey's test (0.05)

Table 1. LT_{50} values for *B. bassiana* isolates at 4×10^8 conidia/ml of concentration on second instar European Chafer, *A. majale*, via direct contact toxicity at 20°C

Isolates	LT_{50} (days)	Confidence interval	Slope ± Stand Error
ISH-252	8.9	7.1 - 14.0	2.26 ± 0.19
OK-372	3.0	2.5 - 3.4	2.34 ± 0.26
OK-373	5.6	-	8.81 ± 2.11
BotaniGard®	2.9	-	1.18 ± 0.18

2019 PMR REPORT # 10 SECTION I: SURVEYS & OUTBREAKS - Insects and Mites

CROP: Nursery Ornamentals
PEST: Aphids

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TITLE: SURVEY OF APHID SPECIES ON OUTDOOR NURSERY ORNAMENTALS IN THE BC LOWER MAINLAND, 2008

MATERIALS: n/a

METHODS: Every two weeks, from May 07 to October 02, 2008, aphids were collected on host material from outdoor ornamental crops at eight wholesale nurseries in the BC Lower Mainland. Samples were selected to represent the diversity and range of host plant species at the nurseries. A few samples were collected from weeds in the crops, also. The nurseries were located in Abbotsford, Chilliwack, Cloverdale, Langley (2), Mission, Pitt Meadows and Richmond. Aphids were identified to genus and species based on morphological characteristics by Dr. Cho-Kai Chan, Vancouver, BC, emeritus entomologist and aphid specialist with Agriculture and Agri-Food Canada. Both alates and aptera were collected however, in some cases, only aptera were present resulting in an identification to genus only, or a tentative identification to species or group.

RESULTS: A total of 431 aphid accessions were collected and identified. Approximately 78 species of aphids comprising 42 aphid genera were found on 81 host plant genera, not counting weeds. The number of accessions does not indicate relative population densities because more samples were collected from some locations and hosts than others and some plant genera were not sampled. Most of the aphid species identified are widely distributed in North America. No previously unknown or regulated species were found. The species with the widest host range was *Macrosiphum euphorbiae* (potato aphid). This aphid, or members of this group, were found on 16 host genera, followed by the *Ericaphis fimbriata* (blueberry aphid) group on eight host genera. The green peach aphid, *Myzus persicae*, which is often considered a common species, was found on only two ornamental hosts (*Capsicum* and one *Hydrangea* sample) plus one weed species. The genus *Rosa* hosted the greatest variety of aphids, with up to 14 species. A summary of results is presented in Table 1.

Table 1. Aphid species on outdoor nursery ornamentals sampled in the BC Lower Mainland, 2008.

Host Crop	Aphid Species	Month	Location	No. of Accessions
Abelia x *grandiflora*	*Myzus ornatus*	June	Pitt Meadows	1
Abies grandis	*Mindarus abietinus*	June	Langley	1
Acer palmatum	*Periphyllus testudinaceus*	May	Langley	1
Acer palmatum	*Periphyllus californiensis*	June	Langley	2
Acer palmatum	*Macrosiphum euphorbiae*	June	Langley	1
Achillea millefolium	*Macrosiphoniella millefolii*	July	Pitt Meadows	4
Achillea millefolium	*Myzus ornatus*	July	Pitt Meadows	1
Achillea millefolium	*Macrosiphoniella millefolii*	August	Langley	1
Aegopodium podagraria	*Cavariella aegopodii*	July	Langley	1
Aegopodium podagraria	*Hyadaphis foeniculi*	July	Langley	1
Agoceris aurantiaca	*Myzus ascalonicus*	May	Langley	1
Alnus rubra	*Pterocallis alni*	September	Langley	1
Alnus viridis ssp. sinuata	*Pterocallis alni*	Aug-Oct	Mission	3
Alnus viridis ssp. sinuata	*Calaphis flava*	October	Mission	1
Alnus viridis ssp. sinuata	*Euceraphis gillettei*	July	Mission	1
Amelanchier alnifolia	*Aphis pomi*	July	Mission	1
Ampelopsis brevipendiculata	*Aulacorthum solani*	June	Abbotsford	1
Ampelopsis brevipendiculata	*Illinoia* sp.	June	Abbotsford	1
Ampelopsis brevipendiculata	*Macrosiphum euphorbiae*	June	Abbotsford	1
Andromeda polifolia	*Ericaphis fimbriata* group	July	Langley	1
Andromeda polifolia	*Illinoia* sp.	July	Langley	1
Arbutus sp.	*Wahlgreniella nervata*	September	Chilliwack	1
Arbutus menziesii	*Wahlgreniella nervata*	May-July	Langley	3
Arbutus unedo	*Aphis vaccinii*	July	Pitt Meadows	1
Arbutus unedo	*Wahlgreniella nervata* ssp. *arbuti*	June	Pitt Meadows	1
Arbutus unedo	*Walhgreniella nervata*	July-Aug	Pitt Meadows	4
Arctostaphylos uva-ursi	*Wahlgreniella nervata*	May	Langley	1
Arctostaphylos uva-ursi	*Wahlgreniella vaccinii*?	June	Chilliwack	1
Aronia melanocarpa	*Aphis pomi?*	September	Abbotsford	1
Aronia melanocarpa	*Illinoia spiraeae?*	September	Abbotsford	2
Artemisia arborescens	*Macrosiphoniella absinthii*	August	Abbotsford	1
Aruncus diocus	*Aphis* sp. nr *gossypii*	August	Abbotsford	2
Aster sp.	*Aulacorthum solani*	May	Abbotsford	1
Aster sp.	*Macrosiphum* sp.	May	Abbotsford	1
Aster sp.	*Macrosiphum pallidum?*	July	Abbotsford	1
Aucuba japonica	*Macrosiphum euphorbiae* grp.	August	Cloverdale	1
Berberis thunbergii	*Liosomaphis berberidis*	May	Langley	1
Berberis thunbergii	*Liosomaphis berberidis*	July -Sept	Abbotsford	2
Berberis thunbergii	*Liosomaphis berberidis*	July	Chilliwack, Richmond	2
Betula occidentalis	*Euceraphis betulae* grp.	July	Mission	3
Betula papyrifera	*Euceraphis punctipennis*	September	Langley	1
Betula pubescens	*Calaphis flava*	October	Mission	2

Brassica oleracea	*Lipaphis pseudobrassicae*	September	Abbotsford	2
Brunnera macrophylla	*Aulacorthum solani?*	May	Abbotsford	1
Capsicum sp.	*Myzus persicae* grp.	June	Abbotsford	1
Caryopteris incana	*Myzus nicotianae?*	August	Abbotsford	1
Caryopteris incana	*Myzus ornatus*	August	Abbotsford	1
Caryopteris x cladonensis	*Macrosiphum* sp.	August	Richmond	1
Caryopteris x cladonensis	*Ovatus* sp.	August	Richmond	1
Chamaecyparis nootkatensis	*Illinoia morrisoni*	August	Langley	1
Chamaecyparis pisifera	*Illinoia morrisoni*	August	Langley	1
Clematis serratifolia	*Aulacorthum solani*	June	Abbotsford	1
Clematis serratifolia	*Macrosiphum* sp.	June	Abbotsford	1
Clematis serratifolia	*Myzus ascalonicus*	June	Abbotsford	1
Compositae[1]	*Uroleucon* sp.	August	Richmond	1
Compositae[1]	*Aphis* sp.	August	Richmond	1
Compositae, *Lactuca* sp.[1]	*Hyperomyzus lactucae*	Aug-Sept	Richmond	2
Compositae, *Lactuca* sp.[1]	*Hyperomyzus* sp.	September	Richmond	1
Coreopsis rosea	*Brachycaudus helichrysi*	June	Abbotsford	1
Coreopsis rosea	*Myzus ornatus*	June	Abbotsford	1
Cornus sp.	*Anoecia corni*	September	Chilliwack	1
Cornus alba 'Aurea'	*Aphis salicariae*	May	Abbotsford	1
Cornus sericea	*Macrosiphum* sp.	June	Pitt Meadows	1
Cornus sericea	*Aphis salicariae*	June	Pitt Meadows	1
Cornus sericea	*Macrosiphum manitobense*	August	Mission	3
Cornus sericea	*Myzus* sp.	August	Mission	2
Cornus sericea	*Anoecia corni*	September	Langley	1
Cornus sericea	*Anoecia corni*	October	Mission	1
Corylus cornuta	*Myzocallis coryli*	August	Langley	1
Cotoneaster acutifolia	*Aphis pomi*	August	Abbotsford	1
Cotoneaster dammeri	*Aphis pomi*	September	Langley	1
Crataegus douglasii	*Brachycaudus helichrysi*	May	Langley	1
Crataegus douglasii	*Nearctaphis bakeri*	May	Langley	1
Cruciferae[1]	*Acyrthosiphon* sp.	August	Richmond	1
Eleagnus commutata	*Capitophorus elaeagni*	September	Langley	1
Epilobium sp.[1]	*Aphis epilobii*	August	Richmond	2
Epilobium sp.[1]	*Aphis* sp.	September	Richmond	2
Epilobium ciliatum ssp. *watsonii*[1]	*Aphis epilobii*	July	Chilliwack	1
Epilobium ciliatum ssp. *watsonii*[1]	*Aphis epilobii*	July-Aug	Pitt Meadows	2
Epilobium ciliatum ssp. *watsonii*[1]	*Myzus persicae*	July	Chilliwack	1
Escallonia x 'Newport Dwarf'	*Macrosiphum euphorbiae* grp.	August	Cloverdale	1
Escallonia x 'Pink Princess'	*Aphis pomi*	September	Langley	1
Escallonia x 'Pink Princess'	*Macrosiphum rosae*	September	Langley	1
Euonymus alatus 'Compactus'	*Aphis pomi?*	July	Langley	1
Euonymus alatus 'Compactus'	*Macrosiphum* sp.	July	Langley	1
Euonymus fortunei	*Macrosiphum euphorbiae*	May	Langley	1

Euonymus fortunei	*Macrosiphum euphorbiae*	July	Chilliwack	1
Euonymus fortunei	*Macrosiphum* sp.	July	Chilliwack	2
Euonymus fortunei	*Macrosiphum euphorbiae* grp.	August	Abbotsford	1
Euonymus fortunei	*Myzus* sp.	July	Chilliwack	1
Fagus sylvatica	*Phyllaphis fagi*	June	Pitt Meadows	1
Fagus sylvatica	*Phyllaphis fagi*	June-Oct	Langley	4
Fagus sylvatica	*Phyllaphis fagi*	July	Cloverdale	1
Fragaria chiloensis	*Ericaphis fimbriata* grp.	September	Langley	1
Fragaria vesca	*Chaetosiphon fragaefolii*	May	Langley	1
Fragaria vesca	*Myzus ascalonicus*	May	Langley	1
Fragaria virginiana	*Chaetosiphon fragaefolii*	May	Langley	1
Fragaria x 'Pink Panda'	*Chaetosiphon fragaefolii*	May	Langley	1
Gaultheria shallon	*Ericaphis fimbriata* grp.	July	Langley	1
Gaultheria shallon	*Macrosiphum euphorbiae*	July	Langley	1
Gaultheria shallon	*Myzus ornatus*	July	Langley	1
Genista lydia	*Aphis genistae*	July	Langley	1
Genista lydia	*Aphis genistae?*	September	Abbotsford	1
Genista tinctoria	*Lipaphis pseudobrassicae*	June	Langley	1
Helenium x 'Mardi Gras'	*Macrosiphum euphorbiae*	May	Abbotsford	1
Heuchera x 'Crimson Curls'	*Nasonovia heucherae?*	May	Abbotsford	1
Hibiscus syriacus	*Aphis gossypii*	May-Sept	Abbotsford	11
Holodiscus discolor	*Illinoia spiraeae*	July	Langley	1
Hydrangea quercifolia	*Macrosiphum euphorbiae* grp.	May-July	Abbotsford	3
Hydrangea quercifolia	*Myzus persicae*	July	Abbotsford	1
Ilex verticillata	*Macrosiphum euphorbiae*	June	Langley	1
Juniperus chinensis	*Illinoia morrisoni*	August	Langley	1
Juniperus chinensis	*Illinoia morrisoni*	September	Abbotsford	1
Juniperus communis	*Cinara juniperi*	June	Langley	1
Juniperus communis	*Illinoia morrisoni?*	June	Langley	1
Juniperus sabina	*Illinoia morrisoni*	June	Abbotsford	1
Juniperus sabina	*Illinoia morrisoni*	June-Aug	Langley	3
Juniperus scopulorum	*Illinoia morrisoni*	June-Aug	Langley	7
Juniperus scopulorum	*Illinoia morrisoni*	July	Abbotsford	1
Juniperus sp.	*Illinoia morrisoni*	September	Abbotsford	1
Lavatera x 'Pink Barnsley'	*Aphis frangulae* grp.	August	Abbotsford	1
Leucanthemum x 'White Knight' (Shasta daisy)	*Aulacorthum solani*	May	Abbotsford	1
Leucanthemum x 'White Knight' (Shasta daisy)	*Myzus ascalonicus*	May	Abbotsford	1
Liriodendron tulipifera	*Macrosiphum* sp.	June	Pitt Meadows	1
Lithodora diffusa	*Myzus ornatus*	May	Langley	1
Lonicera involucrata	*Rhopalomyzus grabhami*	May	Langley	1
Lonicera involucrata	*Illinoia crystleae*	August	Mission	1
Lonicera periclymenum 'Serotina'	*Hyadaphis foeniculi*	July	Abbotsford	1
Lonicera sempervirens	*Hyadaphis foeniculi*	May-June	Abbotsford	3
Lonicera sempervirens	*Aulacorthum* sp.*?*	June	Abbotsford	1
Lonicera sempervirens	*Macrosiphum euphorbiae*	June	Abbotsford	1

Lonicera x 'Dropmore Scarlet'	*Hyadaphis foeniculi*	May-June	Abbotsford	2
Lonicera x 'Dropmore Scarlet'	*Hyadaphis foeniculi*	June	Langley	1
Lonicera x 'Gold Flame'	*Hyadaphis foeniculi*	September	Abbotsford	1
Lonicera x 'Mandarin'	*Hyadaphis foeniculi*	August	Abbotsford	1
Lonicera sp.	*Rhopalomyzus grabhami*	October	Mission	1
Lupinus polyphyllus	*Macrosiphum albifrons*	May-Aug	Langley	2
Mahonia aquifolium	*Liosomaphis berberidis*	July	Langley	1
Mahonia aquifolium	*Macrosiphum euphorbiae*	July	Langley	1
Mahonia aquifolium	*Liosomaphis berberidis*	July	Richmond	1
Mahonia repens	*Liosomaphis berberidis*	July	Langley	1
Malus fusca / diversifolia	*Aphis pomi*	July	Mission	2
Penstemon digitalis	*Aulacorthum solani* grp.	May	Abbotsford	1
Penstemon digitalis	*Macrosiphum* sp.	September	Abbotsford	1
Photinia x *fraseri*	*Macrosiphum euphorbiae* grp.	August	Cloverdale	1
Photinia x *fraseri*	*Aphis frangulae*	September	Chilliwack	1
Photinia x *fraseri*	*Aphis gossypii*	September	Chilliwack	1
Physocarpus capitatus	*Utamphorophora humboldti*	September	Langley	1
Physocarpus capitatus	*Aphis neilliae*	October	Mission	3
Physocarpus opulifolius	*Utamphorophora humboldti*	May	Abbotsford	1
Picea abies 'Cupressina'	*Cinara* sp.	June-Aug	Langley	2
Picea glauca albertiana 'Conica'	*Mindarus obliquus*	June-July	Langley	3
Picea glauca	*Mindarus obliquus*	June-Sept	Langley	5
Picea mariana 'Nana'	*Mindarus obliquus*	August	Langley	1
Picea obovata	*Cinara* sp.	June-Aug	Langley	2
Picea pungens	*Mindarus obliquus*	June	Langley	1
Picea pungens	*Cinara* sp.	August	Langley	1
Picea sitchensis	*Mindarus obliquus*	June-Sept	Langley	3
Picea sitchensis	*Aphis neilliae?*	October	Mission	1
Pieris japonica x 'Mountain Fire'	*Ericaphis fimbriata* grp.	June-Aug	Chilliwack	2
Pieris japonica x 'Mountain Fire'	*Macrosiphum parvifolii*	June	Chilliwack	1
Pieris japonica x 'Mountain Fire'	*Wahlgreniella nervata*	June-Aug	Chilliwack	2
Pieris japonica x 'Mountain Fire'	*Macrosiphum euphorbiae?*	July	Langley	1
Pieris japonica x 'Mountain Fire'	*Wahlgreniella nervata*	July	Langley	1
Pieris japonica x 'Mountain Fire'	*Aulacorthum* sp.	August	Chilliwack	1
Pinus mugo	*Cinara pinea*	August	Langley	1
Pinus mugo	*Cinara* sp.	August	Langley	1
Pinus nigra	*Cinara* sp.	June	Langley	1
Populus trichocarpa	*Chaitophorus populicola*	August	Mission	3

Potentilla (Dasiphora) fruiticosa	*Aulacorthum solani*	May	Abbotsford	1
Potentilla (Dasiphora) fruiticosa	*Ericaphis fimbriata* grp.	May-July	Abbotsford	2
Potentilla (Dasiphora) fruiticosa	*Myzus ornatus*	May	Abbotsford	1
Potentilla (Dasiphora) fruiticosa	*Macrosiphum euphorbiae*	June	Abbotsford	1
Potentilla (Dasiphora) fruiticosa	*Myzaphis rosarum*	June	Chilliwack, Pitt Meadows	2
Potentilla (Dasiphora) fruiticosa	*Macrosiphum* sp.	July	Abbotsford	3
Potentilla (Dasiphora) fruiticosa	*Macrosiphum euphorbiae* grp.	August	Abbotsford	1
Potentilla (Dasiphora) fruiticosa	*Macrosiphum rosae*	August	Abbotsford	1
Prunus cistena	*Brachycaudus cardui*	May	Abbotsford	1
Prunus laurocerasus	*Illinoia* sp.	July-Aug	Chilliwack	2
Prunus laurocerasus	*Myzus ornatus*	July	Chilliwack	1
Prunus virginiana	*Rhopalosiphum nymphaeae*	October	Mission	1
Prunus virginiana	*Rhopalosiphum padi*	October	Mission	1
Pseudotsuga menziesii	*Adelges cooleyi*	June	Langley	1
Quercus robur	*Tuberculatus annulatus*	July	Langley	1
Quercus rubra 'Fastigiata'	*Myzocallis walshii*	September	Langley	1
Rhodiola roseum	*Aphis frangulae* grp.	August	Langley	1
Rhodiola roseum	*Aphis gossypii* grp.	August	Langley	1
Rhodiola roseum	*Aphis* sp.	August	Langley	1
Rhododendron catawbiense	*Illinoia lambersi*	July	Pitt Meadows	1
Rhododendron x 'P.J.M.'	*Illinoia lambersi*	May	Abbotsford	1
Rhododendron x 'P.J.M.'	*Illinoia lambersi*	July	Langley	1
Rhododendron x 'Purple Triumph'	*Illinoia lambersi*	July	Langley	2
Rhododendron x 'Treasure'	*Illinoia lambersi*	July	Cloverdale	1
Ribes alpinum	*Nasonovia (Kakimia) cynosbati*	May-Aug	Abbotsford	2
Ribes alpinum	*Nasonovia ribisnigri*	May	Langley	1
Ribes alpinum	*Nasonovia ribisnigri*	August	Abbotsford	1
Ribes divaricatum	*Nasonovia ribisnigri*	May	Langley	1
Ribes rubrum	*Cryptomyzus ribis*	May-June	Abbotsford	3
Ribes rubrum	*Nasonovia ribisnigri*	May	Abbotsford	1
Ribes sanguineum	*Aphis neomexicana (Aphis oenotherae)*	May	Langley	1
Ribes sanguineum	*Nasonovia ribisnigri*	May	Langley	1
Rosa sp.	*Chaetosiphon* sp.	July	Cloverdale	
Rosa acicularis	*Ericaphis fimbriata* grp.	September	Langley	1
Rosa gymnocarpa	*Chaetosiphon* sp.	August	Mission	1
Rosa gymnocarpa	*Ericaphis fimbriata* grp.	August	Mission	1
Rosa gymnocarpa	*Macrosiphum rosae*	August	Mission	1
Rosa mutabilis	*Ericaphis fimbriata* grp.	June	Pitt Meadows	1
Rosa mutabilis	*Macrosiphum rosae*	June	Pitt Meadows	1

Rosa nutkana	*Myzaphis rosarum*	July	Langley	1
Rosa nutkana	*Ericaphis fimbriata* grp.	July-Oct	Langley	6
Rosa nutkana	*Ericaphis fimbriata* grp.	July	Pitt Meadows	1
Rosa nutkana	*Macrosiphum euphorbiae*	July	Pitt Meadows	2
Rosa nutkana	*Macrosiphum rosae*	July	Mission	1
Rosa nutkana	*Chaetosiphon* sp.	September	Langley	1
Rosa nutkana	*Macrosiphum rosae*	Sept-Oct	Langley	3
Rosa nutkana	*Aphis neilliae?*	October	Mission	1
Rosa nutkana	*Chaetosiphon tetrarhodum*	October	Mission	1
Rosa nutkana	*Cryptomyzus ribis*	October	Mission	1
Rosa nutkana	*Ericaphis fimbriata* grp.	October	Mission	1
Rosa nutkana	*Macrosiphum euphorbiae*	October	Mission	1
Rosa nutkana	*Metopolophium dirhodum*	October	Mission, Langley	2
Rosa pisocarpa	*Ericaphis fimbriata* grp.	September	Langley	1
Rosa rugosa	*Chaetosiphon tetrarhodum*?	June	Langley	1
Rosa rugosa	*Wahlgreniella nervata*	June	Langley	1
Rosa rugosa	*Ericaphis fimbriata* grp.	July	Pitt Meadows	2
Rosa rugosa	*Macrosiphum euphorbiae*	July	Pitt Meadows	3
Rosa rugosa	*Macrosiphum rosae*	July	Pitt Meadows	2
Rosa rugosa	*Chaetosiphon fragaefolii*	August	Cloverdale	1
Rosa rugosa	*Chaetosiphon* sp.	September	Langley	1
Rosa rugosa	*Macrosiphum euphorbiae*	September	Langley	1
Rosa rugosa	*Macrosiphum rosae*	September	Langley	1
Rosa rugosa	*Chaetosiphon tetrarhodum*	October	Mission	1
Rosa rugosa	*Ericaphis fimbriata* grp.	October	Mission	1
Rosa rugosa	*Macrosiphum euphorbiae*	October	Mission	1
Rosa rugosa	*Sitobion fragariae*	October	Mission	1
Rosa woodsii	*Ericaphis wakibae*	May	Langley	1
Rosa woodsii	*Ericaphis fimbriata* grp.	September	Langley	2
Rosa woodsii	*Macrosiphum euphorbiae*	September	Langley	1
Rosa woodsii	*Macrosiphum rosae*	September	Langley	1
Rosa woodsii	*Wahlgreniella* sp.	September	Langley	1
Rosa x *floribunda*	*Macrosiphum euphorbiae*	May	Abbotsford	2
Rosa x *floribunda*	*Ericaphis fimbriata* grp.	May-Sept	Abbotsford	2
Rosa x *floribunda*	*Macrosiphum rosae*	July	Abbotsford, Pitt Meadows	2
Rosa x *floribunda*	*Macrosiphum* sp.	July-Sept	Abbotsford	2
Rosa x *floribunda*	*Chaetosiphon* sp.	September	Abbotsford	1
Rosa x *hybrida*	*Macrosiphum euphorbiae*	July	Abbotsford, Pitt Meadows	2
Rosa x *hybrida*	*Macrosiphum rosae*	July	Abbotsford, Pitt Meadows	3
Rosa x *hybrida*	*Ericaphis fimbriata* grp.	July	Pitt Meadows	1
Rosa x *hybrida*	*Macrosiphum euphorbiae*	July	Pitt Meadows	1
Rubus parviflorus	*Illinoia maxima?*	August	Langley	1
Salix integra	*Cavariella aegopodii*	June-Aug	Abbotsford	8
Salix lasiandra	*Cavariella aegopodii*	May	Langley	1

Salix lasiandra	*Cavariella aegopodii*	August	Mission	1
Salix purpurea	*Cavariella aegopodii*	August	Langley	1
Sarcococca hookeriana var. *humilis*	*Myzus* sp.	July-Aug	Chilliwack, Pitt Meadows	4
Sarcococca hookeriana var. *humilis*	*Aphis* sp.	August	Chilliwack	1
Schefflera octophylla	*Neomyzus circumflexum*	October	Richmond	1
Sedum alba	*Aphis sedi*	June	Pitt Meadows	1
Sedum alba	*Myzus ornatus*	June	Pitt Meadows	1
Sedum x ‘Autumn Joy’	*Aphis sedi*	September	Abbotsford	2
Sedum x 'Bertram Anderson'	*Aphis frangulae* grp.	May	Abbotsford	1
Sedum x 'Bertram Anderson'	*Aphis sedi*	May-Sept	Abbotsford	2
Sedum x 'Matrona'	*Aphis sedi*	September	Abbotsford	1
Sequiodendron giganteum	*Illinoia morrisoni*	August	Langley	1
Shepherdia canadensis	*Capitophorus elaeagni*	September	Langley	2
Sidalcea marviflora	*Aphis gossypii*	September	Langley	1
Solidago canadensis	*Brachycaudus helichrysi*	July	Langley	1
Spiraea fritschiana	*Aphis* sp.	August	Abbotsford	1
Spiraea japonica	*Aphis pomi*	July-Aug	Abbotsford	2
Spiraea japonica	*Illinoia spiraecola*	July	Abbotsford	3
Spiraea japonica	*Macrosiphum* sp.	July-Aug	Abbotsford	2
Spiraea japonica	*Aphis gossypii*	September	Abbotsford	1
Spiraea nipponica	*Aphis* sp.	August	Abbotsford	1
Spiraea nipponica	*Aphis gossypii*	August	Abbotsford	1
Spiraea x 'Snow Storm'	*Illinoia spiraecola*	September	Abbotsford	2
Spiraea x 'Snow Storm'	*Macrosiphum euphorbiae*	September	Abbotsford	1
Symphoricarpos x *doorenbosii*	*Aphthargelia symphoricarpi*	May	Abbotsford	1
Symphoricarpos x *doorenbosii*	*Macrosiphum* sp.	June	Langley	1
Thuja occidentalis	*Aulacorthum solani*	June	Abbotsford	1
Thuja occidentalis	*Illinoia morrisoni*	June-Aug	Abbotsford, Langley	7
Vaccinium corymbosum	*Macrosiphum euphorbiae* grp.	May	Abbotsford	1
Vaccinium corymbosum	*Ericaphis fimbriata* grp.	May-Aug	Abbotsford	7
Vaccinium corymbosum	*Aphis gossypii*	August	Abbotsford	1
Vaccinium corymbosum	*Illinoia azaleae*?	August	Abbotsford	1
Vaccinium corymbosum	*Aphis vaccinii*	September	Langley	1
Vaccinium corymbosum	*Wahlgreniella nervata*	September	Langley	1
Vaccinium ovalifolium	*Aphis vaccinii*	August	Langley	1
Vaccinium ovalifolium	*Ericaphis fimbriata* grp.	September	Langley	2
Vaccinium ovalifolium	*Macrosiphum euphorbiae*	September	Langley	1
Vaccinium ovatum	*Aphis gossypii*	September	Langley	2
Vaccinium uliginosum	*Ericaphis fimbriata* grp.	July	Langley	2
Vaccinium uliginosum	*Neomyzus circumflexum*	July	Langley	1
Vancouveria hexandra	*Aulacorthum solani*	July	Langley	1
Viburnum edule	*Ceruraphis eriophori*	May	Langley	1
Viburnum edule	*Ceruraphis viburnicola*	May	Langley	1
Viburnum opulus	*Ceruraphis eriophori*	May	Langley	2
Viburnum opulus	*Ceruraphis viburnicola*	May	Langley	1

? = identity uncertain; aptera only.
[1]Weed associated with ornamental crop in container.

CONCLUSIONS: A survey of aphid species on outdoor ornamental plants at commercial wholesale nurseries in the BC Lower Mainland in 2008 found approximately 78 species of aphids comprising 42 aphid genera on 81 genera of host plants. Most of the aphid species identified are widely distributed in North America and no previously unknown or regulated species were found. The species with the widest host range was *Macrosiphum euphorbiae* (potato aphid), which appeared on 16 host genera, followed by the *Ericaphis fimbriata* (blueberry aphid) group on seven host genera in addition to *Vaccinium*. Some plant genera, such as juniper, were hosts of only one or two aphid species, while others, such as roses, hosted several different species of aphids, at the same time or in succession, as the season progressed. *Myzus persicae* (green peach aphid), which is often considered a common species, was found on only two ornamental hosts, *Capsicum* and *Hydrangea*. The wide diversity of aphid species and life cycles poses a challenge to management of aphids at commercial nurseries.

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2019 PMR REPORT #11 **SECTION J: NEMATODES**

CROP: Carrot (*Daucus carota* subsp. *sativus* (Hoffm.) Arcang.), cv. Cellobunch
PESTS: Carrot cyst nematode (*Heterodera carotae* Jones)

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TITLE: FIELD EVALUATIONS OF NEMATICIDES AND FUMIGANTS FOR CARROT CYST NEMATODE CONTROL IN CARROTS, 2019

MATERIALS: BUSAN (metam sodium 42%), EXP#019-01 (*Trichoderma* spp.), MAJESTENE (*Burkholderia* spp. strain A396), MOVENTO 240 SC (spirotetramat 240 g/L), PICPLUS (chloropicrin 85.1%), SALIBRO (fluazaindolizine), VYDATE (oxamyl 240 g/L)

METHODS: The trial was conducted in a commercial field known to be infested with carrot cyst nematode (*Heterodera carotae*) in the Holland/Bradford Marsh, Ontario. A randomized complete block design with five replicates per treatment was used. The pre-seeding treatment BUSAN at 467 L/ha rate was applied on 6 June using a 2 meter wide custom fumigator with 14 John Blue fumigant shanks spaced 17 cm apart, applying the product 25 cm below the soil surface. The BUSAN was immediately sealed into the soil with a roller attached to the fumigator.
Treatments at seeding were: EXP#019-01 at 5 g/ha, MAJESTENE at 20 L/ha, MOVENTO at 365 mL/ha, PIC PLUS at 54 L/ha, SALIBRO at 4.48 L/ha and VYDATE at 9.3 L/ha. PICPLUS was applied 25 cm below the carrot hills using shanks attached directly to the bed shaper of the carrot seeder. All other treatments were applied to the soil surface using TeeJet 8003 flat fan nozzles mounted on the front of the carrot bedder/seeder at a rate of 300 L/ha. Two additional drench applications of all nematicide treatments (EXP#019-01, MAJESTENE, MOVENTO, SALIBRO and VYDATE) at a rate of 400 mL/m were applied directly over the carrot beds using watering containers two and four weeks after seeding (WAS). Carrots, cv. Cellobunch, were direct seeded in all treatments at 65 seeds/m on raised beds on 12 June. Each experimental unit consisted of three rows, 66 cm apart and 11 m in length. An untreated check was also included. Ten soil cores were taken from each replicate to create one soil sample on 10 June (pre-plant) and 26 June (post-treatment) using a 25 cm long soil probe. Pre-plant and post-treatment samples underwent nematode extractions at the University of Guelph Muck Crops Research Station using the Baermann pan method for juvenile nematodes.
A harvest sample of carrots from two 1.5 m sections of row were harvested by hand on 23 October and placed in cold storage until assessment on 31 November. Carrot samples were assessed for nematode damage (stunting and forking) and sorted into the following classes: 0 = no galling or forking (healthy); 1 = very minor stunting or forking with no noticeable cysts; 2 = minor stunting and forking with no noticeable cysts; 3 = moderate stunting and forking with visible cysts; 4 = moderate to severe stunting and forking with visible cysts; 5 = very severe stunting with many visible cysts. Marketable yield was also determined from the harvest samples. Carrots were considered marketable if they were assigned classes 0 to 2. Carrots assigned classes 3 to 5 were considered unmarketable. The damage severity index (DSI) was determined using the following equation:

$$DSI = \frac{\sum [(\text{class no.})\ (\text{no. of carrots in each class})]}{(\text{total no. of carrots per sample})\ (\text{no. of classes} - 1)} \times 100$$

Compared to the previous 10-year average, air temperatures in 2019 were above average for July (22.3°C), average for June (17.5°C), August (19.4°C), September (15.8°C), October (9.4°C) and below average for May (11.4°C). The 10-year average temperatures were: May 14.3°C, June 18.4°C, July 21.1°C, August 20.2°C, September 16.4°C and October 9.7°C. Monthly rainfall was above the 10-year average for October (106 mm), average for May (77 mm), September (62 mm), and below average for June (84 mm), July (42 mm) and August (46 mm). The 10-year rainfall averages were: May 77 mm, June 100 mm, July 93 mm, August 80 mm, September 61 mm and October 74 mm.

Data were analyzed using the General Analysis of Variance function of the Linear Analysis section of Statistix V.10. Means separation was obtained using Tukey's test with $P = 0.05$ level of significance.

RESULTS: Data are presented in Tables 1 and 2.

CONCLUSION: There were no significant differences between the nematicide treatments and the UNTREATED check for carrot marketability and carrot cyst nematode damage factors. In addition, there were no differences in carrot cyst nematode populations before and after application among the treatments. Although the nematicide treatments were not significantly different from the UNTREATED check in relation to marketable yield, nematode damage incidence and DSI there are trends indicating that some nematicides, particularly MOVENTO and SALIBRO, may have potential in managing carrot cyst nematode in the field. The significantly lower percent of marketable carrots in the BUSAN treatment compared to the UNTREATED check could be due to phytotoxicity effects. Overall, carrot cyst nematode damage was low throughout the trial.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Ontario Agri-Food Innovation Alliance, the Bradford Cooperative Storage Ltd and the Fresh Vegetable Growers of Ontario.

Table 1. Percent marketable, marketable yield, percent nematode damage and damage severity index (DSI) for carrots, cv. Cellobunch, grown in soil treated with fumigants and nematicides in the Holland Marsh, Ontario, 2019.

Treatment	% Marketable Carrots	Marketable Yield (t/ha)	% Nematode Damage	DSI[1]
MOVENTO	91.4 a[2]	56.6 ns[3]	13.0 a	7.1 a
SALIBRO	91.3 a	56.0	14.4 a	7.7 a
VYDATE	89.9 a	47.2	17.9 ab	9.5 ab
UNTREATED	88.9 a	44.9	18.7 ab	9.8 ab
MAJESTENE	88.8 a	49.9	15.9 ab	9.3 a
PICPLUS	88.5 a	55.4	17.5 ab	9.5 ab
EXP#019-01	85.2 ab	41.7	18.1 ab	11.5 ab
BUSAN	81.5 b	46.4	23.3 b	14.4 b

[1] DSI was calculated using the following equation:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of carrots in each class})]}{(\text{total no. of carrots per sample})\ (\text{no. of classes} - 1)} \times 100$$

[2] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's test
[3] ns indicates that no significant differences were found among the treatments at $P = 0.05$, Tukey's test

Table 2. Carrot cyst nematode soil counts (juveniles/kg of soil) and reproduction ratio from carrot soil before (pre-plant) and after (post-treatment) treatment with fumigants and nematicides in the Holland Marsh, Ontario, 2019.

Treatment	Carrot Cyst Nematode Counts (juveniles/kg soil)		Reproduction Ratio[1]
	Pre-plant (10 June)	Post-treatment (26 June)	
VYDATE	2648 ns[2]	696 ns	-0.5 ns
EXP#019-01	1376	480	-0.3
MAJESTENE	808	456	0.8
BUSAN	600	136	-0.8
UNTREATED	528	432	-0.1
SALIBRO	512	648	0.4
MOVENTO	272	232	1.7
PICPLUS	184	240	0.6

[1] Reproduction ratio = (final population – initial population)/initial population
[2] ns indicates no significant differences were found among the treatments at $P = 0.05$, Tukey's test

2019 PMR REPORT #12 **SECTION J: NEMATODES**

CROP: Garlic (*Allium sativum* L.), cv. Music
PESTS: Stem and bulb nematode (*Ditylenchus dipsaci* (Kühn, 1857)) Filip'ev, 1936

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TITLE: EVALUATION OF NEMATICIDES FOR CONTROL OF STEM AND BULB NEMATODE IN GARLIC, 2018-19

MATERIALS: AGRI-MEK SC (abamectin), EXP#019-01 (*Trichoderma* spp.), PROMAX (thyme oil), RHIZOVITAL 42 (*Bacillus amyloliquefaciens*), VELUM PRIME (fluopyram 50%)

METHODS: The field trial was conducted in a mineral soil field (organic matter 5%, pH 7.6) free of stem and bulb nematode (SBN) near Cookstown, Ontario. A randomized complete block design with four (4) replicates per treatment was used. Three types of garlic cloves (seed) were included in the trial: high SBN infested seed (HN, 18 nematodes/g), low stem and bulb nematode infested seed (LN, 2 nematodes/g) and clean seed free of SBN. Nematode counts were determined at the University of Guelph Muck Crops Research Station using the Baermann pan method. The treatments were AGRI-MEK SC, EXP#019-01, PROMAX, RHIZOVITAL 42 and VELUM PRIME and where applied as a soak (S), drench (D) or seed treatment (ST). Products receiving soak treatments were: AGRI-MEK HN S at 0.9 mL/L, PROMAX HN S at 37 mL/L, and RHIZOVITAL 42 HN S at 5 mL/L and VELUM PRIME HN S and VELUM PRIME S at 1.7 mL/L. Soak treatments were applied by placing the cloves in a mesh bag and soaking for four hours in 10 L of each treatment solution. After treatment, bulbs were air dried before planting. Drench treatments were: VELUM PRIME HN D and VELUM PRIME LN D at 500 mL/ha. Drench treatments were applied directly over the cloves at planting at an application rate of 33 mL per meter. The seed treatment was EXP#019-01 at 1 g/kg of seed. Additionally, an UNTREATED HN check, UNTREATED LN check and a CLEAN SEED check were also included. Each treatment consisted of 30 garlic cloves per plot. Cloves were planted ~5 cm deep and 10 cm apart in 3 m long single rows spaced 40 cm apart. The trial was planted on 25 October 2018. The heights of 10 plants and were taken on 14 and 28 June. A visual assessment of plant showing symptoms of SBN infection was taken on 28 June. Garlic were harvested on 12 August 2019. Garlic bulbs were counted, weighed and rated for nematode damage by assessing the percent of basal plate rot using a 0-4 rating scale to assign the bulbs to different classes, where: 0 = no damage, 1 = 1-24% basal plate missing; 2 = 25-50% basal plate missing; 3 = > 50% basal plate missing and 4 = completely desiccated bulb. These data were used to calculate a disease severity index (DSI) using the formula below.

$$DSI = \frac{\sum [(\text{class no.})\ (\text{no. of garlic bulbs in each class})]}{(\text{total no. of garlic bulbs per sample})\ (\text{no. of classes} - 1)} \times 100$$

Stem and bulb nematodes were extracted from a 10 g sample of cloves after harvest and assessed using the Baermann pan method. Ten soil cores were taken from each treatment by taking the top 5 cm of soil along the treatment row using a soil probe and combined for a treatment sample. A 25 g aliquot of soil was used to extract SBN nematodes from the soil using the sugar centrifugal flotation method.
Compared to the previous 10-year average, air temperatures in 2019 were above average for July (22.3°C), average for June (17.5°C), August (19.4°C), September (15.8°C), October (9.4°C) and below average for May (11.4°C). The 10-year average temperatures were: May (14.3°C), June (18.4°C), July (21.1°C), August

(20.2°C), September 16.4°C and October 9.7°C. Monthly rainfall was above the 10-year average for October (106 mm), average for May (77 mm), September (62 mm), and below average for June (84 mm), July (42 mm) and August (46 mm). The 10-year rainfall averages were: May (77 mm), June (100 mm), July (93 mm), August (80 mm), September (61 mm) and October (74 mm).
Data were analyzed using the General Analysis of Variance function of the Linear Analysis section of Statistix V.10. Means separation was obtained using Tukey's test with $P = 0.05$ level of significance.

RESULTS: Data are presented in Tables 1, 2 and 3.

CONCLUSION: The VELUM PRIME treatments (soak and drench) provided excellent control of the stem and bulb nematode. There was an increase in percent marketability and yield of garlic as well as lower nematode damage in both the low (LN) and high (HN) SBN population seed. The AGRI-MEK treatment also provided good control with lower SBN damage and increased number of marketable bulbs. No statistically significant differences were found in the populations of stem and bulb nematode in the garlic cloves and soil at harvest. The harsh winter resulted in winter kill for some garlic plants in one of the replications.

AKNOWLEDGEMENTS: Funding for this project was provided by the California Garlic and Onion Research Advisory Board, the Plant Production Systems of the Ontario Agri-Food Innovation Alliance, and the Fresh Vegetable Growers of Ontario representing the Ontario Garlic Growers Association.

Table 1. Garlic plant heights and percent of plants showing symptoms of stem and bulb nematode infection on 14 June and 28 June after nematicide application near Cookstown, Ontario, 2019.

Treatment	App. Method[1]	14 June	28 June	
		Height (cm)	Height (cm)	% SBN Symptoms
VELUM PRIME HN	S	56.4 ns[2]	75.7 ns	15.9 ns
UNTREATED HN	-	53.9	68.3	34.3
UNTREATED LN	-	51.4	72.1	10.0
AGRI-MEK HN	S	51.3	69.5	2.9
PROMAX HN	S	51.2	66.6	20.3
VELUM PRIME HN	D	50.7	69.1	16.1
VELUM PRIME LN	S	50.2	69.2	37.5
CLEAN SEED	-	50.2	74.5	17.3
RHIZOVITAL 42 HN	S	48.0	66.8	11.1
VELUM PRIME LN	D	47.6	68.9	17.5
EXP#019-01 HN	ST	45.9	60.4	36.7

[1] Application Method: S = Soak; D = Drench; ST = Seed Treatment
[2] ns indicates that no significant differences were found among the treatments at $P = 0.05$, Tukey's test

Table 2. Marketable yield, percent marketable bulbs, damage incidence and disease severity index (DSI) from harvested garlic in relation to nematicide application to control stem and bulb nematode in a mineral soil field trial near Cookstown, Ontario, 2018-2019.

Treatment	App. Method[1]	% Marketable Bulbs	Marketable Yield (g/plot)	% Nematode Damage	DSI[2]
VELUM PRIME HN	S	100.0 a[3]	466.8 abc	35.9 a	8.4 a
VELUM PRIME LN	S	100.0 a	595.7 ab	25.1 a	6.3 a
VELUM PRIME HN	D	96.9 a	212.6 abc	53.9 abc	15.1 a
CLEAN SEED	-	95.8 a	525.4 abc	33.9 a	11.1 a
VELUM PRIME LN	D	95.7 a	704.9 a	30.1 a	8.9 a
AGRI-MEK HN	S	85.1 a	218.9 abc	45.9 ab	17.8 a
UNTREATED LN	-	76.3 ab	478.0 abc	45.6 ab	22.2 ab
EXP#019-01 HN	ST	33.1 bc	39.2 bc	90.2 cd	55.0 bc
PROMAX HN	S	32.1 bc	95.4 bc	81.9 bcd	52.7 bc
RHIZOVITAL 42 HN	S	11.1 b	52.7 bc	94.4 cd	75.1 cd
UNTREATED HN	-	0.0 b	0.0 c	100.0 d	91.3 d

[1] Application Method: S = Soak; D = Drench; ST = Seed Treatment

[2] DSI was calculated using the following equation:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of garlic bulbs in each class})]}{(\text{total no. of garlic bulbs per sample})\ (\text{no. classes} - 1)} \times 100$$

[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's test

Table 3. Stem and bulb nematode populations at harvest found in garlic cloves and soil following nematicide application in a mineral soil field trial near Cookstown, Ontario, 2018-2019.

Treatment	App. Method[1]	Cloves (SBN/g clove)	Soil (SBN/kg soil)
VELUM PRIME HN	S	0.0 ns[2]	10 ns
CLEAN SEED	-	0.0	0
VELUM PRIME LN	D	0.0	0
VELUM PRIME LN	S	0.2	0
VELUM PRIME HN	D	0.4	0
EXP#019-01HN	ST	3.5	10
AGRI-MEK HN	S	6.3	10
PROMAX HN	S	13.6	1550
UNTREATED HN	-	14.2	130
RHIZOVITAL 42 HN	S	15.5	1100
UNTREATED LN	-	20.7	760

[1] Application Method: S = Soak; D = Drench; ST = Seed Treatment

[2] ns indicates that no significant differences were found among the treatments at $P = 0.05$, Tukey's test

2019 PMR REPORT # 13 **SECTION K: FRUIT - Diseases**

CROP: Plum (*Prunus domestica*) L., c.v. Victory, Vision
PEST: black knot (*Apiosporina morbosa*, (Schwein.) Arx)

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TITLE: FUNGICIDE MANAGEMENT OF BLACK KNOT IN PLUM

MATERIALS: BRAVO 500 (chlorothalonil, 50%), GRANUFLO-T (thiram, 75%), FONTELIS (penthiopyrad, 20%), INDAR (fenbuconazole, 75%), SENATOR 70 WP (thiophanate-methyl, 70%), INSPIRE SUPER (difenoconazole, 8.6% + cyprodinil 24.9%), PRISTINE WG (pyraclostrobin, 25.2% + boscalid, 12.8%)

METHODS: Trials were conducted 2013-2014 and 2015-2016 in Niagara, Ontario. A randomized complete block arrangement with 4 blocks per treatment was used. Each replicate consisted of single tree. All knots from previous infections were removed from trees and 5 knots were attached to the tops of trees with twist ties to provide uniform inoculum. Fungicide sprays were applied to just before drip using a calibrated CO_2 backpack sprayer and tarps were used to minimize drift between trees. Spray volume per tree was variable due to differences in tree size. In 2013, sprays were applied at shuck split (ss) (BBCH 71), and at weekly intervals for 3 weeks following. To identify the critical timing for fungicide application, in 2013, the initiation of Bravo sprays was delayed sequentially by one week to include sprays starting at 1 week split (ss+1), 2 weeks (ss+2) or 2 weeks post shuck split (ss+3). In 2015, all full season treatments were initiated at bloom. To further investigate the critical timing for protection from black knot, the number of weekly Thiram sprays was increased by a week: 1x = bloom spray, 2x, 3x, 4x = were spray at bloom plus 2, 3 and 4 weekly sprays, respectively). The next summer (July 2014 and 2016), once new knots were observed, 25 1-year-old shoots (25 cm long) were arbitrarily selected from each tree. In 2014, the incidence of black knot (number of infected shoots/25) was recorded. In 2016, the incidence and severity (number of knots per shoot) were recorded. ANOVA was applied using XLSTAT and means separations were obtained using Tukey's HSD test at α=0.10.

RESULTS: Data are presented in Tables 1 and 2. In 2013-2014, Bravo, Bravo/Thiram, Indar and Thiram applied 4 times significantly reduced the incidence of black knot compared to the untreated check. The shuck split timing was most important in 2013. In 2015-2016, all treatments but the Thiram bloom spray significantly reduced the incidence and all treatments reduced the severity of black knot. The 1-week post bloom spray (shuck split) was the most important timing for controlling black knot.

CONCLUSIONS: Several of the fungicides registered to manage blossom blight/brown rot in plum also have excellent activity against black knot. In the two years of the trial, the critical timing for fungicide protection was at shuck split.

Table 1. Fungicide treatment and timing for control of black knot in plum, 2013-2014

Treatment	Timing of application	Incidence of black knot (mean # knots/25 shoots)
Check		32.8 a[1]
Bravo	ss, ss+1, ss+2, ss+3	3.5 c
Bravo	ss+1, ss+2, ss+3	35.3 a
Bravo	ss+2, ss+3	25.0 abc
Bravo	ss+3[2]	29.5 a
Bravo	ss, ss+1	
+ Granuflo-T	ss+2, ss+3	7.5 bc
Fontelis	ss, ss+1, ss+2, ss+3	12.7 abc
Indar	ss, ss+1, ss+2, ss+3	6.0 bc
Senator	ss, ss+1, ss+2, ss+3	11.5 abc
Thiram	ss, ss+1, ss+2, ss+3	2.0 c

[1] Means followed by the same letter are not significantly different (Tukey's HSD, α=0.10)

[2] ss = shuck split; ss+1 = 1-week post shuck split; ss+2 wk = 2 weeks post shuck split; ss+3=3 weeks post shuck split

Table 2. Fungicide treatment and timing for control of black knot in plum, 2015-2016

Treatment	Timing of application	Incidence (mean # knots/25 shoots)	Severity (mean number of knots per shoot)
Check		17.5 a[1]	1.4 a
Granuflo-T	bl[2]	10.5 ab	0.8 b
Granuflo-T	bl, bl+1	8.0 b	0.4 bc
Granuflo-T	bl, bl+1, bl+2	2.0 b	0.1 c
Granuflo-T	bl, bl+1, bl+2, bl+3	4.3 b	0.2 c
Fontelis	bl, bl+1, bl+2, bl+3	9.0 b	0.5 bc
Inspire Super	bl, bl+1, bl+2, bl+3	2.5 b	0.1 c
Senator	bl, bl+1, bl+2, bl+3	9.8 b	0.7 b
Pristine	bl, bl+1, bl+2, bl+3	3.5 b	0.2 c
Indar	bl, bl+1, bl+2, bl+3	4.0 b	0.2 c

[1] Means followed by the same letter are not significantly different (Tukey's HSD, P = α=0.10)

[2] bl = bloom; bl+1 = one week post bloom (shuck split); bl+2 = 2 weeks post bloom; bl+3 = post bloom spray.

2019 PMR REPORT # 14 **SECTION K: FRUIT - Diseases**

CROP: Pear, *Pyrus communis* L., c.v. Bosc
PEST: Fire blight, *Erwinia amylovora* (Burrill 1882) Winslow et al. (1920)

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TITLE: INTEGRATING STREPTOMYCIN ALTERNATIVES FOR MANAGEMENT OF FIRE BLIGHT IN PEAR, 2019

MATERIALS: STREPTOMYCIN 17 (streptomycin sulphate, 25.2%), CUEVA (copper octanoate 1.8%), DOUBLE NICKEL LC (*Bacillus amyloliquefaciens* strain D747, 1×10^{10} spores/mL), BLOSSOM PROTECT (*Aureobasidium pullulans* DSM 14940 and DSM 14941, 5 x 10^9 cfu/g), KASUMIN 2 L (kasugamycin, 2.0%), LIFEGARD WG (*Bacillus mycoides* isolate J, 40%), BURAN (garlic powder, 14% + 0.02% Agral)

METHODS: The trial was conducted on Bosc on Bartlett rootstock. Trees (1.25 m row spacing) were planted with 4 m row spacing in 2016. Treatments were applied in a randomized complete block design with 5-tree plots and 4 replicates. Treatments were applied using a CO_2 backpack sprayer. The number of flower clusters per 5-tree plot was determined on April 29. LifeGard WG was applied twice pre-bloom on May 16 and 21. Streptomycin, Cueva, Double Nickel, Blossom Protect and Kasumin treatments were applied the mornings of May 22 (20% bloom) (T1) and 24 (80% bloom) (T2). A suspension of *Erwinia amylovora*, 10^6 cfu, was applied to blossoms in the afternoon of May 22 and 24. Buran was applied May 23 and the afternoon of May 24. Infected blossom clusters were counted May 29, June 3, 6 and 11 and the sum of infections per plot over the 4 evaluation dates determined. Data were arcsine transformed and ANOVA was applied using XLSTAT and means separations were obtained using Tukey's HSD test at α=0.10.

RESULTS: Data are presented in Table 1.

CONCLUSIONS: Both inoculation timings were successful. While there was a trend of all treatments to reduce the incidence of fire blight, the decrease was significant only for Streptomycin applied before each inoculation or Double Nickel followed by Streptomycin.

Table 1. Efficacy of Streptomycin alternatives alone or in rotation with Streptomycin for the management of fire blight in pear, 2019

Treatment	Incidence of infected flower clusters (%)
Water (1, 2)[1]	30.2 a[2,3]
Water (1), Streptomycin (2)	6.6 ab
Streptromycin (1), Water (2)	7.5 ab
Streptomycin (1,2)	1.2 b
Kasumin (1), Streptomycin (2)	5.7 ab
Double Nickel (1), Streptomycin (2)	2.7 b
Blossom Protect (1), Streptomycin (2)	6.3 ab
Cueva (1), Streptomycin (2)	3.6 ab
Blossom Protect (1), Kasumin (2)	5.5 ab
Double Nickel (1), Kasumin (2)	12.1 ab
Double Nickel + Cueva (1), Kasumin (2)	13.4 ab
Double Nickel + Cueva (1), Streptomycin (2)	7.3 ab
LifeGard (2 pre-bloom)	14.1 ab
Buran (2 post-inoculation)	21.4 ab

[1] (1) = 20% bloom; (2) = 80% bloom

[2] Data were transformed using an arcsine transformation and back-transformed means are presented.

[3]Means followed by the same letter are not significantly different (Tukey's HSD, α=0.10)

2019 PMR REPORT #15 **SECTION K: FRUIT – Diseases**

CROP: June bearing Strawberries (*Fragaria* × *ananassa* 'Hood')

PEST: Grey Mold, *Botrytis cinerea*

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TITLE: FOLIAR APPLICATIONS OF *TRICHODERMA ATROVIRIDE* ISOLATES FOR THE CONTROL OF GREY MOLD (*BOTRYTIS CINEREA)* IN STRAWBERRIES

MATERIALS: T-77 (*Trichoderma atroviride* strain 77B), DECREE 50 WDG (Fenhexamid 50%), TA-222 (*Trichoderma atroviride*)

METHODS: A trial was conducted to examine the efficacy of *T. atroviride* isolates to control *Botrytis cinerea* in 6" potted strawberry plants (*Fragaria* × *ananassa* 'Hood') in raised beds at the Institute for Sustainable Horticulture (ISH), Kwantlen Polytechnic University in the summer of 2019. Cloth row cover (Reemay) was used to cover the raised beds to protect the plants from animal pests, such as birds and rabbits, and to increase the humidity among the leaves and fruit by reducing temperature variations and shading the soil to minimize soil moisture loss. The temperatures in June (High: 21.7 ^{0}C, Low: 12.1 ^{0}C) were typical for the area (30-year average High: 21 ^{0}C, Low: 11 ^{0}C). Four overhead sprinklers were placed in each raised bed to ensure the ambient humidity was optimal to achieve *B. cinerea* infection. The sprinklers were set to pulse based on light accumulation (20-second pulses every 500 W/m^2) in addition pulses were set at specific time intervals to imitate dew (6:00, 21:00, 21:45, 22:30 and 23:15). A randomized complete block design was used (6 blocks, 4 reps/block, 1 plant/rep), where the raised bed served as the block and all treatments were replicated four times within each bed. The treatments were applied in a volume of 500 L/ha at the following rates: T-77 low rate, 250 g/ha (1x10^9 conidia/L), T-77 high rate, 500 g/ha (2x10^9 conidia/L), TA-222, 15 g/ha (2.0x10^9 conidia/L), DECREE 50 WDG, 1.12 kg/ha, and a water control. Applications were conducted once a week, beginning at first flower (June 3rd) for six weeks with the exception of Decree which was applied twice, 14 days apart, as per label directions. Potted plants were removed from the raised beds and placed in a 1 m^2 plot for treatment application with a 1.5-gallon handheld battery pressurized sprayer (Green Gorilla, USA). Plants were returned to their location in the raised beds after the spray had dried to remove the possibility of product transfer among treatments. Beds were inoculated twice with a *B. cinerea* conidial suspension. Conidia were harvested in reverse osmosis water from mature *B. cinerea* colonies, originally isolated from organic BC strawberries, grown at 20 ºC with a 16:8 L:D cycle for 21 days on Potato Dextrose Agar (PDA). The first spray inoculation of *B. cinerea* (6.2x10^5 conidia/ml, 100 ml/bed) was applied to strawberry plants two days after the initial treatment applications (June 5th) and the second application (5.25x10^5 conidia/ml, 266 ml/bed) occurred two weeks later (June 20th). The percent diseased foliage, buds, flowers, and fruit (green, white and red) were estimated based on weekly assessments. Fruit was harvested when ripe on two occasions and kept in individual 4oz Solo® cups at 10 °C in the dark. Individual berries were monitored for *B. cinerea* infection, marketability, and weight at one, three, five and seven days post-harvest. Proportion of diseased fruit, marketable fruit, and proportion of fruit with sporulation of *B. cinerea* were analyzed using a Generalized Linear Model with a binomial distribution and logit link

function with bed as a block and treatment as a main effect. Contrasts were used to test for differences among pairs of treatments. Mean berry weights per plant were analyzed using an Analysis of Variance (ANOVA) with bed as a block and treatment as a main effect.

RESULTS: Data are presented in Table 1

CONCLUSIONS: Observed foliar *B. cinerea* lesions remained low and did not exceed 9% in any of the treatments over the study period. There were no disease symptoms observed in buds or flowers and very little disease observed on pre-harvest fruit. In Harvest 1, one and three days post-harvest, T-77 low rate (250 g/ha, $1x10^9$ conidia/L) was the only treatment to show a significant reduction in the occurrence of *B. cinerea* on berries when compared to the water control. By day five post-harvest, *B. cinerea* infection rose in the T-77 low rate treatment and there were no differences in the percent infected berries observed between the treatments and control beyond day five. There was also a significant increase in the percent of marketable fruit per plant in both T-77 low rate and Decree when compared to the control treatment on the first-day post-harvest. Seven days after the first harvest, the percent of fruit-bearing *B. cinerea* spores per plant was significantly reduced by Decree when compared to the control, while the other treatments showed intermediate results between Decree and the control and were not significantly different from either. Results from the second harvest indicated that none of the treatments suppressed *B. cinerea* when compared to the control, however, Decree did show a significant reduction in the percent of diseased berries compared to TA-222 on day three post-harvest. These results indicate that T-77 low has the potential to suppress *B. cinerea* in strawberries post-harvest and could increase the marketability of strawberries.

Table 1. Effect of foliar microbial fungicides on total fruit number, berry weight, percent marketable and diseased fruit, and the percent of fruit-bearing *B. cinerea* spores seven days after harvest.

Harvest	Treatment	Total Fruit	Mean berry weight (g)	% Marketable Fruit	% Diseased Fruit				*B. cinerea* Sporulation on fruit (%)
			Day 1	Day 1	Day 1	Day 3	Day 5	Day 7	Day 7
1	Control	108	10.45	21.1a	39.5a	47.4a	47.4	65.8	36.8a
	T-77 low	148	9.20	54.3b	13.5b	13.5b	26.2	47.8	13.0ab
	T-77 high	124	8.90	50.0ab	23.7ab	31.6ab	39.5	50.0	22.5ab
	TA-222	148	9.75	48.3ab	9.2ab	20.8ab	32.1	42.9	16.7ab
	Decree	120	10.24	63.3b	10.8ab	17.5ab	21.7	26.7	5.0b
2	Control	32	5.21	50.0	16.7	16.7ab	50.0	66.7	16.7
	T-77 low	48	3.55	66.7	29.6	40.7ab	40.7	51.9	29.6
	T-77 high	48	5.00	50.0	40.0	40.0ab	50.0	55.0	20.0
	TA-222	44	4.00	35.4	52.1	64.6a	64.6	64.6	52.1
	Decree	40	5.58	100.0	0.0	0.0b	0.0	25.0	4.2

[1]Significant differences are represented by different letters (a, b).

[2]Values not followed by a letter are not significantly different within the column for each harvest

ACKNOWLEDGEMENT: We thank Sylvar Technologies Inc. for their partnership, RGR Produce for their donation of plant material, and A. Torres, M. Tabert, M. Rachidi, S. Daniel and S. Chalifoux for their assistance throughout the trial.

2019 PMR REPORT # 16 **SECTION L: VEGETABLES and SPECIAL CROPS – Diseases**

CROP: Red Beet (*Beta vulgaris* L. subsp. *vulgaris* (conditiva group)), var. Ruby Queen
PEST: *Cercospora beticola* Sacc.

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TITLE: FIELD EVALUATION OF APROVIA TOP FUNGICIDE FOR CONTROL OF CERCOSPORA LEAF SPOT, 2018

MATERIALS: APROVIA TOP (difenoconazole 117 g/L, benzovindiflupyr 78 g/L), CABRIO EG (pyraclostrobin 20%)

METHODS: Seeds of red beet var. Ruby Queen were planted directly in the field (soil organic matter ≈ 1.6%, pH ≈ 6.9) at the Simcoe Research Station on 6 July, 2018, using a cone planter at a depth of 1.5 cm and a density of 20 seeds per m. A randomized complete block design with four replicates per treatment was used. Each experimental unit consisted of four rows, 30 cm apart, 7 m long. Treatments were untreated check (A), four applications of APROVIA TOP at the rate of 0.643 L/ha (B) and 0.967 L/ha (C), single application of APROVIA TOP @ 0.967 L/ha (D) and three applications of a commercial standard, CABRIO EG, at the rate of 1.1 kg/ha (E). Treatments were applied using a CO_2 backpack sprayer equipped with three TeeJet XR11003 nozzles spaced 50 cm apart and calibrated to deliver 300 L/ha at 220 kPa. Treatments B and C were applied on 25 July, 7, 19 and 30 August, 2018, treatment D was applied on 25 July only and treatment E was applied on 25 July, 7 and 19 August, 2018. Disease occurred naturally, as based on observations of typical symptoms on leaf, so inoculation was not needed. Disease incidence and severity of cercospora leaf spot were assessed on 23, 31 July, 7, 14, 23, 29 Aug, 7, 17 Sep and 4 Oct 2018. Twenty plants from the inside 5 m of the middle two rows of each plot were examined and rated from 0-10 with: 0 = healthy plant; 1 = a single isolated spot on one or more than one leaves of a plant; 2 = 20 spots on a leaf or on more than one leaf of a plant; 3 = 21-50 spots on one leaf or on more than one leaf of a plant; 4 = 51-100 spots on a leaf or more than one leaf; 5 = 50% of the leaf area is infected on one or more leaves of a plant; 6 = 60% of the leaf area is infected; 7 = 70% of the leaf area is infected; 8 = 80% leaf area infected; 9 = the entire foliage is strongly affected; 10 = the foliage is completely covered. Beet roots were harvested on from the inside 2.5 m of the middle 2 rows of each plot on 5 Nov 2018 and rated as marketable based on size (25-76 mm in diameter) and defects such as cracked or misshapen roots. The number and weight of marketable and unmarketable roots was recorded, and total and marketable yield calculated.

Compared to the previous 10-year averages, the air temperatures in 2018 were above average for July (22.5°C), August (22.3°C), September (18.4°C) and below average for October (9.6°C) and November (1.5°C). The 10-yr average temperatures were: July 21.7°C, August 20.6 °C, September 17.1°C, October 10.6°C and November 3.6°C. Monthly rainfall was below the 10-year average for July (58.8 mm) and above average for August (103.8 mm), September (94 mm), October (118 mm) and November (108 mm). The 10-year rainfall averages were: July 77 mm, August 87 mm, September 82 mm, October 97 mm and November (63 mm). Data was analyzed using the General Analysis of Variance function of the Linear Models section of Statistix V.9. Tukey's HSD test was used to detect differences among the treatment means at $P = 0.05$.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Disease pressure was very high but variable, and few statistically significant differences were observed. However, four applications of APROVIA TOP did result in some statistically significant reductions in disease incidence and severity on one of the assessment date (29 August, 2018) and some disease suppression was also indicated by the AUDPC. No significant differences in total, marketable, or percent marketable yield were observed (data not shown).

Table 1. Effect of fungicides to control cercospora leaf spot disease incidence, severity and area under disease progress curve (AUDPC) within each treatment group for red beets on selected dates in Simcoe, Ontario, in 2018.

Treatment and number of Applications	**Disease Incidence (%)[1]**			**Disease Severity Index (DSI[2])**			**AUDPC[3]**
	23 Aug	29 Aug	7 Sept	23 Aug	29 Aug	7 Sept	
A: Untreated Check	89.1 ns[4]	100 a[5]	100 ns	10.6 ns	20 a	44.7 ns	229 ns
B: APROVIA TOP @ 0.643 L/ha, 4 applications	66.4	76.6 b	100	7.7	11 b	30.6	175
C: APROVIA TOP @ 0.967 L/ha, 4 applications	68.1	95.6 ab	100	7.4	14.6 ab	31.7	177
D: APROVIA TOP @ 0.967 L/ha, 1 application	80.5	99.0 a	100	9.2	17.8 ab	37.3	209
E: CABRIO @ 1.1 kg/ha, 3 applications	83.7	97.6 ab	100	10.6	17.6 ab	41.8	218

[1] Disease incidence (%) = Number of plant infected / Total number of plants assessed * 100.
[2] Disease severity ratings were used to calculate severity index (0-100) using the formula below:

$$\text{DSI} = \frac{[(\text{class no.})(\text{no.of plants in each class})]}{(\text{total no. plants per sample})(\text{no.classes}-1)} \times 100$$

[3] Area Under Disease Progress Curve (AUDPC) was calculated using the equation:

$$\text{AUDPC} = \sum_{j=1}^{nj-1} \left(\frac{yj+yj+1}{2}\right)(t\,j+1-tj)$$

[4] No significant differences ($P = 0.05$, Tukey's HSD test) were found among the treatments.
[5] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$ using Tukey's HSD test.

2019 PMR REPORT # 17 **SECTION L: VEGETABLES and SPECIAL CROPS – Diseases**

CROP: Celery (*Apium graveolens* L.) cvs. TZ 6200 and Kelvin
PEST: Anthracnose leaf curl (*Colletotrichum fioriniae* (Marcelino & Gouli) Pennycook)

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TITLE: **EVALUATION OF WEATHER-BASED FORECASTING MODELS TO MANAGE LEAF CURL ON CELERY CROPS IN THE HOLLAND MARSH, ONTARIO, 2019**

MATERIALS: QUADRIS FLOWABLE (250 g/L azoxystrobin), SWITCH 62.5WG (cyprodinil 37.5% and fludioxonil 25.0%)

METHODS: The trial was conducted in 2019 at the Muck Crops Research Station in the Holland Marsh, Ontario. Celery cultivars TZ 6200 and Kelvin, which are moderately and highly susceptible to leaf curl, respectively, were used for this trial. Both cultivars were seeded into 288-cell plug trays on 3 April. On 7 June, celery was transplanted using a mechanical transplanter into the field in organic soil (soil: pH ≈ 7.0, organic matter ≈ 65.6%). A strip plot design was used, with spraying treatments as the main plot, and cultivars as the strip plots, in which each treatment was replicated five times. Each replicate plot consisted of six rows (three rows for Kelvin and three rows for TZ 6200) that were 55 cm apart, 6 m in length with in-row spacing of 15 cm. Fungicide QUADRIS FLOWABLE was alternated with SWITCH 62.5WG. QUADRIS FLOWABLE was applied at a rate of 1.12 L/ha and SWITCH 62.5 WG was applied at 1 kg/ha. Fungicide application timing was determined using weather-based forecasting models: TOMCAST at Disease Severity Value (DSV) threshold of 15, and TOMCAST with a DSV threshold of 25. The weather-based forecasting models were compared to a 7 to 10-day CALENDAR spray program and a non-treated CONTROL. Leaf wetness and temperature data were collected from a weather station on site within a nearby field. The border rows of each replicate plot were inoculated with *Colletotrichum fioriniae* (1×10^5 spores/mL) on 5 July. Three litres of the spore suspension were applied using a CO_2 backpack sprayer fitted with a single nozzle fan-type TeeJet 8002, at a rate of 10 mL per row meter. The inner rows were visually assessed weekly for the presence of leaf curl symptoms. Celery was harvested on 17 and 18 of September, and a total of 20 plants/plot (ten plants/inner row/plot) were assessed. Marketable weight was first determined by removing stalks with lesions or discarding plants with crown rot and weighing only disease-free plants after trimming to marketable length (40 cm). The percent marketable by weight was determined by dividing the marketable weight by the total weight, which was the weight of the marketable and unmarketable tissue. The marketable weight per plant was determined by dividing the marketable weight by the number of marketable plants in each replicate plot.

Compared to the previous 10-year average, air temperatures in 2019 were above average for July (22.3°C), average for June (17.5°C), August (19.4°C), September (15.8°C) and below average for May (11.4°C). The 10-year average temperatures were: May 14.3°C, June 18.4°C, July 21.1°C, August 20.2°C and September 16.4°C. Monthly rainfall was below the 10-year average for June (84 mm), July (42 mm), August (46 mm) and average for May (77 mm) and September (62 mm). The 10-year rainfall averages were: May 77 mm, June 100 mm, July 93 mm, August 80 mm and September 61 mm. All statistical analyses were performed using the General Analysis of Variance function of Statistix 10. Means separation was obtained using Tukey's HSD test with $P = 0.05$ level of significance.

RESULTS: As outlined in Table 1.

CONCLUSION: For both TZ 6200 and Kelvin cultivars, disease incidence was lower in the TOMCAST (15 and 25 DSV) and CALENDAR spray program treatments, relative to the no-spray CONTROL. TOMCAST 15 and 25 provided the same amount of control as the CALENDAR spray program, and resulted in the same percent marketable weight, but were only significantly higher than the no-spray CONTROL for cv. TZ 6200. CALENDAR spray program had seven fungicide applications; however, the number of fungicide applications was reduced to six for TOMCAST 15, and four for TOMCAST 25. Despite cv. Kelvin being highly susceptible to leaf curl, cv. TZ 6200 was more susceptible than Kelvin in the no-spray CONTROL. In conclusion, TOMCAST 15 and 25 resulted in the lowest number of fungicide applications and associated costs, with a comparable reduction in disease incidence compared to the CALENDAR spray program, for both cultivars.

Table 1. Number of sprays, estimated spray cost, disease incidence, and percent marketable yield by weight for forecasting fungicide applications to manage leaf curl on celery cvs. TZ 6200 and Kelvin at the Muck Crops Research Station, Holland Marsh, Ontario, 2019.

Cultivar	Treatment	Application date (DAFA)[1]	No. of sprays	Spray cost ($/ha)[2]	Incidence (%)[3]	Market. by Wt. (%)
TZ 6200	CALENDAR	0, 10, 20, 27, 37, 48, 58	7	1223.71	7.6 c[4]	98.8 a
	TOMCAST 15	0, 10, 20, 30, 44, 57	6	1209.75	5.2 c	96.7 a
	TOMCAST 25	0, 14, 27, 48	4	728.50	12.5 bc	87.1 ab
	CONTROL	--	--	--	29.9 a	73.3 b
Kelvin	CALENDAR	0, 10, 20, 27, 37, 48, 58	7	1223.71	5.4 c	95.6 a
	TOMCAST 15	0, 10, 20, 30, 44, 57	6	1209.75	5.0 c	96.2 a
	TOMCAST 25	0, 14, 27, 48	4	728.50	10.3 bc	93.9 a
	CONTROL	--	--	--	20.6 b	79.6 ab

[1] DAFA = Days after first spray; first fungicide application was on 2 July for TOMCAST 15, TOMCAST 25 and the CALENDAR spray program treatments (first application = 0 days)

[2] Cost per spray: QUADRIS FLOWABLE = $130.96/ha, and SWITCH 62.5WG = $233.29/ha

[3] Disease incidence of inner rows measured prior to harvest

[4] Values with different letters within columns were significantly different at $P = 0.05$, based on Tukey's HSD test

2019 PMR REPORT # 18 **SECTION L: VEGETABLES and SPECIAL CROPS - Diseases**

CROP: Yellow cooking onions (*Allium cepa* L.), cv. Fortress
PEST: Stemphylium leaf blight (*Stemphylium vesicarium* (Wallr.) E.G. Simmons)

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TITLE: FUNGICIDE APPLICATION TIMING FOR MANAGEMENT OF STEMPHYLIUM LEAF BLIGHT OF ONION, 2019

MATERIALS: APROVIA (benzovindiflupyr 100 g/L), BRAVO ZN (chlorothalonil 500 g/L), EVERGOL PRIME (22.7% penflufen), FARMORE F300 (33.3% mefenoxam, MAXIM 4FS [40.3% fludioxonil DYNASTY [9.6% azoxystrobin])

METHODS: Onion cv. Fortress was direct seeded (35 seeds/m) on 17 May 2019 using a Stanhay Precision Seeder into organic soil (organic matter ≈ 69.3, pH ≈ 6.1) at the Muck Crops Research Station, King, Ontario in a randomized complete block design with four replicates. Each plot consisted of two adjacent beds, each 6 m x 1.5 m and seeded with four paired rows, with 7.5 cm between paired rows and 35 cm between pairs of rows. Blocks were separated by a 1.5 m-wide pathway.

The treatments consisted of an untreated control, two fungicide seed treatments (EVERGOL PRIME or FARMORE F300) that either received no foliar fungicide in the growing season or were sprayed every 7–10 days, weekly sprays starting at 2-leaf growth stage, and two forecasting models; TOMCAST at a disease severity value threshold of 15 and a slightly modified version of BSPCAST. EVERGOL PRIME was applied at a rate of 2.5 g ai/kg seed, and the FARMORE F300 was a combination of DYNASTY applied at 0.025 g ai/kg seed, APRON XL at 0.075 g ai/kg seed, and MAXIM 4FS at 0.0275 g ai/kg seed. Foliar sprays of APROVIA (750 mL/ha in 500 L/ha of water) alternated with BRAVO ZN (3.6 L/ha in 500 L/ha of water) were applied at several different timings. A scale of 0 to 4 was used to assess disease severity of the three oldest leaves for 20 onions per plot and separate them into classes: 0 = no yellowing, 1 = 1–10% yellowed, 2 = 11–25% yellowed, 3 = 26–50% yellowed, 4 > 51% yellowed area. A disease severity index (DSI) was calculated as:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of leaves in each class})]}{(\text{total no. leaves assessed})\ (\text{no. classes} - 1)} \times 100$$

On 18 September, onion plants in two 2.3-m-long sections were harvested from the middle rows of each plot, weighed, and graded to determine yield**.** Data were analyzed using the GLIMMIX function of SAS version 9.4 (SAS Institute 2017). Means separation was assessed using Tukey's honest significant difference (HSD) test at $P = 0.05$.

Compared to the previous 10-year average, air temperature in 2019 was below average for May (11.4°C), average for June (17.5°C), August (19.4°C) and September (15.8°C), and above average for July (22.3°C). The 10-year average temperatures were as follows: May (14.3°C), June (18.4°C), July (21.1°C), August

(20.2°C), and September (16.4°C). Monthly rainfall was below the 10-year average for June (84 mm), July (42 mm) and August (46 mm), and within average for May (77 mm) and September (62 mm). The 10-year rainfall averages were: May (77 mm), June (100 mm), July (93 mm), August (80 mm), and September (61 mm).

RESULTS: As presented in Tables 1 and 2.

CONCLUSIONS: Disease pressure was relatively low in 2019. Foliar fungicide applications made weekly or timed using forecasting models did not reduce blight incidence or severity relative to the untreated control. The weekly schedules resulted in seven foliar applications of fungicide. The forecasting models reduced fungicide applications, with six applications recommended by TOMCAST and five applications by BSPCAST. However, EVERGOL PRIME fungicide seed treatment in combination with weekly foliar sprays reduced incidence by 27% and severity by 43% compared to the unsprayed control (Table 1). This is consistent with the 2018 field trial, where this seed treatment reduced incidence by 31% and severity by 53% relative to the control. There were no differences in yield among treatments.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Ontario Agri-Food Innovation Alliance, the Bradford Cooperative Storage Inc., and the Fresh Vegetable Growers of Ontario.

Table 1. Effect of fungicide applications on Stemphylium leaf blight levels at the Muck Crops Research Station on 15 August 2019.

Treatment	# Applications	Incidence (%)	Severity (DSI)
Control (no spray)	0	96 a[1]	37 a
FARMORE F300 seed coating (no spray)	0	84 ab	34 a
FARMORE F300 seed coating + weekly spray	7	88 ab	30 ab
BSPCAST	5	85 ab	28 ab
EVERGOL PRIME seed coating (no spray)	0	84 ab	29 ab
Weekly spray	7	81 ab	27 ab
TOMCAST	6	80 ab	29 ab
EVERGOL PRIME seed coating + weekly spray	7	70 b	21 b

[1] Means in column followed by the same letter do not differ at $P = 0.05$ based on Tukey's HSD test.

Table 2. Effect of fungicide application on yield and size distribution (by weight) of onion in 2019.

Treatment	Yield (t/ha)	Size distribution by weight (%)		
		Cull (<32 mm)	Can. No. 1 (32–76 mm)	Jumbo (>76 mm)
Control (no spray)	74.3 ns[1]	0.8 ns	86.7 ns	12.5 ns
TOMCAST	75.2	1.3	87.5	11.1
EVERGOL PRIME seed coating (no spray)	75.1	3.3	87.3	9.4
FARMORE F300 seed coating + weekly spray	74.3	1.3	80.3	18.4
Weekly spray	73.1	0.6	84.8	14.6
FARMORE F300 seed coating	71.7	1.0	88.6	10.4
EVERGOL PRIME seed coating + weekly spray	71.7	2.9	89.5	7.6
BSPCAST	70.1	1.8	93.7	4.5

[1] ns = No significant differences ($P = 0.05$) were found among the treatments.

2019 PMR REPORT #19 **SECTION L: VEGETABLES and SPECIAL CROPS - Diseases**

CROP: Shanghai pak choi (*Brassica rapa* L. var. *communis* Tsen and Lee), cv. Mei Qing
PEST: Clubroot (*Plasmodiophora brassicae* Woronin)

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TITLE: **EVALUATION OF SOIL FUMIGANTS FOR CLUBROOT CONTROL ON SHANGHAI PAK CHOI, 2019**

MATERIALS: PIC PLUS (85.1% chloropicrin), BUSAN 1236 (metam sodium 42%)

METHODS: The trial was conducted at the Muck Crops Research Station, Holland Marsh, Ontario on a muck soil (pH ≈ 6.0, organic matter ≈ 66%) naturally infested with *Plasmodiophora brassicae*, in 2019. A randomized complete block design with five replicates per treatment was used. Each experimental unit (plot) was 2.0 m × 12 m. Treatments were: PIC PLUS at 164 & 280 kg/ha and BUSAN 1236 at 150 and 300 kg/ha. An untreated and untarped check and an untreated check covered with totally impermeable film (TIF) (Raven Industries, Sioux Falls, South Dakota) were also included. On 9 July, PIC PLUS was applied using a 2 m wide tractor-mounted PIC PLUS fumigator equipped with shanks to inject the product 25-30 cm into the soil and BUSAN 1236 was applied using a separate 2 m wide custom tractor-mounted fumigator with shanks spaced 17 cm apart applying the product 25-30 cm into the soil. After the treatments were applied, each plot was rolled and covered using the TIF product. HOBO pendant dataloggers were placed 5 cm below the soil surface in both the TIF covered check and the uncovered check treatments. After 14 days, on 23 July, the TIF was removed. On 24 July, each plot was seeded with four rows of Shanghai pak choi, cv. Mei Qing Choi, with 40 cm between rows using a Stanhay precision seeder. On 4 September, 50 plants per replicate were removed and top weight recorded. Clubroot incidence and severity were assessed on these roots plus the roots of 50 additional plants (100 roots in total) using a 0 to 4 scale where 0 = no clubbing, 0.2 = small club (2 cm), 1 = <1/4 of root clubbed, 2 = 1/4 – 1/2 of roots clubbed and 3 = > 1/2 of roots clubbed. Disease severity index (DSI) was determined using the following equation:

$$\text{DSI} = \frac{\sum [(\text{class no.})\ (\text{no. of plants in each class})]}{(\text{total no. plants per sample})\ (\text{no. classes} - 1)}\ \text{x}100$$

Data were analyzed using the General Analysis of Variance function of the Linear Models section of Statistix V.10. Means separation was obtained by using Fisher's Protected LSD test at $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: Disease incidence in the trial was high. Significant differences were observed among the treatments in disease incidence, disease severity (DSI) and fresh plant weight. Both PIC PLUS treatments had lower incidence and severity than the uncovered check. Fresh weights were significantly higher in the PIC PLUS treatments. The TIF covered check also had significantly lower disease incidence and severity than the uncovered check and had fresh weights similar to the PIC PLUS treatments. Soil temperatures under the TIF check were 10°C higher than the uncovered check. The high temperatures under

the TIF may provide a solarization effect. More work is needed to investigate the effect of solarization on clubroot spores.

Table 1. Clubroot incidence and severity for Shanghai pak choy grown in muck soil naturally infested with *Plasmodiophora brassicae*, treated with fumigants at the Muck Crops Research Station, Ontario, 2019.

Treatment	Rate (kg/ha)	Incidence (%)	DSI[1]	Fresh Top Wgt/plant (g)
PIC PLUS	164	41.6 a[2]	18.5 a	109.1 ab
PIC PLUS	280	46.5 a	18.1 a	132.6 a
TIF Check	---	47.0 a	26.1 a	97.4 b
BUSAN 1236	300	54.6 a	29.1 a	107.5 ab
BUSAN 1236	150	64.0 ab	24.2 a	95.0 b
Uncovered Check	--	98.2 b	57.2 b	50.2 c

[1] Roots of 100 plants were sorted into the following classes: 0=0%, 0.2 = 2cm club, 1 = 1-25%, 2 = 25-50%, 3= 50 - 100%. DSI was calculated with the following formula:

$$DSI = \frac{\sum[(\text{class no.})\ (\text{no. of plants in each class})]}{(\text{total no. plants per sample})\ (\text{no. classes}-1)} \times 100$$

[2] Numbers in a column followed by the same letter are not significantly different at P = 0.05, Fisher's Protected LSD test.

Table 2. Average daily soil temperatures 5 cm below totally impermeable film (TIF) and an untarped check compared to air temperatures at the Muck Crops Research Station, Ontario, July 9-23, 2019.

Date	TIF		Untarped		Air	
	Max Temp °C[1]	Min Temp °C	Max Temp °C	Min Temp °C	Max Temp °C	Min Temp °C
July 9	34.3	21.3	25.6	21.6	29.0	11.1
July 10	37.5	22.5	25.5	18.6	32.1	9.8
July 11	32.0	25.9	24.4	21.1	29.4	17.1
July 12	29.0	23.8	22.2	19.5	25.6	13.7
July 13	28.8	22.1	23.2	18.0	28.7	13.2
July 14	33.4	22.0	23.9	18.0	26.3	13.7
July 15	34.1	22.3	25.1	17.4	28.7	9.3
July 16	32.1	24.7	24.4	20.3	31.8	18.1
July 17	33.8	25.6	26.3	21.9	29.7	20.2
July 18	36.5	25.5	27.2	21.4	30.4	17.4
July 19	33.6	27.4	25.8	22.5	31.9	21.6
July 20	36.1	27.8	27.9	23.3	34.0	23.4
July 21	36.9	27.1	26.8	22.6	27.9	16.2
July 22	32.9	25.9	25.2	20.5	25.9	14.7
July 23	28.9	24.2	22.6	19.2	26.1	12.1
Average	**37.5**	**21.3**	**27.9**	**17.4**	**29.2**	**15.4**

[1]Average daily soil temperature recorded using a HOBO Pendant temperature data logger buried 5 cm below the soil

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2019 PMR REPORT #20 **SECTION L: VEGETABLES and SPECIAL CROPS - Diseases**

CROP: Parsley (*Petroselinum crispum* (Mill.) Fuss.), cvs. Pinocchio and Gigante d'Italia
PEST: Septoria leaf spot (*Septoria* spp.)

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TITLE: **FIELD EVALUATION OF QUADRIS TOP FOR THE CONTROL OF SEPTORIA LEAF SPOT IN PARSLEY, 2018.**

MATERIALS: QUADRIS TOP (azoxystrobin 200 g/L, difenoconazole 125 g/L), QUADRIS FLOWABLE (azoxystrobin 250 g/L), INSPIRE (difenoconazole, 250 g/L)

METHODS: Two field trials were conducted to assess different fungicides for control of septoria leaf spot on parsley at the Simcoe Research Station (Simcoe, Ontario), in 2018. Parsley cv. Pinocchio was seeded on 10 May 2018 for trial 1 and parsley cv. Gigante d'Italia was seeded on 25 May 2018 for trial 2, into 288 cell black plastic plug trays filled with commercial soil-less mix. Seedlings were raised in a greenhouse and then transplanted by hand into the field (soil organic matter ≈ 1.6%, pH ≈ 6.7) on July 19 for trial 1 and July 30 for trial 2, into beds covered with 1.2 m wide black plastic mulch. Beds were spaced 1.5 m apart, centre to centre. There were three rows per bed spaced 0.20 m apart. Plants were spaced 0.15 m apart in the row. Plots consisted of three rows, 5 m in length with the outside rows of each plot treated as guards to prevent cross contamination between adjacent plots. All data was collected from the inside 3 m of the middle row of each plot. A randomized complete block design with four replicates per treatment was used. Treatments were: QUADRIS TOP (at two different rates: 0.566 and 1 L/ha), QUADRIS FLOWABLE (0.453 L/ha), INSPIRE (0.512 L/ha) and an untreated check. Products were applied using a CO_2 backpack sprayer equipped with three TeeJet XR8003 nozzles spaced 50 cm apart and calibrated to deliver 300 L/ha water at 220 kPa on 1, 12, 19 and 27 September. Septoria leaf spot occurred naturally so inoculation was not needed. Infected leaf samples were sent to the University of Guelph Laboratory Services to confirm fungal identity. Disease incidence and severity were rated on 30 August, 11, 18, 27 September, 4, 11, October, 2018 on sixteen randomly selected plants from the middle row of each plot using a scale of 0 to 10; where: 0= no symptoms; 1= small lesions with less than 1% leaf area infected; 2= 2–5% leaf area; 3= 6–20% leaf area showing multiple lesions; 4= 21–40% leaf area infected; 5= 41–50% leaf area with lesions and 6= 51-60% leaf area, 7 = 61-70% leaf area, 8= 71-80% leaf area showing lesions, 9= entire foliage affected and 10= completely dead. A 3 m section of one of the middle row of each plot was harvested by hand on 17 October and total and marketable yields were recorded, as well as the disease severity and incidence on a sub-sample of 50 stems from each plot. Disease incidence was calculated as the number of plants with septoria leaf spot symptoms/total number of plants assessed*100. Disease severity index (DSI) was calculated using the equation:

$$\text{DSI}= \frac{[(\text{class no.})(\text{no.of plants in each class})]}{(\text{total no.of plants per sample})(\text{no.classes}-1)} \text{ x}100$$

Area Under Disease Progress Curve (AUDPC) was calculated using the equation:

$$\text{AUDPC} = \sum_{j=1}^{nj-1} \left(\frac{yj+yj+1}{2}\right)(t\,j+1-tj)$$

where: *y*= leaf lesion severity at *j*th observation, *t* = time (days) since the previous rating at *j*th observation and *n* = total number of observations.

Compared to the previous 10-year averages, the air temperatures in 2018 were above average for July (22.5°C), August (22.3°C), September (18.5°C) and below average for October (9.6°C). The 10-yr average temperatures were: July 21.8°C, August 20.7°C, September 17.2°C and October 10.7°C. Monthly rainfall was below the 10-year average for July (59 mm) and above average for August (103.8 mm), September (94 mm) and October (118.4 mm). The 10-year rainfall averages were: July 77.3 mm, August 87 mm, September 82.4 mm, and October 98 mm. Data was analyzed using the General Analysis of Variance function of the Linear Models section of Statistix V.9. Means separation was obtained using Tukey's HSD at $P = 0.05$ level of significance.

RESULTS: As outlined in Tables 1, 2 and 3.

CONCLUSIONS: Natural infection occurred, but disease severity remained low throughout the trial period. The pathogen was determined as *Septoria* sp. through molecular analysis. Applications of INSPIRE or QUADRIS TOP reduced disease incidence and severity during the growing season and increased percent marketable at harvest. Increasing the rate of QUADRIS TOP from 0.566 to 1L/ha did not improve efficacy. QUADRIS FLOWABLE provided some suppression but did not consistently reduce disease compared to the untreated check.

Table 1: Effect of fungicides on Disease incidence, disease severity index (DSI) and area under disease progress curve (AUDPC) for septoria leaf spot as reported on selected dates for Parsley, trial 1, grown at the Simcoe Research Station, Ontario, in 2018.

Treatment	Disease Incidence (%)			DSI (0-100)			AUDPC
	27 Sept	4 Oct	11 Oct	27 Sept	4 Oct	11 Oct	
Untreated Check	76.5 a[1]	42.9 ns[2]	64.2 a	24.3 a	11.7ns	17.9 a	66.6 ns
QUADRIS TOP @ 1L/ha	48.4 ab	7.8	10.7 b	10.8 ab	2.5	2.4 bc	32.2
QUADRIS TOP @ 0.566 L/ha	50.0 ab	8.6	7.4 b	8.7 ab	2.6	1.4 c	28.2
QUADRIS FLOWABLE @ 0.453 L/ha	71.8 ab	29.7	36.8 a	18.3 ab	7.7	9.6 ab	47.6
INSPIRE @ 0.512 L/ha	25.0 b	0.9	0.89 b	4.2 b	0.3	0.2 c	12.2

[1] Numbers in a column followed by the same letter are not significantly different (as above).
[2] No significant differences ($P = 0.05$, Tukey's HSD) were found among the treatments.

Table 2: Effect of fungicides on Disease incidence, disease severity index (DSI) and area under disease progress curve (AUDPC) for septoria leaf spot as reported on selected dates for Parsley, trial 2, grown at the Simcoe Research Station, Ontario, in 2018.

Treatment	Disease Incidence (%)			DSI (0-100)			AUDPC
	27 Sept	4 Oct	11 Oct	27 Sept	4 Oct	11 Oct	
Untreated Check	46.2 ns[1]	16.2 a[2]	35.3 a	8.8 ns	3.8 a	6.0 a	18.5 ns
QUADRIS TOP @ 1L/ha	8.1	0.6 bc	0.0 b	1.6	0.08 b	0.0 b	3.8
QUADRIS TOP @0.566 L/ha	4.6	0.0 c	0.0 b	0.9	0.0 b	0.0 b	2.3
QUADRIS FLOWABLE @ 0.453 L/ha	12.3	4.7 ab	4.9 b	3.0	0.9 b	1.1 ab	6.0
INSPIRE @ 0.512 L/ha	4.1	0.0 c	0.0 b	0.6	0.0 b	0.0 b	0.9

[1] No significant differences ($P = 0.05$, Tukey's HSD) were found among the treatments.
[2] Numbers in a column followed by the same letter are not significantly different (as above).

Table 3: Effect of fungicides to control septoria leaf spot on total yield, percent marketable (Mkt %) and percent infected stems and disease severity index (DSI) within each treatment group for parsley trial 1 and trial 2, grown at the Simcoe Research Station, Ontario, in 2018, as assessed on 17 October.

	Trial 1				Trial 2			
Treatment	Total Yield (t/ha)	Mkt (%)	Infected (%)	DSI	Total Yield (t/ha)	Mkt (%)	Infected (%)	DSI
Untreated Check	30.3 ns[1]	77.7 b[2]	19.9 a	6.7 a	42.1 ns	83.6 b[2]	14.8 a	2.8 a
QUADRIS TOP @ 1L/ha	31.9	97.1 a	2.8 bc	0.2 b	36.6	99.9 a	0.2 b	0.0 b
QUADRIS TOP @0.566 L/ha	38.4	97.8 a	2.2 bc	0.2 b	40.1	100 a	0.0 b	0.0 b
QUADRIS FLOWABLE @ 0.453 L/ha	27.5	93.8 ab	6.0 ab	1.4 b	40.5	97.4 a	2.5 b	0.3 b
INSPIRE @ 0.512 L/ha	28.4	99.8 a	0.3 c	0.0 b	36.9	98.9 a	1.2 b	0.0 b

[1] No significant differences ($P = 0.05$, Tukey's HSD) were found among the treatments.
[2] Numbers in a column followed by the same letter are not significantly different (as above).

2019 PMRR # 21 **SECTION O: CEREALS, FORAGE CROPS and OILSEED - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several

PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **EVALUATION OF CANADIAN EASTERN WHITE WINTER (CEWW) AND HARD RED WINTER (CEHRW) WHEAT FOR RESISTANCE TO FUSARIUM HEAD BLIGHT (FHB) IN INOCULATED AND MISTED PLOTS**

METHODS: The winter wheat from the University of Guelph, Ridgetown Campus breeding program and checks were planted in a randomized complete block design, replicated trial on October 20, 2018 at Ridgetown, Ontario. Ten breeding lines and four checks represented the CEWW class, while eleven breeding lines and two checks represented the CEHRW class. Included checks had different levels of resistance to Fusarium head blight (FHB). The plots were planted in three replications at 270 seeds/plot, in single rows, 2 m long and spaced 17.8 cm apart. Each plot was fertilized and maintained using provincial recommendations and spray inoculated with 100 mL of combined suspension of macroconidia (50,000 spores/mL) of four *Fusarium graminearum* isolates per plot. Plots were misted daily beginning after the first plots were inoculated. The overhead mister was set to run from 11:00-16:00 and misted for approximately 60-90 seconds every 8-10 minutes. The mist system was engaged until three days after the last variety was inoculated with *F. graminearum*. FHB symptoms were recorded as incidence (percent of heads infected) and severity (percent of spikelets infected). FHB severity was estimated according to Stack and McMullen (1995). FHB index for each plot was the product of severity and incidence divided by 100. All data were analyzed using ANOVA test (ARM 8 software). Student-Newman-Keuls test was used to detect least significant differences (LSD) among the treatments at $P<0.05$.

RESULTS: The results are given in Table 1.

CONCLUSION: The FHB index ranged from 65.8 % (12W913-59) to 11.2 % (12W924-145). Average FHB index for both market classes was similar (27.7% for CEWW vs. 29.5% for CEHRW). The highest FHB index among the checks was CEWW wheat E0028W, which is rated as a FHB highly susceptible (HS) wheat by Ontario Cereal Crop Committee (OCCC). The most FHB resistant lines will be used in the future crosses.

ACKNOWLEDGEMENT: Funding for this project was provided by OMAFRA/University of Guelph Partnership Research Program (UoG2018-3243), Grain Farmers of Ontario and SeCan.

Table 1. Fusarium head blight severity, incidence and index across winter wheat breeding lines and checks in inoculated and misted plots at Ridgetown, Ontario. 2018-2019.

Name	Market class	FHB severity (%)	FHB incidence (%)	FHB index (%)
12W925-318	CEWW	50.0	63.3	31.7
12W925-328	CEWW	44.3	63.3	28.3
12W925-331	CEWW	49.7	43.3	23.2
12W925-355	CEWW	50.0	70.0	35.0
12W925-335	CEWW	70.3	66.7	46.2
12W925-336	CEWW	60.7	73.3	44.1
12W925-337	CEWW	48.3	50.0	21.1
12W924-144	CEWW	29.0	53.3	16.0
12W924-145	CEWW	21.0	53.3	11.2
12W924-150	CEWW	29.0	56.7	17.1
25W31 (check)	CEWW	29.0	76.7	22.1
Ava (check)	CEWW	44.3	53.3	23.3
Venture (check)	CEWW	29.0	76.7	22.1
E0028W (check)	CEWW	70.3	66.7	47.0
CEWW Mean		**44.6**	**61.9**	**27.7**
12w920-90	CEHRW	33.0	80.0	26.4
12w920-93	CEHRW	25.0	76.7	19.3
12w920-94	CEHRW	33.0	73.3	24.2
12w920-110	CEHRW	78.3	73.3	57.0
12w920-113	CEHRW	38.7	70.0	26.5
12W913-51	CEHRW	29.0	80.0	23.2
12W913-54	CEHRW	33.0	83.3	27.5
12W913-59	CEHRW	79.0	83.3	65.8
12W913-62	CEHRW	44.3	60.0	26.6
12W913-64	CEHRW	38.7	70.0	27.1
12W913-66	CEHRW	55.0	33.3	16.5
Gallus (check)	CEHRW	25.0	80.0	20.0
AC Morley (check)	CEHRW	44.3	50.0	22.7
CEHRW Mean		**42.8**	**70.2**	**29.5**
CV		23.6	17.2	24.5
LSD (P=.05)		17.0	18.4	11.5

2019 PMRR #22 **SECTION O: CEREALS, FORAGE CROPS and OILSEED - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several

PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **EVALUATION OF CANADIAN EASTERN SOFT RED WINTER (CESRW) WHEAT FOR RESISTANCE TO FUSARIUM HEAD BLIGHT (FHB) IN INOCULATED AND MISTED PLOTS**

METHODS: The winter wheat from the University of Guelph, Ridgetown Campus breeding program and checks were planted in a randomized complete block design, replicated trial on October 20, 2018 at Ridgetown, Ontario. Twelve breeding lines from cross 12w931, eight breeding lines from cross 12w933 and seven checks from CESRW class were included. Checks had different levels of resistance to Fusarium head blight (FHB). All checks, except CM 614 and Branson were from our breeding program and registered with CFIA/VRO. The plots were planted in three replications at 270 seeds/plot, in single rows, 2 m long and spaced 17.8 cm apart. Each plot was fertilized and maintained using provincial recommendations and spray inoculated with 100 mL of combined suspension of macroconidia (50,000 spores/mL) of four *Fusarium graminearum* isolates per plot. Plots were misted daily beginning after the first plots were inoculated. The overhead mister was set to run from 11:00-16:00 and misted for approximately 60-90 seconds every 8-10 minutes. The mist system was engaged until three days after the last variety was inoculated with *F. graminearum*. FHB symptoms were recorded as incidence (percent of heads infected) and severity (percent of spikelets infected). FHB severity was estimated according to Stack and McMullen (1995). FHB index for each plot was the product of severity and incidence divided by 100. All data were analyzed using ANOVA test (ARM 8 software). Student-Newman-Keuls test was used to detect differences among the treatments at $P<0.05$.

RESULTS: The results are given in the Table 1.

CONCLUSION: The FHB index ranged from 49.0 % (12w933-1) to 8.9 % (12w931-250). Average FHB severity, incidence and index were 35.7 %, 56.0 % and 20.1 %, respectively. The lowest FHB index among the checks was wheat Marker (10.5%), which is rated as a FHB moderately resistant (MR) wheat by the Ontario Cereal Crop Committee (OCCC). The most FHB resistant lines with good agronomic performance will be used in future crosses.

ACKNOWLEDGEMENT: Funding for this project was provided by OMAFRA/University of Guelph Partnership Research Program (UoG2018-3243), Grain Farmers of Ontario and SeCan.

Table 1. Fusarium head blight severity, incidence and index across winter wheat breeding lines and checks in inoculated and misted plots at Ridgetown, Ontario. 2018-2019.

Name	FHB severity (%)	FHB incidence (%)	FHB index (%)
12w931-216	22.7	50.0	11.1
12w931-226	22.7	46.7	9.4
12w931-232	38.7	53.3	19.9
12w931-238	38.7	73.3	27.6
12w931-241	22.7	43.3	9.4
12w931-242	33.0	56.7	18.7
12w931-248	33.0	70.0	23.1
12w931-250	18.7	50.0	8.9
12w931-251	30.7	60.0	18.4
12w931-254	25.0	73.3	18.6
12w931-258	25.0	40.0	9.6
12w931-259	29.0	46.7	13.8
12w933-1	55.3	73.3	40.9
12w933-2	49.7	63.3	31.5
12w933-4	33.0	56.7	18.7
12w933-5	55.3	63.3	34.9
12w933-11	40.3	46.7	18.5
12w933-18	40.0	56.7	22.2
12w933-19	49.7	43.3	22.1
12w933-20	44.3	50.0	22.7
Marker (check)	21.0	50.0	10.5
Measure (check)	44.3	66.7	28.8
CM 614 (check)	49.7	43.3	20.4
OAC Flight (check)	33.0	53.3	17.6
UGRC GL164 (check)	34.7	46.7	15.7
Branson (check)	34.7	70.0	23.3
UGRC Ring (check)	38.7	66.7	26.0
Mean	**35.7**	**56.0**	**20.1**
LSD (P=.05)	**18.7**	**18.2**	**10.3**
CV	**30.8**	**19.2**	**29.9**

2019 PMRR #23 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS-Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. UGRC Ring, Venture, OAC Flight, Gallus

PEST: Stripe rust (*Puccinia striiformis* f. sp. *tritici* Erikss.)

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TITLE: **THE EFFECT OF FUNGICIDE, CULTIVARS AND SEEDING RATE ON DISEASE LEVEL, YIELD AND QUALITY OF WINTER WHEAT**

MATERIALS: QUILT (azoxystrobin plus propiconazole), STRATEGO (trifloxystrobin plus propiconazole), PROSARO (prothioconazole plus tebuconazole)

METHODS: Experimental plots of four winter wheat cultivars were planted in October 2017 at Ridgetown, Ontario. Treatments were organized as a randomized complete block design in a factorial arrangement across 3 replications. The treatments included three seeding rates (400, 500 and 600 seeds/m^2), four cultivars (UGRC Ring, Venture, OAC Flight, Gallus) and three fungicide regimes consisting of an untreated control, QUILT (750 mL product/ha), STRATEGO (500 mL product/ha) and PROSARO (800 mL product/ha) applied at flag leaf stage (Zadoks Growth Stage, ZGS 39). Each plot was 1.15 m by 4.00 m. Fungicides were applied with a CO_2-pressurized backpack sprayer calibrated to 200 L ha^{-1}. Three flat-fan nozzles spaced 0.50 m apart were used for application. Disease severity was estimated when present by visually rating the plots on a 0-9 scale. Grain was harvested by a small plot combine and reported at 14% moisture content. Test weight was recorded in kg/hL, and thousand kernel weights (TKW) in grams. All data were analyzed using ANOVA test (ARM 8 software). Student-Newman-Keuls test was used to detect differences among the treatments at $P<0.05$.

RESULTS: The results are given in Table 1.

CONCLUSION: Level of stripe rust was low in winter wheat in 2018 and stripe rust ratings across the treatments were not statistically different (Table 1). However, cultivar OAC Flight was the most susceptible to stripe rust. There was a tendency when the seeding rate increased that the stripe rust severity decreased, with the lowest average stripe rust rating recorded at 600 seeds/m^2 (Table 1). Average stripe rust ratings, yields, test weights and thousand kernel weights, across all treatments, were 2.85, 4.85 t/ha, 72.5 kg/hL and 42.0 g, respectively. All fungicides increased the yield compared to the control, but the highest increase was after Prosaro application. The highest yield was of cultivar UGRC Ring (5.41 t/ha) planted at a seeding rate of 600 seeds/m^2 and treated with Stratego, while the lowest yield was of cultivar Gallus (4.19 t/ha) planted at seeding rate of 500 seeds/ m^2 (Table 1). Test weight values across the treatments were not statistically different, but the highest test weight was for cultivar Gallus (74.7 kg/hL) planted at seeding rate of 600 seeds/m^2 and treated with Prosaro. The lowest test weight was of cultivar Venture (70.5 kg/hL) planted at seeding rate of 600 seeds/m^2 and treated with Stratego (Table 1). TKW values across the treatments were statistically different. The lowest TKW was of cultivar Venture (35.0 g) after Prosaro application and planted at 500 seeds/m^2, while the highest TKW was of cultivar Gallus (46.9

g) planted at 400 seeds/m^2. Application of fungicide increased the yield of winter wheat even when stripe rust levels were low.

ACKNOWLEDGEMENT: Funding for this project was provided by OMAFRA/University of Guelph Partnership Research Program (UoG2016-2685) and Bayer Crop Science.

Table 1. Effect of seeding rate (400, 500 and 600 seeds/m^2), cultivar (Venture, OAC Flight, UGRC Ring, Gallus) and fungicide treatment (Quilt, Stratego and Prosaro) on stripe rust rating, yield, test weight and thousand kernel weights of winter wheat. Ridgetown, Ontario, 2018.

Treatment	Stripe Rust (0-9)		Yield (t/ha)		Test Weight (kg/hL)		TKW (g)	
Venture, control, 400 seeds/m^2	2.0	a	4.94	a-j	72.6	a	35.6	f-j
Venture, control, 500 seeds/m^2	2.0	a	4.54	b-j	72.1	a	35.4	hij
Venture, control, 600 seeds/m^2	2.3	a	4.98	a-j	71.9	a	35.1	ij
Venture, Quilt, 400 seeds/m^2	2.3	a	4.74	a-j	72.5	a	36.3	e-j
Venture, Quilt, 500 seeds/m^2	2.0	a	4.82	a-j	73.3	a	36.2	e-j
Venture, Quilt, 600 seeds/m^2	2.3	a	5.17	a-e	72.5	a	35.5	g-j
Venture, Stratego, 400 seeds/m^2	2.7	a	4.70	a-j	72.5	a	36.3	e-j
Venture, Stratego, 500 seeds/m^2	3.0	a	4.92	a-j	71.8	a	35.9	e-j
Venture, Stratego, 600 seeds/m^2	2.3	a	4.95	a-j	70.5	a	36.6	e-j
Venture, Prosaro, 400 seeds/m^2	2.0	a	4.76	a-j	73.1	a	35.7	e-j
Venture, Prosaro, 500 seeds/m^2	2.3	a	5.04	a-h	71.5	a	35.0	j
Venture, Prosaro, 600 seeds/m^2	2.3	a	5.00	a-h	72.5	a	35.1	j
OAC Flight, control, 400 seeds/m^2	3.0	a	4.69	a-j	71.6	a	40.1	c-h
OAC Flight, control, 500 seeds/m^2	2.7	a	4.71	a-j	72.6	a	39.4	c-j
OAC Flight, control, 600 seeds/m^2	2.3	a	5.03	a-h	71.6	a	38.0	d-j
OAC Flight, Quilt, 400 seeds/m^2	2.3	a	5.05	a-h	72.3	a	40.5	c-f
OAC Flight, Quilt, 500 seeds/m^2	2.7	a	5.10	a-f	72.7	a	40.3	c-h
OAC Flight, Quilt, 600 seeds/m^2	2.7	a	5.04	a-h	74.0	a	40.0	c-j
OAC Flight, Stratego, 400 seeds/m^2	3.0	a	4.85	a-j	72.4	a	39.9	c-j
OAC Flight, Stratego, 500 seeds/m^2	2.7	a	5.02	a-h	73.4	a	40.4	c-g
OAC Flight, Stratego, 600 seeds/m^2	2.7	a	4.95	a-j	72.0	a	39.2	c-j
OAC Flight, Prosaro, 400 seeds/m^2	3.0	a	5.22	abc	72.9	a	40.3	c-h
OAC Flight, Prosaro, 500 seeds/m^2	3.0	a	5.07	a-g	72.8	a	38.4	d-j
OAC Flight, Prosaro, 600 seeds/m^2	2.0	a	5.11	a-f	73.2	a	37.5	d-j
UGRC Ring, control, 400 seeds/m^2	2.3	a	5.18	a-d	72.7	a	40.2	c-h
UGRC Ring, control, 500 seeds/m^2	2.7	a	5.04	a-h	70.8	a	40.1	c-i
UGRC Ring, control, 600 seeds/m^2	2.0	a	5.29	ab	72.0	a	39.7	c-j
UGRC Ring, Quilt, 400 seeds/m^2	2.3	a	5.03	a-h	71.5	a	40.4	c-g
UGRC Ring, Quilt, 500 seeds/m^2	2.7	a	5.10	a-f	72.5	a	38.7	c-j

UGRC Ring, Quilt, 600 seeds/m^2	2.3	a	4.92	a-j	73.0	a	42.1	bcd
UGRC Ring, Stratego, 400 seeds/m^2	2.3	a	5.24	abc	72.5	a	40.4	c-g
UGRC Ring, Stratego, 500 seeds/m^2	2.0	a	4.98	a-i	71.5	a	39.8	c-j
UGRC Ring, Stratego, 600 seeds/m^2	2.3	a	5.41	a	72.6	a	39.3	c-j
UGRC Ring, Prosaro, 400 seeds/m^2	2.7	a	5.04	a-h	71.5	a	39.4	c-j
UGRC Ring, Prosaro, 500 seeds/m^2	2.7	a	5.20	abc	72.8	a	40.6	bde
UGRC Ring, Prosaro, 600 seeds/m^2	2.3	a	5.15	a-e	71.1	a	39.9	c-j
Gallus, control, 400 seeds/m^2	3.0	a	4.37	f-j	73.2	a	46.9	a
Gallus, control, 500 seeds/m^2	2.3	a	4.50	c-j	71.4	a	45.4	ab
Gallus, control, 600 seeds/m^2	2.3	a	4.58	b-j	74.4	a	43.6	abc
Gallus, Quilt, 400 seeds/m^2	3.0	a	4.21	ij	74.3	a	45.8	ab
Gallus, Quilt, 500 seeds/m^2	3.0	a	4.19	j	72.1	a	44.8	ab
Gallus, Quilt, 600 seeds/m^2	2.7	a	4.72	a-j	73.8	a	45.5	ab
Gallus, Stratego, 400 seeds/m^2	2.7	a	4.27	hij	72.6	a	45.8	ab
Gallus, Stratego, 500 seeds/m^2	3.0	a	4.41	d-j	72.7	a	44.8	ab
Gallus, Stratego, 600 seeds/m^2	2.3	a	4.40	e-j	73.8	a	45.9	ab
Gallus, Prosaro, 400 seeds/m^2	2.7	a	4.36	f-j	74.0	a	46.1	ab
Gallus, Prosaro, 500 seeds/m^2	2.3	a	4.31	g-j	72.5	a	45.6	ab
Gallus, Prosaro, 600 seeds/m^2	2.0	a	4.54	b-j	74.7	a	45.9	ab
Mean	2.5		4.85		72.5		40.2	

Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)