2015 Pest Management Research Report (PMRR) 2015 Growing Season

2015 Rapport de recherches sur la lutte dirigée (RRLD) pour la saison 2015

Canada

English

2015 PEST MANAGEMENT RESEARCH REPORT

Prepared by: Pest Management Centre, Agriculture and Agri-Food Canada
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[1] This is the 16th 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 27 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 2016 Annual PMR Report will be sent in fall, 2016. They will also be available from Allison Plunkett.

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 2015 has been assigned a Volume number for the 16th 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 Volume 54.

An individual report will be cited as follows:
Author(s). 2015. Title. 2015 Pest Management Research Report - 2015 Growing Season. Agriculture and AgriFood Canada. April 2016. Report No. x. Vol. 54: pp-pp.

Français

Rapport de recherches sur la lutte dirigée - 2015

Préparé par: Centre de la lutte antiparasitaire, Agriculture et Agroalimentaire Canada
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Titre officiel du document
2015 Rapport de recherches sur la lutte dirigée - pour la saison 2015. Compilé par Agriculture et Agroalimentaire Canada, 960 avenue Carling, Ed. 57, Ottawa ON K1A 0C6, Canada
Avril 2016 volume 54. 64 pp. 27 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 27 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 2016 seront distribuées à l'automne 2016. Elles seront aussi disponibles via Allison Plunkett.

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.

Modèle de référence:
Nom de l'auteur ou des auteurs. 2015. Titre. 2015 Rapport de recherche sur la lutte dirigée. Agriculture et Agroalimentaire Canada. Avril, 2016. Rapport n^{o} x. vol. 54: pp-pp.

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PEST: Carrot rust fly, *Psila rosae* (Fabricius), Carrot weevil, *Listronotus oregonensis* (LeConte)

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Tel: (519) 824-4120 ext. 52477 **Fax:** (519) 837-0442 **Email:** cscottdu@uoguelph.ca

TITLE: **EVALUATION OF AN EXISTING INTEGRATED PEST MANAGEMENT PROGRAM FOR CARROT RUST FLY AND CARROT WEEVIL ON CARROTS, 2015**

MATERIALS: RIPCORD 400 EC (cypermethrin 407 g/L), IMIDAN 70 WP (phosmet 70%)

METHODS: The trial was conducted near the Holland Marsh, Ontario, in organic soil (pH ≈ 6.8, organic matter ≈ 64.8) in 2015. Carrots, cv. Enterprise, were direct seeded (70 seeds/m) onto raised beds using a precision seeder custom built at the Muck Crops Research Station on 21 May. To determine the effectiveness of an existing IPM program for carrot weevil (CW) and carrot rust fly (CRF), treatments consisted of either the CW and CRF IPM program recommended thresholds for insecticide applications (RIPCORD applied at 0.1 CRF/trap/day and IMIDAN applied when 1.5 and 5 cumulative CW/trap/day) or a control which received no insecticide applications. Each plot consisted of a 14 x 25 m block and treatments were planted in a linear pattern, alternating between each treatment, with three replicates per treatment. Soybean (*Glycine max* L.) was planted in the outermost and center plots in 14 x 25 m blocks. Anecdotal evidence suggested soybean could increase the presence of CRF. On 19 June, 4 and 25 August, RIPCORD was applied at 175 mL/ha using a tractor mounted sprayer fitted with TeeJet Air Induction Even Flat spray tips (AI9503 EVS) at 415 kPa calibrated to deliver 500 L/ha. IMIDAN was applied at 1.6 kg/ha on the 19 June using the same application equipment. On 14 October, carrots in three random 1.5 m row sections from each plot were harvested to assess CW and CRF damage. On 15-17 October, samples were washed in a small drum washer, visually examined for CW and CRF damage, and numbers and weights of damaged and marketable carrots recorded. For CRF damage analysis, carrots with CW damage were removed and not considered to be either damaged or marketable. Similarly for CW damage analysis, carrots with CRF damage were removed and not considered to be either damaged or marketable. Data were analyzed using the Mixed Procedure in SAS 9.4 University Edition (SAS Institute, Cary, NC).

RESULTS: Results can be found in table 1.

CONCLUSIONS: Overall, CW and CRF pressure was low in 2015. No significant differences in CRF damage were found when insecticides were applied following the IPM program recommendations compared to no insecticide applications. Low CRF damage in the control plot suggests the soybean planting did not act as a CRF refuge and/or reservoir. IMIDAN did not significantly reduce CW damage in this trial. IMIDAN has been the primary insecticide for CW control in Canada for over thirty years and there is growing concern that the CW population in the Holland Marsh region may be developing phosmet resistance; however, this trial had limited replication and further field and laboratory trials are needed to determine the susceptibility of CW populations to phosmet.

ACKNOWLEDGEMENTS: Funding for this project was provided by OMAFRA, Bradford Co-op Storage Ltd., Fresh Vegetable Growers of Ontario, Engage Agro, and E.I. DuPont Canada Co. We would like to thank the staff at the Muck Crops Research Station for their invaluable technical advice and assistance maintaining these research plots.

Table 1: Evaluation of carrot rust fly and carrot weevil damage on carrots, cv. Enterprise, when insecticides are applied following an existing IPM program c, Holland Marsh, Ontario, 2015.

Program	Insecticides	Rates	Rust fly damage (%)[1]	Carrot weevil damage (%)[1]	Mktb yield (t/ha)
IPM recommendations	Imidan 70 WP Ripcord 400 EC	1.6 kg/ha 175 ml/ha	2.3 ns[2]	3.2 ns	70.7 ns
Control	--	--	0.34	5.6	66.3

[1]Percentage of the number of marketable carrots
[2] ns = no significant differences ($p \geq 0.05$)

2015 PMR REPORT # 02 **SECTION B: VEGETABLES and SPECIAL CROPS - Insect Pests**

CROP: Carrot (*Daucus carota* subsp. *sativus* (Hoffm.) Arcang), cv. Belgrado
PEST: Carrot rust fly, *Psila rosae* (Fabricius), Carrot weevil, *Listronotus oregonensis* (LeConte)

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TITLE: EVALUATION OF PARASITIC NEMATODES FOR CONTROL OF DAMAGE BY CARROT WEEVIL IN CARROTS, 2015

MATERIALS: MATADOR 120 EC (120 g/L), NEMASYS (*Steinernema feltiae*)

METHODS: The trial was conducted in the Holland Marsh, Ontario, in organic soil (pH ≈ 5.7, organic matter ≈ 72.3%). Carrots, cv. Belgrado, were direct seeded (70 seeds/m) onto raised beds using a custom built precision seeder at the Muck Crops Research Station on 18 June 2015. Each experimental unit consisted of three rows, 10 m in length, 66 cm apart. A randomized complete block design with four replicates per treatment was used. The three treatments were: NEMASYS at 750,000 individuals/m applied in-furrow at seeding, NEMASYS at 750,000 individuals/m applied in-furrow at seeding followed by NEMASYS at 750,000 individuals/m applied as a drench to the base of the plant on 6 August and MATADOR at 83 mL/ha applied as a foliar spray on 6 August. An untreated check was also included. The in-furrow treatments were applied at 14.0 mL/m using 9.32 litres of nematodes in suspension. The suspension was applied over the seed. The NEMASYS base of the plant drench was applied using a CO_2 backpack spray equipped with a single 8004 VK fan nozzle delivered at the rate of 30 mL/m. The MATADOR foliar spray was applied at a spray volume of 400 L/ha using a CO_2 back pack sprayer equipped with a single TeeJet 8004 fan nozzle. On 20 October, carrots in two 1.5 m sections from two rows were pulled for a harvest damage assessment. On 2 November samples were washed in a small drum washer, visually examined for carrot rust fly and weevil damage and numbers and weights of damaged and marketable carrots recorded. 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 $P \geq 0.05$ level of significance.

RESULTS: As presented in table 1

CONCLUSIONS: Carrots were seeded later in the season than is average in the Holland Marsh (18 June). Carrots treated in-furrow with NEMASYS at seeding followed by NEMASYS applied at the base of the carrots application on 6 August had significantly less weevil damage than untreated carrots and did not differ from carrots treated with MATADOR as a foliar spray (6 August)(Table 1).Both the MATADOR and the NEMASYS applications on 6 August were applied long after 90% oviposition of weevils (14 June) was predicted. Since the NEMASYS applied on 6 August provided effective control, this may suggests that the weevils are be depositing eggs past the current degree day model which reached threshold in 2015 on 16 June. This may suggest that the oviposition period has been extended in the Holland Marsh population of weevils. Rust fly damage was low and no significant differences were found among the treatments. No significant difference in yield was found among the treatments (Table 1). Two treatments, NEMASYS applied in-furrow at seeding with a 2nd application applied on 6 August and MATADOR applied on 6 August reduced weevil damage to carrots seeded on 18 June.

ACKNOWLEDGMENTS: Funding for this project was provided by BASF Canada Inc.

Table 1. Carrot weevil and rust fly damage in carrots, cv. Belgrado, treated with in-furrow and base of plant applications of parasitic nematodes (*Steinernema feltiae)*, Holland Marsh, Ontario, 2015.

Treatment	# App'ns	% Marketable[2]	Rust Fly Damage (%)[2]	Weevil Damage (%)[2]	Mkb Yield (t/ha)
NEMASYS[1]	2	93.8 a[3]	1.7 ns[4]	5.1 a	93.8 ns
NEMASYS[1]	1	90.3 a	2.0	9.0 ab	87.4
MATADOR	1	92.0 a	1.8	7.1 a	84.6
Check	--	84.2 b	1.6	17.2 b	78.9

[1] 1st application was in-furrow at seeding 18 Jun & 2nd application (if used) was applied to base of plant on 6 Aug.
[2] Percentage is based on numbers of carrots.
[3] Numbers in a column followed by the same letter are not significantly different at $P \geq 0.05$ Fisher's Protected LSD Test.
[5] ns = not significantly different.

2015 PMR REPORT # 03 **SECTION B: VEGETABLES and SPECIAL CROPS - Insect Pests**

CROP: Carrots (*Daucus carota* subsp. *sativus* (Hoffm.) Arcang), cv. Bolero
PEST: Carrot Weevil, *Listronotus oregonensis* (LeConte), Carrot Rust Fly, *Psila rosae* (Fab.)

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Tel: (519) 824-4120 ext. 52791 **Fax:** (519) 763-8933 **Email:** mrmcdona@uoguelph.ca

TITLE: **FIELD EVALUATION OF SEED TREATMENT INSECTICIDES FOR CONTROL OF CARROT WEEVIL AND CARROT RUST FLY IN CARROT, 2015**

MATERIALS: SEPRESTO 75 WS (clothianidin 56.25% + imidacloprid 18.75%), SIVANTO PRIME FS480 (flupyradifurone 480 g/L), TRIGARD (cyromazine 75%), HGW86 (cyantraniliprole 50%), IMIDAN 70 WP (phosmet 70%), RIPCORD (cypermethrin 407 g/L), SIVANTO PRIME SL 200 (flupyradifurone 17.09%)

METHODS: Carrots (cv. Bolero) were direct seeded (70 seed/m) onto raised beds using a push cone seeder on 28 May 2015 at the Muck Crops Research Station, Holland Marsh, ON (soil: pH ≈ 6.8, organic matter ≈ 64.8%). A randomized complete block arrangement with four replications per treatment was used. Each plot consisted of two rows, 66 cm apart and 6 m in length. Seed treatments (applied as seed film coatings with 4.51 g AI/100 g seed) consisted of: SEPRESTRO 75 WS, SIVANTO PRIME FS480, TRIGARD, and HGW86. Three foliar treatments consisted of IMIDAN 70 WP (1.6 kg / ha), RIPCORD (175 ml / ha) and SIVANTO PRIME SL 200 (1.0 L/ha), and an untreated control. IMIDAN and RIPCORD served as industry standards for carrot weevil (CW) and carrot rust fly (CRF) control, respectively. All seed treatments were treated with THIRAM 42S (0.21 g AI/100 g seed) for fungal disease control. The three foliar treatments were applied using a CO_2 backpack sprayer equipped with 4 TeeJet 8004 fan nozzles calibrated to deliver 500 L / ha at 240 kPa. They were applied on 21 June 2015, and RIPCORD and SIVANTO PRIME SL 200 were applied again on 4 and 27 August 2015 for CRF control. On 13 August and 14 October 2015, two random 1.5 m row sections were harvested from each plot to assess CW and CRF damage. Between 19-21 August and 15-16 October 2015, carrot samples were washed in a small drum washer and visually inspected for CW and CRF damage, recording the number and weight of CW damaged, CRF damaged, and undamaged (marketable) carrots. For CRF damage analysis, carrots with CW damage were removed and not considered to be either damaged or marketable. Similarly for CW damage analysis, carrots with CRF damage were removed and not considered to be either damaged or marketable. Data were analysed using a repeated measures ANOVA in Proc Mixed using SAS 9.4 University Edition (SAS Institute, Cary, NC) to determine the impact of treatments on CW damage, CRF damage, and yield. For CW, both harvest dates were assessed in the same analysis and Dunnett's Test was performed for mean separation.

RESULTS: Results can be found in Table 1.

CONCLUSIONS: Overall, CW damage was extremely high while CRF damage was low for all treatments. No seed or foliar treatment provided significant CRF control. HGW86 was the only treatment

to reduce CW damage compared to the control, and only when all treatment dates were combined, but damage still reached 36.7%. Across all plots, CW damage significantly increased by 9.18 ± 1.89 % at the second harvest which is surprising as Canadian populations of CW have been historically univoltine. Since the CW oviposition period, modelled using degree days, was completed in mid-June, the August harvest should have captured all CW damage caused by the progeny of the overwintered adult CW. This increase in damage suggests that emergent adult CW may now be ovipositing in the same field season they developed prior to overwintering or the overwintered adult CW may no longer be following the established degree day model in the Holland Marsh region of Ontario.

ACKNOWLEDGEMENTS: The authors thank Dr. Al Taylor (Cornell University) for applying seed film coatings and staff at the University of Guelph – Muck Crop Research station for technical advice and assistance. Funding for this project comes from the OMAFRA-University of Guelph Research Program, Bradford Co-Op Storage, Ltd., Engage Agro, E.I. DuPont Canada Co., and Fresh Vegetable Growers of Ontario.

Table 1. Average carrot weevil (CW) and carrot rust fly (CRF) damage and yield in a seed and foliar treatment carrot trial at the University of Guelph-Muck Crops Research Station, Holland Marsh, ON, 2015.

Treatment	Application Method	CW Damage (%)[1,2]			CRF Damage (%)[1]	Yield (t/ha)[1]
		Aug. 13	Oct. 15	Dates Combined		
Control		41.6 ns	55.7 ns	48.6	1.51 ns	31.5 ns
Sepresto 75S	ST[3]	46.0	46.3	46.2	0.96	37.7
Trigard	ST	44.9	46.9	44.9	0.86	40.8
HGW86	ST	33.5	40.0	36.7*	1.66	42.1
Sivanto Prime FS480	ST	47.2	54.7	51.0	1.73	24.9
Imidan 70 WP	F[4]	42.2	57.5	49.9	1.20	32.5
Ripcord	F	43.4	57.9	50.7	0.00	29.5
Sivanto Prime SL 200	F	48.1	59.1	53.6	0.42	31.6

[1]Data from both harvests were assessed together.
[2]Percent damaged is based on carrot number.
[3] ST = seed treatment
[4] F = foliar treatment
ns indicates all numbers in the column are not significantly different compared to the control at p = 0.05 according to Dunnett's Test.
* indicates a significant difference compared to the control at p = 0.05 according to Dunnett's Test.

2015 PMR REPORT # 04 **SECTION F: ORNAMENTALS AND GREENHOUSE - Insect Pests**

CROP: Sweet pepper (*Capsicum annuum* L.), cucumber (*Cucumis sativus* L.), eggplant (*Solanum melongena* L.)
PEST: Two spotted spider mite, *Tetranychus urticae* (Koch) (Acari: Tetranychidae)

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TITLE: **ACARICIDE SUSCEPTIBILITY IN ONTARIO AND B.C. POPULATIONS OF TWO SPOTTED SPIDER MITE *TETRANYCHUS URTICAE***

MATERIALS: AGRI-MEK SC (Abamectin), NEXTER (Pyridaben), ACRAMITE 50 WS (Bifenazate), VYDATE (Oxamyl), KANEMITE 15 SC (Acequinocyl), CARZOL SP (Formetanate HCl), OBERON 4 SC (Spiromesifen) and ENVIDOR 240 SC (Spirodiclofen) were provided by the respective chemical companies.

METHODS: Populations of two spotted spider mites (TSSM) *Tetranychus urticae* were collected in 2011, 2012 and 2013 from Bleneim, Harrow and Leamington Ontario research and commercial production greenhouses (GH1, GH2, GH3, GH5 and GH6). TSSM were collected from cucumber, eggplant and pepper plants. In 2012, a population was also collected from a greenhouse in Agassiz B.C. (GH4). The TSSM strains were maintained afterward at AAFC London on young bean (*Phaseolus vulgaris* L.) plants and held in an insectarium at 25±2 ^{o}C, 50±5 RH% and a photoperiod of 16:8 h (L:D). An acaricide-susceptible laboratory strain has been cultured at AAFC for many years and has had no exposure to pesticides within the past 10 years. The lab strain has previously been determined not to be susceptible to mitochondrial complex election transport inhibitor (METIs) acaricides, for example pyridaben and acequinocyl, or carbamate acaricides, for example oxamyl and formetanate HCl.
All acaricides were prepared in RO water at stock concentrations of 1000 ppm (or 5000 ppm for VYDATE). Working solutions were prepared in a range of 5 to 6 concentrations and stored for 2 weeks at 4°C.
Acaracide toxicity bioassays were conducted with single adult females using the leaf disc method. *P. vulgaris* leaf discs (40 mm dia) had been placed ad axial surface down on 5 ml of 0.7% solidifying agar medium (pH 5.8) in 50 mm Gelman plates. Leaf discs were dipped in solutions of each formulated chemical for 10 s, and dried on a wire mesh for 20 min or until dry. Ten adult TSSM were transferred on to each leaf disc with a fine paint brush, with the exception of trials using spirodiclofen, formetanate HCl and spiromesifen, which used 10 TSSM larvae and nymphs per disc.
At least 3 separate series of bioassays were run with the laboratory strain at each of 5-6 concentrations for each acaricide giving a minimum of 120 TSSM (3 bioassays x 4 replicates/bioassay x 10 adults/nymphs/replicate) for each concentration tested. Tested concentrations were selected based on preliminary trials to provide a range of 0%-100% mortality. Probit analysis (SAS Institute, 2008) of the data generated was then completed to develop regression lines and determine the LC_{50}, LC_{90} and fiducial limits (FL) for the lab strain.
For each greenhouse-collected population and each acaricide, a minimum of at least 3-4 replicates of 10 TSSM was exposed to the LC_{90}, a discriminating concentration (DC), on 3 separate days. Those

populations where average mortality at the DC fell below 30% were selected for LC_{50} and LC_{90} determination as described previously.
The resistance ratio (RR) was determined for populations tested with acaricides to which the lab strain is still considered susceptible (excludes the METIs and carbamates). The RR is calculated as the LC_{50} GH strain/LC_{50} lab strain.

RESULTS: As outlined in Tables 1 and 2.

CONCLUSIONS: *T. urticae* populations collected from Ontario and B.C. greenhouses and tested with the 8 acaricides showed a wide range of susceptibility (Table 1). In general, the populations collected from one research greenhouse (GH1), where minimal or no chemical treatments were used, indicated no resistance. In contrast, the populations collected from commercial vegetable production greenhouses following more conventional chemical control practices were determined to have higher levels of resistance to a greater number of the acaricides tested. For example, TSSM from GH2 had recently been exposed to several acaricides, and there was a > 600-fold RR to bifenazate, and >100-fold RR for abamectin for the LC_{90} compared to the laboratory strain. Based on the criteria that resistance can be defined as a response to the DC (LC_{90}) where less than 30% mortality is determined, GH3 was resistant to 4 of the 6 acaricides tested. Unfortunately LC_{50} and LC_{90} values for abamectin, acequinocyl, oxamyl and pyridaben could not be calculated as this strain was lost due to contamination of the colony by predatory mites. Tests with a TSSM collection from an Agassiz BC greenhouse (GH4) detected resistance to 3 of 8, including formetanate HCl, spirodiclofen and spiromesifen. The RR for spirodiclofen was determined to be >50 at the LC_{50} and >100 at the LC_{90} relative to the lab strain (Table 2). Of the two remaining populations, GH5 was more susceptible to the acaricides tested. Only resistance to pyridaben was observed using the discriminating concentration (LC_{90}) (Table 1) and the RR was determined to be >10 at the LC_{50} and >30 at the LC_{90}. In contrast, GH6 was determined to be resistant to acequinocyl, pyridaben, formetanate HCl and spiromesifen (Table 1). A minimum of 20000 ppm was estimated for the pyridaben LC_{50}, indicating a RR of >100, while the RRs for acequinocyl, formetanate HCl and spiromesifen in GH6 TSSM were between 10 and 40.
Acaricide-resistance and cross-resistance is a growing concern for Canadian greenhouse vegetable growers. For many years growers have relied heavily on foliar treatments of chemical acaricides and it appears that this reliance has led to resistance in an increasing number of *T. urticae* populations. These findings indicate that caution should be taken by growers in selecting acaricides and a resistance management plan implemented.

ACKNOWLEDGEMENTS: We greatly appreciate acaricide samples provided by Arysta, Bayer, DuPont, Gowan and Syngenta. Technical assistance from R. Muth and Y. James Duran is gratefully acknowledged.

Table 1. Mean percent mortality of six *T. urticae* greenhouse populations collected from Ontario and B.C. greenhouses between 2011 and 2013 exposed to a discriminating concentrations (DC) or lab strain LC_{90} values for 8 registered acaricides.

Acaricide (a.i.)	Lab strain LC_{90} (FL)	Slope	Mean percent mortality at LC_{90} for each acaricide					
			GH 1	GH 2	GH 3	GH 4	GH 5	GH 6
ACRAMITE (Bifenazate)	12 ppm (8.1, 22)	1.6	80.0	0	93	100	67.1	64.6
AGRI-MEK (Abamectin)	4.4 ppm (2.6, 10.7)	1.2	95.0	40.0	24.0	46.4	64.5	96.3
CARZOL (Formetanate HCl)	23.5 ppm (17.3, 39.4)	2.1	ND	ND	ND	57.4	50.9	27.5
ENVIDOR (Spirodiclofen)	394 ppm (177, 1533)	1.1	75.0	34.0	51.4	3.3	64.9	65.7
KANEMITE (Acequinocyl)	53.5 ppm (41, 78.8)	2.5	100	43.3	22.6	100	91.8	28.1
NEXTER (Pyridaben)	820 ppm (605, 1268)	1.9	65.0	80.0	26.7	82.6	24.5	7.1
OBERON (Spiromesifen)	274 ppm (31.1, 12315)	0.3	ND	ND	ND	48.5	69.4	27.5
VYDATE (Oxamyl)	4640 ppm (2690, 12240)	1.5	100	100	24	82.3	100	100

Table 2. The acaricide LC_{50} and LC_{90} values (± FL) and resistance ratios determined for the lab *T. urticae* strain and two greenhouse strains collected from one Ontario and one B.C. greenhouse.

Acaricide (a.i.)	Lab strain LC_{50} / LC_{90} (FL)	Slope	GH4 strain LC_{50} / LC_{90} (FL)	RR LC_{50} / RR LC_{90}	GH6 strain LC_{50} / LC_{90} (FL)	RR LC_{50} / RR LC_{90}
ENVIDOR (Spirodiclofen)	24.7 ppm (16.2, 40.9) / 394 ppm (177, 1533)	1.1	1396 ppm[1] (788, 5244) / 421062 ppm (NA)	56.5 / 1069	ND	
OBERON (Spiromesifen)	0.35 ppm (0.13, 1.5) / 274 ppm (31.1, 12315)	0.3	ND		8.2 ppm[2] (<0.1, 32.5)/ 1102 ppm (N.A.)	23.4 / 4

[1] slope = 0.5 for GH4 strain with spirodiclofen; [2] slope = 0.4 for GH6 strain with spiromesifen; ND = not determined; NA = not available.

2015 PMR REPORT # 05 **SECTION H: PEST MANAGEMENT METHODS - Biological Control**

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

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TITLE: PARASITISM AND LIFE HISTORY OF *APHIDIUS AVENAPHIS* (HYMENOPTERA: BRACONIDAE) ON TWO CEREAL APHID SPECIES IN SASKATCHEWAN (2015)

METHODS: A survey to identify and track populations of cereal aphid species and their natural enemies in cereal crops on the prairies to develop a dynamic action threshold (DAT) equation was undertaken in 2012 and 2013 (Wist et al. 2013, 2015) funded by the Pesticide Risk Reduction Program (PRRP). A new project to refine this DAT and create a smartphone app again funded by the PRRP began in 2015. The life history and in particular, the voracity (number of aphids killed per day, or, in the case of a parasitoid, number of aphid mummies created per day) of the dominant *Aphidius* parasitoid species on cereal aphids had not been studied previously. The cereal aphid DAT equation was currently using a proxy voracity from the closely related *A. colemani* on cotton aphid (van Steenis 1993). It was important to study the life history parameters and determine the voracity of *A. avenaphis* on the two main cereal aphid species on the Canadian Prairies.

Parasitoids were collected and reared from 250-300 aphid mummies from each of five wheat and barley fields in Saskatchewan (n=5 fields total). Species determination of *Aphidius* parasitoids was only possible post-mortem and could only occur with the use of a powerful stereomicroscope (Nikon SMZ25) to examine the "petiole" of the wasps (metasomal-tergite 1) for species-specific striations (Fig. 1). Ten female wasps that emerged from field collected aphid mummies were caged individually for 24 h with two males each of the same species and fed 10% honey water. Post-mortem identification confirmed that all experimental individuals were *Aphidius avenaphis* (Hymenoptera: Braconidae). One hundred English grain aphids (EGA), *Sitobion avenae*, and 100 Bird cherry-Oat aphids (BCO), *Rhopalosiphum padi*, were offered each day on a pot of barley seedlings to each female (n=5 reps with EGA/day, n= 5 reps OBC/day) and a new group of 100 aphids of the same species was offered daily until the female *A. avenaphis* died. In OBC replicates, the experiment was stopped after two attack days due to shortage of BCO (1000 aphids offered total).

RESULTS: Preliminary counts and identifications of the first set of field collected mummies revealed that nearly all were EGA and most of the mummification was of the brown *Aphidius* type (Pike 1997). The first mummies were noted on 11-Aug 2015 which places the first attacks by *Aphidius* (Hymenoptera: Braconidae) parasitoids eight days prior on August 2 or 3, 2015 (see parasitism results below). Of the primary parasitoids that emerged from this sample, *Aphidius avenaphis* was the dominant parasitoid

(88%), with several *A. ervi* and one *Diaeretiella rapae* (Hymenoptera: Braconidae) as the remaining 12%. The percentage of hyper-parasitism (by *Asaphes, Dendrocerus* and *Alloxysta* spp.) was 13.4%. The sex ratio of female to male *Aphidius avenaphis* was 1.5:1 (i.e. 60% of wasps that emerge are female). This figure is important to the DAT equation because when using the number of mummies counted as a proxy we now know that the number of mummies must be multiplied by 0.6 to give an accurate account of the number of females that will emerge.

Aphidius avenaphis females that emerged from field collected-mummies were capable of mating and reattacking cereal aphids within one day following emergence from mummies. They can live for up to six days while actively attacking aphids but four days was more common. This finding is important to the cereal aphid DAT equation because it proves that females that emerge from mummies counted in the field can continue to attack aphids in the same field. Newly emerged *A. avenaphis* females have an average daily voracity of 30.6 ± 22 SE aphids per day on EGA with an average of 130 ± 22 SE aphids over their adult life (n=5). These daily voracities are approximately half of the number of aphids attacked by *A. colemani* on cotton aphids (van Steenis 1993). However, the methods of van Steenis (1993) were different. This result allows for the DAT to be refined using the voracity of a common *Aphidius* species on a cereal aphid. *Aphidius avenaphis* females however, rarely attacked the BCO aphids (2 mummies in 1000 aphids) (n=5 replicates), even though the experimental setup gave them no choice of aphids.
The development time at 20°C for *A. avenaphis* from attack (egg) to mummification of the aphid is ~8 days and the emergence of adult wasps is ~15 days from the initial oviposition into the aphid.

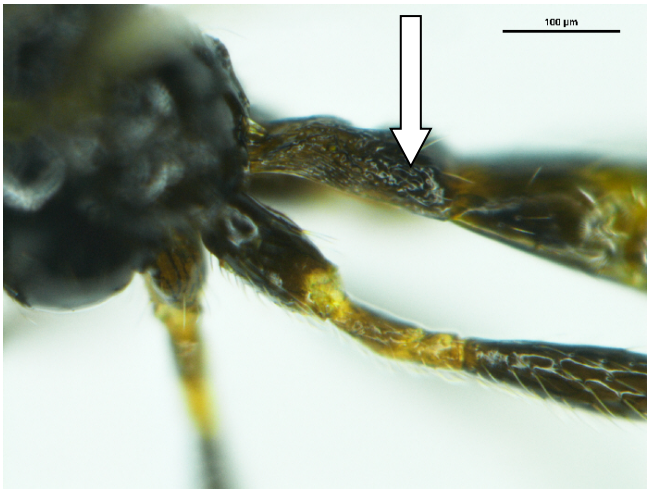

Fig. 1 Lateral profile of metasomal tergum one ("petiole") of a female *Aphidius avenaphis* (Hymenoptera: Braconidae) parasitoid wasp. Note the many thin striations (arrow) that give the petiole a " costulate" appearance (Pike et al. 1997).

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2015 PMR REPORT # 06 **SECTION J: NEMATODES**

CROP: Carrot (*Daucus carota* subsp. *sativus* (Hoffm.) Arcang.) cv. Cellobunch
PEST: Carrot cyst nematode (*Heterodera carotae* Jones, 1950), pin nematode (*Paratylenchus* spp. Micoletzky, 1922), root lesion nematode (*Pratylenchus penetrans* Cobb, 1917), and root-knot nematode (*Meloidogyne hapla* Chitwood, 1949)

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TITLE: FIELD EVALUATION OF FUMIGANTS AND NEMATICIDES FOR NEMATODE CONTROL ON MUCK SOIL IN ONTARIO, 2015

MATERIALS: PIC PLUS (chloropicrin 86%), NIMITZ (fluensulfone 480 g/L)

METHODS: The trial was conducted on muck soil with a history of nematode damage to carrots near Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block design with six replicates was used. The treatments were: PIC PLUS at 78 kg/ha, NIMITZ at 8.3 L/ha, PIC PLUS at 78kg/ha + NIMITZ at 8.3 L/ha, and an untreated check. On 23 May, NIMITZ (8.3 L/ha in 400 L/ha water) was applied using a 2 m wide custom fumigator 15 cm below the soil surface with fourteen John blue fumigant shanks spaced 17cm apart, and four Teejet 8008 flat fan nozzles mounted on the front of the fumigator to apply NIMITZ to the soil surface. The soil was immediately sealed following application with a roller attached to the unit. PIC PLUS was applied at seeding at the rate of 78 kg/ha using a custom-built carrot seeder equipped with shanks to inject the product 25 cm below the seeds. Carrots, cv. Cellobunch (~65 seeds/m) were direct seeded on 29 May on raised beds. Each experimental unit consisted of three rows, 66 cm apart and 75 m long. Carrots were managed as part of a commercial carrot field for the entire growing season. Soil samples were taken on 22 May (pre-plant), 2 July (mid-season), and 2 November (harvest) to determine soil nematode counts. Ten soil cores were from each plot using a 25 cm long soil sampler. Samples were sent for analysis to University of Guelph Agriculture and Food Laboratory which uses the Pan Method (a modified Baermann method) for nematode extraction. On 27 October carrots in two 1.5 m sections of row were pulled and topped by hand and put into cold storage. On 5 November, carrots were assessed for forking, stunting and nematode damage and sorted into the following classes; 0= no galling or forking, 1= 1-10 galls on secondary roots, 2= 10-50 galls with light forking, 3= 50-100 galls with forking, 4= >100 galls with severe forking, 5= >100 galls with severe forking and severe stunting. Disease severity index (DSI) was calculated using the following formula:

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

Compared to the previous 10 year averages, air temperatures in 2015 were above average for May (15.9°C) and September (18.9°C), below average for June (17.7°C), and average for July (20.5°C), August (19.5°C) and October (9.3°C). The 10 year average temperatures were: May 13.4°C, June 18.9°C, July 20.9°C, August 19.6°C, September 15.5°C and October 9.5°C. Monthly rainfall was below the 10 year average for May (40 mm), July (36 mm), September (27 mm) and October (54 mm), above average for June (171 mm), and average for August (79 mm). The 10 year rainfall averages were: May 66 mm, June 75 mm, July 94 mm, August 69 mm, September 85 mm and October 72 mm. Data were analyzed using Statistix V.10.using Tukey's HSD test at P = 0.05 level of significance.

RESULTS: Carrots grown in soil treated with PIC PLUS had higher yields, lower DSI and a lower average gall rating than the untreated check (Table 1). No significant differences in percent marketable carrots were found among the treatments (Table 1). No differences in cyst nematode, lesion nematode, pin nematode, or root knot nematode soil counts at pre-plant, mid-season, or harvest were found among the treatments. Similarly, there were no differences in total plant parasitic nematode soil counts among treatments at any assessment time (Table 2).

CONCLUSIONS: PIC PLUS increased carrot yield while reducing disease severity and average gall rating. Although PIC PLUS, PIC PLUS + NIMITZ and NIMITZ were not significantly different from each other in terms of yield, DSI or average gall rating, PIC PLUS + NIMITZ and NIMITZ did not differ significantly from the untreated check. There was a negative correlation between DSI and yield ($r= -0.58$, $p= 0.003$). DSI and average gall ratings were positively correlated ($r= 0.77$, $p= 0.000$). There were no correlations between nematode soil counts at any sampling date and damage. There was a negative correlation between yield and total nematode count at the mid-season sampling date ($r= -0.44$, $p= 0.032$). This coincides with the timing of carrot taproot establishment, which indicates that higher nematode counts five weeks after seeding can cause a decrease in yield at harvest.

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Table 1. Yield, percent healthy carrots, disease severity index, and average gall rating for carrots (cv. Cellobunch) treated with fumigants and non-fumigant nematicides and grown near the Muck Crops Research Station, Holland Marsh, Ontario, 2015.

Treatment	Marketable Yield (t/ha)	Percent Marketable	DSI[3]	Average Gall Rating
PIC PLUS	81.7 a[1]	76.8 ns[2]	34.5 a	2.3 a
NIMITZ + PIC PLUS	73.9 ab	70.6	50.5 ab	2.6 ab
NIMITZ	71.9 ab	68.7	60.5 ab	3.1 ab
Check	60.1 b	60.3	81.5 b	3.2 b

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

[2] ns indicates that no significant differences were found among the treatments

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

Table 2. Total plant parasitic nematode (carrot cyst nematode, pin nematode, lesion nematode, root-knot nematode) soil counts taken throughout the season on 22 May (Pre-plant), 2 July (Mid-season), and 2 November (Harvest) using the Baermann pan method of extraction near the Muck Crops Research Station, Holland Marsh, Ontario, 2015.

Treatment	Average total plant parasitic nematode soil counts (juvenile/kg soil)		
	Pre-plant (22 May)	Mid-season (2 July)	Harvest (2 November)
PIC PLUS	370 ns[1]	313 ns	21017 ns
NIMITZ + PIC PLUS	443	303	14743
NIMITZ	543	367	27193
Check	263	453	26537

[1] ns indicates that no significant differences were found among the treatments

2015 PMR REPORT # 07 **SECTION J: NEMATODES**

CROP: Garlic (*Allium sativum* (L.)) cv. Music
PEST: Stem and bulb nematode (*Ditylenchus dipsaci* (Kuhn) Filipjev)

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TITLE: EFFECT OF APPLYING DIFFERENT RATES OF AGRI-MEK AS A FOLIAR APPLICATION IN THE SPRING TO GARLIC PLANTS GROWN FROM STEM AND BULB NEMATODE-INFESTED GARLIC CLOVES CV. MUSIC COMPARED TO SOAKING INFESTED GLOVES IN AN AGRI-MEK SOLUTION PRIOR TO PLANTING ON YIELD, NEMATODE DAMAGE AND NEMATODE POPULATIONS IN THE BULBS AT HARVEST IN 2015

MATERIALS: AGRI-MEK EC (19 g/L abamectin a.i.); AGRI-MEK SC (84 g/L abamectin a.i.); AGRAL 90 (92% nonylphenoxy polyethoxy ethanol)

METHODS: Garlic cloves cv. Music infested with *Ditylenchus dipsaci* (958 nematodes/g dry cloves) were either soaked in a solution of AGRI-MEK EC (19 g /L abamectin) at 3.79 ml /litre of water (0.072 g abamectin/L water) for 4 hours (AGRI-MEK EC SOAK) + 0.25% non-ionicsurfactant (AGRAL 90), or AGRI-MEK SC (84 g /L abamectin) at 0.86 ml/litre of water (0.072 g abamectin/L water) + 0.25% non-ionicsurfactant (AGRAL 90) for 4 hours (AGRI-MEK SC SOAK) or soaked in water (approximately 17^{o}C) for 4 hours (WATER SOAK). Treated and untreated cloves were planted 30 per plot, 5 cm deep and 15.2 cm apart in 3 row plots with rows spaced 45.7 cm apart on 25 September 2014. Clean nematode-free cloves cv. Music (NEMATODE-FREE) obtained from the University of Guelph, New Liskard were planted in separate plots for comparison. Six additional plots of untreated nematode infested garlic cloves cv. Music were also planted in separate plots on 25 September 2014 and sprayed the following spring on 7 May 2015, 14 May 2015 and 21 May 2015 with either water alone (WATER), AGRI-MEK SC at 0.27 L/ha (1x registered rate to control thrips) (AGRI-MEK SC 1X), 0.54 L/ha (AGRI-MEK SC 2X), 0.81 L/ha (AGRI-MEK SC 3X), 1.08 L/ha (AGRI-MEK SC 4X) or 1.35 L/ha (AGRI-MEK SC 5X) in 1476 L of H_2O/ha using a hand held 3 nozzle boom sprayer (R&D Sprayers, Opelousas, LA) with adjustable cone nozzles spaced 30 cm apart, propelled with CO_2 at 280 kPa. Treatments were replicated 4 times and arranged in a randomized complete block design. Garlic scapes were removed on 29 June 2015 to improve bulb growth. Garlic bulbs were harvested, counted, weighed and rated for stem and bulb nematode damage (0 = no damage; 1= slight damage; 2= moderate damage; 3= severe damage, 4= dead ie shrivelled, desiccated) on 23 July 2015. Stem and bulb nematodes were extracted from 10 randomly selected bulbs harvested from each plot using Baermann funnels in a mist chamber for 24 hours. The nematodes extracted from the garlic bulbs were identified to genus and enumerated. The garlic bulbs were then dried at 80^{o}C for 72 hours to obtain the dry weight. Nematode data was transformed using the Log (nematode/g dried bulb +1) to improve normality and additivity prior to statistical analysis. All data was analyzed using the General Analysis of Variance function of the Linear Models section of Statistix V.9. Protected LSD test was used to detect differences among the

means at P=0.05.

RESULTS: Planting clean nematode-free garlic cloves cv. Music resulted in significantly higher number of bulbs/plot and yield at harvest with the lowest nematode damage compared to all other treatments (Table 1). A significantly higher number of bulbs were harvested from plots planted with nematode infested garlic cloves soaked in AGRI-MEK SC 0.83 ml/L water or a solution of AGRI-MEK EC 3.79 ml/L water prior to planting compared to soaking nematode infested cloves in water alone. Applying AGRI-MEK SC three times as a foliar spray during the mid-spring to plants grown from cloves infested with nematodes did not significantly increase the number of bulbs harvested from plots compared to applying water or soaking cloves in water, AGRI-MEK EC or AGRI-MEK SC prior to planting. Yields were higher from plots planted with nematode infested garlic cloves soaked in a solution of AGRI-MEK SC or AGRI-MEK EC prior to planting than from plots planted with cloves soaked in water or sprayed 3 times during the spring with water or AGRI-MEK SC. Applying AGRI-MEK SC three times as a foliar spray during mid-spring to plants grown from cloves infested with nematodes did not significantly increase the yield compared to plots sprayed with water. Stem and bulb nematode damage was significantly lower on bulbs harvested from plots planted with nematode infested cloves soaked in a solution of AGRI-MEK SC or AGRI-MEK EC prior to planting than on bulbs harvested from plots planted with cloves soaked in water or sprayed 3 times during mid- spring with water or AGRI-MEK SC. Fewer stem and bulb nematodes were extracted from bulbs harvested from plots planted with clean nematode free garlic cloves compared to plots planted with nematode infested garlic cloves either soaked in a solution of AGRI-MEK SC or water for prior to planting or applied with AGRI-MEK SC three times as a foliar spray during mid-spring. Stem and bulb nematode populations were also significantly lower in bulbs harvested from plots planted with nematode infested cloves soaked in a solution of AGRI-MEK EC prior to planting compared to bulbs harvested from plots planted with nematode infested cloves soaked in AGRI-MEK SC or water prior to planting or sprayed 3 times during the spring with water or AGRI-MEK SC up to the 3X rate. Applying AGRI-MEK SC three times as a foliar spray during the mid-spring to did not reduce the number of stem and bulb nematodes extracted from bulbs at harvest compared to applying water.

CONCLUSIONS: Planting clean stem and bulb nematode free cloves is the best method to effectively manage stem and bulb nematode in garlic. Soaking nematode infested cloves in a solution of AGRI-MEK SC prior to planting did not appear to be as effective at reducing nematode damage or populations in bulbs at harvest compared to soaking cloves in a solution of AGRI-MEK EC prior to planting in this trial. Further research is required to determine if AGRI-MEK EC is more effective for reducing stem and bulb nematodes than AGRI-MEK SC. Applying AGRI-MEK SC up to 5X the labelled rate for thrip management, three times as a foliar spray during the mid-spring to plants grown from cloves infested with nematodes did not appear to reduce nematode damage, nematode populations in bulbs or increase the yield of harvested garlic compared to applying water.

ACKNOWLEDGEMENTS: Funding for this project was provided Horticulture Crops Ontario.

Table 1. The effect of foliar applications of AGRI-MEK SC at 0.27 L/ha (1X), 0.54 L/ha (2X), 0.81 L/ha (3X), 1.08 L/ha (4X) and 1.35 L/ha (5X) in mid-spring to garlic plants grown from cloves infested with *D. dipsaci* compared to planting nematode-free cloves or soaking infested cloves in 3.79 ml of AGRI-MEK EC/L H_2O or 0.84 ml of AGRI-MEK SC/L H_2O for 4 hours prior to planting on the number of garlic bulbs, yield weight, nematode damage and population of *D. dipsaci* in bulbs harvested in 2015.

Treatment	Rate	Mean Number of garlic bulbs harvested/plot	Yield weight (g/m^2)	Nematode Damage (0-4)[1]	*D. dipsaci* per g dried bulb at harvest[2]
NEMATODE-FREE	NA	30.0 a[3]	2074.2 a	0.35 d	68.7 c
WATER SOAK	NA	14.3 d	398.5 c	2.43 a	211.8 a
AGRI-MEK EC SOAK	3.79 ml/L H_2O	18.3 bc	976.1 b	1.03 c	76.5 bc
AGRI-MEK SC SOAK	0.83 ml/L H_2O	18.8 b	798.0 b	1.61 b	238.0 a
WATER	NA	17.3 bcd	412.0 c	2.52 a	267.0 a
AGRI-MEK SC 1X	0.27 L/ha	17.0 bcd	479.2 c	2.40 a	180.8 a
AGRI-MEK SC 2X	0.54 L/ha	16.0 bcd	392.8 c	2.47 a	338.3 a
AGRI-MEK SC 3X	0.81 L/ha	17.8 bcd	459.9 c	2.40 a	187.8 a
AGRI-MEK SC 4X	1.08 L/ha	14.8 cd	297.0 c	2.58 a	154.4 ab
AGRI-MEK SC 5X	1.35 L/ha	15.3 bcd	354.2 c	2.36 a	157.8 ab

1. Nematode damage 0 = no damage; 1= slight damage; 2= moderate damage; 3= severe damage, 4= dead
2. Data was transformed using the Log (No. of nematodes/g dried bulb +1) to improve normality and additivity prior to statistical analysis however, actual means are presented
3. Figures within columns followed by different letters are significantly different using Protected LSD test ($P<0.05$)

2015 PMR REPORT # 08 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus (*Asparagus officinalis* L), cv. Millennium
PEST: Rust, *Puccinia asparagi* DC, purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: FIELD EVALUATION OF FUNGICIDES FOR THE CONTROL OF ASPARAGUS RUST AND PURPLE SPOT IN A 4-YEAR-OLD FIELD, 2011.

MATERIALS: ALLEGRO 500F (fluazinam 500 g a.i./L), ALTO 100SL (cyproconazole 100 g a.i./L), BRAVO 500SC (chlorothalonil 500 g a.i./L), CABRIO EG (pyraclostrobin 20%), APROVIA 100EC (benzovindiflupyr 100 g a.i./L), EXPERIMENTAL1, EXPERIMENTAL2, FOLICUR 432F (tebuconazole 432 g a.i./L), POLYRAM DF (metiram 80%), PRISTINE WG (boscalid 25.2% and pyraclostrobin 12.8%), QUADRIS XTRA 280SC (azoxystrobin 200 g a.i./L and cyproconazole 80 g a.i./L), QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L) and TILT 250E (propiconazole 250 g a.i./L)

METHODS: The trial was conducted in a commercial asparagus field in Norfolk County, Ontario on sandy soil. The field was established with 'Millennium' asparagus crowns in 2008 and maintained according to commercial practice. The crowns were spaced approximately 0.2 m apart in the row and 1.2 m between rows. Individual experiment plots were 6 m long by 1 row wide. Each treatment plot was separated by an untreated buffer row to prevent spray drift among treatments. Treatments (ALLEGRO, ALTO, BRAVO, CABRIO, APROVIA, EXPERIMENTAL1, EXPERIMENTAL2, FOLICUR, POLYRAM, PRISTINE, QUADRIS XTRA, QUADRIS TOP and TILT) were applied to four replications, arranged in a randomized complete block design. Untreated plots were established for comparison (UNTREATED CHECK). Replications were separated by a 2-m-long space of untreated fern to prevent spray drift among replications. Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom equipped with 50 mesh screens and 11005XR nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Treatments were applied on 27 Jun, 12 Jul, 25 Jul, 10 Aug, 23 Aug, and 9 Sep. Several types of disease severity estimates were made. Rust and purple spot lesions were counted on five ferns per plot on 23 Aug and 20 Sep. On 28 Sep, rust severity was estimated using the following scale: 1=no foliar infection, 2=trace to 10% foliar infection, 3=10-20% foliar infection, 4=20-30% foliar infection, 5=30-40% foliar infection and trace defoliation, 6=40-50% foliar infection, 7=50-65% foliar infection, 8=65-80% foliar infection, 9=80-90% foliar infection, and 10=90-100% foliar infection. The defoliation (%) was also visually estimated on 28 Sep. The area under the disease progress curve (AUDPC) for the number of rust lesions per plant was calculated using the following equation: where Yi is number of rust lesions at day Xi and Yi-1 is number of rust lesions at day Xi-1: $AUDPC = \Sigma [((Y_i + Y_{i-1}) (X_i - X_{i-1}))/2]$. Data were analyzed using SAS PROC MIXED and statistical differences were compared using Fisher's Least Significant Differences test ($P \leq 0.05$).

RESULTS: As outlined in Table 1.

CONCLUSIONS: Rust and purple spot incidence was high through the duration of the trial (Table 1). Significant differences were observed among treatments. On 23 Aug, all treatments had significantly lower rust lesion counts per plant than the untreated control except PRISTINE, CABRIO, BRAVO, and the tank-mixture of EXPERIMENTAL1, EXPERIMENTAL2, and TILT. By 20 Sep, all treatments had significantly lower rust lesion counts per plant than the untreated control. All treatments, except TILT, had significantly lower rust severity than the untreated control. APROVIA, QUADRIS TOP, QUADRIS XTRA, ALLEGRO, ALTO, POLYRAM, FOLICUR, and the tank-mixture of EXPERIMENTAL1, EXPERIMENTAL2 and TILT had statistically lower rust AUDPC values than the untreated control. Also, the tank-mixture of EXPERIMENTAL1, EXPERIMENTAL2, and TILT had significantly less AUDPC values and defoliation (%) than the individual components applied separately. All treatments, except TILT, had significantly less defoliation (%) than the untreated control.

Table 1. Field evaluation of foliar fungicides for asparagus rust and purple spot control, 2011.

Treatment and rate/ha, applied at 14-day intervals	Rust lesions/plant				Rust severity (1-10 IS)[1]		Rust AUDPC[2]		Purple spots/fern		Defoliation[3]	
	23 Aug		20 Sep		28 Sep				20 Sep		(%)	
UNTREATED CHECK	32.0	d[4]	99.0	g	7.2	d	1722	d	70.1	a-d	83.2	e
PRISTINE 870 g	12.0	bcd	59.0	f	3.1	bc	1099	cd	61.4	abc	4.2	a
EXPERIMENTAL1 18.7 L + EXPERIMENTAL2 1200 ml + TILT 250 ml	8.0	abc	12.0	a-d	1.9	ab	392	ab	84.7	b-e	4.7	a
QUADRIS TOP 1000 ml	1.8	a	5.6	abc	1.0	a	110	a	42.5	ab	6.6	ab
APROVIA 750 ml	9.0	abc	4.1	abc	1.4	a	313	ab	37.8	a	7.9	ab
FOLICUR 290 ml	4.3	a	6.9	abc	1.4	a	215	a	122.5	cde	10.7	abc
QUADRIS XTRA 500 ml	8.0	a	5.3	ab	1.2	a	288	a	70.9	a-e	13.2	abc
POLYRAM 3250 g	7.1	ab	13.0	bcd	2.0	ab	379	ab	140.8	de	13.7	abc
ALLEGRO 1000 ml	6.7	abc	18.0	b-e	1.9	ab	442	abc	105.8	cde	14.0	abc
CABRIO 560 g	46.0	d	56.0	ef	4.8	cd	1784	d	120.3	cde	15.5	a-d
ALTO 400 ml	3.6	ab	1.2	a	1.8	ab	112	a	134.8	de	21.0	abc
BRAVO 3400 ml	9.3	a-d	44.0	c-f	4.5	cd	878	bcd	147.2	e	39.0	bcd
EXPERIMENTAL1 18.7 L + EXPERIMENTAL2 1200 ml	44.0	cd	57.0	abc	4.2	c	1611	cd	76.2	a-e	43.0	cd
TILT 250 ml	14.0	bcd	61.0	def	4.7	cd	1166	cd	143.0	de	54.0	de

[1]Severity was estimated using the following scale: 1=no foliar infection, 2=trace to 10% foliar infection, 3=10-20% foliar infection, 4=20-30% foliar infection, 5=30-40% foliar infection and trace defoliation, 6=40-50% foliar infection, 7=50-65% foliar infection, 8=65-80% foliar infection, 9=80-90% foliar infection, and 10=90-100% foliar infection.

[2]Area Under the Disease Progress Curve (AUDPC).

[3]Defoliation (%) was visually estimated and can be caused by both rust and purple spot.

[4]Figures in columns followed by the same letter are not significantly different (Fisher's LSD; $P \leq 0.05$).

2015 PMR REPORT # 09 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus (*Asparagus officinalis* L.), cv. Millennium
PEST: Rust, *Puccinia asparagi* DC

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TITLE: FIELD EVALUATION OF FUNGICIDES FOR THE CONTROL OF ASPARAGUS RUST IN A 3-YEAR-OLD FIELD, 2011

MATERIALS: ALLEGRO 500F (fluazinam 500 g a.i./L), ALTO 100SL (cyproconazole 100 g a.i./L), BRAVO 500SC (chlorothalonil 500 g a.i./L), CABRIO EG (pyraclostrobin 20%), APROVIA 100EC (benzovindiflupyr 100 g a.i./L), EXPERIMENTAL1, EXPERIMENTAL2, FOLICUR 432F (tebuconazole 432 g a.i./L), POLYRAM DF (metiram 80%), PRISTINE WG (boscalid 25.2% and pyraclostrobin 12.8%), QUADRIS XTRA 280SC (azoxystrobin 200 g a.i./L and cyproconazole 80 g a.i./L), QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L) and TILT 250E (propiconazole 250 g a.i./L)

METHODS: The trial was conducted in a commercial field in Norfolk County, Ontario on sandy soil. The field was established with 'Millennium' asparagus crowns in 2009 and maintained according to commercial practice. The crowns were spaced approximately 0.2 m apart in the row and 1.0 m between rows. Individual experiment plots were 6 m long by 1 row wide. Each treatment plot was separated by an untreated buffer row to prevent spray drift among treatments.Treatments (ALLEGRO, ALTO, BRAVO, CABRIO, APROVIA, EXPERIMENTAL1, EXPERIMENTAL2, FOLICUR, POLYRAM, PRISTINE, QUADRIS XTRA, QUADRIS TOP and TILT) were applied to four replications, arranged in a randomized complete block design. Untreated plots were established for comparison (UNTREATED CHECK). Replications were separated by a 2-m-long space of untreated fern to prevent spray drift among replications. Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom with 50 mesh screens and 11005XR nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Treatments were applied on 31 May, 14 Jun, 27 Jun, 12 Jul, 25 Jul, and 10 Aug. Rust lesions were counted on five ferns per plot on 27 Jun and 25 Jul. On 23 Sep, rust severity was estimated using the following scale: 1=no foliar infection, 2=trace to 10% foliar infection, 3=10-20% foliar infection, 4=20-30% foliar infection, 5=30-40% foliar infection and trace defoliation, 6=40-50% foliar infection, 7=50-65% foliar infection, 8=65-80% foliar infection, 9=80-90% foliar infection, and 10=90-100% foliar infection. The area under the disease progress curve (AUDPC) for the number of rust lesions per plant was calculated using the following equation: where Yi is number of rust lesions at day Xi and Yi-1 is number of rust lesions at day Xi-1: $AUDPC = \Sigma [((Yi + Yi\text{-}1) (Xi – Xi\text{-}1))/2]$. Data were analyzed using SAS PROC MIXED and statistical differences were compared using the Fisher's Least Significant Differences test ($P \leq 0.05$).

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among treatments (Table 1). On 27 Jun, all treatments had significantly fewer rust lesions per plant than the UNTREATED CHECK, except the tank-mixture of EXPERIMENTAL1 and EXPERIMENTAL2, POLYRAM, TILT, CABRIO, BRAVO, ALLEGRO, and PRISTINE. By 25 Jul, all treatments had significantly fewer rust lesions per plant than the UNTREATED CHECK, except the tank-mixture of EXPERIMENTAL1 and EXPERIMENTAL2, CABRIO, BRAVO, ALLEGRO, and PRISTINE. All treatments had significantly less rust severity than the UNTREATED CHECK except PRISTINE. QUADRIS TOP, QUADRIS XTRA, ALTO, APROVIA, FOLICUR, TILT, POLYRAM, and the tank-mixture of EXPERIMENTAL1, EXPERIMENTAL2 and TILT had significantly lower AUDPC values than the UNTREATED CHECK.

Table 1. Field evaluation of foliar fungicides for asparagus rust control, 2011.

Treatment and rate/ha, applied at 14-day intervals	Rust lesions/plant				Rust severity (1-10 scale)[1]		AUDPC[2]	
	27 Jun		25 Jul		23 Sep			
Untreated control	209.7	d[3]	264.1	fg	10	g	8836	de
QUADRIS TOP 1000 ml	50.1	a	73.1	abc	3	ab	2528	a
QUADRIS XTRA 500 ml.....	62.8	a	51.1	a	3	a	2825	a
ALTO 400 ml.....	72.4	ab	57.5	ab	6	c-f	3094	a
APROVIA 750 ml.....	49.8	a	83.9	abc	3	ab	3256	a
FOLICUR 290 ml	82.6	ab	92.7	abc	5	abc	3832	a
EXPERIMENTAL1 18.7 L EXPERIMENTAL2 1200 ml TILT 250 ml.....	98.2	ab	118.9	bcd	6	cde	4274	ab
TILT 250 ml.....	140.5	bcd	166.0	de	7	c-f	6214	bc
POLYRAM 3250 g	156.1	bcd	132.1	cd	6	c-f	6265	bc
EXPERIMENTAL1 18.7 L EXPERIMENTAL2 1200 ml.....	182.0	cd	186.7	def	5	bcd	7071	cde
BRAVO 3400 ml	140.1	bcd	257.3	efg	8	ef	7088	cd
ALLEGRO 1000 ml.....	181.0	cd	184.5	def	8	ef	7416	cde
CABRIO 560 g	95.3	abc	392.6	g	7	def	8002	cde
PRISTINE 870 g	283.3	d	294.9	efg	8	fg	10702	e

[1]Severity was estimated using the following scale: 1=no foliar infection, 2=trace to 10% foliar infection, 3=10-20% foliar infection, 4=20-30% foliar infection, 5=30-40% foliar infection and trace defoliation, 6=40-50% foliar infection, 7=50-65% foliar infection, 8=65-80% foliar infection, 9=80-90% foliar infection, and 10=90-100% foliar infection.

[2]Area Under the Disease Progress Curve (AUDPC)

[3]Figures in columns followed by the same letter are not significantly different (Fisher's LSD; $P \leq 0.05$).

2015 PMR REPORT # 10 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus (*Asparagus officinalis* L.), cv. Millennium
PEST: Purple spot, *Pleospora herbarium* (Pers.:Fr.) Rabenh

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TITLE: EVALUATION OF CULTURAL AND CHEMICAL CONTROL METHODS TO CONTROL PURPLE SPOT ON ASPARAGUS SPEARS, 2012-2013.

MATERIALS: KOCIDE 2000 54DF (copper hydroxide 53.8 %) and UAN (urea-ammonium nitrate 28%).

METHODS: In November 2012, two trials were established in commercial fields in Elgin and Norfolk County, Ontario, on Wauseon loamy fine sand and Brady sand soil, respectively. The field in Elgin County was established in 2009 with 'Millennium' asparagus seed. The field in Norfolk County was established in 2009 with 1-year-old 'Millennium' asparagus crowns. The final plant stand was spaced approximately 0.2 m apart in the row and 1.2 m between rows. Main plots were arranged in split-block design with whole plot factors (60 m long by 7 rows) being MOWING TIMING and subplot factors (15 m long by 7 rows) being FUNGICIDE and FERTILIZER applications replicated three times. Prior to fall foliar treatment applications, half of the whole plot factors (FALL MOWING) were mowed by the grower. The remaining whole plot factors (SPRING MOWING) were mowed the first week of April by the grower cooperators prior to harvest. Copper hydroxide (KOCIDE 2000) was applied at 6.0 kg a.i./ha and UAN was applied at 39 kg N ha^{-1} to the appropriate subplots with a CO_2-powered backpack sprayer (Bellspray Inc., Opelousas, LA) equipped with Teejet XR11002 nozzles (Spraying Systems Co., Wheaton, IL) calibrated to deliver 200 L/ha on 9 November, 2012. Spring fertility, and weed and insect control were managed by the growers, according to normal standard practice. In the spring of 2013, ten marketable sized spears were collected from the middle row of each plot weekly through the duration of commercial harvest; in 2013, plots were harvested 30 May, 4 June, 11 June and 18 June, and in 2014, plots were harvested 22 May, 4 June, 13 June, and 20 June. Spears were assessed for purple spot incidence and rated on a scale of 0 to 4, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, and 4 > 90 lesions. A disease severity index was calculated using the following formula:

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

Data were analyzed using SAS PROC MIXED and statistical differences were compared using Student's t-test ($P \leq 0.05$).

RESULTS: As outlined in Tables 1 and 2.

CONCLUSIONS: Purple spot incidence and severity varied from low disease pressure to moderate among harvests, and significant differences were observed only between mowing treatments at both sites

(Table 1). An interaction was observed between locations in 2012-2013, and the data for each site were analyzed separately. At the Elgin County site, plots which were mowed in the fall had significantly less purple spot DSI than plots that were mowed in the spring. At the Norfolk County site, plots which were mowed in the fall had significantly less purple spot incidence (%) than plots that were moved in the spring (Table 2). The study was repeated in 2013-2014 at two sites and no differences were observed.

Table 1. Analysis of variance (*P*-value) for factors and interactions.

Factor or interaction[1]	Elgin County site *P*-values		Norfolk County site *P*-values	
	Incidence	DSI	Incidence[2]	DSI[d]
MOWING	0.1256	**0.0061**	**0.0488**	0.2235
NITROGEN	0.9264	0.9418	0.9641	0.6372
FUNGICIDE	0.9692	0.8889	0.9328	0.7933
MOWING*NITROGEN	0.9880	0.8856	0.3518	0.5127
MOWING*FUNGICIDE	0.8839	0.8332	0.5390	0.8052
NITROGEN*FUNGICIDE	0.8417	0.8610	0.7830	0.9892
MOWING*NITROGEN*FUNGICIDE	0.9026	0.6466	0.3606	0.8174

[1]Each factor had two treatment levels: MOWING (FALL MOWING or SPRING MOWING), NITROGEN (UNTREATED or UAN applied at 39 kg N ha^{-1}) and FUNGICIDE (UNTREATED or KOCIDE 2000 applied at 6.0 kg a.i. ha^{-1}).
[2]Data were square-root transformed to satisfy normality assumptions.

Table 2. Comparison of the effect timing of fern mowing has on purple spot incidence (%) and disease severity index (DSI) on asparagus spears harvested four times from two sites.

Treatment level	Elgin County			Norfolk County		
	Incidence (%)	DSI[1]		Incidence (%)[2]		DSI[x]
FALL MOWING	48.8	13.5	a	62.4	a	23.0
SPRING MOWING	60.7	21.8	b	75.0	b	27.8

[1]Column means with a letter in common or no letter at all are not significantly different (Student's t-test, $P \leq 0.05$), n=12.
[2]Data were square-root transformed to satisfy normality assumptions. Presented means are back-transformed.

2015 PMR REPORT # 11 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus (*Asparagus officinalis* L)
PEST: Rust, *Puccinia asparagi* DC and purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: EVALUATION OF ASPARAGUS CULTIVARS AND BREEDING LINES FOR TOLERANCE TO RUST AND PURPLE SPOT, 2015

MATERIALS: MILLENNIUM, JERSEY GIANT, TIESSEN, UG010, UG020 AND UG023

METHODS: The trial was established at Simcoe Horticultural Experiment Station in Norfolk County, Ontario. The field was established in 2011 with asparagus seedlings (MILLENNIUM, JERSEY GIANT, TIESSEN, UG010, UG020 and UG023) produced from seed in a greenhouse. The seedlings were spaced approximately 0.2 m apart in the row and 1.2 m between rows. Individual experiment plots were 6 m long by 1 row wide and arranged in a randomized complete block design. Each asparagus breed line and cultivar was replicated five times, and blocks were separated by a 2-m-long space. In the spring of 2015, 10 spears were harvested from each plot four times (May 5, May 7, May 13 and May 15) 1 day after natural rainfall occurred at the trial site. Spears were assessed for purple spot incidence and rated on a scale of 0 to 4, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, and 4 > 90 lesions. A disease severity index was calculated using the following formula: DSI = [∑[(class no.)(no. of spears in each class)]]/(total no. of spears per sample)(no. classes - 1) x 100. Following harvest, the ferns were assessed weekly from 9 June to 7 October 2015 for purple spot and 9 June to 13 October for rust severity. Ten branches were assessed per plot and rated for purple spot and rust severity on a scale of 0 to 4, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 91 to 150 lesions, and 5 > 150 lesions per branch. The area under the emergence progress curve (AUDPC) was calculated from weekly DSI ratings on asparagus fern from 9 June to 13 October, using the following formula where Y_i is number of DSI at day X_i and Y_{i-1} is DSI at day X_{i-1}: AUDPC = Σ [((Y_i + Y_{i-1}) (X_i – X_{i-1}))/2]. Data were analyzed using SAS PROC MIXED and statistical differences were compared using Tukey's HSD test ($P \leq 0.05$).

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

CONCLUSIONS: Purple spot disease severity varied among each harvest. The greatest DSI was observed on 15 May, and breeding line UG020 had significantly less purple spot than UG023 (Table 1). When the data were pooled from all four harvests, UG020 had significantly less purple spot than UG023. Low levels of purple spot and rust (less than 5 DSI) were detected on the asparagus fern from 30 June to 7 September, and the DSI for the remaining assessments were presented in Tables 2 and 3. On 16 September, JERSEY GIANT had less purple spot DSI on the fern than UG023 (Table 2). No differences in purple spot AUDPC were observed. At most assessments from 16 September to 13 October, JERSEY GIANT had less rust DSI than TIESSEN and MILLENNIUM (Table 3). Also, during the same evaluation

period, the breeding lines had similar rust DSI as JERSEY GIANT. The breeding lines and JERSEY GIANT had less rust AUDPC than TIESSEN.

Table 1. Field evaluation of asparagus cultivars and breeding lines for tolerance to purple spot on harvested spears.

Cultivar or breeding line	spear assessments (DSI[1])							
	5 May	7 May		13 May	15 May		Mean	
UG020	2.1	7.5	ab[2]	5.5	30.2	a	11.3	a
UG010	5.0	7.5	ab	7.0	37.8	ab	14.3	ab
MILLENNIUM	3.8	3.5	a	9.0	44.0	ab	15.1	ab
TIESSEN	0.5	8.5	ab	7.0	56.3	ab	17.2	ab
JERSEY GIANT	8.2	14.0	b	11.1	39.7	ab	18.2	ab
UG023	2.3	13.5	b	13.0	57.5	b	21.6	b
P-value	0.0618	0.0121		0.0967	0.0209		0.0042	

[1]DSI is the disease severity index calculated based on the following formula: DSI = [∑[(class no.)(no. of spears in each class)]]/(total no. of spears per sample)(no. classes - 1) x 100.
[2]Figures in columns followed by the same letter are not significantly different (Tukey's HSD, $P \leq 0.05$).

Table 2. Field evaluation of asparagus cultivars and breeding lines for tolerance to purple spot on fern.

Cultivar or breeding line	fern[1] assessments (DSI[1])					AUDPC[2]
	16 Sep		25 Sep	2 Oct	7 Oct	
JERSEY GIANT	15.6	a[3]	26.8	32.4	34.4	1019
TIESSEN	26.0	ab	24.0	24.4	38.0	1089
UG010	20.0	ab	32.0	28.8	41.2	1105
MILLENNIUM	23.2	ab	26.4	30.8	48.4	1220
UG020	23.6	ab	32.0	30.0	44.0	1211
UG023	30.8	b	33.2	36.0	44.8	1401
P-value	0.0217		0.0701	0.3833	0.4673	0.1792

[1]DSI is the disease severity index calculated based on the following formula: DSI = [∑[(class no.)(no. of spears in each class)]]/(total no. of spears per sample)(no. classes - 1) x 100.
[2]AUDPC is the area under the disease progress curve calculated from DSI ratings made weekly on asparagus fern from 9 June to 7 October, n=5.
[3]Figures in columns followed by the same letter are not significantly different (Tukey's HSD, $P \leq 0.05$).

Table 3. Field evaluation of asparagus cultivars and breeding lines for tolerance to rust on fern.

Cultivar or breeding line	fern[1] assessments (DSI[1])										AUDPC[2]	
	16 Sep		25 Sep		2 Oct		7 Oct		13 Oct			
UG023	7.2	a	2.8	a	5.2	A	8.4	abc	9.2		264	a
UG010	8.8	a	5.2	a	4.0	A	6.8	ab	8.8		295	a
JERSEY GIANT	10.4	a[3]	6.4	a	6.8	A	2.8	a	3.2		307	a
UG020	8.8	a	6.0	a	8.8	ab	12.4	abc	11.2		380	a
MILLENNIUM	18.4	ab	23.6	b	12.4	ab	20.0	bc	10.8		744	ab
TIESSEN	27.6	b	23.6	b	22.8	B	21.2	c	17.2		988	b
P-value	0.0447		<0.0001		0.0108		0.0019		0.1281		0.0019	

[1]DSI is the disease severity index calculated based on the following formula: DSI = [∑[(class no.)(no. of branches in each class)]]/(total no. of branches per sample)(no. classes - 1) x 100
[2]AUDPC is the area under the disease progress curve calculated from DSI ratings made weekly on asparagus fern from 9 June to 13 October, n=5.
[3]Columns which share a letter in common or no letter at all are not significantly different (Tukey's HSD, $P \leq 0.05$).

2015 PMR REPORT # 12 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus (*Asparagus officinalis* L.)
PEST: Purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: EVALUATION OF ASPARAGUS CULTIVARS AND BREEDING LINES FOR TOLERANCE TO PURPLE SPOT, 2015

MATERIALS: MILLENNIUM, JERSEY GIANT, TIESSEN, UG010, UG020, and UG023

METHODS: The trial was established at a private research farm in Oxford County, Ontario. The field was established in 2011 with asparagus seedlings produced from seed in a greenhouse. The seedlings were spaced approximately 0.2 m apart in the row and 1.5 m between rows. Individual experiment plots were 6 m long by 1 row wide and arranged in a randomized complete block design. Each asparagus breeding line (UG010, UG020, and UG023) and variety (MILLENNIUM, JERSEY GIANT, and TIESSEN) were replicated five times, and blocks were separated by a 2-m-long space. In the spring 2015, 10 spears were harvested from each plot six times (6 May, 11 May, 29 May, 1 June, 3 June, and 8 June) 1 day after natural rainfall occurred at the trial site; disease severity is greatest following periods of significant rainfall (Granke and Hausbeck, 2010). Spears were assessed for purple spot incidence and rated on a scale of 0 to 4, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, and 4 > 90 lesions. A disease severity index was calculated using the following formula: DSI = [$\sum$[(class no.)(no. of spears or branches in each class)]]/(total no. of spears or branches per sample)(no. classes - 1) x 100. Following harvest, the ferns were assessed weekly from 9 June to 13 October for purple spot severity. Ten ferns were assessed per plot and rated for purple spot severity on a scale of 0 to 4, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 91 to 150 lesions, and 5 > 150 lesions per branch. The area under the emergence progress curve (AUDPC) was calculated DSI ratings made weekly on asparagus fern from Jun 9 to Oct 13, using the following formula where Y_i is the DSI at day X_i and Y_{i-1} is DSI day X_{i-1}: AUDPC = Σ [((Y_i + Y_{i-1}) (X_i – X_{i-1}))/2]. Data were analyzed using SAS PROC MIXED and statistical differences were compared using Tukey's HSD test ($P \leq 0.05$).

RESULTS: As outlined in Table 1.

CONCLUSIONS: When the data were pooled from all six harvests, UG010 had significantly less purple spot severity (DSI) than TIESSEN. Purple spot severity in the fern was low for the duration of the season with less than 5 DSI at any evaluation from 6 June to 16 September. No differences were observed when purple spot severity was higher (16 September to 13 October). No differences in AUDPC were observed among the treatments.

REFERENCES: Granke, L.L. and Hausbeck M.K. 2010. Influence of environment on airborne spore concentrations and severity of asparagus purple spot. Plant Disease 94:843-850.

Table 1. Field evaluation of asparagus cultivars and breeding lines for tolerance to purple spot.

Cultivar or breeding line	spear[1] DSI[2]		fern (branches) DSI					fern
			16 Sep	25 Sep	2 Oct	7 Oct	13 Oct	AUDPC[4]
UG020.....	22.8	ab[3]	13.2	9.6	8.8	9.6	11.6	171
TIESSEN	25.4	b	7.2	5.6	13.2	11.2	10.8	175
UG010.....	17.1	a	8.8	6.4	2.8	8.0	10.0	203
MILLENNIUM.....	22.0	ab	19.2	14.8	13.2	18.0	8.8	213
UG023.....	19.0	ab	17.6	12.8	10.8	14.8	12.0	213
JERSEY GIANT.....	19.9	ab	15.2	18.4	11.2	10.0	12.0	233
P-value	0.0105		0.6312	0.4939	0.5937	0.6209	0.8403	0.3501

[1]Spears were harvested six times (n=30) and figures below are the means for each variety.
[2]DSI is the disease severity index calculated based on the following formula: DSI = [∑[(class no.)(no. of spears or branches in each class)]]/(total no. of spears or branches per sample)(no. classes - 1) x 100.
[3]Columns which share a letter in common or no letter at all are not significantly different (Tukey's HSD, $P \leq 0.05$).
[4]AUDPC is the area under the disease progress curve calculated from DSI ratings made weekly on asparagus fern from 9 June to 13 October, n=5.

2015 PMR REPORT # 13 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus, *Asparagus officinalis* L., cv. Millennium
PEST: Purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: FIELD EVALUATION OF TOM-CAST FORECASTING MODEL FOR THE CONTROL OF PURPLE SPOT IN ASPARAGUS, 2014

MATERIALS: BRAVO 500SC (chlorothalonil 500 g a.i./L), POLYRAM 80DF (metiram 80%), and QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L)

METHODS: The trial was conducted in 2014 in a commercial asparagus field in Elgin County, Ontario, on Wauseon loamy fine sand. The field was established in 2009 with 'Millennium' asparagus seed, and the final plant stand was spaced approximately 0.2 m apart in the row and 1.2 m between rows. Individual experiment plots were 6 m long by 1 row wide. Treatments were applied to four replications, arranged in a randomized complete block design. Each treatment plot was separated by an untreated buffer row to prevent spray drift among treatments. Blocks were separated by a 2-m-long space of untreated fern to prevent spray drift among replications. Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom equipped with 50 mesh screens and Teejet 11005XR nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Fungicides programs were applied either on a 14-day schedule or according to the forecasting model TOM-Cast with a 20 disease severity value (DSV) trigger point. There were two fungicide programs applied according to TOM-Cast, and the DSV calculated using either an in-field weather station or a site-specific weather station (Weather Innovation Decision Support Models) that uses nearby weather stations to predict weather conditions at the specified site. The 14-day interval treatments were applied 10 July, 24 July, 8 August, 20 August and 4 September. The in-field TOM-Cast treatment was applied 20 July, 28 July, 8 August, 14 August, 28 August and 4 September. The site-specific TOM-Cast treatment was applied 22 July, 5 August, 18 August and 28 August. Disease assessments were made every 14 days following the first application in the 14 day schedule application treatments through to 16 October. Purple spot was assessed per plot and rated on a scale of 0 to 5, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 90 to 150 lesions and 5 > 150 lesions. The area under the disease progress curve (AUDPC) was calculated using the following equation: where Yi is the rating score at day Xi and Yi-1 is the rating score at day Xi-1: $AUDPC = \Sigma [((Yi + Yi\text{-}1) (Xi – Xi\text{-}1))/2]$. Fern yellowing (%area) and needle drop (%), common symptoms of purple spot, were visually estimated. Data were analyzed using SAS PROC MIXED and statistical differences were compared using Tukey's HSD test ($P \leq 0.05$).

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

CONCLUSIONS: Disease pressure increased through the summer. In September and October, fungicide programs applied according to the forecasting model TOM-Cast had less fern yellowing and needle drop than fungicide applied on a14 day schedule. On 19 September and 2 October, fungicides applied

according to both TOM-Cast forecast programs had significantly less fern yellowing and needle drop than the untreated control. By the end of the season, fungicide programs applied according to TOM-Cast had significantly lower AUDPC than the untreated control.

Table 1. Field evaluation of the TOM-Cast forecasting model and application timing of fungicides for their effect on fern yellowing (% area) in asparagus, 2014.

Treatment, rate/ha, (no. of apps) application timing	Fern yellowing (% leaf area) 21 Aug	4 Sep	19 Sep		2 Oct		16 Oct
Untreated control	30.0	42.5	73.8	b[1]	72.5	b	98.6
BRAVO 3.4 L (3); POLYRAM 3.25 kg (2) 14-day schedule	8.8	48.8	31.3	ab	40.0	ab	90.6
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (2) 14-day schedule	3.8	26.0	37.5	ab	33.8	ab	95.4
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (3) in-field TOM-Cast	11.3	4.0	6.3	a	8.8	a	84.8
BRAVO 3.4 L (2); QUADRIS TOP 750 ml (2) site-specific TOM-Cast	21.3	25.0	20.0	a	23.8	a	89.3

[1]Figures in columns which the same a letter are not significantly different (Tukey's HSD, P≤0.05, n=4).

Table 2. Field evaluation of the TOM-Cast forecasting model and application timing of fungicides for their effect on defoliation (%) in asparagus, 2014.

Treatment, rate/ha, (no. of apps) application timing	Defoliation (%) 21 Aug	4 Sep	19 Sep		2 Oct		16 Oct
Untreated control	5.1	8.1	75.0	b[1]	86.3	b	97.8
BRAVO 3.4 L (3); POLYRAM 3.25 kg (2) 14-day schedule	1.2	14.4	26.3	a	30.0	a	97.1
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (2) 14-day schedule	0.2	6.5	36.3	ab	38.8	a	97.1
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (3) in-field TOM-Cast	0.9	1.9	3.8	a	5.0	a	94.0
BRAVO 3.4 L (2); QUADRIS TOP 750 ml (2) site-specific TOM-Cast	2.6	6.0	17.5	a	25.0	a	96.7

[1]Figures in columns with the same letter are not significantly different (Tukey's HSD, P≤0.05, n=4).

Table 3. Field evaluation of the TOM-Cast forecasting model and application timing of fungicides for their effect on purple spot in asparagus fern, 2014.

Treatment, rate/ha, (no. of apps) application timing	Purple spot AUDPC[1]	
Untreated control	179	b[2]
BRAVO 3.4 L (3); POLYRAM 3.25 kg (2) 14-day schedule	131	ab
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (2) 14-day schedule	140	ab
BRAVO 3.4 L (3); QUADRIS TOP 750 ml (3) in-field TOM-Cast	89	a
BRAVO 3.4 L (2); QUADRIS TOP 750 ml (2) site-specific TOM-Cast	117	a

[1]AUDPC (area under the emergence progress curve)

[2]Figures in columns with the same letter are not significantly different (Tukey's HSD, P≤0.05, n=4).

2015 PMR REPORT # 14 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus, *Asparagus officinalis* L, cv. Millennium
PEST: Purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: FIELD EVALUATION OF FUNGICIDE PROGRAMS AND FERTILIZER FOR THE CONTROL OF PURPLE SPOT IN ASPARAGUS, 2014

MATERIALS: BRAVO 500SC (chlorothalonil 500 g a.i./L) and QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L)

METHODS: The trial was conducted in 2014 in a commercial asparagus field in Elgin County, Ontario, on Wauseon loamy fine sand. The field was established in 2009 with 'Millennium' asparagus seed, and the final plant stand was spaced approximately 0.2 m apart in the row and 1.2 m between rows. Experimental plots were 6 m long by 7 rows wide and arranged in split-block design with whole plot factors fertilizer treatment and subplot factors being fungicide. The fungicide treatments were replicated four times, and separated by an untreated buffer row to prevent spray drift among treatments. Fertilizer blocks were separated by a 2-m-long space of untreated fern to prevent spray drift among replications. A standard fertilizer program was applied to the entire plot area prior to harvest in the spring of 2014 (184 kg N/ha, 59 kg P_2O_5/ha, 121 K_2O/ha, 77 kg S/ha, 4.5 kg Zn/ha, 25 kg Mg/ha, 2 kg Cu/ha, 1 kg Fe/ha, 4 kg Mn/ha, 7 kg Cl/ha, and 1 kg Ca/ha). Following harvest in 2014, plots received either no fertilizer (NO POST HARVEST FERTILIZER) or fertilizer (POST HARVEST FERTILIZER) applied with a commercial spreader (167 kg N/ha, 130 kg K_2O/ha, 73 kg S/ha, 39 kg Mg/ha, 7 kg Cl/ha, and 26 kg Ca/ha). Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom equipped with 50 mesh screens and 11005XR nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Fungicide treatment programs were applied a 14 day schedule or according to the forecasting model TOM-Cast with a 20 disease severity value (DSV) trigger point. The 14 day schedule treatments were applied 10 July, 24 July, 8 August, 20 August and 4 September. The 20 DSV TOM-Cast treatment was applied 20 July, 28 July, 8 August, 14 August, 28 August and 4 September. Disease assessments were initiated 24 July and continued every 14 days following the first application in the 14 day schedule treatments through to 16 October. Purple spot was assessed per plot and rated on a scale of 0 to 5, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 90 to 150 lesions and 5 > 150 lesions. The area under the disease progress curve (AUDPC) was calculated using the following equation: where Yi is the rating score at day Xi and Yi-1 is the rating score at day Xi-1: $AUDPC = \Sigma [((Yi + Yi\text{-}1) (Xi – Xi\text{-}1))/2]$. Fern yellowing (%area) and needle drop (%) was visually estimated. Data were analyzed using SAS PROC MIXED and statistical differences were compared using Tukey's HSD test ($P \leq 0.05$).

RESULTS: As outlined in Table 1.

CONCLUSIONS: Disease pressure increased through the summer, and disease severity was high by October. No differences were observed among the treatments in fern yellowing (% area) or needle drop (%), except on 4 September plots treated with a post-harvest fertilizer program had less defoliation than the plots not treated with a post-harvest fertilizer (P=0.0232). Plots that received a post-harvest fertilizer program had significantly lower AUDPC than plots treated not treated with a post-harvest fertilizer program (P=0.0090).

Table 1. Field evaluation of fertilizer treatments and application timing of fungicides for their effect on purple spot in asparagus fern, 2014.

Factor	Treatment level		P-value	Purple spot AUDPC[1]	
FERTILIZER			0.0090		
	NO POST-HARVEST FERTILIZER		-	107	a[2]
	POST-HARVEST FERTILIZER		-	121	b
FUNGICIDE			0.6473		
	UNTREATED CHECK		-	124	
	14-DAY SCHEDULE		-	109	
	TOM-CAST		-	109	
FERTILIZER*FUNGICIDE			0.8962		
	NO POST-HARVEST FERTILIZER	UNTREATED CHECK	-	136	
	NO POST-HARVEST FERTILIZER	14-DAY SCHEDULE	-	113	
	NO POST-HARVEST FERTILIZER	TOM-CAST	-	115	
	POST-HARVEST FERTILIZER	UNTREATED CHECK	-	112	
	POST-HARVEST FERTILIZER	14-DAY SCHEDULE	-	104	
	POST-HARVEST FERTILIZER	TOM-CAST	-	104	

[1]AUDPC (area under the emergence progress curve)

[2]Figures within Factors with the same letter are not significantly different (Tukey's HSD, $P \leq 0.05$, n=4).

2015 PMR REPORT # 15 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus, *Asparagus officinalis* L., cv. Millennium
PEST: Purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: FIELD EVALUATION OF FUNGICIDES FOR THE CONTROL OF PURPLE SPOT IN A 3-YEAR-OLD ASPARAGUS FIELD, 2015.

MATERIALS: QUADRIS 250SC (azoxystrobin 250 g a.i./L), INSPIRE 250EC (difenoconazole 250 g a.i./L) and QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L)

METHODS: The trial was conducted in a commercial asparagus field in Elgin County, Ontario on sandy soil. The field was established with 'Millennium' asparagus crowns in 2013 and maintained according to commercial practice. The crowns were planted approximately 0.2 m apart in rows spaced 1.2 m apart. Individual experiment plots were 6 m long by 1 row wide. Each treatment plot was separated by an untreated buffer row to prevent spray drift among treatments. Each treatment was replicated four times and arranged in a randomized complete block design. Replications were separated by a 2-m-long space of untreated ferns to prevent spray drift among replications. Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom equipped with 50 mesh screens and AI11005 nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Treatments were applied on 16 June, 1 July, 16 July, 30 July, and 11 Aug. Disease assessments were made every 14 days following the first application through to the end of October. Purple spot was assessed per plot and rated on a scale of 0 to 5, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 90 to 150 lesions and 5 > 150 lesions. The area under the disease progress curve (AUDPC) was calculated using the following equation: where Y_i is rating at day X_i and Y_{i-1} is the rating at day X_{i-1}: $AUDPC = \Sigma [((Y_i + Y_{i-1}) (X_i - X_{i-1}))/2]$. Fern yellowing (% area) and needle drop (%), common symptoms of purple spot, were visually estimated. Data were analyzed using SAS PROC MIXED and statistical differences among means were separated using Tukey's HSD test ($P \leq 0.05$).

RESULTS: As outlined in Table 1.

CONCLUSIONS: Disease severity was low until September, and differences were observed among the treatments by the end of the summer. QUADRIS TOP (1 L/ha) and INSPIRE (376 and 500 ml/ha) had significantly lower AUDPC values than the UNTREATED CHECK. By 30 September, all fungicide treatments had significantly less fern yellowing and needle drop than the UNTREATED CHECK. At 26 October, only INSPIRE (500 ml/ha) and both application rates of QUADRIS TOP had significantly less needle drop than the UNTREATED CHECK.

Table 1. The effect of foliar fungicides on purple spot in asparagus.

Treatment rate/ha	AUDPC[1]		fern yellowing (%area)				defoliation or needle drop (%)			
			25 Aug	30 Sep		26 Oct	25 Aug	30 Sep		26 Oct	
UNTREATED CHECK.....	127	c[2]	17.5	56.3	b[z]	93.8	5.0	43.8	c[z]	100.0	d[z]
INSPIRE 188 ml	100	abc	3.8	27.5	a	87.5	7.5	15.0	ab	90.0	cd
INSPIRE 376 ml	97	ab	5.0	20.0	a	86.3	0.0	10.0	ab	85.0	bcd
INSPIRE 500 ml	91	ab	5.0	17.5	a	82.5	5.0	8.8	ab	66.3	ab
QUADRIS 0.6 L	106	abc	7.5	23.8	a	85.0	5.0	10.0	ab	95.0	d
QUADRIS 0.8 L	114	bc	15.0	28.8	a	91.3	2.5	18.8	b	92.5	d
QUADRIS TOP 0.75 L.....	100	abc	5.0	13.8	a	85.0	2.5	5.0	a	70.0	abc
QUADRIS TOP 1 L.....	83	a	2.5	6.3	a	83.8	1.3	3.8	a	58.8	a
P-value	0.0012		0.0878	<0.0001		0.7788	0.6396	<0.0001		<0.0001	

[1]Area Under the Disease Progress Curve (AUDPC).

[2]Figures in column with the same letter are not significantly different (Tukey's HSD; $P \leq 0.05$).

2015 PMR REPORT # 16 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Asparagus, *Asparagus officinalis* L., cv. Millennium
PEST: Rust, *Puccinia asparagi* DC and purple spot, *Stemphylium vesicarium* (Wallr.) Simmons

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TITLE: FIELD EVALUATION OF FUNGICIDES FOR THE CONTROL OF ASPARAGUS RUST AND PURPLE SPOT IN A 2-YEAR-OLD FIELD, 2015.

MATERIALS: QUADRIS 250SC (azoxystrobin 250 g a.i./L), INSPIRE 250EC (difenoconazole 250 g a.i./L) and QUADRIS TOP 325SC (azoxystrobin 200 g a.i./L and difenoconazole 125 g a.i./L)

METHODS: The trial was conducted in a commercial asparagus field in Elgin County, Ontario on sandy soil. The field was established with 'Millennium' asparagus crowns in 2014 and maintained according to commercial practice. The crowns were planted approximately 0.2 m apart in rows spaced 1.2 m apart. Individual experiment plots were 6 m long by 1 row wide. Each treatment plot was separated by an untreated buffer row to prevent spray drift among treatments. Treatments were replicated four times and arranged in a randomized complete block design. Replications were separated by a 2-m-long space of untreated fern to prevent spray drift among replications. Fungicide treatments were applied with a CO_2 backpack sprayer (Bellspray Inc., Opelousas, LA) and a 3-nozzle boom equipped with 50 mesh screens and AI11005 nozzles spaced 50 cm apart, calibrated to deliver 400 l/ha. Treatments were applied on 22 July, 5 August, 18 August, 1 September, and 15 September. Disease assessments were made every 14 days following the first application through to 26 October. Rust severity (% area) was assessed by estimating the area (%) of the fern covered in rust pustules on 3 August and 30 August. Purple spot was assessed per plot and rated on a scale of 0 to 5, where 0 = no lesions, 1 = 1 to 20 lesions, 2 = 21 to 50 lesions, 3 = 51 to 90 lesions, 4 = 90 to 150 lesions and 5 > 150 lesions. The area under the disease progress curve (AUDPC) was calculated using the following equation: where Y_i is rating at day X_i and Y_{i-1} is the rating at day X_{i-1}: $AUDPC = \Sigma [((Y_i + Y_{i-1}) (X_i - X_{i-1}))/2]$. Fern yellowing (% area) and needle drop (%), common symptoms of purple spot, were visually estimated. Data were analyzed using SAS PROC MIXED and statistical differences among means were separated using Tukey's HSD test ($P \leq 0.05$).

RESULTS: As outlined in Tables 1 and 2.

CONCLUSIONS: Rust and purple spot severity was low throughout the summer, and purple spot disease severity was moderate by the end of the summer (Tables 1 and 2). The disease progressed slower in all treated plots compared to the UNTREATED CHECK except in plots treated with INSPIRE at 376 ml/ha (Table 2). By 30 September, all treatments had significantly less fern yellowing and needle drop than the UNTREATED CHECK. Similarly, at 26 October, all treatments had less needle drop than the UNTREATED CHECK (Table 2).

Table 1. The effect of foliar fungicides on rust and purple spot in asparagus.

Treatment rate/ha	rust severity (% area)		purple spot	
	3 Aug	30 Aug	AUDPC	
UNTREATED CHECK.....	6.3	8.8	128	b[1]
INSPIRE 188 ml	0.0	0.0	80	a
INSPIRE 376 ml	1.3	2.5	83	ab
INSPIRE 2500 ml	1.3	3.8	70	a
QUADRIS 0.6 L	0.0	0.0	73	a
QUADRIS 0.8 L	1.3	1.3	59	a
QUADRIS TOP 0.75 L.....	0.0	0.0	58	a
QUADRIS TOP 1 L.....	0.0	0.0	52	a
P-value	0.1598	0.3335	0.0007	

[1]Figures in column with the same letter are not significantly different (Tukey's HSD; P≤0.05).

Table 2. The effect of foliar fungicides on fern yellowing (%area) and needle drop or defoliation (%) in asparagus.

Treatment rate/ha	fern yellowing (% area)				needle drop or defoliation (%)			
	3 Sep	30 Sep		26 Oct	3 Sep	30 Sep		26 Oct	
UNTREATED CHECK.....	5.0	60.0	b[1]	95.0	5.0	51.3	b	92.5	b
INSPIRE 188 ml	4.0	12.5	a	83.8	2.5	6.3	a	50.0	a
INSPIRE 376 ml	22.5	15.0	a	82.5	1.3	7.5	a	57.5	a
INSPIRE 500 ml	2.5	10.0	a	78.8	2.5	7.5	a	48.8	a
QUADRIS 0.6 L	2.5	8.8	a	86.3	1.3	5.0	a	52.5	a
QUADRIS 0.8 L	5.0	8.8	a	67.5	6.3	6.3	a	37.5	a
QUADRIS TOP 0.75 L.....	1.3	6.3	a	72.5	1.3	2.5	a	27.5	a
QUADRIS TOP 1 L.....	1.3	6.3	a	62.5	1.3	3.8	a	28.8	a
P-value	0.3346	<0.0001		0.1950	0.3657	<0.0001		<0.0001	

[1]Figures in column with the same letter are not significantly different (Tukey's HSD; *P*≤0.05).

2015 PMR REPORT # 17 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Carrot (*Daucus carota* sub sp. s*ativus* (Hoffm.) Arcang.), cv. Cellobunch
PEST: Fusarium spp.

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TITLE: **EVALUATION OF PIC PLUS FUMIGANT FOR CONTROL OF FUSARIUM ROOT ROT ON CARROTS, 2015**

MATERIALS: PIC PLUS (chloropicrin 86%)

METHODS: The trial was conducted in a commercial carrot field with a history of fusarium root rot of carrots in the Holland/Bradford Marsh, Ontario. Carrots, cv. Cellobunch, were direct seeded at 65 seeds/m on raised beds on 27 May, using a Stanhay Precision Seeder. Each experimental unit consisted of three hills, 66 cm apart. PIC PLUS was applied the entire length of the field. Treatments were PIC PLUS at 108, 70 and 54 L/ha applied using a custom-built carrot seeder equipped with shanks to inject the product 25 cm below the carrot seed. Eight 10 meter check plots were randomly placed throughout the treatment area. A 50-carrot sample (9 September) and a harvest sample of carrots from 1.5 m of row (27 October) were harvested by hand, topped and placed in storage. Samples were washed in a small drum washer and visually assessed for fusarium rot lesions and sorted into classes based on the number of lesions per carrot. Marketable yield was also determined from the harvest sample. The grading classes were: healthy or disease free, 1 lesion per carrot, 2 lesions per carrot, 3 lesions per carrot, 4 or greater-than lesions per carrot. The disease severity index (DSI) was determined using the following equation:

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

Compared to the previous 10 year averages, air temperatures in 2015 were above average for May (15.9°C) and September (18.9°C), below average for June (17.7°C), and average for July (20.5°C), August (19.5°C) and October (9.3°C). The 10 year average temperatures were: May 13.4°C, June 18.9°C, July 20.9°C, August 19.6°C, September 15.5°C and October 9.5°C. Monthly rainfall was below the 10 year average for May (40 mm), July (36 mm), September (27 mm) and October (54 mm), above average for June (171 mm), and average for August (79 mm). The 10 year rainfall averages were: May 66 mm, June 75 mm, July 94 mm, August 69 mm, September 85 mm and October 72 mm. 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 with $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: There were significant differences in disease incidence and severity among the treatments. Fusarium incidence and severity increased from September to harvest in October. PIC PLUS at 108 L/ha reduced fusarium root rot incidence in the September and November assessments compared to the 54 L/ha and the check (Table 1). However, PIC PLUS at 108 L/ha had the highest percentage of forked carrots compared to all other treatments (Table 2). At harvest (3 November), the 108 L/ha rate of

PIC PLUS had significantly higher percentage of fusarium free carrots compared to the 54 L/ha rate and the check. The 54 L/ha rate also had (numerically) the highest percentage of carrots with four or more lesions per carrot (Table 2).Using PIC PLUS at 108 L/ha resulted in the lowest fusarium incidence and the highest rate of forking. Adjustments may need to be made to the timing of seeding in relation to fumigating to prevent seedling damage.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Plant Production Systems of the Ontario Ministry of Agriculture and Food and Ministry of Rural Affairs and the University of Guelph partnership**.**

Table 1. Incidence and severity of fusarium root rot of carrots treated with various rates of PIC PLUS in muck soil in the Holland Marsh, Ontario, 2015.

Treatment	Rate L/ha	Disease Incidence (%)		DSI[1]	
		9 Sept	3 Nov	9 Sept	3 Nov
PIC PLUS	108	0.3 a[2]	7.5 a	0.1 a	1.9 ns[3]
PIC PLUS	70	15.0 ab	20.8 ab	5.2 a	5.9
PIC PLUS	54	34.7 b	39.1 b	15.3 b	15.8
Check	---	23.4 b	32.0 b	9.6 ab	12.4

[1] Disease Severity Index (DSI) was determined using the following equation:

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

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

[3] ns= no significant differences were found among the treatments

Table 2. Marketable yield and disease incidence and severity of fusarium root rot of carrots following treatments with PIC PLUS in muck soil in the Holland Marsh, Ontario, 2015.

Treatment	Rate L/ha	% Fusarium Free	% Forked	% Carrots with Lesions				Yield t/ha
				1 Lesion	2 Lesions	3 Lesions	4 Lesions	
PIC PLUS	108	92.5 a[1]	38.4 b	7.3 a	0.2 a	0.0 ns[2]	0.0 ns	67.7 ns
PIC PLUS	70	79.2 ab	3.8 a	18.5 b	1.9 ab	0.0	0.4	50.8
PIC PLUS	54	60.9 b	0.3 a	23.4 b	11.0 b	1.0	3.7	32.5
Check	---	68.0 b	2.4 a	19.7 b	8.5 ab	2.5	1.3	49.5

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

[2] ns = no significant differences were found among the treatments

2015 PMR REPORT # 18 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Celery (*Apium graveolens*) cv.TZ 6200
PEST: Celery Anthracnose (*Colletotrichum acutatum*)

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TITLE: **EVALUATION OF FUNGICIDES FOR THE CONTROL OF CELERY LEAF CURL, 2015**

MATERIALS: ALLEGRO (fluazinam 40.0%), BRAVO (chlorothalonil 50%), FLINT (trifloxystrobin 50%)

METHODS: The trial was conducted on organic soil at the Muck Crops Research Station (pH ≈ 5.9, organic matter ≈ 66%), Holland Marsh, Ontario. Celery, cultivar TZ6200 were seeded in the greenhouse on 7 May, and hand transplanted in the field plots on 24 June, with in-row plant spacing of 18 cm. A randomized complete block arrangement with four replicates per treatment was used. Each plot consisted of 3 rows, 55 cm apart and 5 m in length. BRAVO 500 at 2.4 L/ha, FLINT at 210 g/ha and ALLEGRO at 1.16 L/ha were applied on 31 July, 13 August and 8 September using a R&D Sprayers CO_2 backpack sprayer equipped with four TeeJet 8002 VS fan nozzles spaced 40 cm apart and calibrated to deliver 500 L/ha at 275 kPa. Unsprayed check plots were included for comparison. Plots were arranged in a randomized complete block design with four replicates per treatment. The trial was inoculated with *Colletotrichum acutatum* made from freshly collected diseased celery leaves, grown on V8 agar at 25°C and allowed to colonize the plate. On 18 August, conidia were scraped from the plates and suspended in sterile water to a concentration of 100,000 spores/mL. Tween 20 was added as a surfactant. Four liters of the condia suspension was immediately sprayed evenly over the entire trial area using a CO_2 backpack sprayer fitted with four fan-type TeeJet 8002 nozzles to inoculate the trial. On 2 September Plants in the outside two rows in each replicated plot were counted on 2 September and the number of plants with disease symptoms was recorded. Fifteen celery plants were harvested from the centre row of each replicated plot on 13 October, trimmed to 40 cm, weighted and assessed to determine marketable yield. Plants were inspected for the presence of leaf curl based on visual symptoms such as leaf cupping and petiole twisting and the presence of lesions in the heart of the celery.
Compared to the previous 10 year averages, air temperatures in 2015 were above average for September (18.9°C), below average for June (17.7°C) and average for July (20.5°C), August (19.5°C) and October (9.3°C). The 10 year average temperatures were: June 18.9°C, July 20.9°C, August 19.6°C, September 15.5°C and October 9.5°C. Monthly rainfall was below the 10 year average for July (36 mm), September (27 mm) and October (54 mm), above average for June (171 mm), and average for August (79 mm). The 10 year rainfall averages were: June 75 mm, July 94 mm, August 69 mm, September 85 mm and October 72 mm. All data were analyzed using the General Analysis of Variance function of Statistics V.l0. Means separation was obtained using Fisher's Protected LSD test with $P = 0.05$ level of significance.

RESULTS: as presented in Table 1

CONCLUSIONS: Inoculation of the trial provided an even distribution of disease throughout the experimental area. Significant differences were observed among the treatments on both assessment dates (Table 1). All fungicides reduced celery anthracnose compared to the check. Celery sprayed with FLINT had the lowest percent disease on both assessment dates. Celery sprayed with ALLEGRO did not differ in disease incidence compared to the check at harvest. Both FLINT and BRAVO are currently registered for leaf blight control in celery and may help control celery leaf curl as well. No significant differences in marketable weight were found among the treatments.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Fresh Vegetable Growers of Ontario**.**

Table 1. Leaf curl incidence and weight per head for celery, cv. TZ 6200, inoculated with *Colletotrichum acutatum* and grown at Muck Crops Research Station, Holland Marsh, Ontario, 2015.

Treatment	% Disease 2 Sept[1]	% Disease at harvest[2]	Marketable Yield (g)
FLINT	6.9 a[3]	34.3 a	1044.6 ns[4]
BRAVO	9.9 a	44.5 a	1127.1
ALLEGRO	11.3 a	51.8 ab	1059.6
Check	27.5 b	83.0 b	924.7

[1]Celery was assessed for leaf curl incidence in the field 2 September.
[2] Percent disease by weight was based only on leaf curl incidence at harvested 13 October.
[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Fisher's Protected LSD Test.
[4] ns = no significant difference among the treatments

2015 PMR REPORT # 19 **SECTION L: VEGETABLE and SPECIAL CROPS - Diseases**

CROP: Cucumber (*Cucurbita moschata* Duch.) cv. Marketmore
PEST: Downy Mildew (*Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rosotvzer)

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TITLE: **EVALUATION OF FUNGICIDES FOR CONTROL OF DOWNY MILDEW IN CUCUMBER, 2015**

MATERIALS: F9170-1 (experimental), F9177-1 (experimental), F4134-2 (experimental), AGRAL 90 (nonylphenoxy polyethoxy ethanol 92%), BRAVO 500 (chlorothalonil 50%), PHOSTROL (mono- and dibasic sodium, potassium, and ammonium phosphites 53.6%), TATTOO C (propamocarb HCl 375 g/L chlorothalonil 375 g/L), DITHANE (mancozeb 75%)

METHODS: The trial was conducted at a mineral soil site (pH ≈ 7.1, organic matter ≈ 1.8%) near the Muck Crops Research Station, Holland Marsh, Ontario. On 3 June, cucumbers, cv. Marketmore, were hand-seeded into holes cut into 1.5 m wide, 3 mm thick black plastic mulch. Each experimental unit consisted of an 8 m long staggered twin row spaced 1.25 apart with 1 m in-row spacing. A randomized complete block arrangement with four replicates was used. Separate plots were treated with F9170 + AGRAL 90 (300 g/ha + 2.5 mL/L), F9177-1 (1000 and 1500 g/ha), F9177-1 + AGRAL 90 (1000 and 1500 g/ha + 2.5mL/L AGRAL 90), BRAVO 500 (1.95 L/ha), F4134-2 (3.3 L/ha), PHOSTROL (2.0 L/ha), and TATTOO C or DITHANE (2.7 L/ha or 1.5 kg/ha) on 23 July when the first symptoms of downy mildew appeared. Subsequant applications were applied on 29 July, 5, 12 and 21 August. All treatments were applied using a tractor mounted sprayer fitted with AI TeeJet Air Induction Even Flat spray tips (AI9503 EVS) at 415 kPa calibrated to deliver 550 L/ha. An untreated check was included for comparison. On 28 July, 4, 11, 14 and 25 August downy mildew severity was assessed by rating each replicate for the percentage of leaf area damaged by downy mildew using the following scale: 0 = no damage, 1 = 1-3 %, 2 = 4-6%, 3 = 7-12%, 4 = 13-25%, 5 = 26-50%, 6 = 51-75%, 7 = 76-87%, 9 = 94-97%, 10 = 98-100% leaf area damaged. Disease severity values were used to calculate the area under disease progress curve (AUDPC) using the following formula:

$$\text{AUDPC} = \sum_{j=1}^{N_{j-1}} \left(\frac{y_j + y_{j+1}}{2}\right)\left(t_{j+1} - t_j\right)$$

Where y = DM incidence at the jth observation, t = time (days) since the previous DM incidence at the jth observation and n = total number of observations.
On 4, 7, 11, 14, 18 and 24 August, mature cucumbers were harvested from a 2 m section of row from each replicate and sorted into marketable and unmarketable fruit to determine yield.
Compared to the previous 10 year averages, air temperatures in 2015 were below average for June (17.7°C) and average for July (20.5°C) and August (19.5°C). The 10 year average temperatures were: June 18.9°C, July 20.9°C and August 19.6°C. Monthly rainfall was below the 10 year average for July (36 mm), above average for June (171 mm) and average for August (79 mm). The 10 year rainfall averages were: June 75 mm, July 94 mm and August 69 mm. All data were analyzed using the General

Analysis of Variance function of Statistics V.l0. Means separation was obtained using Fisher's Protected LSD test with $P = 0.05$ level of significance.

RESULTS: Downy mildew progressed quickly in the trial. Cucumbers sprayed with F9177-1 at 1.5 kg/ha + AGRAL 90, F9177-1 at 1.0 and 1.5 kg/ha and BRAVO had significantly lower disease severity ratings than PHOSTROL at 2 L/ha and F9170-1 at 300 g/ha + AGRAL 90 and the untreated check on the 11, 14 and 25 August (Table 1). All treatments containing F9177-1 had significantly lower AUDPC than the PHOSTROL, F9170-1 + AGRAL 90 treatments and untreated check.
Cucumber fruit harvested from plots sprayed with F9177 at 1.0 and 1.5 kg/ha + AGRAL 90 had significantly higher marketable yield and more marketable cucumbers than plots sprayed with TATTOO C or DITHANE and PHOSTROL and the untreated check (Table 2).

CONCLUSIONS: F9177-1 at 1.5 kg/ha effectively reduced downy mildew severity and increased marketable yield in cucumber cv. Marketmore in 2015. The addition of AGRAL 90 also improved effectiveness of F9177-1.

ACKNOWLEDGEMENTS: Funding for this project was provided by FMC Agricultural Solutions.

Table 1. Downy mildew severity for cucumber, cv. Marketmore, treated with various fungicides, grown near the Muck Crops Research Station, Holland Marsh, 2015.

Treatment	Rate (per ha)	Downy mildew severity ratings[1]					AUDPC
		28 Jul	4 Aug	11 Aug	14 Aug	25 Aug	
F9177-1 + Agral 90	1.5 kg + 0.25% v/v	1.3 ns[2]	2.0 a[3]	3.0 a	3.0 a	5.3 a	83.3 a
F9177-1	1.5 kg	1.3	1.8 a	3.0 a	3.5 ab	5.8 ab	87.8 ab
F9177-1	1.0 kg	1.0	1.5 a	3.3 ab	3.5 ab	6.0 ab	87.8 ab
BRAVO 500	1.95 L	1.0	1.6 a	3.3 ab	3.5 ab	6.4 ab	90.7 ab
F9177-1 + Agral 90	1.0 kg + 0.25% v/v	1.0	1.5 a	3.8 abc	4.0 abc	6.6 bc	97.2 ab
F4134-2	3.3 L	1.3	2.0 a	3.8 abc	4.0 abc	6.8 bc	102.3 abc
TATTOO C or DITHANE	2.7 L or 1.5 kg	1.5	2.5 a	4.8 bcd	4.8 bc	6.8 bc	116.9 bc
PHOSTROL	2.0 L	1.0	3.0 ab	5.3 cd	5.5 cd	7.8 cd	131.9 cd
F9170-1 + Agral 90	300 g + 0.25% v/v	1.5	4.3 b	6.0 de	7.0 de	8.5 d	160.8 de
Check	--	1.5	6.3 c	7.0 e	8.0 e	9.0 d	189.5 e

[1] Percent leaf area with DM lesions was estimated and ratings were made using the following scale: 0 = no DM, 1 = 1-3%, 2 = 4-6%, 3 = 7-12%, 4 = 13-25%, 5 = 26-50%, 6 = 51-75%, 7 = 76-87%, 9 = 94-97%, 10 = 98-100%.
[2] ns = no significant differences were found among the treatments
[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Fisher's Protected LSD Test.

Table 2. Season total yield for cucumbers, cv. Marketmore, treated with fungicides, grown near the Muck Crops Research Station, Holland Marsh, 2015.

Treatment	Rate	Marketable Yield for Season[1]	
		Weight (kg)	Number of fruit
F9177-1 + AGRAL 90[2]	1.5 kg	13.6 a[3]	50.0 a
F9177-1 + AGRAL 90	1 kg	13.1 ab	47.5 a
BRAVO	1.95 L	12.2 abc	45.3 abc
F9177-1	1.5 kg	13.0 ab	45.3 ab
F9177-1	1.0 kg	12.0 abc	41.0 a-d
F4134-2	3.3 L	9.6 bcd	34.0 bcd
TATTOO C or DITHANE	2.7 L or 1.5 kg	9.0 cd	31.3 cd
PHOSTROL	2.0 L	8.1 d	30.0 d
F9170-1 + AGRAL 90	300 g	7.8 d	29.8 d
Check	--	6.6 d	28.5 d

[1] Marketable cucumbers harvested on 4, 7, 11, 14, 18 and 24 August from a 2 m section of row.
[2] AGRAL 90 used at 0.25% v/v
[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Fisher's Protected LSD Test.

2015 PMR REPORT # 20 **SECTION L: VEGETABLE and SPECIAL CROPS – Diseases**

CROP: Yellow cooking onions (*Allium cepa* L.), cv. La Salle
PEST: *Stemphylium vesicarium* (Wallr.)

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TITLE: COMPARISON OF SPRAY TIMING PROGRAMS FOR MANAGEMENT OF STEMPHYLIUM LEAF BLIGHT OF ONION, 2015

MATERIALS: LUNA TRANQUILITY (fluopyram 12.5%, pyrimethanil 37.5%)

METHODS: Three disease forecasting programs were evaluated in field trials for their efficacy in the management of Stemphylium leaf blight on onions. Plugs of onion cultivar La Salle were transplanted on 26 May with 2-3 plant per transplant plug, into organic soil organic matter ≈ 62%, pH ≈ 7.2) near the Muck Crops Research Station, Holland Marsh, Ontario. The trials were arranged in a randomized complete block design with four replicates. Each experimental unit (plot) consisted of two beds of onions. Each bed had four rows, 42 cm apart and 5 m in length. Insects and weeds were managed according to regional recommendations. LUNA TRANQUIL-ITY was applied with a custom-built CO_2 backpack sprayer equipped with four TeeJet 8002 VS fan nozzles spaced 40 cm apart on the boom and calibrated to deliver 400 L ha^{-1} at 240 kPa.
The timing of fungicide application was determined using BOTCAST (Botrytis leaf blight forecasting model), TOMCAST (Tomato forecasting model for Septoria leaf spot and fruit anthracnose) at a threshold of DSV15, a new model for Stemphylium leaf blight (STEMCAST), the first appearance of spores in a spore trap (SPORE TRAP), a routine calendar spray schedule (CALENDER) starting on 29 June, and nontreated control (CONTROL). The number of sprays that resulted from each treatment was recorded and the cost associate with spraying was calculated. The number of Stemphylium lesions was counted on 32 onion leaves per plot (four leaves on each of eight transplant plugs) on 02 July and the mean number of lesions per leaf was calculated. Disease incidence (%) was assessed on 02 July, 9 July, 16 July and 23 July by counting the number of plants per plot with leaf blight symptoms. Severity (%) was assessed on 23 July, 31 July, 06 August and 13 August by measuring the length of leaf dieback on 32 plants within an experimental plot. On 10 September, onions in two 2.3-m sections of row from each replicate were harvested and stored at 20–23 °C. The onions were weighed and graded for bulb size on 21 October. Compared to the previous 10-year average, air temperatures in 2015 were above average for May (15.9° vs. 13.4°C) and September (18.9° vs. 15.5°C), below average for June (17.7° vs. 18.9°C), and near-normal for July (20.5° vs. 20.9°C), August (19.5° vs. 19.6°C) and October (9.3° vs. 9.5°C). Monthly rainfall was below the 10-year average for May (40 vs. 66 mm), July (36 vs. 94 mm), September (27 vs. 85 mm) and October (54 vs. 72 mm), above average for June (171 vs. 75 mm), and near-normal for August (79 vs. 69 mm). Data were analyzed using the Proc Mixed function of SAS 9.4 (SAS Institute, Cary, USA). Mean separation was conducted using Tukey's multiple range test (α=0.05).

RESULTS: Presented in Tables 1 and 2.

CONCLUSIONS: Stemphylium leaf blight lesions were observed in the trial in early July, when plants were at the 5- to 7-leaf growth stage. The number of lesions observed was lower in plots that were sprayed compared to nontreated control (Table 1). Onions sprayed according to TOMCAST and spore trap assessment had the lowest incidence of leaf blight. The disease progressed rapidly, with final incidence of 74–98% for all treatment. Application of fungicides reduced disease severity by 18–22% compared the nontreated control (Table 1). LUNA TRANQUILITY was applied 10 times based on spore trap counts, whereas the BOTCAST and STEMCAST models prompted 8 applications, which was similar to the calendar spray schedule (Tables 1 and 2). The TOMCAST model prompted 6 applications. There were no differences in marketable yield, but the treatment sprayed according to spore trap counts had more jumbo onions than the control. Applying fungicides to manage Stemphylium blight based on the TOMCAST forecast model provided a saving of 2-4 fungicides applications equivalent to $266–$532 per hectare.

ACKNOWLEDGEMENTS: Funding provided by Ontario Ministry of Agriculture, Food and Rural Affairs/Univ. of Guelph Partnership and The Bradford Cooperative Storage and the Fresh Vegetable Growers of Ontario through Growing Forward 2.

Table 1. Incidence and severity (% leaf area) of Stemphylium leaf blight on onion cv. La Salle sprayed with fungicide based on selected forecasting treatments near the Muck Crops Research Station, Holland Marsh, ON, 2015.

		Lesions	Incidence (%)		Severity (%)	
Treatment	Spray dates	(#/plant)	2 Jul	23 Jul	23 Jul	13 Aug
BOTCAST	Jun 28, Jul 8, 15, 22, 29, Aug 5, 12, 19	6.5 a[1]	50 ab	85 b	10 b	43 b
TOMCAST 15	Jun 13, 30, Jul 14, 26, Aug 4, 12	4.2 b	37 bc	79 bc	10 b	42 b
STEMCAST	Jun 29, Jul 8, 15, 22, 29, Aug 5, 12, 19	6.7 a	52 a	85 b	15 b	47 b
SPORE TRAP	Jun 13,19,28, Jul 8, 15, 22, 29, Aug 5, 12, 19	4.0 a	33 c	74 c	12 b	46 b
CALENDAR	Jun 29, Jul 8, 15, 22, 29, Aug 5, 12, 19	7.0 a	59 a	90 ab	14 b	44 b
Control	Not sprayed	6.8 a	61 a	98 a	28 a	65 a

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

Table 2. Marketable yield and bulb size distribution of onion cv. La Salle sprayed with fungicide and the saving associated with selected forecasting models in a field trial at the Muck Crops Research Station, Holland Marsh, ON in 2015.

			Bulb size distribution (%)			
Treatment	Spray dates	Yield (t/ha)	Jumbo (>76 mm)	Medium	Cull (<45 mm)	Savings ($/ha)
BOTCAST	Jun 28, Jul 8, 15, 22, 29, Aug 5, 12, 19	52.0 ns	13 ab[1]	39 ns	3 ns	0
TOMCAST 15	Jun 13, 30, Jul 14, 26, Aug 4, 12	53.0	15 ab	39	4	$266–532
STEMCAST	Jun 29, Jul 8, 15, 22, 29, Aug 5, 12, 19	45.8	13 ab	33	5	0
SPORE TRAP	Jun 13,19,28, Jul 8, 15, 22, 29, Aug 5, 12, 19	55.0	21 a	34	4	-$266
CALENDER	Jun 29, Jul 8, 15, 22, 29, Aug 5, 12, 19	45.8	12 ab	34	4	0
Control	Not sprayed	46.0	9 b	38	4	Unsprayed

[1]Numbers in a column followed by the same letter do not differ based on Tukey's multiple range test at $P = 0.05$. ns = not significant.

[2]Savings relative to a calendar spray program.

2015 PMR REPORT # 21 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS - Diseases**

CROP: Canola (*Brassica napus* L., *B. rapa* L. and *B. juncea* (L.) Vassiliĭ Matveievitch Czernajew)
PEST: Clubroot (*Plasmodiophora brassicae* Woronin)

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TITLE: IDENTIFICATION OF BORON TOLERANT CANOLA CULTIVARS AND CLUBROOT SEVERITY FOLLOWING BORON APPLICATION

MATERIALS: Solubor (boron 20.5%)

METHODS: An experiment to assess the impact of an application of boron on phytotoxic and clubroot severity on lines of *Brassica napus*, *B. rapa* and *B. juncea*, was conducted on a muck soil (~70% organic soil) infested with *P. brassicae* pathotype 6 at the Muck Crops Research Station (MCRS) in Bradford Ontario. Seed of the lines was provided by Plant Gene Resource Canada, Saskatoon, SK. From May 11–13, 150 lines were seeded in germination trays with 120 seeds per line. The germinating seedlings were maintained in a greenhouse at 18°-25° C, 13-hr photoperiod and 70% R.H, and received water and fertilizer as needed. Germination was assessed after 3 weeks. The germination was low in many of the lines, so only 88 of the 150 lines produced sufficient seedlings to transplant to the field. Seedlings were hand transplanted from 08-10 June. The trial was laid out in a split-plot design with four replicates, with boron (treated vs. control) as the whole plot factor and lines as the subplot factor. Each plot consisted of a single row of 10 plants. Boron (Solubor, 20.5% B) was applied as a drench on June 12 using a CO_2 backpack sprayer at a rate of 39 kg/ha in1500 L H_2O per ha. Heavy rains after treatment (June 13-14) removed boron from the soil and no symptoms of phytotoxicity were apparent by June 19. Therefore, a second application of Solubor at the same rate was made on June 20. Boron toxicity on each plant was assessed on June 26 on a 0-3 scale, where 0 = no symptoms, 1 = light marginal burning, 2 = marginal burning + cupping, and 3 = substantial marginal burning + cupping. The toxicity score for each plot was calculated using the equation below. The lines with the highest and lowest toxicity scores (Table 1) were selected for additional analysis. Data for one additional cultivar in the susceptible group were later disqualified due to physical damage at harvest.

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

Clubroot incidence and severity on each plant were assessed on a 0-3 scale, where 0 = no symptoms, 1 > 1/3 clubbing, 2 = 1/3 to 2/3 clubbing, and 3 > 2/3 of the root clubbed. Fresh and dry top weights were measured for the 10 tolerant and 9 sensitive cultivars.

A mixed model analysis of variance (Proc GLIMMIX) and Tukey's test at $\alpha = 0.05$ were used to assess differences between treatments and sensitivity grouping (SAS v 9.3). Uneven distribution of resting

spores within the field had a large effect on clubroot severity in some lines, so these data points, along with outliers identified with Lund's test, were removed from the data set.

RESULTS: as outlined in Figure 1, Table 1.

CONCLUSIONS: The 88 lines differed in boron-induced phytotoxicity (data not shown). Mean clubroot severity in the nontreated control did not differ between the most boron-sensitive lines and the tolerant group. Also, there were no differences in fresh or dry weight between the boron sensitive and tolerant groups (not shown).

Among the 19 most sensitive / most tolerant lines examined, clubroot severity was reduced by application of boron, but the effect was stronger in the boron-tolerant lines. Within the boron-tolerant group, clubroot severity was affected by both line ($P = 0.001$) and treatment ($P = 0.03$) (not shown).

Differences in boron induced phytotoxicity among lines may be the result of an alternate boron allocation pathway or a decrease in the rate of boron transport into the xylem. Reduced clubroot severity from boron application demonstrated that boron had a negative impact on clubroot. Boron may affect colonization of the root after secondary infection, or possible affect cytokinin and auxin metabolism, which are altered as a result of *P. brassicae* secondary infection.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Canola Council of Canada and Agriculture and Agri-Food Canada through the Canola Science Cluster of Growing Forward 2.

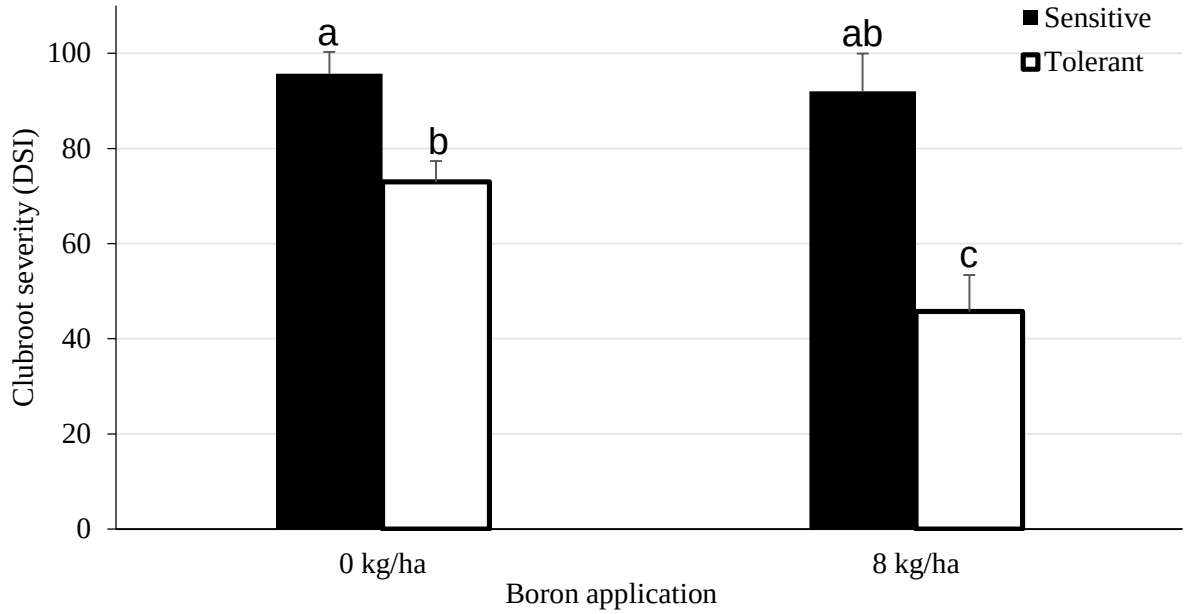

Figure 1. Mean clubroot severity (disease severity index, DSI) of boron sensitive and tolerant cultivar groups after a 1500L drench application of boron at 8 kg/ha at the Muck Crops Research Station in Bradford ON, in 2015. Bars with the same letter do not differ based on Tukey's test at $P < 0.05$.

Table 1. Phytotoxicity and clubroot severity in boron-tolerant and sensitive lines of *Brassica napus* treated with a 1500 L ha^{-1} drench application of boron at 8 kg ha^{-1}, trial conducted at the Muck Crops Research Station in Bradford ON, summer 2015.

	Phytotoxicity		Clubroot severity	
Line	Control	Treated	Control	Treated
B-sensitive lines				
Lonto	2 ns[1]	77 ab[2]	97 ns	99 ns
Prominent	0	43 b	93	96
SRS 3531	0	71 ab	100	97
SRS 3490	0	66 ab	100	94
SRS 3483	1	83 a	91	90
SRS 3481	0	65 ab	100	98
SRS 3376	0	64 ab	89	97
SRS 3466	2	68 ab	96	77 [2]
SRS 3461	0	66 ab	100	98
B-tolerant lines				
Ghobi	0 b[1]	25 bc	69 abc	37 abc
GhobiSaron CN_101868	0 b	27 bc	86 ab	64 abc
GhobiSaron CN_101869	0 b	26 bc	72 abc	47 abc
Jumbo	0 b	25 bc	97 a	57 abc
Nevin	0 b	21 bcd	48 abc	43 abc
PAK_85903	1 b	26 bc	55 abc	18 bc
Peace	0 b	27 bc	81 abc	84 abc
R_3420	8 a	55 a	77 abc	34 abc
UC77_1047	0 b	39 ab	67 abc	69 abc
UC77_1251	0 b	30 bc	66 abc	8 c

[1] Values in B-sensitive or B-tolerant columns followed by the same letter do not differ based on Tukey's test at $P = 0.05$. ns = No significant differences
[2]Mean value calculated based on only two repetitions

2015 PMR REPORT # 22 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several
PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **DEOXYNIVALENOL LEVEL AND *FUSARIUM GRAMINEARUM* 15-ADON AND 3-ADON CHEMOTYPES OF WINTER WHEAT IN ONTARIO**

METHODS: Grain samples from six winter wheat cultivars included in the '2013 Ontario Performance Trial' from Ridgetown, Palmerston, Elora, Inwood and Woodslee location were selected at harvest to assess the percentage of *Fusarium*- infected kernels, the percentage of *F. graminearum* and the relative frequency of *F. graminearum* 15-ADON and 3-ADON chemotypes. The cultivars chosen were E0028W, AC Mackinnon, Emmit, 25R39, Whitebear and AC Morley. One hundred and fifty kernels of each cultivar were surface-sterilized in 0.16% NaOCl (dilute commercial bleach) for three minutes, air dried, and plated on acidified potato dextrose agar. The kernels were incubated for seven days under a 12:12 hr light:dark cycle at room temperature. Subsequently, single spore cultures of *F. graminearum* were recovered and identified morphologically according to the methods described by Nelson *et al.* (1983) as well as molecular markers developed by Nicholson *et al.* (1998). Genomic DNA was extracted from single spore isolates of *F. graminearum.* 15-ADON and 3-ADON chemotypes of the fungal strains were identified using PCR-based molecular markers (Starkey *et al*., 2007 and Ward *et al*., 2002). Harvested grain was analyzed for DON levels using the ELISA method (Diagnostix Ltd, Mississauga, ON).

RESULTS: The results are given in the Table 1 and 2.

CONCLUSIONS: Significantly higher level of DON was found from wheat grown at Elora compared to Woodsle, Palmerston and Ridgetown and significantly higher frequency of 15-ADON chemotype was recorded at Woodsle and Inwood compared to Palmerston (Table 1). 3-ADON chemotype was found at Palmerston, Ridgetown and Elora (Table 1).There was no significant difference among cultivars for any trait recorded (Table 2). However, the highest average percentage of *Fusarium* infected kernels was found in cv E0028W and 25R39 (72.4%), while the highest percentage of *F. graminearum* was observed in cv 25R39 (70.1%) (Table 2). Overall, the frequency of 3-ADON chemotype was higher at Palmerston location than reported in past years from Ontario, but variable between locations. 100%, 93% and 98% of isolates were of the 15-ADON chemotype in 2004, 2008 and 2011, respectively (Tamburic-Ilincic *et al*., 2006; Amarasinghe *et al*., 2009; Burlakoti *et al*., 2013).

ACKNOWLEDGEMENTS: Funding for this project was provided by the Grain Farmers of Ontario, WGRF and AAFC under National Wheat Improvement Program.

Table 1. Averaged *Fusarium graminearum* (%), *Fusarium* infected kernels (%), *Fusarium graminearum* 15-ADON and 3-ADON chemotypes (%) and deoxynivalenol (DON) level from winter wheat grown at five locations in Ontario in 2013.

Location		*Fusarium graminearum* (%)		F. infected kernels (%)		15-ADON (%)		3-ADON (%)		DON (ppm)	
1	Woodslee	65.3	a	59.6	c	100.0	a	0.0	a	2.5	b
2	Palmerston	60.5	a	69.8	b	79.2	b	14.6	a	1.1	b
3	Ridgetown	60.3	a	47.1	d	89.6	ab	8.3	a	1.6	b
4	Elora	59.9	a	75.0	b	91.7	ab	8.3	a	10.5	a
5	Inwood	78.2	a	85.1	a	100.0	a	0.0	a	7.6	ab
LSD (P=.05)		14.5		9.3		11.3		10.9		5.7	
Standard Deviation		12.1		7.8		9.4		9.0		4.7	
Mean		64.8		67.3		92.1		6.2		4.7	

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

Table 2. Averaged *Fusarium graminearum* (%), *Fusarium* infected kernels (%), *Fusarium graminearum* 15-ADON and 3-ADON chemotypes (%) and deoxynivalenol (DON) level from six winter wheat cultivars grown in Ontario in 2013.

Cultivar		*Fusarium graminearum* (%)		F. infected kernels (%)		15-ADON (%)		3-ADON (%)		DON (ppm)	
1	Whitebear	63.6	a	64.5	a	92.5	a	7.5	a	7.8	a
2	E0028W	67.6	a	72.4	a	92.5	a	5.0	a	6.3	a
3	AC Mackinnon	67.3	a	72.1	a	92.5	a	5.0	a	6.7	a
4	AC Morley	60.5	a	62.1	a	90.0	a	10.0	a	2.7	a
5	Emmit	59.9	a	60.3	a	92.5	a	2.5	a	1.5	a
6	25R39	70.1	a	72.4	a	92.5	a	7.5	a	2.8	a
LSD (P=.05)		15.9		10.2		12.4		11.9		6.3	
Standard Deviation		12.1		7.8		9.4		9.0		4.7	
Mean		64.8		67.3		92.1		6.3		4.7	

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

2015 PMR REPORT #23 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several
PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **2015 SURVEY FOR DEOXYNIVALENOL LEVEL IN WINTER WHEAT IN ONTARIO**

METHODS: Harvested grain from eight winter wheat cultivars from the Ontario Winter Wheat Performance trials in 2015 was sampled to determine deoxynivalenol (DON) level. Locations were Inwood, Ridgetown, Woodslee, Palmerston and Nairn. DON level was obtained using the ELISA method with a detection limit of 0.25 ppm.

RESULTS: The results are given in the Table 1.

CONCLUSIONS: The lowest average level of DON was detected at the Palmerston location (0.9 ppm) and the highest at Woodslee location (5.9 ppm). Cultivar Marker (rated as moderately resistant to fusarium head blight) had the lowest DON level at Ridgetown and Nairn compared to other cultivars at the same locations suggesting genetic tolerance to DON accumulation. DON was not detected in grain from AC Morley and Emmit at Palmerston location. The highest level of DON, across all locations and cultivars, was obtained from cultivar 25R40 (rated as susceptible to fusarium head blight) at Woodslee location (9.5 ppm).

ACKNOWLEDGEMENTS: Funding for this project was provided by the Grain Farmers of Ontario, WGRF and AAFC under National Wheat Improvement Program.

Table 1. Deoxynivalenol (DON) level (ppm) in grain of winter wheat cultivars in Ontario in 2015.

Cultivar	Inwood	Ridgetown	Woodslee	Palmerston	Nairn
AC Morley	2.0	3.9	8.0	nd	4.6
Marker	0.5	3.3	3.5	0.3	0.9
Ava	1.8	4.5	5.8	0.6	1.4
UGRC Ring	2.4	3.4	5.3	1.4	1.3
OAC Flight	4.9	6.8	7.2	1.3	3.8
Emmit	0.5	4.6	4.2	nd	1.4
Princeton	3.4	5.1	3.4	0.7	1.7
25R40	4.4	8.0	9.5	1.1	1.0
Mean	2.5	5.0	5.9	0.9	2.0

nd=not detected

2015 PMR REPORT # 24 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several
PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **NUWWSN-EVALUATION OF WINTER WHEAT BREEDING LINES FOR RESISTANCE TO FUSARIUM HEAD BLIGHT (FHB) IN INOCULATED AND MISTED PLOTS**

METHODS: The winter wheat breeding lines from NUWWSN tests were planted on October 20, 2014 at Ridgetown, Ontario. The plots were planted in a randomized block design with three replications at 270 seeds/plot, in single rows, 2 m long and spaced 17.8 cm apart. The plots were fertilized and maintained using provincial recommendations. Each plot was inoculated with100 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*. Fusarium head blight (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. The test also included three FHB moderately resistant checks (Truman, Ernie and Freedom) and one FHB susceptible check (Pioneer 2545).

RESULTS: The results are given in the Table 1.

CONCLUSIONS: The highest FHB index was 76.9 % and recorded in Pioneer 2545 (FHB susceptible check). Line VA12FHB-4 had the lowest FHB index (19.4 %) compared to all other lines in the test. The best performing lines will be used in the future crosses at University of Guelph, Ridgetown Campus breeding program.

ACKNOWLEDGEMENTS: Funding for this project was provided by the Grain Farmers of Ontario, WGRF and AAFC under National Wheat Improvement Program.

Table 1: Fusarium head blight severity, incidence and index across winter wheat breeding lines in inoculated and misted plots at Ridgetown, Ontario. 2014-2015.

Line	FHB Severity (%)	FHB Incidence (%)	FHB Index (%)
TRUMAN	66.0	85.0	56.1
ERNIE	54.0	85.0	46.6
FREEDOM	55.0	90.3	49.2
PIONEER2545	79.6	96.7	76.9
NY99056-161	65.0	85.0	55.7
NY09067-2-69-1097	59.3	93.7	55.4
NY05152-818	85.3	61.7	48.5
NY05152-825	66.6	94.2	62.5
NY05152-821	58.6	94.2	54.9
KWS050	79.0	91.7	72.4
KWS051	66.0	93.3	61.6
KWS052	34.7	85.0	29.7
KWS036	79.0	93.3	73.7
ES12-3030	34.7	88.3	30.6
ES12-1358	38.0	86.7	35.7
ES12-1275	49.7	90.0	45.5
F1014	79.0	93.3	73.7
E6012	65.0	90.0	58.8
OH09-207-24	78.3	91.7	72.2
OH09-281-10	70.3	91.7	64.4
OH10-200-49	70.3	91.7	64.6
10641B1-9-11-7	59.7	90.0	53.7
0762A1-2-8	22.7	86.7	20.2
08334A1-31	44.3	91.7	40.7
0566A1-3-1-6	44.3	93.3	41.3
10512RA1-8	45.7	90.0	41.6
M11-2024#	44.0	86.7	37.4
M12-3312CW	44.3	90.0	39.9
M12-3301	32.3	88.3	28.6
M12-2036#	34.7	86.7	30.5
M12-2031#	49.7	81.7	40.3
CA9-72	70.3	95.0	66.8
CA9-76	79.0	91.7	72.4
DH5-15	82.0	95.0	77.9
CA13-53	70.3	90.0	63.1
CA13-63	44.3	91.7	42.2
IL10-19464	48.3	86.7	42.4
IL10-21934	65.0	86.7	56.1

IL10-21937	49.7	93.3	46.1
IL11-36131	38.7	86.7	34.0
IL11-27667	30.7	85.0	26.6
KY06C-1195-37-2-5	68.7	88.3	61.9
KY06C-1201-18-6-3	40.0	90.0	35.3
KY06C-1107-7-2-5	63.3	90.0	57.0
KY06C-2020-10-5-3	55.0	96.7	53.9
KY06C-2020-11-12-1	44.3	87.0	39.0
MO122246	34.7	86.7	30.6
MO130203	59.3	88.3	53.1
MO130765	55.3	90.0	51.0
MO131838	60.7	91.7	56.0
NE05548	59.3	93.3	55.3
NE10589	63.0	90.0	56.7
NW13455	58.7	93.3	54.9
NE13511	78.3	93.3	73.3
NE06545	60.7	91.7	55.7
VA11W-108	44.0	88.3	38.5
VA11W-182	60.7	93.3	56.5
VA12W-150	59.3	95.0	56.4
VA12FHB-4	22.7	86.7	19.4
VA12FHB-55	44.3	85.0	40.4
Mean	55.9	89.7	50.5
LSD (P=.05)	28.1	13.9	28.3

2015 PMR REPORT # 25 **SECTION O: CEREALS, FORAGE CROPS and OILSEEDS - Diseases**

CROP: Winter wheat (*Triticum aestivum* L.), cv. Several
PEST: Fusarium head blight, *Fusarium graminearum* Schwabe

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TITLE: **EVALUATION OF WINTER WHEAT FROM EASTERN AND WESTERN CANADA FOR RESISTANCE TO FUSARIUM HEAD BLIGHT (FHB) IN INOCULATED AND MISTED PLOTS**

METHODS: The winter wheat from Eastern and Western Canada were planted on October 20, 2014 at Ridgetown, Ontario. 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*. Fusarium head blight (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.

RESULTS: The results are given in the Table 1.

CONCLUSIONS: The FHB index ranged from 71.8 % (Flourish) to 20.7 % (Emerson). Both lines were from Western Canada. Heading date was similar among wheat from Eastern and Western Canada included in the test and ranged from 147 to 156 days. The lowest FHB index, among the wheat from Eastern Canada, was in cultivar CRGB.A-10-045.0.304 (21.8 %).

ACKNOWLEDGEMENTS: Funding for this project was provided by Canadian Field Crop Research Alliance, WGRF and AAFC under National Wheat Improvement Program.

Table 1: Heading date, Fusarium head blight severity, incidence and index across winter wheat breeding lines in inoculated and misted plots at Ridgetown, Ontario. 2014-2015.

Name	Heading Date (Julian)	FHB Severity (%)	FHB Incidence (%)	FHB Index (%)
2AFN-020-0190-West	152.3	44.0	88.3	39.1
AAC Gateway-West	152.0	59.3	90.0	53.8
AC Morley-check	149.0	66.0	91.7	60.5
Accipiter-West	152.3	70.3	80.3	55.9
Branson-check	147.0	65.0	90.0	58.7
Carnaval-check	149.0	74.7	76.7	56.5
CRGB.A-10-0031.0.304-East	152.0	60.7	73.3	45.7
CRGB.A-10-0032.0.310-East	151.0	60.7	76.7	47.9
CRGB.A-10-045.0.304-East	148.7	29.0	75.0	21.8
CRGB.A-12-0619-East	151.0	50.0	78.3	39.2
Emerson-West	152.0	25.0	83.3	20.7
Flourish-West	151.0	78.3	91.7	71.8
FN9C-025-0220-West	148.7	48.7	88.3	45.3
LN147-East	151.0	74.7	86.7	64.6
LN609-East	152.0	64.7	88.3	57.0
LN610-East	152.0	66.0	85.0	56.1
LN611-East	152.0	55.0	90.0	50.1
Marker-East	147.7	49.7	86.7	42.8
Moats-West	155.7	49.7	78.3	39.5
OAC Flight-East	147.7	65.0	88.3	57.4
Ruby-check	147.0	68.7	91.7	63.0
UGRC C2-5-East	153.3	55.3	86.7	47.9
UGRC Ring-East	147.0	55.0	95.0	52.3
W495-West	152.0	60.7	91.7	56.0
Wentworth-check	149.0	79.0	90.0	71.1
Mean (SD)	150.6 (2.3)	58.1(13.5)	83.9 (6.2)	49.2(12.6)

2015 PMR REPORT # 26 **SECTION P: GREENHOUSE CROPS, ORNAMENTALS AND TURF - Diseases**

CROP: Greenhouse cucumber (*Cucumis sativus* L.) cv. 'Jawell'
PEST: Gummy stem blight (*Didymella bryoniae* (Fuckel) Rehm (1881))

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TITLE: **EVALUATION OF POLYOXIN D ZINC SALT 5SC FOR THE CONTROL OF GUMMY STEM BLIGHT OF GREENHOUSE CUCUMBER**

MATERIALS: NOVA 40W (myclobutanil 40%), POLYOXIN D ZINC SALT 5SC (polyoxin D zinc salt 5%), PRISTINE WDG (boscalid 25.2%, pyraclostrobin 12.8%)

METHODS: On May 12, 2015 4-week-old mini-cucumber plants cultivar 'Jawell' in rock wool blocks were purchased from a local commercial propagator and transplanted into RichGrow™ cocoa fibre bags in a shaded poly house at Kwantlen Polytechnic University, Langley, BC. Each plot consisted of 4 plants in 2 bags ($2m^2$) with 4 replicates per treatment in a randomized complete block (RCB) design. Plant Products™ Greenhouse Vegetable Fertilizer 7-11-27 at 229.3g plus 170g $CaNO_3$ per 20L was delivered via a single emitter to each plant using a Dosatron™ for 2 minutes once a day; then 3 min. twice a day, then 4 min. twice a day, as the plants grew. The nutrient solution pH was adjusted to 5.0-5.5 using phosphoric acid, as needed. After transplanting, the plants were drenched with SUBDUE MAXX (metalaxyl-m) at a rate of 0.16mL/L in 25mL per plant to prevent pythium root rot. Four weekly applications of POLYOXIN D Zinc Salt 5SC at 0.3, 0.5 or 1.0 L/ha (15, 25 or 50g a.i./ha) and 2 biweekly (14-day) applications at 1.0 or 1.5L/ha (50 or 75g a.i./ha), were compared to a standard fungicide program of PRISTINE WDG at 1.3kg/ha followed by NOVA 40W at 340g/ha, 14 days later. Check plants were sprayed with water alone. Treatments were applied as foliar sprays using a CO_2 backpack sprayer at 276kPa (40psi) equipped with a single Teejet 8001VS "fine mist" nozzle. Plants were surrounded by a movable plastic shield to prevent cross-contamination. The first application was made on June 1, when the plants were flowering and fruiting and were approximately 60-100 cm tall. Applications 1-3 were made on June 1, June 8 and June 15 in a solution volume of 1000L/ha (200mL/$2m^2$ plot) which was increased to 1500L/ha (300mL/plot) for the 4^{th} application on June 22, when the plants were approximately 2m tall. On June 2, 24h after the first application, the plants were inoculated with an isolate of *Didymella bryoniae* isolated from a local greenhouse cucumber crop. **Inoculum** was grown on PDA plates, blended in sterile DH_2O for 10 seconds and strained to remove large agar pieces. After diluting diluted 50:50 with sterile DH_2O, 8L of the final solution containing 1.6×10^5 cfu/mL by dilution plating (no conidia were produced *in vitro)*, was applied to the plants as a foliar spray using a CO_2 backpack sprayer at 193kPa (28psi) with a single Teejet 8006VS nozzle, to cover all of the plant foliage, including leaves, flowers, and young fruit. A second inoculation was made on June 18, 72h after the third treatment application, at 0.9×10^5cfu/mL. The trial was enclosed in a clear plastic tent for 24h after each inoculation. The percentage of diseased leaves (number of leaves with necrotic spots divided by the total number of expanded leaves per plant x 100) and the percentage of diseased (necrotic) leaf area per plant were assessed 3 days after the first application and weekly thereafter. The percentage of leaf area diseased was rated visually on the Horsfall-Barratt (H-B) scale of 0-11, where 0 = no disease, 1 = 0-3% leaf area affected; 2 = 3-6%; 3 = 6-12%; 4 = 12-25%; 5 = 25-50%; 6 = 50-70%; 7 = 70-88%; 8 = 88-94%; 9 = 94-

97%; 10 = 97-100%; 11 = 100%. H-B ratings were transformed to percentages following the standard grade formula of Redman, King and Brown (ELANCO 1982), *i.e.*, grade 0=1.17%, grade 1=2.34%, grade 2=4.68%, grade 3=9.37%, grade 4=18.75%, grade 5=37.5%, grade 6=62.5%, grade 7=81.25%, grade 8=90.63%, grade 9=95.31%, grade 10=97.66%, grade 11=98.82%), and the area under the disease progress curve (AUDPC) was calculated. Fruit of marketable size were harvested every 1-2 days, counted, weighed and cut open at the blossom-end to check for internal necrosis caused by *D. bryoniae*. Fruit with internal necrosis were counted and weighed and necrotic tissue from four fruit was cultured in the laboratory to confirm the presence of *D. bryoniae*. Data was analyzed statistically (ANOVA) using CoStat, Version 6.400, 2008, CoHort Software, Monterey California, USA, © 1998-2008, and treatment means compared in LSD, Duncan's MRT and Tukey's HSD at P=0.05.

RESULTS: As in Tables 1, 2 and 3. A high percentage of infected blooms and young fruit aborted as reflected in marketable yield (Table 3). *D. bryoniae* was re-isolated from 3/4 fruit with internal necrosis.

CONCLUSIONS: Under high disease pressure, POLYOXIN D Zinc Salt 5SC applied every 7-14 days at 1.0 L/ha (50 g a.i./ha) controlled gummy stem blight of greenhouse mini-cucumber cv. 'Jawell', caused by *Didymella bryoniae*, as well as an alternating program of the standard fungicides PRISTINE WDG and NOVA 40W and produced a statistically higher marketable yield and a lower level of leaf necrosis than the water check. Weekly or biweekly (14-day) applications of POLYOXIN D at 1.0 L/ha reduced the mean AUDPC for the percentage of necrotic leaf area by 85% compared to the water check, significantly different in Tukey's HSD (P=0.05) and not significantly different from biweekly applications at 1.5L/ha, or PRISTINE/NOVA. Weekly applications of POLYOXIN D at 0.3-0.5 L/ ha resulted in a higher mean percentage of diseased leaves and leaf area diseased than the 1.0-1.5 L rate, or PRISTINE/NOVA, though still statistically lower than the check in Tukey's HSD at P=0.05. The higher rates of POLYOXIN D and PRISTINE/NOVA reduced the incidence of internal fruit necrosis by 75-100% versus the check but not statistically, as few fruit were affected. No phytotoxicity was seen.

ACKNOWLEDGEMENTS: Funding was provided by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Canada-BC Agri-Innovation Program under Growing Forward 2, a federal-provincial-territorial initiative delivered by the Investment Agriculture Foundation of BC. Additional funding was provided by Kaken Pharmaceutical, the BC Greenhouse Growers' Association, the Ontario Greenhouse Vegetable Growers, le Syndicat des producteurs en serre du Québec, and the Red Hat Co-operative, Alberta.

Table 1. POLYOXIN D 5SC: CUC GSB 2015: Mean percentage of diseased leaves per date.[1, 2, 3]

Treatment Product Rate	No. App. & Interval	June 04	June 08	June 15	June 22	June 29	July 06	July 13
Check (water)	4 @ 7d	79.4 a	84.5 a	64.7 a	66.8 a	66.1 a	90.8 ab	88.2 a
POLYOXIN D 0.3 L/ha	4 @ 7d	48.4 b	57.4 b	61.4 a	63.5 a	63.2 a	83.3 a	77.6 b
POLYOXIN D 0.5 L/ha	4 @ 7d	42.1 bc	55.8 b	58.5 a	55.9 a	56.3 ab	83.5 a	79.1 ab
POLYOXIN D 1.0 L/ha	4 @ 7d	19.0 d	26.3 c	40.2 b	39.1 b	51.7 ab	83.2 a	78.4 ab
POLYOXIN D 1.0 L/ha	2 @ 14d	24.9 cd	34.4 c	39.3 b	40.1 b	43.9 b	81.6 a	77.9 b
POLYOXIN D 1.5 L/ha	2 @ 14d	24.2 cd	30.1 c	42.1 b	41.6 b	56.0 ab	92.0 a	77.2 b
PRISTINE/NOVA 1.3kg/ha/340g/ha	1 each @ 14d	7.0 d	21.8 c	28.2 b	34.7 b	44.2 b	87.2 a	71.1 b

[1] Weekly treatments applied on June 1, 8, 15 and 22; bi-weekly treatments on June 1 and June 15.
[2] Mean of 4 plants per plot, 4 replicates per treatment, RCB design.
[3] Numbers in the same column followed by the same letter are not significantly different in Tukey's HSD @ P=0.05.

Table 2. POLYOXIN D 5SC: CUC GSB 2015: Mean percentage of leaf area diseased (necrotic) per date and mean area under the disease progress curve (AUDPC) over the course of the trial.[1, 2, 3]

Treatment Product Rate	No. App. & Interval	June 04	June 08	June 15	June 22	June 29	July 06	July 13	Mean AUDPC
Check (water)	4 @ 7d	21.8a	38.6a	69.7a	63.3a	53.2a	72.5a	21.8a	319.2 a
POLYOXIN D 0.3 L/ha	4 @ 7d	4.8 b	6.1 b	30.7b	29.9b	27.4b	39.2 b	4.8 b	138.2 b
POLYOXIN D 0.5 L/ha	4 @ 7d	4.0 b	3.6 b	32.9b	16.2 c	16.5c	27.1 bc	4.0 b	100.4 bc
POLYOXIN D 1.0 L/ha	4 @ 7d	2.1 b	2.4 b	10.7c	5.3 c	8.6 c	20.3 bc	2.1 b	49.4 cd
POLYOXIN D 1.0 L/ha	2 @ 14d	2.7 b	2.9 b	6.4 c	11.7 c	7.2 c	17.9 c	2.7 b	48.8 cd
POLYOXIN D 1.5 L/ha	2 @ 14d	2.4 b	2.6 b	4.0 c	9.5 c	9.2 c	20.0 bc	2.4 b	47.8 cd
PRISTINE/NOVA 1.3 kg/ha/340g/ha	1 each @ 14d	1.8 b	2.5 b	4.1 c	4.1 c	6.0 c	14.2 c	1.8 b	32.7 d

[1] Weekly treatments applied on June 1, 8, 15 and 22; biweekly treatments on June 1 and June 15.
[2] Mean of 4 plants per plot, 4 replicates per treatment, RCB design.
[3] Numbers in the same column followed by the same letter are not significantly different in Tukey's HSD @ P=0.05.

Table 3. POLYOXIN D 5SC: CUC GSB 2015: Mean healthy marketable and diseased fruit per plot.[1, 2]

Treatment	No. Applications & Interval	Mean No. of Healthy Marketable Fruit	Mean Weight of Healthy Mrkt. Fruit (g)	Mean No. of Diseased Fruit[3]	Mean Weight of Diseased Fruit (g)[3]
Check (water)	4 @ 7d	103.2 (b) [b]	6321.2 (b)	0.8 a	42.6 a
POLYOXIN D 0.3 L/ha	4 @ 7d	123.2 (a) [ab]	7298.8 (ab)	0.8 a	49.8 a
POLYOXIN D 0.5 L/ha	4 @ 7d	120.0 (ab) [ab]	7561.5 (a)	1.0 a	52.5 a
POLYOXIN D 1.0 L/ha	4 @ 7d	129.2 (a) [ab]	7950.2 (a)	0.5 a	32.2 a
POLYOXIN D 1.0 L/ha	2 @ 14d	121.0 (ab) [ab]	7608.4 (a)	0.2 a	19.5 a
POLYOXIN D 1.5 L/ha	2 @ 14d	132.0 (a) [a]	8083.2 (a)	0.2 a	17.0 a
PRISTINE/NOVA 1.3kg/ha/340g/ha	1 each @ 14d	131.0 (a) [ab]	8098.5 (a)	0.0 a	0.0 a

[1] Mean of 4 plants per plot, 4 replicates per treatment, RCB design.

[2] Numbers in the same column followed by the same letter are not significantly different in LSD, (Duncan's MRT) or [Tukey's HSD] at P=0.05.

[3] Fruit of marketable size with internal necrosis.

2015 PMR REPORT # 27 **SECTION P: GREENHOUSE CROPS, ORNAMENTALS AND TURF - Diseases**

CROP: Greenhouse tomato (*Solanum lycopersicum* L.) cv. 'Torero'
PEST: Powdery mildew (*Pseudoidium neolycopersici* L. Kiss (L. Kiss) 2012

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TITLE: **EVALUATION OF POLYOXIN D ZINC SALT 5SC FOR THE CONTROL OF POWDERY MILDEW OF GREENHOUSE TOMATO**

MATERIALS: NOVA 40W (myclobutanil 40%), POLYOXIN D ZINC SALT 5SC (polyoxin D zinc salt 5%), PRISTINE WDG (boscalid 25.2%, pyraclostrobin 12.8%)

METHODS: On March 26, 2015, 4-week-old tomato plants cv. 'Torero' (a beef-steak type) were purchased in rock wool blocks from a local commercial propagator and transplanted into RichGrow™ cocoa fibre bags in a shaded poly house at Elmhirst Diagnostics & Research, Abbotsford, BC. The bags were placed on top of a moist capillary mat that covered the greenhouse floor. Each plot consisted of 4 plants in 2 bags (2m2) with 4 replicates per treatment in a randomized complete block (RCB) design. Plants were fertigated with 172g of Plant Products™ Greenhouse Vegetable Fertilizer 7-11-27 and 127g of $CaNO_3$ in 15L water via a single emitter to each plant using a DOSATRON™ for 2 minutes every 12 hours then 2 min. every 6 hours starting in mid-June. After transplanting, all plants were drenched with SUBDUE MAXX (metalaxyl-m) at 0.16 ml/L in 25mL of solution to the base of each plant to prevent pythium root rot. Five weekly applications of POLYOXIN D Zinc Salt 5SC at 0.3, 0.5 or 1.0 L/ha (15, 25 or 50g a.i./ha) and 3 biweekly (14-day) applications at 1.0 or 1.5L/ha (50 or 75g a.i./ha) were compared to a standard fungicide program of PRISTINE WDG at 1.3kg/ha followed by NOVA 40W at 340g/ha then PRISTINE WDG again, at a 14-day interval. Treatments were applied as foliar sprays using a CO_2 backpack sprayer at 276kPa (40psi) equipped with a single Teejet 8001VS "fine mist" nozzle. Plants were surrounded by a movable plastic shield to prevent cross-contamination from overspray. Check plants were sprayed with water alone. **Inoculum:** Tomato leaves with sporulating powdery mildew, from a local greenhouse, were tapped over the test crop leaves on May 7 and again on May 17. The first application of all treatments was made preventively on May 6, 24h prior to the first inoculation; no mildew was present at this time. The second application (Treatments 1-4) was made 7 days later on May 13, when the plants were about one meter tall and first flowers were present; again, no mildew was observed. The first mildew was observed on May 20, 3 days after the second inoculation and prior to the third application. The outdoor environment was hot and dry, so the walls of the greenhouse and the capillary mat were sprayed with water every 2-3 days starting on May 17 to increase humidity in the greenhouse. The third application (all treatments) was made on May 20, 72h after the second inoculation when the plants were 1.3 m tall and the first mildew had been observed on the check plants. The fourth application (Treatments 1-4) was made on May 27 when the plants were 1.5-2.0m tall with green fruit; the spray volume was doubled to accommodate the larger plants. The fifth application of all treatments was made on June 3, when green fruit were present. The percentage of diseased leaves (number of leaves with at least one mildew spot divided by the total number of expanded leaves per plant x 100), the number of mildew colonies on the bottom 8 leaves per plant, and the percentage of leaf area per plant covered with mildew were assessed weekly, up to 28 days after the last application. The percentage of leaf area

diseased was rated visually on the Horsfall-Barratt (H-B) scale of 0-11, where 0 = no disease, 1 = 0-3% leaf area affected; 2 = 3-6%; 3 = 6-12%; 4 = 12-25%; 5 = 25-50%; 6 = 50-70%; 7 = 70-88%; 8 = 88-94%; 9 = 94-97%; 10 = 97-100%; 11 = 100%. H-B ratings were transformed to percentages following the standard grade formula of Redman, King and Brown (ELANCO 1982), *i.e.*, grade 0=1.17%, grade 1=2.34%, grade 2=4.68%, grade 3=9.37%, grade 4=18.75%, grade 5=37.5%, grade 6=62.5%, grade 7=81.25%, grade 8=90.63%, grade 9=95.31%, grade 10=97.66%, grade 11=98.82%), and the area under the disease progress curve (AUDPC) was calculated. Data was analyzed statistically (ANOVA) using CoStat, Version 6.400, 2008, CoHort Software, Monterey California, USA, © 1998-2008, and treatment means compared in LSD, Duncan's Multiple Range Test (MRT) and Tukey's HSD at P=0.05.

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

CONCLUSIONS: Under high disease pressure, weekly applications of POLYOXIN D ZINC SALT 5SC at 1.0L/ha controlled powdery mildew of greenhouse tomato as well as an alternated spray program of PRISTINE/NOVA/PRISTINE every 14 days, for up to 28 days after the last application. Weekly applications of POLYOXIN D at 0.3 or 0.5 L/ha, or biweekly applications at 1.0-1.5 L/ha controlled the disease as well as PRISTINE/NOVA up to 14 days after the last application, but had a slightly higher number of mildew colonies and percentage of diseased leaves at 21-28 days after the last application. All of the fungicide treatments reduced the mean percentage of diseased leaves, the mean number of mildew colonies per plant and the mean leaf area diseased by over 90% compared to the check. No phytotoxicity was observed.

ACKNOWLEDGEMENTS: Funding was provided by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Canada-BC Agri-Innovation Program under Growing Forward 2, a federal-provincial-territorial initiative delivered by the Investment Agriculture Foundation of BC. Additional funding was provided by Kaken Pharmaceutical, the BC Greenhouse Growers' Association, the Ontario Greenhouse Vegetable Growers, le Syndicat des producteurs en serre du Québec, and the Red Hat Co-operative, Alberta.

Table 1. POLYOXIN D 5SC: GH TOMATO PM 2015: Mean percentage of diseased leaves per date.[1, 2, 3]

Treatment Product Rate	No. App. & Interval	20-May	27-May	3-Jun	10-Jun	17-Jun	24-Jun	1-Jul
Check (water)	5 @ 7d	9.5 a	41.1 a	38.4 a	39.4 a	33.9 a	40.5 a	46.9 a
POLYOXIN D 0.3 L/ha	5 @ 7d	0.0 b	2.7 b	2.2 b	4.6 b	7.6 b	21.5 b	25.1 b
POLYOXIN D 0.5 L/ha	5 @ 7d	0.0 b	1.8 b	2.4 b	3.8 b	5.7 b	17.9 b	26.0 b
POLYOXIN D 1.0 L/ha	5 @ 7d	0.0 b	1.8 b	2.3 b	6.9 b	7.7 b	9.2 bc	15.6 bc
POLYOXIN D 1.0 L/ha	3 @ 14d	0.0 b	0.8 b	7.4 b	10.8 b	9.3 b	20.8 b	23.2 b
POLYOXIN D 1.5 L/ha	3 @ 14d	0.0 b	3.5 b	8.8 b	13.4 b	8.9 b	17.1 bc	21.7 b
PRISTINE/NOVA/PRISTINE 1.3kg/ha/340g/ha	3 @ 14d	0.0 b	4.4 b	3.8 b	3.3 b	1.2 b	3.5 c	2.3 c

[1] Weekly treatments applied May 6, 13, 20, 27 and June 3; biweekly on May 6, May 20 and June 3.
[2] Mean of 2 plants per plot, 4 replicates per treatment, RCB design.
[3] Numbers in the same column followed by the same letter are not significantly different in Tukey's HSD @ P=0.05.

Table 2. POLYOXIN D 5SC: GH TOMATO PM 2015: Mean percentage of leaf area diseased (necrotic) per date and mean area under the disease progress curve (AUDPC) over the course of the trial.[1, 2, 3]

Treatment Product Rate	No. App. & Interval	20-May	27-May	3-Jun	10-Jun	17-Jun	24-Jun	1-Jul	Mean AUDPC
Check (water)	5 @ 7d	1.9 a	7.6 a	27.1 a	31.6 a	49.2 a	49.2 a	62.5 a	1379.3 a
POLYOXIN D 0.3 L/ha	5 @ 7d	0.0 b	1.6 b	1.3 b	2.0 b	1.9 b	4.2 b	4.4 b	99.3 b
POLYOXIN D 0.5 L/ha	5 @ 7d	0.0 b	1.5 b	1.3 b	1.9 b	2.0 b	5.0 b	4.7 b	102.4 b
POLYOXIN D 1.0 L/ha	5 @ 7d	0.0 b	1.5 b	1.6 b	2.0 b	2.9 b	3.2 b	2.8 b	92.7 b
POLYOXIN D 1.0 L/ha	3 @ 14d	0.0 b	1.3 b	1.9 b	2.5 b	2.9 b	4.7 b	4.6 b	113.7 b
POLYOXIN D 1.5 L/ha	3 @ 14d	0.0 b	1.5 b	1.9 b	2.3 b	2.6 b	3.7 b	3.5 b	100.3 b
PRISTINE/NOVA /PRISTINE 1.3kg/ha/340g/ha	3 @ 14d	0.0 b	1.8 b	1.6 b	1.8 b	1.5 b	1.6 b	1.5 b	66.5 b

[1] Weekly treatments applied May 6, 13, 20, 27 and June 3; biweekly on May 6, May 20 and June 3.
[2] Mean of 2 plants per plot, 4 replicates per treatment, RCB design.
[3] Numbers in the same column followed by the same letter are not significantly different in Tukey's HSD @ P=0.05.

Table 3. POLYOXIN D 5SC: GH TOMATO PM 2015: Mean number of mildew colonies (lesions) on the bottom eight leaves per plant.[1, 2, 3]

Treatment Product Rate	No. App. & Interval	20-May	27-May	3-Jun	10-Jun	17-Jun	24-Jun	1-Jul
Check (water)	5 @ 7d	4.0 a	86.3 a	172.4 a	198.9 a	330.6 a	372.0 a	426.1 a
POLYOXIN D 0.3 L/ha	5 @ 7d	0.0 b	1.1 b	1.5 b	2.6 b	5.8 b	25.1 b	59.3 b
POLYOXIN D 0.5 L/ha	5 @ 7d	0.0 b	0.3 b	0.9 b	1.0 b	2.6 b	24.1 b	46.8 b
POLYOXIN D 1.0 L/ha	5 @ 7d	0.0 b	0.3 b	0.6 b	1.6 b	2.6 b	6.0 b	17.3 b
POLYOXIN D 1.0 L/ha	3 @ 14d	0.0 b	0.4 b	3.8 b	4.1 b	4.8 b	31.1 b	36.5 b
POLYOXIN D 1.5 L/ha	3 @ 14d	0.0 b	0.8 b	3.0 b	2.9 b	6.0 b	13.3 b	19.8 b
PRISTINE/NOVA /PRISTINE 1.3kg/ha/340g/ha	3 @ 14d	0.0 b	1.6 b	1.3 b	1.4 b	0.3 b	0.9 b	0.6 b

[1] Weekly treatments applied May 6, 13, 20, 27 and June 3; biweekly on May 6, May 20 and June 3.
[2] Mean of 2 plants per plot, 4 replicates per treatment, RCB design.
[3] Numbers in the same column followed by the same letter are not significantly different in Tukey's HSD @ P=0.05.