2017 Pest Management Research Report (PMRR) 2017 Growing Season

2017 Rapport de recherches sur la lutte dirigée (RRLD) pour la saison 2017

Canada

English

2017 PEST MANAGEMENT RESEARCH REPORT

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[1] This is the 18th 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 20 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 2018 Annual PMR Report will be sent in fall, 2018. They will also be available from Stefan Bussmann.

Pest Management Research Report History.

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

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

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

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

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

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

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

The publication of the Report for the growing season 2017 has been assigned a Volume number for the 18th 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 56.

An individual report will be cited as follows:
Author(s). 2017. Title. 2017 Pest Management Research Report - 2017 Growing Season. Agriculture and AgriFood Canada. July 2018. Report No. x. Vol. 56: pp-pp.

Français

Rapport de recherches sur la lutte dirigée - 2017

Préparé par: Centre de la lutte antiparasitaire, Agriculture et Agroalimentaire Canada
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Titre officiel du document
2017 Rapport de recherches sur la lutte dirigée - pour la saison 2017. Compilé par Agriculture et Agroalimentaire Canada, 960 avenue Carling, Ed. 57, Ottawa ON K1A 0C6, Canada
Juillet 2018 volume 56[1]. 56 pp. 20 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 20 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 2018 seront distribuées à l'automne 2018. Elles seront aussi disponibles via Stefan Bussmann.

Historique du Rapport de recherche sur la lutte dirigée

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

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

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

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

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

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

Modèle de référence:
Nom de l'auteur ou des auteurs. 2017. Titre. 2017 Rapport de recherche sur la lutte dirigée. Agriculture et Agroalimentaire Canada. Juillet, 2018. Rapport n^{o} x. vol. 56: pp-pp.

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2017 PMR REPORT # 01 **SECTION B: VEGETABLES and SPECIAL CROPS**
Insect Pests

CROP: Cabbage (*Brassica oleracea*. L. var. *capitata*) cv. Bronco
PEST: Cabbage maggot, (*Delia radicum* (L.))

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TITLE: EVALUATION OF PARASITIC NEMATODES FOR CONTROL OF CABBAGE MAGGOT IN CABBAGE, 2017

MATERIALS: PYRINEX 480 EC (chlorpyrifos 480 g/L), NEMASYS (*Steinernema feltiae*)

METHODS: Green cabbage, cv. Bronco, was seeded on 17 April into 128-cell plug trays, grown in the greenhouse and hand-transplanted 11 May into muck soil (organic matter ≈ 71.3, pH ≈ 6.0) at the Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block design with four replicates per treatment was used. Each experimental unit consisted of four rows, 86 cm apart, 5 m long with 40 cm in-row spacing. Treatments were: NEMASYS at approximately 12,138, 24,242 and 47,108 individual nematodes per plant and PYRINEX at the rate of 210 mL/1000 linear m (2,500 plants/1,000 linear m). An untreated check was also included. NEMASYS rates per plant are equivalent to 1.37 billion, 353 million and 705 million nematodes/ha based on 29,082 plants/ha. Treatments were applied using a CO_2 backpack sprayer equipped with a single TeeJet 8002VK nozzle calibrated to deliver 25 mL/plant. NEMASYS treatments were applied 12 and 31 May (1 & 19 Days After Transplanting (DAT), respectively) and the PYRINEX treatment was applied 12 May only. On 15 May, the number of cabbage plants per replicate was recorded. On 29 May, all wilting plants in the replicate were pulled and the roots examined for the presence of cabbage maggots. The number of rogued out plants and the cause of damage was recorded. On 15 June, all plants in one of the four rows per replicate were pulled and roots examined for cabbage maggot damage and numbers of damaged and undamaged cabbage roots recorded. On 25 July, 15 cabbage heads (five from each of the remaining three rows) were cut and weighed to determine yield. The roots of the harvested plants were examined for cabbage maggot damage and numbers of damaged and undamaged roots recorded. Compared to the previous 10-year average, air temperatures in 2017 were below average for May (11.8°C), and average for June (18.1°C) and July (20.7°C). The 10-year average temperatures were: May 14.1°C, June 18.7°C and July 21.0°C. Monthly rainfall was above the 10-year average for May (120 mm) and June (206 mm) and below average for July (70 mm). The 10-year rainfall averages were: May - 66 mm, June - 83 mm and July - 92 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 at P = 0.05 level of significance.

RESULTS: as presented in Table 1

CONCLUSIONS: Very little maggot damage was observed on 29 May (18 DAT). By 15 June, significant differences in maggot damage were observed among the treatments. Plants treated with PYRINEX had significantly less damage (5%) compared to cabbage treated with NEMASYS where damage ranged from 55 – 60% and untreated cabbage (76%) (Table 1). On 25 July (harvest), cabbage treated with NEMASYS at 24,242 individuals per plant had maggot damage incidence similar to cabbage treated with PYRINEX and significantly less damage than untreated cabbage. However, cabbage treated with NEMASYS at 47,108 and 12,138 individuals per plant had maggot damage incidence similar to untreated cabbage (Table 1).
No significant differences in percent marketable, weight per head or yield were observed among the treatments (Table 1).

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

Table 1. Incidence of maggot damage in cabbage treated with various rates of insect parasitic nematodes, Muck Crops Research Station, Holland Marsh, 2017.

Treatment	Rates/plant[1]	Cabbage Maggot Damage (%)			% Mkb by Wgt	Avg Wgt/head (kg)	Yield t/ha
		29 May	15 June	25 July			
PYRINEX 480 EC	210 mL/1000 m^2	0.0 ns[3]	5.4 a[4]	21.7 a	90.8 ns	1.6 ns	38.8 ns
NEMASYS	24,242	0.5	59.6 b	31.7 ab	89.8	1 6	36.6
NEMASYS	47,108	0.4	55.2 b	45.0 bc	86.0	1.5	32.0
NEMASYS	12,138	0.9	58.3 b	46.7 bc	87.7	1.4	32.5
Check	--	0.0	76.2 b	48.3 c	71.3	1.4	23.6

[1] The number of nematodes/plant applied 12 May (1 DAT) and 31 May (19 DAT) to the base of the plant.
[2] PYRINEX 480 EC (chlorpyrifos 480 g/L) was applied at the rate of 210 mL/1000 linear m on 12 May (1 DAT).
[3] ns = no significant differences were found among the treatments.
[4] Numbers in a column followed by the same letter are not significantly different at P = 0.05, Fisher's Protected LSD test.

2017 PMR REPORT # 02 **SECTION B: VEGETABLES and SPECIAL CROPS**
Insect Pests

CROP: Radish (*Raphanus raphanistrum* subsp. *sativus* (L.)), cv. Champion
PEST: Cabbage maggot, (*Delia radicum* (L.))

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TITLE: **EVALUATION OF PARASITIC NEMATODES FOR CONTROL OF CABBAGE MAGGOT IN RADISH, 2017**

MATERIALS: LORSBAN 15 G (chlorpyrifos 15%), NEMASYS (*Steinernema feltiae*)

METHODS: The trial was conducted on organic soil (pH ≈ 6.2, organic matter ≈ 70.4%) at the Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block design with four replicates per treatment was used. Each experimental unit consisted of four rows, spaced 40 cm apart, 8 m in length. Radish, cv. Champion, was seeded (≈ 35 seeds/m) on 12 May using a Stanhay precision seeder equipped to apply in-furrow treatments. Treatments applied in-furrow at seeding were: NEMASYS at approximately 137,104, 35,260 and 70,520 nematodes/m in a 12.0 mL/m suspension over the seed and LORSBAN 15 G at 16 kg/ha. An untreated check was also included. NEMASYS rates per plant are equivalent to 1.37 billion, 353 million and 705 million nematodes/ha. On 31 May the NEMASYS treatments were reapplied to the base of the radishes in a 50 mL/m suspension using a CO_2 backpack sprayer equipped with a single Syngenta high impact stainless steel 06 nozzle. On 13 & 22 June, radishes from a 1 m section of row were pulled and roots examined for the presence of cabbage maggots and numbers of damaged and undamaged radishes were recorded. Weights of marketable radishes recorded on 22 June were used to determine yield. Compared to the previous 10-year average, air temperatures in 2017 were below average for May (11.8°C), and average for June (18.1°C). The 10-year average temperatures were: May 14.1°C, June 18.7°C. Monthly rainfall was above the 10-year average for May (120 mm) and June (206 mm). The 10-year rainfall averages were: May - 66 mm and June - 83 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 at P = 0.05 level of significance.

RESULTS: as presented in Table 1

CONCLUSIONS: Significant differences in cabbage maggot incidence were found on 14 June. Radishes treated with NEMASYS at 35,360 nematodes/m had significantly less cabbage maggot damage compared to all other treatments (Table 1). No significant differences in cabbage maggot incidence, percent marketable or yield at harvest on 22 June were found among the treatments.

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

Table 1. Incidence of maggot damage in radishes treated with various rates of insect parasitic nematodes, Muck Crops Research Station, Holland Marsh, 2017.

Treatment	Rates[1]	Maggot Damage (%)		% Mkb by Wgt	Yield (t/ha)
		14 June	22 June		
NEMASYS	35,360	13.0 a[3]	30.7 ns[4]	67.1 ns	2.8 ns
LORSBAN 15 G	13.3 kg/ha[2]	20.4 b	22.9	72.8	3.4
NEMASYS	10,520	22.5 b	23.9	72.4	2.9
NEMASYS	137,104	23.5 b	24.8	70.4	2.7
Check	--	21.6 b	33.2	67.6	2.9

[1] The number of nematodes/m applied both in-furrow at seeding (12 May) and to the base of the plant (31 May).
[2] LORSBAN 15 G was applied in-furrow at seeding (12 May).
[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 differences were found among the treatments.

2017 PMR REPORT # 03 **SECTION B: VEGETABLES AND SPECIAL CROPS – Insect Pests**

CROPS: Cabbage, Kale, Broccoli (*Brassica oleracea* L.)
Rutabaga (*Brassica napus* L. cv. napobrassica)
Radish (*Raphanus raphanistrum* subsp. *sativus* L.)

PEST: Cabbage maggot, *Delia radicum* L.

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TITLE: SURVEY FOR CHLORPYRIFOS SUSCEPTIBILITY IN CABBAGE MAGGOT POPULATIONS IN CANADIAN BRASSICA GROWING REGIONS, 2013-2016

MATERIALS: chlorpyrifos methyl technical (99%)

METHODS: In July and August 2013, cabbage maggot *Delia radicum* pupae in four British Columbia (BC) Brassica field sites: BC1 (2x in July and August), BC2 (1x in July), BC3 (1x in August) and BC4 (1x in August) were collected and shipped overnight to London Research and Development Centre (LoRDC), Agriculture and Agri-Food Canada (AAFC) where they were maintained in a growth cabinet at 25°C, 50% RH and 16:8 L:D conditions until the flies eclosed and the insecticide bioassay was performed. In August 2015, pupae and larvae of *D. radicum* were collected from three Newfoundland Brassica field sites (NL1, NL2 and NL3). Collected *D. radicum* pupae were held in diapause conditions at the St. John's Research and Development Centre over-winter (4°C, 24h dark) and shipped to LoRDC in early May 2016. Another collection of *D. radicum* from a fourth Newfoundland Brassica field site (NL4) was made in November 2016, held in diapause conditions and then sent to LoRDC in March 2017. The pupae were brought out of diapause in late April 2017 to complete testing with flies that eclosed in May. In June and July 2016, pupae and larvae of *D. radicum* were collected from four Brassica field sites in Southern Ontario, ON1, ON2, ON3 and ON4. The pupae were kept at LoRDC in separate cages until flies eclosed and the insecticide bioassay was performed.

The chlorpyrifos LC_{50}, LC_{80} and LC_{90} values were determined with the LoRDC insecticide susceptible *D. radicum* laboratory strain using a Potter's spray tower. Four to five concentrations of chlorpyrifos in acetone/olive oil mix were used to spray 10 adult *D. radicum* flies/replicate concentration (3x). Controls were sprayed with acetone/olive oil only. Treated *D. radicum* were kept in a holding room with a water wick and mortality was monitored 24 h post-application. The collected populations were screened with the chlorpyrifos discriminating concentration (DC), the estimated LC_{80} or LC_{90}. Half the available flies were treated with the acetone control and half with the DC. Populations were considered susceptible to chlorpyrifos if the average mortality at the DC exceeded 70% while populations were classed as resistant when the average mortality at the DC fell below 30%. When mortality between 30 and 70% was determined, these populations were considered to have reduced susceptibility to chlorpyrifos. When collections were obtained from sites where mortality to the DC was low (< 30%), a dose-response with three to five chlorpyrifos concentrations was generated and analyzed by standard probit analysis (Proc Probit, SAS Institute 2008) to estimate the response slope, 50% lethal concentrations (LC_{50}), and fiducial limits (FL).

RESULTS: As outlined in Tables 1 and 2.

CONCLUSIONS: The chlorpyrifos susceptibility survey of 12 *D. radicum* populations from Brassica growing regions in three provinces indicated that reduced susceptibility and resistance in 75% (9 of 12) of the populations tested was related to past use of Lorsban and other chlorpyrifos-containing products. The BC1 and BC2 populations collected in July 2013 were determined to be resistant (mortality < 30%) to chlorpyrifos based on the screening with the DC (Table 1). When the BC1 population was re-sampled in August 2013 the chlorpyifos LC_{50} was determined to be almost 14-fold less, or a resistance ratio of 14, compared to the lab strain, and resistance was confirmed. Lorsban had been used several times prior to collection of pupae on rutabaga roots at BC1. The BC2 pupae were collected from kale and broccoli where the grower had used Lorsban only once, in part because past experience indicated low efficacy. The LC_{50} for the BC3 population could not be determined, but the mortality at a 10-fold higher concentration than the DC was less than 30% and therefore could be considered resistant. The BC4 *D. radicum* population was observed to have a reduced chlorpyrifos susceptibity compared to the lab strain, a resistance ratio of approximately seven. No history of insecticide use for BC3 or BC4 was provided.

Compared to the laboratory *D. radicum* strain, the populations collected from three Newfoundland field sites (NL1, NL2 and NL3) in 2015 were determined to have lower mortality at the chlorpyrifos DC (Table 1). The NL2 and NL3 flies were classified as having reduced susceptibility to chlorpyrifos, while the NL1 population may be considered resistant. The *D. radicum* collected from NL4 in November 2016 were determined to have reduced susceptibility to chlorpyrifos compared to the laboratory strain (Table 1). At all NL sites rutabaga was grown and chlorpyrifos had been applied.

The *D. radicum* collected from three of four Ontario sites in 2016 (ON1, ON2 and ON3) were determined as susceptible to chlorpyrifos since mortality was greater than 90%, similar to the lab strain. The ON1 field site had no insecticide applications in 2016, but chlorpyrifos was used over previous years with noted loss of efficacy. The ON2 site was a cabbage and broccoli field and Lorsban had been applied in 2016. The ON3 site was planted in radish, but no insecticide history was provided. The remaining field collected population, ON4, had lower *D. radicum* mortality than expected, possibly associated with the development of resistance (Table 1). The ON4 site was mixed vegetables, and *D. radicum* pupae were collected on radish which had been treated with chlorpyrifos, Actara (thiamethoxam) and Pounce (permethrin).

AAFC and its partners are in the process of integrating these results along with field history, cultural and chemical practise history to produce practical maps of relative abundance of *Delia* species in relation to crop and other regional characteristics, and the prevalence of chlorpyrifos resistance. These will be made available to growers across the country to guide effective pesticide use and pesticide resistance management in the future.

ACKNOWLEDGEMENTS: We gratefully appreciate samples of technical chlorpyrifos provided by Dow AgroSciences Canada Inc. and collections of cabbage maggot pupae: in British Columbia by personnel from Agassiz Research and Development Centre (AAFC), the BC Ministry of Agriculture and ES cropconsult; in Newfoundland by personnel from St. John’s Research and Development Centre (AAFC) and the NL Department of Fisheries and Land Resources; and in Ontario by personnel from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and Sylvite. Funding to support the project was provided in part by AAFC A-base and the Pest Management Centre (AAFC).

Table 1. The average percent mortality with a chlorpyrifos discriminating concentration and the estimated resistance status of *Delia radicum* British Columbia, Newfoundland and Ontario populations relative to a laboratory insecticide-susceptible strain.

Collection site	Month/Year Collected	[1]N	Average mortality (%)	Resistance status
[2]Lab		80	82.0	Susceptible
BC1	07/2013	40	19.3	Resistant
BC2	07/2013	60	6.7	Resistant
Lab		115	80.0	Susceptible
NL1	08/2015	29	12.5	Resistant
NL2	08/2015	88	41.7	Reduced susceptibility
NL3	08/2015	99	65.1	Reduced susceptibility
Lab		221	80.0	Susceptible
NL4	11/2016	51	43.1	Reduced susceptibility
Lab		115	80.0	Susceptible
ON1	06/2016	83	91.6	Susceptible
ON2	06/2016	115	100	Susceptible
ON3	06/2016	171	98.3	Susceptible
Lab		60	90.0	Susceptible
ON4	07/2016	130	36.9	Reduced susceptibility

[1]N = number of adult *D. radicum* tested with the DC; [2]Lab strain *D. radicum* was same for all tests, but a new DC was determined prior to bioassays in each year.

Table 2. The estimated median lethal toxicity value, fiducial limits (FL) and resistance status of *Delia radicum* British Columbia populations relative to a laboratory insecticide-susceptible strain.

Collection site	N	[1]LC_{50} (FL)	Slope	Resistance Ratio	Resistance status
Lab	800	0.0032 (0.0027, 0.0040)	4.4	-	Susceptible
[2]BC1	40	0.044 (0.028, 0.081)	3.7	13.7	Resistant
BC3	60	> 0.06	[3]ND	N.D.	Resistant
BC4	50	0.022 (0.015, 0.036)	3.1	6.9	Reduced susceptibility

[1]LC_{50} = estimated median lethality concentration; [2]All populations collected in August 2013; [3]ND = not determined.

2017 PMR REPORT # 04 **SECTION F: ORNAMENTALS AND GREENHOUSE – Insect Pests**

CROP: tomato (*Solanum lycopersicum* L.)
PEST: two spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae)

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TITLE: SURVEY FOR ACARICDE SUSCEPTIBILITY IN TWO-SPOTTED SPIDER MITE POPULATIONS IN ONTARIO TOMATO PRODUCTION GREENHOUSES, 2016

MATERIALS: AVID 1.9% EC (abamectin 1.9%), FLORAMITE SC (bifenazate 22%), FORBID 240 SC (spiromesifen 240 g/L), PYLON (chlorfenapyr 240 g/L), SHUTTLE 15 SC (acequinocyl 15%).

METHODS: Three populations of two spotted spider mites (TSSM) *Tetranychus urticae* were collected in 2016 from two Leamington Ontario commercial vegetable production greenhouses. Population GH1 was collected on tomato at the first greenhouse, and populations GH2 and GH3 were collected on tomato from the second greenhouse. The greenhouse where GH2 and GH3 were collected did not have a TSSM problem in 2015. However, in 2016 growers from both greenhouses reported having the red form of *T. urticae* and that the acaricide program was not effective (only 10% of the populations were killed by the rotation or combination of two to three products). Acaricide bioassays were conducted in order to determine whether the observed lack of spider mite control could be attributed to acaricide resistance. The TSSM were sent to the London Research and Development Centre (LoRDC), Agriculture and Agri-Food Canada (AAFC) and afterwards maintained 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 maintained at LoRDC for many years and has had no exposure to pesticides in the past 10 years. The lab TSSM strain has previously been determined not to be susceptible to mitochondrial complex election transport inhibitor (METIs) acaricides ($^{ie.}$ bifenazate and acequinocyl) or carbamate acaricides ($^{ie.}$ oxamyl and formetanate HCl).
All acaricides were prepared in reverse osmosis (RO) water at stock concentrations of 1000 ppm. Working solutions were prepared in a range of 5 to 6 concentrations and stored for 2 weeks at 4°C. Bean leaf disks were pre-cut (2 cm diameter) and dipped into RO water or a gradient concentration (4-5 concentrations) of acaricide for 5 seconds, and let dry for approximately 20 minutes in the fume hood. Three treated bean leaf disks were placed on wet cotton-like material in a clear plastic container. Each treated bean leaf disk was infested with 5 age-synchronized larvae (< 24 h old) using a single bristle brush. All bioassay containers trays were held in a growth chamber maintained at 25 ± 1°C, 65% ± 5% RH under a 16:8 L:D photoperiod for 4 days. The numbers of proto/deuto nymphs 4 days post-infestation were counted. Unsuccessful molted larvae were considered as dead. At mortality readings, larvae were nudged several times with the brush, and recorded as alive if they either advanced in a coordinated way. Tests were repeated if control mortality exceeded 20% or if the concentration series did not produce an appropriate range of mortality around the 50% lethal level. Dose-response data generated through the bioassay were analyzed by probit analysis (Proc Probit, SAS Institute 2008) and used to model the concentration-mortality responses to estimate the response slope, 80-90% lethal concentrations (LC_{80}, LC_{90}), the 94% inhibitory concentration (IC_{94}, for spiromesifen only) and fiducial limits (F.L.). For each greenhouse-collected population and each acaricide, a minimum of at least 3 replicates of 5 TSSM was exposed to the LC_{80}, LC_{90}, or IC_{94} discriminating concentrations (DC), on 3 separate days.

RESULTS: As outlined in Tables 1 and 2.

CONCLUSIONS: The acaricide survey results indicate that the three TSSM strains maintained on bean could be considered susceptible to the five acaricide discriminating concentrations (DCs) tested. The GH1 TSSM strain was the exception, as reduced susceptibility was observed with both abamectin and chlorfenapyr (Table 1). GH1 had been treated at least twice during the 2016 growing season with abamectin, bifenazate, and spiromesifen, but not chlorfenapyr. The GH2 TSSM strain was susceptible to all five acaricide DCs tested (Table 1). GH2 was treated twice during 2016 with spiromesifen and the high rate of chlorfenapyr. The GH3 TSSM were determined to have reduced susceptibility to acequinocyl but were susceptible to the remaining four acaricide DCs (Table 1). GH3 was treated twice in 2016 with spiromesifen, a spot spray of spiromesifen combined with bifenazate, and the low rate of chlorfenapyr. Cross-resistance is known to occur between the METI III acaricide class compounds, so even though acequinocyl was not applied in GH3, bifenazate had been. In 2015, both the GH2 and GH3 TSSM populations were not considered to be a problem, but spiromesifen was applied and Dichlorvos/DDVP was used as a cleanup application after the tomato plants were removed.

Based on the results of the bioassays we are not certain why the acaricide applications in the two greenhouses were not considered effective in 2016. The recommended application rates for all five products are much higher than the DCs used in the bioassays (Table 2), yet the TSSM strains were susceptible. One explanation could be that the larva used in the bioassay are considered the most sensitive stage in the TSSM life-cycle, more sensitive than the nymphs or adult stages that would also be present in the greenhouse. Even the lower bioassay DCs were effective for larvae from populations where reduced susceptibility or resistance may have developed. Another reason that could influence the three greenhouse populations of TSSM is their removal from acaricide selection pressure, since the mites were taken from tomato plants and maintained on bean plants for 6 to 12 months and not exposed to pesticides during the period when bioassays were conducted. Other factors that might explain the lack of effective control in both tomato greenhouses, and should also be considered, include proper spray coverage and the timing of sprays early in the mite infestation.

Acaricide-resistance is a growing concern for Ontario greenhouse vegetable growers who depend on foliar treatments of chemical acaricides for TSSM control. This reliance has led to resistance in an increasing number of *T. urticae* populations. Timely use of bioassays to detect reduced susceptibility or resistance is an important part of a resistance management program and the development of molecular diagnostic tools would improve the speed of resistance detection. The current findings still provide evidence that caution should be taken by growers in selecting and using acaricides and implementing a resistance management plan.

ACKNOWLEDGEMENT: We gratefully appreciate acaricide samples provided by Arysta LifeScience Canada Inc., BASF Canada, Bayer CropScience Canada Inc., and Syngenta Crop Protection Canada Inc. and greenhouse spider mite collections by Cara McCreary, OMAFRA, Harrow Ontario.

Table 1. Mean percent mortality of three *T. urticae* greenhouse populations collected from two Ontario greenhouses in 2016 exposed to a discriminating concentration (DC), the laboratory strain LC_{80}/LC_{90} or IC_{94} values for five registered acaricides.

Acaricide (a.i.)	DC (ppm) (FL)	Slope	% Mortality		
			GH1	GH2	GH3
Avid (abamectin)	[1]4.5 (3.2, 8.5)	2.1	[§]66.8	83.1	73.9
Floramite (bifenazate)	[1]22 (12, 178)	1.6	100	77.0	75.8
Pylon (chlorfenapyr)	[1]8.2 (4.1, 1998)	1.8	[§]61.5	94.7	77.2
Shuttle (acequinocyl)	[2]117 (48, 19739)	1.2	94.5	71.9	[§]68.5
Forbid (spiromesifen)	[3]5 (2.5, 18.8)	1.6	95.8	78.6	100

[1]LC_{90} value; [2]LC_{80} value; [3]IC_{94} value; [§] mortality < 70% indicates a reduced susceptibility to the DC.

Table 2. Comparison of discriminating concentration (DC) and recommended application rate for five acaricides registered for greenhouse tomato spider mite control.

Acaricide (a.i.)	[1]IRAC Group	[2]MoA	Low rate (ppm)	High rate (ppm)	[3]Relative to DC
Avid (abamectin)	6	[4]GluCl	174	348	↑
Floramite (bifenazate)	20D	[5]METI III	331	331	↑
Pylon (chlorfenapyr)	13	[6]UOP	230	350	↑
Shuttle (acequinocyl)	20B	METI III	436	956	↑
Forbid (spiromesifen)	23	[7]IACoAc	315	525	↑

[1]IRAC = Insecticide Resistance Action Committee chemical grouping; [2]MOA = insecticide/acaricide mode of action classification; [3]Acaricide application rate where ↑ = higher concentration relative to the bioassay DC; [4]GluCl = Glutamate-gated chloride channel allosteric modulators; [5]METI III = Mitochondrial complex III electron transport inhibitors; [6]UOP = Uncouplers of oxidative phosphorylation; [7]IACoAc = Inhibitors of acetyl CoA carboxylase.

2017 PMR REPORT # 05 **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 SOAKING OR TREATING STEM AND BULB NEMATODE-INFESTED GARLIC CLOVES CV. MUSIC WITH VELUM PRIME, AGRI-MEK SC OR EXPOSING INFESTED CLOVES TO PHOSTOXIN PRIOR TO PLANTING ON PLANT STAND, YIELD, NEMATODE DAMAGE AND NEMATODE POPULATIONS IN THE BULBS AT HARVEST IN 2017

MATERIALS: AGRI-MEK SC (84 g/L abamectin a.i.); VELUM PRIME (500 g/L a.i.); PHOSTOXIN (55% aluminum phosphide); AGRAL 90 (92% nonylphenoxy polyethoxy ethanol)

METHODS: Garlic cloves cv. Music infested with *Ditylenchus dipsaci* (832 nematodes/g dry cloves) were soaked in WATER alone for 2 and 4 hours; a solution of 0.8 ml of VELUM PRIME (500 g.a.i. fluopyram/L) per L of water (final concentration 0.4 g.a.i. fluopyram/L) for 1 and 2 hours; 0.858 ml of AGRI-MEK SC (84 g.a.i. abamectin/L) per L of water (final concentration 0.072 g.a.i. abamectin/L water) + 0.25% non-ionic surfactant (92% nonylphenoxy polyethoxy ethanol)(v/v) for 4 hours, or treated with 0.8 ml of VELUM PRIME (500 g.a.i. fluopyram/L) in 100 ml of water/kg garlic cloves to coat the cloves evenly prior to planting. Soaking and treating nematode infested seed was conducted at 20-24^{o}C in the field just prior to planting. Nematode infested garlic cloves were also exposed to 9.0 g of PHOSTOXIN (55% aluminum phosphide gas) in a 2.26 m^{3} enclosed space for 72 hours at 29^{o}C on 7-9 October, 2016. The treated garlic cloves were planted in plots 5 cm deep, spaced 15 cm apart within row, in 152.4 cm long rows spaced 75 cm apart with 3 rows/plot on 19 October 2016. NEMATODE-FREE garlic cloves were planted for comparison. The plots were arranged in a randomized complete block design with 4 replications at a commercial garlic farm near Scotland, Ontario. The field did not have a history of stem and bulb nematodes; however other fields planted with garlic on the commercial farm had previous history with stem and bulb nematode. Scapes were removed from plants on 20 June 2017 to encourage bulb growth. Plant stand were evaluated on 1 April, 9 May, 9 June, and 18 July 2017. Garlic bulbs were harvested from plots on 18 July 2017, measured for size (diameter), weighed and assessed for stem and bulb nematode damage 0-4 (0 = no damage; 1= slight damage; 2= moderate damage; 3= severe damage, 4= dead). Stem and bulb nematodes were extracted from 10 randomly selected bulbs harvested from each plot by placing the bulbs on Baermann funnels in a mist chamber for 24 hours. Extracted nematodes were identified to genera and enumerated. The garlic bulbs were then dried at 80^{o}C for 72 hours to obtain the dry weight. Plant stand and nematode data were transformed using Arcsine (% stand count) and Log (nematode/g dried bulb +1) respectively to improve normality and additivity prior to statistical analysis however, actual means are presented. All data was analysed using the General Analysis of Variance function of the Linear Models section of Statistix V.9. Tukey's HSD test was used to detect differences among the treatment means at $P<0.05$.

RESULTS: Plant stands declined in all plots from April through July 2017, however very little plant stand decline was observed in plots planted with NEMATODE-FREE cloves (Table 1). Plant stand decline was less in plots planted with nematode infested cloves that were either soaked in a solution of VELUM PRIME for 1 hour or coated with VELUM PRIME prior to planting. Significantly more garlic bulbs were harvested from plots planted with NEMATODE-FREE cloves than from plots planted with nematode infested cloves soaked in AGRI-MEK SC for 4 hours, WATER for 1 and 2 hours, VELUM PRIME for 2 hours or nematode infested cloves exposed to PHOSTOXIN prior to planting (Table 2). Soaking nematode infested cloves in VELUM PRIME for 1 hour or coating nematode infested cloves with VELUM PRIME prior to planting yielded higher number of bulbs than soaking infested cloves in WATER for 1 and 2 hours or exposing infested cloves to PHOSTOXIN gas prior to planting. Plots planted with NEMATODE-FREE cloves or nematode infested cloves soaked in AGRI-MEK SC for 4 hours, VELUM PRIME for 1 and 2 hours or coated with VELUM PRIME just prior to planting yielded larger bulbs than plots planted with infested cloves soaked in WATER for 1 and 2 hours or exposing infested cloves to PHOSTOXIN. The yield harvested from plots planted with NEMATODE-FREE cloves was also significantly higher than from plots planted with infested cloves regardless of the treatment. However, the yield harvested from plots planted with infested cloves soaked in VELUM PRIME for 1 and 2 hours or coated with VELUM PRIME prior to planting was significantly higher than from plots planted with infested cloves soaked in WATER for 1 and 2 hours or exposed to PHOSTOXIN just prior to planting. Soaking infested cloves in AGRI-MEK SC for 4 hours prior to planting also resulted in a higher yield compared to soaking infested cloves in WATER for 1 and 2 hours or exposing them to PHOSTOXIN just prior to planting. Plots planted with NEMATODE-FREE cloves had a significantly higher number and yield of marketable bulbs per plot than plots planted with infested cloves soaked in WATER for 1 and 2 hours, AGRI-MEK SC for 4 hours, VELUM PRIME for 2 hours, exposed to PHOSTOXIN or coated with VELUM PRIME prior to planting. Soaking infested cloves in VELUM PRIME for 1 hours prior to planting also resulted in a significantly higher number and yield of marketable bulbs per plot than soaking infested cloves in WATER for 1 and 2 hours, AGRI-MEK SC for 4 hours, or exposing infested cloves to PHOSTOXIN prior to planting. Soaking infested cloves in VELUM PRIME for 2 hours, AGRI-MEK SC for 4 hours or coating with VELUM PRIME prior to planting, yielded higher number and weight of marketable bulbs per plot than soaking in WATER for 1 and 2 hours or exposing infested cloves to PHOSTOXIN prior to planting. Garlic bulbs harvested from plots planted with NEMATODE-FREE cloves or nematode infested cloves that were soaked for 1and 2 hours in VELUM PRIME solution or coated with VELUM PRIME prior to planting had significantly less stem and bulb nematode damage at harvest than bulbs harvested from plots planted with nematode infested garlic cloves soaked in water for 1 or two hours, soaked in AGRI-MEK SC for 4 hours or exposed to PHOSTOXIN prior to planting. Bulbs harvested from plots planted with nematode infested cloves that were soaked in AGRI-MEK SC for 4 hours prior to planting had significantly less stem and bulb nematode damage than bulbs harvest from plots planted with nematode infested cloves soaked in WATER for 2 hours just prior to planting. Significantly fewer stem and bulb nematodes were extracted from bulbs harvested from plots planted with NEMATODE-FREE cloves or plots planted with nematode infested cloves soaked in VELUM PRIME for 1 or 2 hours or coated with VELUM PRIME just prior to planting than from bulbs harvested from plots planted with nematode infested cloves soaked in WATER for 1 and 2 hours or exposed to PHOSTOXIN prior to planting. Exposing nematode infested cloves to PHOSTOXIN just prior to planting did not reduce stem and bulb nematode populations in harvested bulbs compared to bulbs harvested from plots planted with nematode infested cloves soaked in WATER prior to planting.

CONCLUSIONS: Planting NEAMTODE-FREE cloves resulted in the best yields with very little nematode damage and lower nematode populations in harvested bulbs the following summer. Regardless, soaking nematode infested cloves in VELUM PRIME for 1 hour or coating with VELUM PRIME prior to planting significantly reduced nematode damage, populations in bulbs and improved yields at harvest.

Table 1. The effect of soaking stem and bulb nematode infested garlic cloves cv. Music in WATER for 1 and 2 hours, a solution of VELUM PRIME for 1 and 2 hours, a solution of AGRI-MEK SC for 4 hours, coating infested cloves with VELUM PRIME, or exposing infested cloves to PHOSTOXIN gas for 72 hours at 29°C just prior to planting compared to planting NEMATODE-FREE cloves in the fall 2016 on plant stand in 2017.

Treatment	Rate	Exposure Method	% Plant Stand[1]			
			1 April	9 May	9 June	18 July
NEMATODE-FREE	NA	NA	85.0 a[2]	83.3 a	82.5 a	82.5 a
WATER	NA	1 hour soak	72.5 a	63.3 b	58.3 cd	42.5 c
WATER	NA	2 hour soak	73.3 a	60.0 b	53.3 d	38.3 c
AGRI-MEK SC	0.85 ml/L	4 hour soak	74.2 a	65.8 b	60.8 bcd	50.83 bc
VELUM PRIME	0.7 ml/L	1 hour soak	79.2 a	75.8 ab	75.0 ab	69.2 ab
VELUM PRIME	0.7 ml/L	2 hour soak	75.8 a	67.5 b	64.2 bcd	54.2 bc
VELUM PRIME	0.8 ml/kg of cloves	Clove Coating	83.3 a	76.7 ab	72.5 abc	66.7 ab
PHOSTOXIN	3.98 g/m^3	Gas 72 hours @ 29°C	77.5 a	60.8 b	50.0 d	34.2 c

1. Data was transformed using the Arcsine (% stand count) to improve normality and additivity prior to statistical analysis however, actual means are presented
2. Figures within columns followed by the same letter are not significantly different using Tukey's HSD test (P<0.05)

Table 2. The effect of soaking stem and bulb nematode infested garlic cloves cv. Music in WATER for 1 and 2 hours, a solution of VELUM PRIME for 1 and 2 hours, a solution of AGRI-MEK SC for 4 hours, coating infested cloves with VELUM PRIME, or exposing infested cloves to PHOSTOXIN gas for 72 hours at 29°C just prior to planting compared to planting NEMATODE-FREE cloves in the fall 2016 on number of bulbs harvested, yield weight, bulb size, number of marketable bulbs harvested, marketable yield weight, nematode damage and number of *D. dipsaci*/g dried bulb at harvest.

Treatment	Rate	Exposure Method	Mean Number of bulbs Harvested per plot	Mean Total Yield wt. (g/plot)	Mean Bulb Diameter (cm)	Mean Number of Marketable Bulbs Harvested per plot	Marketable Yield wt. (g/plot)	Nematode Damage on Harvested Bulbs (0-4)[1]	No. of *D. dipsaci* per g Dried Bulb[2]
NEMATODE-FREE	NA	NA	24.8 a[3]	1719.4 a	5.7 a	21.0 a	1506.9 a	1.0 d	3.5 b
WATER	NA	1 hour soak	12.8 c	238.0 d	2.5 b	0.0 d	0.0 e	4.0 a	288.3 a
WATER	NA	2 hour soak	11.5 c	246.0 d	2.8 b	1.0 d	70.0 de	3.8 a	287.0 a
AGRI-MEK SC	0.85 ml/L	4 hour soak	15.3 bc	777.3 c	4.9 a	8.5 c	574.3 cd	2.8 b	109.3 a
VELUM PRIME	0.7 ml/L	1 hour soak	20.8 ab	1227.7 b	5.3 a	16.3 ab	1107.5 ab	1.5 cd	0.0 b
VELUM PRIME	0.7 ml/L	2 hour soak	16.3 bc	1010.0 bc	5.7 a	12.8 bc	653.0 bc	2.0 c	0.3 b
VELUM PRIME	0.8 ml/kg of cloves	Clove Coating	20.0 ab	1019.1 bc	5.0 a	13.0 bc	795.83 bc	1.6 cd	0.0 b
PHOSTOXIN	3.98 g/m^3	Gas 72 hours @ 29°C	10.3 c	228.2 d	2.4 b	0.0 d	0.0 e	3.9 a	312.0 a

[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 the same letter are not significantly different using Tukey's HSD test (P<0.05)

2017 PMR REPORT # 06 **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 DRENCHING VELUM PRIME, AGRI-MEK SC AND VIVE-ABA OVER ROWS PLANTED WITH GARLIC CLOVES CV. MUSIC INFESTED WITH STEM AND BULB NEMATODE ON PLANT STAND, YIELD, NEMATODE DAMAGE AND NEMATODE POPULATIONS IN THE BULBS AT HARVEST IN 2017

MATERIALS: AGRI-MEK SC (84 g/L abamectin a.i.); VELUM PRIME (500 g/L a.i.); VIVE-ABA (12% abamectin)

METHODS: Garlic cloves cv. Music infested with *Ditylenchus dipsaci* (832 nematodes/g dry cloves) were planted in plots 5 cm deep, spaced 15 cm apart within row, in 152.4 cm long rows spaced 75 cm apart with 3 rows/plot on 19 October 2016. The plots were drenched in the FALL on 19 October 2016 prior to closing the furrows, or over top of the rows the following SPRING on 27 April 2017 or both FALL + SPRING with WATER (2845 L water/ha), VELUM PRIME (500 g.a.i. fluopyram/L) at 500 ml in 2845 L water/ha; VIVE-ABA (12% abamectin) at 189 ml in 2845 L water/ha or AGRI-MEK SC (84 g.a.i. abamectin/L) at 270 ml in 2845 L water/ha. The plots were arranged in a randomized complete block design with 4 replications at a commercial garlic farm near Scotland Ontario. The field did not have a history of stem and bulb nematodes; however other fields planted with garlic on the commercial farm had previous history with stem and bulb nematode. Scapes were removed from plants on 20 June 2017 to encourage bulb growth. Plant stand were evaluated on 1 April, 9 May, 9 June, and 18 July 2017. Garlic bulbs were harvested from plots on 18 July 2017, measured for size (diameter), weighed and assessed for stem and bulb nematode damage 0-4 (0 = no damage; 1= slight damage; 2= moderate damage; 3= severe damage, 4= dead). Stem and bulb nematodes were extracted from 10 randomly selected bulbs harvested from each plot by placing the bulbs on Baermann funnels in a mist chamber for 24 hours. Extracted nematodes were identified to genera and enumerated. The garlic bulbs were then dried at 80^{o}C for 72 hours to obtain the dry weight. Plant stand and nematode data were transformed using Arcsine (% stand count) and Log (nematode/g dried bulb +1) respectively to improve normality and additivity prior to statistical analysis however, actual means are presented. All data was analysed using the General Analysis of Variance function of the Linear Models section of Statistix V.9. Tukey's HSD test was used to detect differences among the treatment means at $P<0.05$.

RESULTS: Plant stands declined in all plots from April through July 2017 (Table 1). VELUM PRIME drenched over the rows at in the FALL at planting, both FALL + SPRING and AGRI-MEK SC drenched in both the FALL + SPRING resulted in significantly better plant stands than WATER drenched in the FALL, and AGRI-MEK SC or VIVE-ABA drenched in SPRING only. Plant stands were significantly better in plots drenched with VIVE-ABA in the FALL + SPRING than plots drenched with WATER in the FALL.

Significantly higher number of bulbs were harvested from plots drenched with VELUM PRIME in the FALL or FALL + SPRING and AGRI-MEK SC drenched in the FALL + SPRING than from plots drenched with WATER in the FALL, or AGRI-MEK SC and VIVE-ABA drenched in the SPRING (Table 2). Significantly higher numbers of bulbs were also harvested from plots drenched with VIVE-ABA in both the FALL + SPRING than from plots drenched with WATER in the FALL. The yield of the bulbs harvested was also significantly higher from plots drenched with VELUM PRIME in the FALL than from plots drenched with VELUM PRIME in the SPRING, or WATER, AGRI-MEK SC and VIVE-ABA drenched in the FALL, SPRING or both FALL + SPRING. Drenching plots with VELUM PRIME in both the FALL + SPRING also resulted in higher yield than from plots drenched with VELUM PRIME in the SPRING only; WATER drenched in the FALL, SPRING or both FALL + SPRING and plots drenched with AGRI-MEK SC or VIVE-ABA in the FALL or SPRING only. AGRI-MEK SC or VIVE-ABA drenched over plots in both the FALL + SPRING had higher yield than from plots drenched with WATER in the FALL and AGRI-MEK SC or VIVE-ABA drenched in the SPRING only. The size of bulbs harvested from plots drenched with VELUM PRIME in the FALL and both the FALL + SPRING were larger than from plots drenched with WATER in the FALL or both FALL + SPRING, and AGRI-MEK SC or VIVE-ABA drenched in the SPRING. Larger bulbs were harvested from plots drenched with VIVE-ABA in both the FALL + SPRING than from plots drench with AGRI-MEK SC in the SPRING or WATER drenched in the FALL. Significantly more marketable bulbs were harvested from plots drenched with VELUMPRIME in the FALL or both FALL + SPRING than from plots drenched with VELUM PRIME in the SPRING or WATER, AGRI-MEK SC and VIVE-ABA drenched in the FALL, SPRING or both FALL + SPRING. Significantly higher marketable yield was harvested from plots drenched with VELUM PRIME in the FALL than from plots drenched with VELUM PRIME in the SPRING or WATER and AGRI-MEK SC drenched in the FALL, SPRING or both FALL + SPRING or VIVE-ABA drenched in the SPRING. Drenching VELUM PRIME in the FALL + SPRING resulted in significantly higher marketable yield at harvest than drenching VELUM PRIME in the SPRING only, WATER in the FALL, SPRING or both FALL + SPRING or AGRI-MEK SC and VIVE-ABA in the SPRING. Garlic bulbs harvested from plots drenched with VELUM PRIME either in the FALL or both FALL + SPRING had significantly less stem and bulb nematode damage than garlic bulbs harvested from plots drenched with VELUM PRIME in the SPRING or WATER, AGRI-MEK SC and VIVE-ABA drenched in the FALL, SPRING or both FALL + SPRING. Similarly, significantly fewer stem and bulb nematodes were extracted from bulbs harvested from plots drenched with VELUME PRIME either in the FALL at planting and both FALL + SPRING than from garlic bulbs harvested from plots drenched with VELUM PRIME in the SPRING only or WATER, AGRI-MEK SC and VIVE-ABA drenched in the FALL, SPRING or both FALL + SPRING. Bulbs harvested from plots drenched with VIVE-ABA in both FALL + SPRING had significantly less nematode damage than bulbs harvested from plots drenched with WATER in the FALL.

CONCLUSIONS: Better plant stands, higher mean number of bulbs, marketable bulbs, bulb size with less nematode damage and fewer nematodes was harvested from plots planted with nematode invested cloves drenched with VELUM PRIME in the FALL at planting than drenching in the SPRING or drenching with AGRI-MEK SC or VIVE-ABA in the FALL, SPRING or both FALL + SPRING. Although drenching VELUM PRIME in both the FALL + SPRING also resulted in better plant stands, higher number of harvested bulbs, marketable bulbs, bulb size with less nematode damage and fewer nematodes, the improvement at harvest could be attributed to the FALL drench regardless if followed with a second drench the following spring since very little improvement was observed with a single SPRING drench.

Table 1. The effect of drenching VELUM PRIME , AGRI-MEK SC or VIVE-ABA compared to WATER over stem and bulb nematode infested garlic cloves cv. Music in the FALL 2016 at planting, SPRING 2017 or both FALL (2016) and SPRING (2017) on plant stand the following spring and summer 2017.

Treatment	Drench Rate L/ha	Application Time	% Plant Stand[1]			
			1 April	9 May	9 June	18 July
WATER	2845	**FALL**	50.8 a[2]	28.3 a	25.8 a	14.2 c
WATER	2845	**SPRING**	64.2 a	54.2 a	45.8 a	32.5 abc
WATER	2845	**FALL + SPRING**	62.5 a	53.3 a	48.3 a	35.0 abc
AGRI-MEK SC	0.27	**FALL**	70.0 a	55.8 a	51.7 a	43.3 abc
AGRI-MEK SC	0.27	**SPRING**	59.2 a	47.5 a	38.3 a	20.8 bc
AGRI-MEK SC	0.27	**FALL + SPRING**	80.0 a	72.5 a	68.3 a	64.2 a
VELUM PRIME	0.5	**FALL**	87.5 a	83.3 a	74.2 a	68.3 a
VELUM PRIME	0.5	**SPRING**	68.3 a	58.3 a	51.7 a	37.5 abc
VELUM PRIME	0.5	**FALL + SPRING**	75.8 a	75.0 a	67.5 a	65.0 a
VIVE-ABA	0.189	**FALL**	69.2 a	55.0 a	47.5 a	38.3 abc
VIVE-ABA	0.189	**SPRING**	52.5 a	40.8 a	35.0 a	25.8 bc
VIVE-ABA	0.189	**FALL + SPRING**	73.3 a	65.0 a	61.7 a	55.8 ab

[1.] Data was transformed using the Arcsine (% stand count/100) to improve normality and additivity prior to statistical analysis however, actual means are presented

[2.] Figures within columns followed by the same letter are not significantly different using Tukey's HSD test (P<0.05)

Table 2. The effect of drenching VELUM PRIME, AGRI-MEK SC or VIVE-ABA compared to WATER over stem and bulb nematode infested garlic cloves cv. Music in the FALL (2016) at planting, SPRING (2017) or both FALL (2016) + SPRING (2017) on number of bulbs harvested, yield, bulb size, number of marketable bulbs harvested, marketable yield, nematode damage and number of *D. dipsaci*/g dried bulb at harvest.

Treatment	Drench Rate L/ha	Application Time	Mean Number of bulbs Harvested per plot	Mean Yield wt. (g/plot)	Mean Bulb Diameter (cm)	Mean Number of Marketable Bulbs Harvested per plot	Marketable Yield wt. (g/plot)	Nematode Damage (0-4)[1]	No. of *D. dipsaci* per g dried bulb at harvest[2]
WATER	2845	**FALL**	4.3 c[3]	83.9 d	1.2 c	0.0 b	0.0 c	4.0 a	495.0 a
WATER	2845	**SPRING**	9.8 abc	240.0 cd	3.0 abc	0.3 b	16.3 c	3.8 ab	245.3 a
WATER	2845	**FALL + SPRING**	10.5 abc	214.3 cd	2.0 bc	0.3 b	26.0 c	3.9 ab	620.3 a
AGRI-MEK SC	0.27	**FALL**	13.0 abc	434.2 cd	3.3 abc	1.0 b	56.4 bc	3.6 ab	260.8 a
AGRI-MEK SC	0.27	**SPRING**	6.3 bc	128.2 d	1.5 c	0.0 b	0.0 c	3.9 ab	317.5 a
AGRI-MEK SC	0.27	**FALL + SPRING**	19.25 a	703.4 bc	3.9 abc	2.0 b	115.2 bc	3.4 ab	252.0 a
VELUM PRIME	0.5	**FALL**	20.5 a	1207.7 a	5.2 a	15.8 a	1052.0 a	1.5 c	0.0 b
VELUM PRIME	0.5	**SPRING**	11.3 abc	218.4 cd	2.5 abc	0.3 b	20.4 c	3.9 ab	216.8 a
VELUM PRIME	0.5	**FALL + SPRING**	19.5 a	1160.5 ab	5.2 a	13.5 a	961.8 ab	1.7 c	0.3 b
VIVE-ABA	0.189	**FALL**	11.5 abc	428.3 cd	2.8 abc	1.5 b	124.53 abc	3.5 ab	222.8 a
VIVE-ABA	0.189	**SPRING**	7.8 bc	181.1 d	2.1 bc	0.0 b	0.0 c	4.0 a	890.3 a
VIVE-ABA	0.189	**FALL + SPRING**	16.8 ab	698.1 bc	4.4 ab	3.0 b	802.8 abc	3.2 b	281.0 a

[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 the same letter are not significantly different using Tukey's HSD test (P<0.05)

2017 PMR Report 07 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.), cv. McIntosh
PEST: Gray mold (*Botrytis cinerea* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST GRAY MOLD IN 'MCINTOSH' APPLES, 2017-18.

MATERIALS: *Pseudomonas fluorescens* 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 15th and stored at 4^{o}C until ready for processing. On September 20th, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 solution for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4^{o}C. On September 21th, 2017, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Botrytis cinerea* and/or treatments. Each treatment consisted of 1 L of inoculum containing 1x10^{4} spores/mL water of the pathogen (*B. cinerea*, Bc-34R) and/or the required concentration of *Pseudomonas fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without *B. cinerea*, (2) Sodium Bicarbonate at 5 g/L with and without *B. cinerea*, (3) Salicylic Acid at 0.1 g/L with and without *B. cinerea*, (4) Calcium Chloride at 10g/L with and without *B. cinerea*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *B. cinerea*, (5) *P. fluorescens* strain 4-6, 1x10^{9} CFU/mL and SBC, $CaCl_2$ or SA at the above mentioned concentrations with and without *B. cinerea*, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *B. cinerea*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 111 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of first fruit disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for gray mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison

procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS:

Significant differences were observed among the treatments. The control (with *B. cinerea*) had the highest gray mold incidence at all observation points. The positive control treatment, SCHOLAR at 0.6 g/L had a complete control of gray mold for up to 111 days and in shelf-life study. After28 days of incubation, in 'McIntosh' apples, the percent disease incidence in the combination of *P. fluorescens* strain 4-6 and the GRAS compounds treatments ranged between 50 - 73% and was significantly lower than the control treatment with *B. cinerea* ($P = 0.001$). With the exception of SA, the two GRAS compounds treated alone had higher disease incidence. The treatments of antagonists, *P. fluorescens* 4-6 or BIOSAVE, had 83.3% and 93% incidence of gray mold, respectively. The combination treatments of *P. fluorescens* strain 4-6 and one GRAS compound (SBC) had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone in cold storage. The combination of antagonist *P. fluorescens* 4-6 and $CaCl_2$ or SBC was the best treatment for the control of gray mold in this study. With the exception of *P. fluorescens* strain 4-6 and $CaCl_2$ and SCHOLAR treatments, a high disease incidence was observed in all other treatments for up to 111 days after treatment and in the shelf-life study.

ACKNOWLDGEMENT: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* 4-6 in combination with different GRAS compounds on the control of postharvest gray mold (*Botrytis cinerea*) in 'McIntosh' apples, 2017-18.

Treatment	Percent gray mold incidence[a]				
	28 days[b]	56 days	84 days	111 days	Shelf-life[c]
Water + *B. cinerea* [d]	90[e] f	96.7 ef	100 f	100 e	100 e
Sodium Bicarbonate @ 5 g/L + *B. cinerea*	96.7 f	100 f	100 f	100 e	100 e
Salicylic Acid @ 0.1g/L + *B. cinerea*	16.7 b	16.7 b	20 b	20 b	20 b
Calcium Chloride @ 10g/L + *B. cinerea*	80 e	93.3 e	93.3 d	93.3 d	93.3 e
BIOSAVE @ 1.59 g/L+ *B. cinerea*	83.3 e	86.7 d	96.7 e	100 e	100 e
P. fluorescens[f] strain 4-6 + *B. cinerea*	90 f	93.3	93.3 d	93.3 d	96.7 e
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	50 c	70 c	73.3 c	76.7 c	80 d
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	73.3	80 d	90 d	90 d	90 e
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *B. cinerea*	50 c	66.7 c	70 c	72.6 c	72.6 c
SCHOLAR @ 0.6g/L + *B. cinerea*	0 a	0 a	0 a	0 a	0 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] 7 days at 20ºC after 4ºC storage
[d] *B. cinerea* was used at a concentration of $1x10^4$ spores/mL
[e] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[f] *P. fluorescens* strain 4-6 was used at a concentration of $1x10^9$ cfu/mL

2017 PMR Report # 08 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.) cv. McIntosh
PEST: Blue mold (*Penicillium expansum* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST BLUE MOLD IN 'MCINTOSH' APPLES, 2017-18.

MATERIALS: *Pseudomonas fluorescens* strain 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 15, 2017 and stored at 4ºC until ready for processing. On October 2, 2017, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 and water for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On October 3rd 2017, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Penicillium expansum* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen *P. expansum* (Pe-S) and/or the required concentration of the *P. fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without inoculum, (2) Sodium Bicarbonate at g/L with and without inoculum of *P. expansum*, (3) Salicylic Acid at 0.1 g/L with and without *P. expansum* , (4) Calcium Chloride at 10 g/L with and without *P. expansum*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *P. expansum*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL with and/or without *P. expansum* and or SBC, $CaCl_2$ and SA at the above mentioned concentrations, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *P. expansum*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 107 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the initial evaluation of disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for blue mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple

comparison procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: The experiment is in progress at the time of report writing in January 2017. Significant differences were observed among the treatments. The control (with *P. expansum*) had the highest blue mold incidence at all observation points beginning at 44 days after treatment. The positive control fungicide treatment, SCHOLAR at 0.6 g/L had a complete control of blue mold until the day 107 and 6.7% blue mold was observed in the shelf-life study.
At 28 days after treatment, the combination treatments had 3.3 - 13.3% blue mold incidence. At 44 days and 82 days after treatment, the combination of antagonist *P. fluorescens* strain 4-6 and $CaCl_2$ treatment had lower disease incidence than the GRAS compounds applied alone and the control. With the exception of fungicide treatment, SCHOLAR, an increase in disease incidence was observed in all treatments after 85 days of incubation. The combination treatments of antagonist *P. fluorescens* strain 4-6 and $CaCl_2$ had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone for up to107 days after treatment.

ACKNOWLDGEMENTS: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* strain 4-6 alone or in combination with different GRAS compounds on the control of postharvest blue mold (*Penicillium expansum*) in 'McIntosh' apples, 2017-18.

Treatment	Percent blue mold incidence[a]				
	28 days[b]	44 days	81 days	107 days	Shelf-life
Water + *P. expansum* [c]	60 [d] e	100 h	100 f	100 e	100 c
Sodium Bicarbonate @ 5 g/L + *P. expansum*	60 e	93.3 g	93.3 e	93.3 d	96.7 c
Salicylic Acid @ 0.1g/L + *P. expansum*	73.3 f	96.7gh	100 f	100 e	100 c
Calcium Chloride @ 10g/L + *P. expansum*	20 d	63.3 e	80 c	83.3 c	100 c
BIOSAVE @1.59 g/L + *P. expansum*	10 c	70 e	86.7 c	96.7 d	96.7 c
P. fluorescens strain 4-6 [e] + *P. expansum*	0 a	56.7 c	83.3 c	83.3 c	96.7 c
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *P. expansum*	10 c	73.3 e	80 c	80 c	96.7 c
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *P. expansum*	13.3 c	86.7 f	92.3 d	92.9 d	100 c
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *P. expansum*	3.3 b	30 b	33.3 b	50 b	76.7 b
SCHOLAR @ 0.6g/L + *P. expansum*	0 a	0 a	0 a	0 a	6.7 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] *P. expansum* was used at a concentration of $1x10^4$ spores/mL
[d] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[e] *P. fluorescens* was used at a concentration of $1x10^9$ cfu/mL

2017 PMR Report # 9 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.), cv. Gala
PEST: Gray mold (*Botrytis cinerea* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST GRAY MOLD IN 'GALA' APPLES, 2017-18.

MATERIALS: *Pseudomonas fluorescens* 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'Gala' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 12th and stored at 4ºC until ready for processing. On September 20th, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 solution for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On September 21st, 2017, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Botrytis cinerea* and/or treatments. Each treatment consisted of 1 L of inoculum containing 1x10^4 spores/mL water of the pathogen (*B. cinerea*, Bc-34R) and/or the required concentration of *Pseudomonas fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without *B. cinerea*, (2) Sodium Bicarbonate at 5 g/L with and without *B. cinerea*, (3) Salicylic Acid at 0.1 g/L with and without *B. cinerea*, (4) Calcium Chloride at 10g/L with and without *B. cinerea*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *B. cinerea*, (5) *P. fluorescens* strain 4-6, 1x10^9 CFU/mL and SBC, $CaCl_2$ or SA at the above mentioned concentrations with and without *B. cinerea*, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *B. cinerea*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 111 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of first fruit disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for gray mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *B. cinerea*) had the highest gray mold incidence at all observation points. The positive control treatment, SCHOLAR at 0.6 g/L had a complete control of gray mold for up to 111 days and in shelf-life study. After 28 days of incubation, in 'Gala' apples, the percent disease incidence in the combination of *P. fluorescens* strain 4-6 and the GRAS compounds treatments ranged between 3.3 – 26.7% and was significantly lower than the control treatment with *B. cinerea* ($P = 0.001$). With the exception of SA, the two GRAS compounds treated alone had higher disease incidence. The treatments of antagonists, *P. fluorescens* 4-6 and BIOSAVE, had 20% and 33.3% incidence of gray mold, respectively. The combination treatments of *P. fluorescens* strain 4-6 and SBC or $CaCl_2$ had better control than the treatment of either *P. fluorescens* strain 4-6 or SBC or $CaCl_2$ alone in cold storage. The combination of antagonist *P. fluorescens* 4-6 and $CaCl_2$ was the best treatment for the control of gray mold for 111 days and in the shelf-life study. With the exception of *P. fluorescens* strain 4-6 and $CaCl_2$ and SCHOLAR treatments, a high disease incidence was observed in all other treatments for up to 111 days after incubation.

ACKNOWLDGEMENTS: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* 4-6 in combination with different GRAS compounds on the control of postharvest gray mold (*Botrytis cinerea*) in 'Gala' apples, 2017-18.

Treatment	Percent gray mold incidence [a]				
	28 days[b]	56 days	84 days	111 days	Shelf-life[c]
Water + *B. cinerea* [d]	86.7 [e] j	90 h	90 i	93.3 f	93.3 f
Sodium Bicarbonate @ 5 g/L + *B. cinerea*	56.7 i	70 g	70 h	70 e	76.7 e
Salicylic Acid @ 0.1g/L + *B. cinerea*	13.3 c	13.3 c	13.3 c	13.3 b	16.7 b
Calcium Chloride @ 10g/L + *B. cinerea*	40 g	43.3 e	46.7 f	56.7 d	76.7 e
BIOSAVE @ 1.59 g/L+ *B. cinerea*	33.3 f	40 e	63.3 g	73.3 e	80 e
P. fluorescens[f] strain 4-6 + *B. cinerea*	20 d	23.3 d	23.3 d	27 c	30.7 c
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	26.7 e	26.7 d	30 e	30 c	33.3 c
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	46.7 h	56.7 f	56.7 g	56.7 d	60 d
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *B. cinerea*	3.3 b	6.7 b	6.7 b	13.3 b	17 b
SCHOLAR @ 0.6g/L + *B. cinerea*	0 a	0 a	0 a	0 a	0 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] Apples incubated at 20°C for 7 days.
[d] *B. cinerea* was used at a concentration of $1x10^4$ spores/mL
[e] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[f] *P. fluorescens* strain 4-6 was used at a concentration of $1x10^9$ cfu/mL

2017 PMR Report # 10 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.) cv. Gala
PEST: Blue mold (*Penicillium expansum* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST BLUE MOLD IN 'GALA' APPLES, 2017-18.

MATERIALS: *Pseudomonas fluorescens* strain 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 12, 2017 and stored at 4ºC until ready for processing. On October 2, 2017, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 and water for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On October 3, 2017, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Penicillium expansum* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen *P. expansum* (Pe-S) and/or the required concentration of the *P. fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without inoculum, (2) Sodium Bicarbonate at g/L with and without inoculum of *P. expansum*, (3) Salicylic Acid at 0.1 g/L with and without *P. expansum* , (4) Calcium Chloride at 10 g/L with and without *P. expansum*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *P. expansum*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL with and/or without *P. expansum* and or SBC, $CaCl_2$ and SA at the above mentioned concentrations, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *P. expansum*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 107 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the initial evaluation of disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for blue mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple

comparison procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *P. expansum*) had the highest blue mold incidence at all observation points beginning at 44 days after treatment. The positive control fungicide treatment, SCHOLAR at 0.6 g/L had a complete control of blue mold until the day 107 and 6.7% blue mold was observed in the shelf-life study. At 28 days after treatment, the combination treatments had 0 – 6.7% blue mold incidence. At 44 days and 81 days after treatment, the combination of antagonist *P. fluorescens* strain 4-6 and $CaCl_2$ treatment had lower disease incidence than the GRAS compounds applied alone and the control. With the exception of fungicide treatment, SCHOLAR, an increase in disease incidence was observed in all treatments after 81 days of incubation. The combination treatments of antagonist *P. fluorescens* strain 4-6 and $CaCl_2$ had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone for up to 81 days after treatment.

ACKNOWLDGEMENT: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* strain 4-6 alone or in combination with different GRAS compounds on the control of postharvest blue mold (*Penicillium expansum*) in 'Gala' apples, 2017-18.

Treatment	Percent blue mold incidence				
	28 days[b]	44 days	81 days	107 days	Shelf-life
Water + *P. expansum* [c]	3.3 [d] b	89.2 g	96.7 g	96.7 f	96.7 de
Sodium Bicarbonate @ 5 g/L + *P. expansum*	3.3 b	80 f	86.7 f	96.7 f	100 e
Salicylic Acid @ 0.1g/L + *P. expansum*	26.7 d	96.7 h	100 g	100 f	100 e
Calcium Chloride @ 10g/L + *P. expansum*	0 a	50 e	60 e	66.7 d	90 d
BIOSAVE @1.59 g/L + *P. expansum*	0 a	0 a	16.7 b	43.3 b	80 c
P. fluorescens strain 4-6 [e] + *P. expansum*	0 a	10 b	46.7 c	53.3 c	73.3 b
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *P. expansum*	6.7 c	36.7 d	56.7 d	70 e	76.7 b
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *P. expansum*	0 a	30 c	53.3 d	70 e	83.3 c
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *P. expansum*	0 a	6.7 b	23.3 b	67.8 d	74.4 b
SCHOLAR @ 0.6g/L + *P. expansum*	0 a	0 a	0 a	0 a	3.3 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] *P. expansum* was used at a concentration of $1x10^4$ spores/mL
[d] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[e] *P. fluorescens* was used at a concentration of $1x10^9$ cfu/mL

2017 PMR Report # 11 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.), cv. McIntosh
PEST: Blue mold (*Penicillium expansum* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST BLUE MOLD IN 'MCINTOSH' APPLES, 2016-17.

MATERIALS: *Pseudomonas fluorescens* strain 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 7-8, 2016 and stored at 4ºC until ready for processing. On September 15, 2016, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 and water for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On September 16, 2016, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Penicillium expansum* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen *P. expansum* (Pe-S) and/or the required concentration of the *P. fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without inoculum, (2) Sodium Bicarbonate at g/L with and without inoculum of *P. expansum*, (3) Salicylic Acid at 0.1 g/L with and without *P. expansum* , (4) Calcium Chloride at 10 g/L with and without *P. expansum*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *P. expansum*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL with and/or without *P. expansum* and or SBC, $CaCl_2$ and SA at the above mentioned concentrations, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *P. expansum*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 84 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of initial disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for blue mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *P. expansum*) had the highest blue mold incidence at all observation points. The positive control fungicide treatment, SCHOLAR at 0.6 g/L had a complete control of blue mold in cold storage 3.7% blue mold was observed in the shelf-life study. At 28 days after treatment, all the treatments including the control had 0 - 20.0% blue mold incidence. At 56 days to 108 days after treatment, the combination of antagonist *P. fluorescens* strain 4-6 and each of the GRAS compounds (SA and $CaCl_2$) treatments had lower disease incidence than the GRAS compounds applied alone and the control. With the exception of fungicide treatment, SCHOLAR, an increase in disease incidence was observed in all treatments after 85 days of incubation. The combination treatments of antagonist *P. fluorescens* strain 4-6 and each of the GRAS compounds, SA and $CaCl_2$, had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone for up to 82 days after treatment.

ACKNOWLDGEMENT: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* strain 4-6 alone or in combination with different GRAS compounds on the control of postharvest blue mold (*Penicillium expansum*) in 'McIntosh' apples, 2016-17.

Treatment	Percent blue mold incidence[a]				
	28 days[b]	56 days	82 days	108 days	Shelf-life
Water + *P. expansum* [c]	13.3 [d] c	70 f	90 f	96.7 e	96.7 d
Sodium Bicarbonate @ 5 g/L + *P. expansum*	20 d	70 f	100 g	100 e	100 e
Salicylic Acid @ 0.1g/L + *P. expansum*	10 c	86.7	96.7 g	96.7 e	100 e
Calcium Chloride @ 10g/L + *P. expansum*	0 a	36.7 d	53.3 c	73.3 c	93.3d
BIOSAVE @1.59 g/L + *P. expansum*	13.3 c	53.3 e	70 d	83.3 d	86.7 c
P. fluorescens strain 4-6 [e] + *P. expansum*	3.3 b	70 f	90 f	93.3	96.7 d
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *P. expansum*	3.3 b	63.3 f	80 e	86.7 d	96.7 d
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *P. expansum*	3.3 b	36.7 d	73.3 d	86.7 d	90 cd
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *P. expansum*	0 a	26.7 c	36.7 b	49.6 b	62.2 b
SCHOLAR @ 0.6g/L + *P. expansum*	0 a	0 a	0 a	0 a	3.7 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] *P. expansum* was used at a concentration of $1x10^4$ spores/mL
[d] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[e] *P. fluorescens* was used at a concentration of $1x10^9$ cfu/mL

2017 PMR Report # 12 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.), cv. McIntosh
PEST: Gray mold (*Botrytis cinerea* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST GRAY MOLD IN 'MCINTOSH' APPLES, 2016-17.

MATERIALS: *Pseudomonas fluorescens* 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 7-8th and stored at 4ºC until ready for processing. On September12, 2016, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 solution for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On September 13, 2016, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Botrytis cinerea* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen (*B. cinerea*, Bc-34R) and/or the required concentration of *Pseudomonas fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without *B. cinerea*, (2) Sodium Bicarbonate at 5 g/L with and without *B. cinerea*, (3) Salicylic Acid at 0.1 g/L with and without *B. cinerea*, (4) Calcium Chloride at 10g/L with and without *B. cinerea*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *B. cinerea*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL and SBC, $CaCl_2$ or SA at the above mentioned concentrations with and without *B. cinerea*, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *B. cinerea*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 114 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of first fruit disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for gray mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison

procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *B. cinerea*) had the highest gray mold incidence at all observation points. The positive control treatment, SCHOLAR at 0.6 g/L had a complete control of gray mold for up to 120 days and in shelf-life study. After 4 weeks of incubation, in 'McIntosh' apples, the percent disease incidence in the combination of *P. fluorescens* strain 4-6 and the GRAS compounds treatments ranged between 30 - 36% and was significantly lower than the control treatment with *B. cinerea* ($P = 0.001$). With the exception of SA, the two GRAS compounds treated alone had higher disease incidence. The treatments of antagonists, *P. fluorescens* 4-6 and BIOSAVE, had 26.7% and 33% incidence of gray mold, respectively. The combination treatments of *P. fluorescens* strain 4-6 and only one GRAS compound (SBC) had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone in cold storage. The combination of antagonist *P. fluorescens* 4-6 and $CaCl_2$ was the best treatment for the control of gray mold in this study. With the exception of *P. fluorescens* strain 4-6 and $CaCl_2$ and SCHOLAR treatments, a high disease incidence was observed in all other treatments for up to 120 days after treatment and in the shelf-life study.

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Table 1. Effect of *Pseudomonas fluorescens* 4-6 in combination with different GRAS compounds on the control of postharvest gray mold (*Botrytis cinerea*) in 'McIntosh' apples, 2016-17.

Treatment	Percent gray mold incidence [a]				
	28 days[b]	56 days	91 days	120 days	Shelf-life [c]
Water + *B. cinerea* [d]	53.3 [e] e [f]	83.3 e	83.3 f	83.3 f	83.3 e
Sodium Bicarbonate @ 5 g/L + *B. cinerea*	60 e	83.3 e	83.3 f	86.7 fg	86.7 ef
Salicylic Acid @ 0.1g/L + *B. cinerea*	16.7 b	26.7 b	30 b	43.3 b	63.6 c
Calcium Chloride @ 10g/L + *B. cinerea*	36.7 d	70 d	71.8 e	71.8 e	75.5 d
BIOSAVE @ 1.59 g/L+ *B. cinerea*	26.7 c	56.7 e	59.2 d	62.6 d	62.5 c
P. fluorescens[f] strain 4-6 + *B. cinerea*	33.3 d	70 d	76.7 e	76.7 e	76.7 d
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	30 d	80 e	86.7 f	90 g	90 f
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	36.7 d	56.7 e	96.7 g	96.7 h	96.7 g
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *B. cinerea*	30 d	45 c	45 c	50 c	53.9 b
SCHOLAR @ 0.6g/L + *B. cinerea*	0 a	0 a	0 a	0 a	0 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] 7 days at 20ºC after 4ºC storage
[d] *B. cinerea* was used at a concentration of $1x10^4$ spores/mL
[e] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[f] *P. fluorescens* strain 4-6 was used at a concentration of $1x10^9$ cfu/mL

CROP: Apples (*Malus domestica* Borkh.), cv. Gala
PEST: Gray mold (*Botrytis cinerea* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST GRAY MOLD IN 'GALA' APPLES, 2016-17.

MATERIALS: *Pseudomonas fluorescens* 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'Gala' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 6, 2016 and stored at 4ºC until ready for processing. On September12, 2016, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 solution for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On September 13, 2016, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Botrytis cinerea* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen (*B. cinerea*, Bc-34R) and/or the required concentration of *Pseudomonas fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without *B. cinerea*, (2) Sodium Bicarbonate at 5 g/L with and without *B. cinerea*, (3) Salicylic Acid at 0.1 g/L with and without *B. cinerea*, (4) Calcium Chloride at 10g/L with and without *B. cinerea*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *B. cinerea*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL and SBC, $CaCl_2$ or SA at the above mentioned concentrations with and without *B. cinerea*, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *B. cinerea*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 114 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of first fruit disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for gray mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison

procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *B. cinerea*) had the highest gray mold incidence at all observation points. The positive control treatment, SCHOLAR at 0.6 g/L had a complete control of gray mold for up to 120 days and in shelf-life study. After 29 days of incubation, in 'Gala' apples, the percent disease incidence in the combination of *P. fluorescens* strain 4-6 and the GRAS compounds treatments ranged between 0 – 3.3% and was significantly lower than the control treatment with *B. cinerea* ($P = 0.001$). With the exception of SA, the two GRAS compounds treated alone had higher disease incidence. The treatments of antagonists, *P. fluorescens* 4-6 and BIOSAVE, had 6.7% incidence of gray mold. A 6.7% incidence of gray mold was observed in SA treated apples for up to 148 days. The combination treatments of *P. fluorescens* strain 4-6 and all three GRAS compound had better control than the treatment of either *P. fluorescens* strain 4-6 or SBC or $CaCl_2$ alone in cold storage. The combination of antagonist *P. fluorescens* 4-6 and $CaCl_2$ was the best treatment for the control of gray mold for up to 120 days in this study.

ACKNOWLDGEMENT: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* 4-6 in combination with different GRAS compounds on the control of postharvest gray mold (*Botrytis cinerea*) in 'Gala' apples, 2016-17.

Treatment	Percent gray mold incidence [a]						
	29 days[b]	56 days	91 days	120 days	148 days	189 days	Shelf-life[c]
Water + *B. cinerea* [d]	56.7[e] e[f]	90 g	90 g	90 f	90 f	90 e	90 g
Sodium Bicarbonate @ 5 g/L + *B. cinerea*	43.3 d	76.7 f	76.7 f	76.7 e	76.7 e	76.7 d	80 e
Salicylic Acid @ 0.1g/L + *B. cinerea*	3.3 b	6.7 b	6.7 b	6.7 b	6.7 b	36.7 b	40 d
Calcium Chloride @ 10g/L + *B. cinerea*	43.3 d	66.7 e	55.3 d	73.3 e	73.3 e	76.7 d	83.3 f
BIOSAVE @ 1.59 g/L+ *B. cinerea*	6.7 c	50 d	66.7 e	72.6 e	75.9 e	75.9 d	79.2 f
P. fluorescens[f] strain 4-6 + *B. cinerea*	6.7 c	26.7 c	28.5 c	28.5 d	32.2 d	35.5 c	38.9 c
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	3.3 b	20 c	23.3 c	26.7 d	30 cd	36.7 c	50 e
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *B. cinerea*	3.3 b	20 c	23.3 c	26.7 d	26.7 c	26.7 b	36.7 c
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *B. cinerea*	0 a	6.7 b	11.1 b	16.7 c	25.1 c	28.9 b	32.6 c
SCHOLAR @ 0.6g/L + *B. cinerea*	0 a	0 a	0 a	0 a	0 a	0 a	0 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] Apples incubated at 20°C for 7 days.
[d] *B. cinerea* was used at a concentration of $1x10^4$ spores/mL
[e] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[f] *P. fluorescens* strain 4-6 was used at a concentration of $1x10^9$ cfu/mL.

2017 PMR Report # 14 **SECTION K: FRUIT – Diseases**

CROP: Apples (*Malus domestica* Borkh.), cv. Gala
PEST: Blue mold (*Penicillium expansum* Link.)

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TITLE: EFFECT OF BIOLOGICAL CONTROL AGENT IN COMBINATION WITH GRAS COMPOUNDS ON THE CONTROL OF POSTHARVEST BLUE MOLD IN 'GALA' APPLES, 2016-17.

MATERIALS: *Pseudomonas fluorescens* strain 4-6, BIOSAVE (*Pseudomonas syringae*), Sodium Bicarbonate (Anachemia), Calcium Chloride (Fisher Scientific), Salicylic Acid (Sigma), SCHOLAR (20.4% Fludioxonil, Syngenta).

METHODS: A postharvest study was conducted using 'McIntosh' apples which were obtained from trees maintained according to standard orchard practices at the Agriculture and Agri-Food Canada Farm in Jordan Station, Ontario. Apples were harvested on September 6, 2016 and stored at 4ºC until ready for processing. On September 15, 2016, apples were surface disinfested in 40 L of a 0.6% sodium hypochlorite and 0.001% Tween 20 and water for 4 minutes followed by a 4 minute rinse in water. After the surface disinfestation, the apples were allowed to air dry before being placed into mesh bags, ten per bag. The bags were placed into plastic crates and stored overnight in cold storage at 4ºC. On September 16, 2016, the apples were punctured once with a nail-tapered probe to a depth of 5 mm deep and 4 mm wide at its base. Wounded fruit were then drenched for 30 seconds with the inoculum of *Penicillium expansum* and/or treatments. Each treatment consisted of 1 L of inoculum containing $1x10^4$ spores/mL water of the pathogen *P. expansum* (Pe-S) and/or the required concentration of the *P. fluorescens* strain 4-6, BIOSAVE, GRAS compounds or fungicide. Three compounds, Sodium Bicarbonate (SBC), Calcium Chloride ($CaCl_2$), and Salicylic Acid (SA), Generally Recognised as Safe (GRAS), were tested in this study. The treatments were as follows: (1) Water as control with and without inoculum, (2) Sodium Bicarbonate at g/L with and without inoculum of *P. expansum*, (3) Salicylic Acid at 0.1 g/L with and without *P. expansum* , (4) Calcium Chloride at 10 g/L with and without *P. expansum*, (4) *P. syringae* (BIOSAVE) at 1.59 g/L with and without *P. expansum*, (5) *P. fluorescens* strain 4-6, $1x10^9$ CFU/mL with and/or without *P. expansum* and or SBC, $CaCl_2$ and SA at the above mentioned concentrations, and (6) SCHOLAR (Fludioxonil 20.4%) at 0.6 g/L with *P. expansum*. Ten apples were used for each replicate and each treatment had three replicates. The apples were incubated for 84 days at 4°C and evaluated for disease incidence approximately once every 4 weeks. To determine the efficacy of fungicides on the shelf-life of the fruit, after the evaluation of initial disease incidence following incubation in cold storage, the fruits were placed at 20°C and 85% RH, and incubated for 7 days. The fruits were again evaluated for blue mold incidence (percent infected apples). Fruits were considered diseased when a lesion was developed on the fruit. The general linear model (GLM) procedures were used for the analysis of variance (ANOVA; SigmaStat 2.0 for Windows, SPSS Science, Chicago, IL). Data recorded as percentage were subjected to arcsine square-root transformation before subjected to ANOVA. All pair-wise multiple comparison procedures were determined using Tukey test. Only data obtained from treatments containing pathogen were analysed.

RESULTS: As outlined in Table 1.

CONCLUSIONS: Significant differences were observed among the treatments. The control (with *P. expansum*) had the highest blue mold incidence at all observation points beginning at 55 days after treatment. The positive control fungicide treatment, SCHOLA at 0.6 g/L had a complete control of blue mold until the day 82 and 3.5% blue mold was observed at 108 days and 136 days after treatment. At 28 days after treatment, all the treatments including the control had 0 - 3.3% blue mold incidence. At 55 days and 82 days after treatment, the combination of antagonist *P. fluorescens* strain 4-6 and each of the GRAS compounds (SBC, SA and $CaCl_2$) treatments had lower disease incidence than the GRAS compounds applied alone and the control. With the exception of fungicide treatment, SCHOLAR, an increase in disease incidence was observed in all treatments after 85 days of incubation. The combination treatments of antagonist *P. fluorescens* strain 4-6 and each of the GRAS compounds had better control than the treatment of either *P. fluorescens* strain 4-6 or GRAS compounds alone for up to 82 days after treatment.

ACKNOWLDGEMENT: This project is generously funded through the Canadian Agri-Science Cluster for Horticulture 2, in partnership with Agriculture and Agri-Food Canada's AgriInnovation Program, a Growing Forward 2 initiative, the Canadian Horticultural Council and industry contributors.

Table 1. Effect of *Pseudomonas fluorescens* strain 4-6 alone or in combination with different GRAS compounds on the control of postharvest blue mold (*Penicillium expansum*) in 'Gala' apples, 2016-17.

Treatment	Percent blue mold incidence [a]						
	28 days[b]	55 days	82 days	108 days	136 days	189 days	Shelf-life
Water + *P. expansum*[c]	0[d] b	90 e	96.7 f	96.7 f	100 e	100 f	100 d
Sodium Bicarbonate @ 5 g/L + *P. expansum*	3.3 b	76.7 d	90 e	90 e	90 d	90 d	93.3 c
Salicylic Acid @ 0.1g/L + *P. expansum*	0 a	86.7 de	90 e	90 e	90 d	96.7 e	100 d
Calcium Chloride @ 10g/L + *P. expansum*	0 a	80 d	90 e	90 e	90 d	93.3 d	100 d
BIOSAVE @1.59 g/L + *P. expansum*	0 a	13.3 b	76.7 c	86.7 e	90 d	96.7 d	96.7 cd
P. fluorescens strain 4-6[e] + *P. expansum*	3.3 b	26.7 c	53.3 b	56.7 b	60 b	70 b	86.7 b
Sodium Bicarbonate @ 5 g/L + *P. fluorescens* strain 4-6 + *P. expansum*	0 a	54.4 c	79.23 cd	82.6 d	82.6 c	82.6 c	96.3 c
Salicylic Acid @ 0.1g/L + *P. fluorescens* strain 4-6 + *P. expansum*	0 a	16.7 b	80 d	86.7 e	90 d	90 d	93.3 c
Calcium Chloride @ 10g/L *P. fluorescens* strain 4-6 + *P. expansum*	0 a	50 c	73.3 c	76.7 c	80 c	90 d	93.3 c
SCHOLAR @ 0.6g/L + *P. expansum*	0 a	0 a	0 a	3.3 a	3.3 a	3.3 a	3.3 a

[a] Data represent the mean of three replicates.
[b] Number of days apples stored at 4ºC after treatment.
[c] *P. expansum* was used at a concentration of $1x10^4$ spores/mL
[d] Means within the column followed by the same letter are not significantly different according to the Tukey test (P = 0.05)
[e] *P. fluorescens* was used at a concentration of $1x10^9$ cfu/mL

2017 PMR REPORT # 15 **SECTION L: VEGETABLES and SPECIAL CROPS – Diseases**

CROP: Celery (*Apium graveloens* L.) cv. TZ 6200
PEST: Leaf Curl Anthracnose, *Colletotrichum fioriniae* ((Marcelino & Gouli) R.G. Shivas & Y.P. Tan)

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TITLE: **EVALUATION OF WEATHER-BASED FORECASTING MODELS TO MANAGE LEAF CURL ON CELERY CROPS IN ONTARIO**

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

METHODS: The trial was conducted in 2017 at the Muck Crops Research Station in the Holland Marsh, Ontario. Celery cultivar TZ 6200 was seeded into 288-cell plug trays on 4 May. On 6 July, celery was transplanted using a mechanical transplanter into the field in organic soil (soil: pH ≈ 7.5, organic matter ≈ 49.1%). A randomized complete block design with five replicates per treatment was used. Each replicate plot consisted of two subplots, with a total of six rows that were 55 cm apart, 5 m in length with in-row spacing of 15 cm. Fungicide QUADRIS FLOWABLE was alternated with SWITCH 62.5WG. QUADRIS FLOWABLE was applied at a rate of 1.12 L/ha and SWITCH 62.5WG was applied at 1 kg/ha. Fungicide application timing was determined using weather-based forecasting models: BOTCAST (Botrytis leaf blight forecasting) with at a Cumulative Disease Severity Index value of 21, TOMCAST at Disease Severity Value (DSV) threshold of 15, TOMCASAT with a DSV threshold of 25, and the strawberry anthracnose model (SAM) with a modified threshold of ≥0.15. All weather-based forecasting models were compared to a 7 to 10-day CALENDAR spray program and a non-treated CONTROL. Leaf wetness and temperature data were collected from a weather station on site within a nearby field. The border rows of each treatment were inoculated with *Colletotrichum fioriniae* (1 x 10^5 spores/mL) on 27 July. Three litres of the spore suspension were sprayed using a CO_2 backpack sprayer fitted with a single nozzle fan-type TeeJet 8002, where the rate was applied at 10 mL per meter. The inner four rows were visually assessed weekly for the presence of leaf curl. Celery was harvested on 3 October, and a total of 20 plants/plot (five plants/row/plot) were assessed. Marketable weight was first determined by removing stalks with lesions or discarding plants with crown rot and weighing only disease-free plants after trimming to marketable length (40 cm). The percent marketable by weight was determined by dividing the marketable weight by the total weight, which was the weight of the marketable and unmarketable tissue. The marketable weight per plant was determined by dividing the marketable weight by the number of marketable plants in each replicate plot.
Compared to the previous 10-year average, air temperatures in 2017 were average for June (18.1°C), July (20.7°C) and August (19.4°C) and above average for September (17.7°C) and October (11.6°C). The 10-year average temperatures were: June 18.7°C, July 21.0°C, August 20.1°C, September 16.1°C and October 9.7°C. Monthly rainfall was above the 10-year average for June (206 mm) and October (82 mm) and below average for July (70 mm), August (60 mm) and September (38 mm). The 10-year rainfall averages were: June 83 mm, July 92 mm, August 73 mm, September 68 mm and October 67 mm. All statistical analyses were performed using the General Analysis of Variance function of Statistix 10. Means separation was obtained using a Fisher's protected LSD at P = 0.05.

RESULTS: As outlined in Table 1.

CONCLUSION: Disease pressure and the incidence of leaf curl was very low in 2017. There were no significant differences in disease incidence and percent marketable weight for all disease forecasting treatments, when compared to the no-spray CONTROL. However, the number of fungicide applications was reduced from seven in the CALENDAR spray program to six for both BOTCAST and SAM, four for TOMCAST 15, and two for TOMCAST 25. Timing fungicide application using both TOMCAST thresholds 15 and 25 resulted in fewer applications and lower costs compared to using BOTCAST and SAM models, and the CALENDAR spray program. Despite the low disease pressure, TOMCAST was better suited for predicting leaf curl than BOTCAST or SAM in 2017.

Table 1. The number of sprays, estimated cost per spray, disease incidence, and percent marketable yield by weight for forecasting fungicide application to manage leaf curl on celery cv. TZ 6200 at the Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	Application date (DAFA)[1]	No. Sprays	Cost per spray ($/ha)[2]	Incidence (%)[3]	Market. by Wt. (%)
CALENDAR	0, 10, 16, 25, 36, 46, 56	7	1,223.71	0.0	100.0 ns[4]
BOTCAST	9, 16, 25, 36, 46, 56	6	1,092.75	0.2	100.0
SAM	0, 10, 16, 25, 36, 56	6	1,092.75	0.0	100.0
TOMCAST 15	0, 10, 21, 46	4	728.50	0.0	100.0
TOMCAST 25	0, 16	2	364.25	0.2	100.0
CONTROL	--	--	--	0.7	97.6

[1] DAFA = Days after first spray; first fungicide application was on 24 July for SAM, TOMCAST 15, TOMCAST 25 and the CALENDAR spray program treatments (first application = 0 days)
[2] Cost per spray used: QUADRIS FLOWABLE = $130.96/ha, and SWITCH 62.5WG = $233.29/ha
[3] Disease incidence measured one week prior to harvest
[4] ns = no significant differences were found at $P = 0.05$, based on Fisher's LSD test

2017 PMR REPORT # 16 **SECTION L: VEGETABLES and SPECIAL CROPS**
Diseases

CROP: Onion (*Allium cepa* L.), cv. Ridgeline
PEST: Onion downy mildew (*Peronospora destructor*) (Berk.) Casp. in Berk.

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TITLE: **EVALUATION OF FUNGICIDES FOR CONTROL OF DOWNY MILDEW ON DRY BULB ONIONS, 2017**

MATERIALS: ALIETTE WDG (fosetyl-al 80%), CUEVA (copper octanoate 1.8%), DITHANE 750 F (mancozeb 75%), ORONDIS ULTRA (oxathiapiprolin 30 g/L, mandipropamid 250 g/L), LI 700 (surfactant blend 80%), REASON (fenamidone 500 g/L), REVUS (mandipropamid 250g/L), RIDOMIL GOLD MZ 68WG (metalaxyl-M and S-isomer 4%, mancozeb 64%), SYLGARD 309 (siloxylated polyether 76%), ZAMPRO (ametoctradin 300 g/L, dimethomorph 225 g/L)

METHODS: Onions, cv. Ridgeline, were direct seeded (35 seeds/m) using a Stanhay precision seeder into organic soil (organic matter ≈ 67.3%, pH ≈ 6.8) on 15 May near the University of Guelph Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block arrangement with four replicates per treatment was used. Each replicate consisted of four rows spaced 40 cm apart, and 5 m in length. Treatments were applied using a 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. Treatments were: DITHANE at 3.25 kg/ha, ORONDIS ULTRA PREMIX at 350 mL/ha + LI 700 at 0.2% v/v, ZAMPRO at 1.0 L/ha + SYLGARD 309 at 0.25% v/v, REASON at 402 mL/ha, RIDOMIL MZ at 2.5 kg/ha alternated with ALIETTE at 2.8 kg/ha, CUEVA at 2% solution, REVUS at 400 mL/ha. An untreated CHECK was also included. Treatments were applied on 18 and 25 July, and 2, 10, 23, and 31 August. On 4, 15, and 21 August, all onions in each replicate were visually examined for downy mildew (DM) lesions and the number of lesion/plot recorded. On 28 August, 10 plants from the middle two rows in each replicate were examined for DM lesions and the number of lesions/plant recorded. On 25 September, onions in two, 2.32 m sections of row per replicate were harvested and placed in storage to cure. On 28 October, onions were removed from storage, sorted into size categories, weighed and counted to determine yield. Compared to the previous 10-year average, air temperatures in 2017 were below average for May (11.8°C), average for June (18.1°C), July (20.7°C) and August (19.4°C) and above average for September (17.7°C). The 10-year average temperatures were: May 14.1°C, June 18.7°C, July 21.0°C, August 20.1°C and September 16.1°C Monthly rainfall was above the 10-year average for May (120 mm) and June (206 mm) and below average for July (70 mm), August (60 mm) and September (38 mm). The 10-year rainfall averages were: May 66 mm, June 83 mm, July 92 mm, August 73 mm and September 68 mm. Data were analyzed using the General Analysis of Variance function of Statistix V.10. Means separation was obtained by using Fisher's Protected LSD test at $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: In 2017, conditions for downy mildew (DM) infection were favourable and by 4 August lesions were found in the trial. Significant differences in DM incidence were found among the treatments at all assessment dates (Table 1). On 21 August, onions treated with RIDOMIL MZ alternated with ALIETTE, ORONDIS + LI 700, ZAMPRO + SYLGARD, REASON or DITHANE had fewer DM lesions than onions treated with REVUS, CUEVA or the untreated onions. On 28 August, onions treated

with ORONDIS + LI700, DITHANE, ZAMPRO + SYGLARD had significantly fewer DM lesions than onions treated with REASON, REVUS, CUEVA and untreated onions (Table 1). Significant differences in yield, the percentage of jumbo and Canada No. 1 onions were found among the treatments (Table 2). Onions treated with ORONDIS + LI 700, DITHANE, or ZAMPRO + SYLGARD had higher yields than onions treated with REVUS, CUEVA or untreated onions. ORONDIS + LI 700, DITHANE, ZAMPRO + SYGLARD and RIDOMIL MZ alternated with ALIETTE reduced DM incidence and produced higher yields in onions.

ACKNOWLEDGEMENT: Funding for this project was provided by the California Garlic and Onion Research Advisory Board.

Table 1. Downy mildew (DM) incidence for onions, cv. Ridgeline, treated with fungicides and grown near the Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	DM Lesions/plot[1]			DM Lesions/plant 28 Aug[2]	AUDPC[3]
	4 Aug	15 Aug	21 Aug		
ORONDIS + LI700	0.3 a	0.5 a	10.0 a	0.7 a	35.3 a
DITHANE	0.3 a	0.8 a	35.5 a	1.0 a	114.0 a
ZAMPRO+SYLGARD	0.0 a	0.3 a	12.8 a	1.1 a	40.5 a
RIDOMIL MZ/ALIETTE[4]	0.0 a[5]	0.0 a	8.8 a	2.3 ab	26.3 a
REASON	0.5 a	3.3 a	33.3 a	3.9 b	130.5 a
REVUS	3.3 b	19.0 b	186.3 b	6.6 c	739.5 b
CUEVA	1.3 a	17.3 b	209.8 b	8.4 c	788.3 b
CHECK	2.8 b	10.0 ab	222.3 b	8.1 c	765.0 b

[1] The entire plot was visually examined for DM lesions and numbers recorded.
[2] On 28 August, ten plants per replicate were examined for DM lesions and numbers recorded.
[3] Area under the disease progress curve (AUDPC) was determined using lesions/plot on 4, 15, 21 Aug and the following formula:

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

[4] RIDOMIL MZ was applied on 18, 25 July, 10 & 31 August. ALIETTE was applied 2 & 23 August.
[5] Numbers in a column followed by the same letter are not significantly different at P=0.05 Fisher's Protected LSD test.

Table 2. Yield data for onions, cv. Ridgeline, treated with fungicides and grown near the Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	Size Distribution (%)[1]			# Jumbo	% Mkb	Yield (t/ha)
	Jumbo (>76 mm)	Can No. 1 (45-76 mm)	Small (<45 mm)			
ORONDIS + LI700	37.4 ab[2]	58.8 cd	3.8 ns[3]	14.3 a	96.2 ns	48.5 a
DITHANE	53.4 a	44.1 d	2.5	17.8 a	97.5	48.1 a
ZAMPRO+SYLGARD	28.7 bc	66.8 bc	4.5	11.5 ab	98.5	46.2 a
RIDOMIL MZ/ALIETTE[4]	37.1 ab	58.9 cd	4.0	13.3 a	96.0	43.3 ab
REASON	14.5 cd	76.3 ab	9.2	4.8 bc	90.8	34.7 abc
REVUS	13.5 cd	76.6 ab	9.9	3.5 bc	90.1	29.0 bc
Check	14.5 cd	80.0 ab	5.5	3.5 bc	94.5	28.0 bc
CUEVA	1.7 d	89.2 a	9.1	0.5 c	90.9	23.9 c

[1] Percentage was determined by weight.
[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
[4] RIDOMIL MZ was applied on 18, 25 July, 10 & 31 August. ALIETTE was applied 2 & 23 August.

2017 PMR REPORT # 17 **SECTION L: VEGETABLES and SPECIAL CROPS**
Diseases

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

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TITLE: EVALUATION OF VARIOUS FUNGICIDES FOR CONTROL OF STEMPHYLIUM LEAF BLIGHT ON ONIONS, 2017

MATERIALS: FONTELIS (penthiopyrad 200 g/L), LUNA TRANQUILITY (fluopyram 125 g/L, pyrimethanil 375 g/L), MERIVON (fluxapyroxad 21.25%, pyraclostrobin 21.25%), PRISTINE (pyraclostrobin 25.2%, boscalid 12.8%), QUADRIS TOP (azoxystrobin 200 g/L, defenoconazole 125 g/L), SERCADIS (fluxapyroxad 300 g/L), SYN A196449B (experimental)

METHODS: Onions, cv. Ridgeline, were direct seeded (35 seeds/m) on 15 May using a Stanhay Precision Seeder into organic soil (organic matter ≈ 67.3%, pH ≈ 6.8) near the University of Guelph Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block arrangement with four replicates per treatment was used. Each experimental unit consisted of eight rows (40 cm apart), 6 m in length. Treatments were: LUNA TRANQUILITY at 1.2 L/ha, MERIVON at 800 mL/ha, FONTELIS at 1.4 L/ha, QUADRIS TOP at 1.0 L/ha, SERCADIS at 333 mL/ha, PRISTINE at 1.3 kg/ha and SYN A19649B at 375 mL/ha. An untreated CHECK was also included. Treatments were applied on 15 and 25 July, 3 and 14 August using a tractor-mounted sprayer fitted with hollow cone D-3 spray tips at 620 kPa to deliver 500 L solution/ha. On 30 August, 20 onions were pulled from each replicate. Leaves were removed and green leaves sorted into classes based on the percentage of the leaf area infected with Stemphylium. The seven classes were: 0= no disease, 1 = 1-4%, 2 = 5-10%, 3 = 11-25%, 4 = 26-50%, 5 = 51-75%, 6 > 75% infected with stemphylium. These classes were used to determine the disease severity index (DSI) using the following formula:

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

On 22 September, the onions in two 2.32 m sections of row were harvested from the middle six rows for a yield sample and onions were stored at 20°C temperature. Onions were weighed and graded for size on 17 November to determine yield**.** Compared to the previous 10 year averages, air temperatures in 2017 were below average for May (11.8°C), average for June (18.1°C), July (20.7°C) August (19.4°C) and above average for September (17.7°C). The 10 year average temperatures were: May 14.1°C, June 18.7°C, July 21.0°C, August 20.1°C and September 16.1°C Monthly rainfall was above the 10 year average for May (120 mm) and June (206 mm) and below average for July (70 mm), August (60 mm) and September (38 mm), The 10-year rainfall averages were: May 66 mm, June 83 mm, July 92 mm, August 73 mm and September 68 mm. Data were analyzed using the General Analysis of Variance function of Statistix V.10. Means separation was obtained by using Fisher's Protected LSD test at $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: Onions treated with LUNA TRANQUILITY had significantly less stemphylium than all other treatments in the rating on 30 August. Onions treated with LUNA TRANQUILITY also had

significantly lower DSI than all other treatments. (Table 1). No significant differences in yield or percent marketable were found among the treatments (Table 2).

ACKNOWLEDGEMENT: Funding for this project was provided by Plant Production Systems of the Ontario Ministry of Agriculture, Food and Rural Affairs and the University of Guelph partnership and the Bradford Co-operative and Storage.

Table 1. Stemphylium field rating, incidence and severity for onions, cv. Ridgeline, treated with fungicides and grown near Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	30 August Leaf Sort[1]		
	% Leaves rated 0 or 1	Stemphylium Incidence (%)	DSI[2]
LUNA TRANQUILITY	65.6 a[3]	52.8 ns[4]	25.3 a
QUADRIS TOP	45.6 b	66.5	41.6 b
PRISTINE	44.0 b	68.9	41.8 b
SYN A19649B	38.9 b	68.8	48.5 b
MERIVON	34.3 b	74.0	50.9 b
SERCADIS	37.7 b	70.3	52.2 b
FONTELIS	30.3 b	77.1	55.4 b
CHECK	34.5 b	71.8	50.3 b

[1] On 30 Aug, leaves of 20 plants/replicate were removed and sorted into the following classes: 0 = 0 stemphylium, 1 = 1-4%, 2 = 5-10%, 3 = 11-25%, 4 = 26-50%, 5 =51-75%, 6 = >75% of the leaf area diseased.

[2] DSI was calculated with the following formula:

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

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

[4]ns indicates no significant differences were found among the treatments.

Table 2. Yield data for onions, cv. Ridgeline, treated with fungicides and grown near Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	Yield (t/ha)	% Mkb	Size Distribution (%)[1]		
			Jumbo (>76 mm)	Can No. 1 (45-76 mm)	Small (<45 mm)
LUNA TRANQUILITY	39.9 ns[2]	96.3 ns	31.8 ns	64.5 ns	3.7 ns
QUADRIS TOP	47.9	98.5	51.2	47.2	1.5
PRISTINE	39.8	98.6	33.8	64.8	1.4
SYN A19649B	43.4	96.8	25.4	71.4	3.2
MERIVON	47.1	97.9	25.7	72.2	2.1
SERCADIS	32.4	95.7	25.9	69.8	4.3
FONTELIS	38.6	98.2	28.4	69.8	1.8
CHECK	39.5	98.2	31.0	67.2	1.8

[1] Percentage was determined by weight.

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

2017 PMR REPORT # 18 **SECTION L: VEGETABLES and SPECIAL CROPS Diseases**

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

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TITLE: EVALUATION OF EXPERIMENTAL FUNGICIDES FOR CONTROL OF STEMPHYLIUM LEAF BLIGHT ON ONIONS, 2017

MATERIALS: LUNA TRANQUILITY (fluopyram 125 g/L, pyrimethanil 375 g/L), QUADRIS TOP (azoxystrobin 200 g/L, defenoconazole 125 g/L), SYN A19334D (experimental), SYN A19649B (experimental), SYN A20259E (experimental), AGRAL 90 (nonyl phenol ethoxylates 90-95%, isobutanol 5-10%)

METHODS: Onions, cv. La Salle, were direct seeded (35 seeds/m) on 11 May using a Stanhay Precision Seeder into organic soil (organic matter ≈ 72.5%, pH ≈ 6.1) at the University of Guelph Muck Crops Research Station, Holland Marsh, Ontario. A randomized complete block arrangement with four replicates per treatment was used. Each experimental unit consisted of four rows (40 cm apart), 5 m in length. Treatments were: SYN A19649B at 375 mL/ha, SYN A20259 at 1,000 mL/ha with and without AGRAL 90 at 0.2% v/v, QUADRIS TOP at 1.0 L/ha, SYN A19334 at 967 mL/ha with and without AGRAL 90 at 0.2% v/v, LUNA TRANQUILITY at 1.2 L/ha. An untreated CHECK was also included. Treatments were applied on 12, 20, 28 July and 5, 15 August using a CO_2 backpack sprayer equipped with four TeeJet 8002 VS fan nozzles spaced 40 cm apart and calibrated to deliver 500 L solution/ha at 255 kPa. On 4 August, three leaves on 20 onions per replicate were visually examined for stemphylium symptoms and rated on a 0-2 scale where 0 = no stemphylium symptoms, 1 = 1-50% of leaf with stemphylium symptoms, 2 = >51% of leaf stemphylium symptoms. The rating for the plant was the sum of the score of each leaf (6 maximum score per plant). On 22 August, 20 onions were pulled from each replicate. Leaves were removed and green leaves sorted into classes based on the percentage of the leaf area infected with stemphylium. The seven classes were: 0= no disease, 1 = 1-4%, 2 = 5-10%, 3 = 11-25%, 4 = 26-50%, 5 = 51-75%, 6 > 75% infected with stemphylium. These classes were used to determine the disease severity index (DSI) using the following formula:

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

On 13 September, the onions in two 2.32 m sections of row were harvested from the middle two rows for a yield sample and onions were stored at 20°C temperature. Onions were weighed and graded for size on 6 November to determine yield. Data were analyzed using the General Analysis of Variance function of Statistix V.10. Means separation was obtained by using Fisher's Protected LSD test at $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: In 2017, stemphylium leaf blight incidence was high in the trial and ranged from 91 – 77%. Onions treated with LUNA TRANQUILITY, Syngenta products A20259 (with and without AGRAL 90), A19334 + AGRAL 90 or QUADRIS TOP had a significantly higher percentage of healthy

leaves (rated 0 or 1) and lower disease severity compared to untreated onions. Onions treated with A19334 without AGRAL 90 or A19649 did not differ from the check (Table 1). No significant differences in yield or percent marketable were found among the treatments (Table 2).

ACKNOWLEDGEMENT: Funding for this project was provided by Syngenta Crop Protection, Guelph, Ontario.

Table 1. Stemphylium field rating, incidence and severity for onions, cv. La Salle, treated with experimental fungicides and grown at Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	4 Aug Field Rating[1]	22 August Leaf Sort[2]		
		% Leaves rated 0 or 1	Stemphylium Incidence (%)	DSI
LUNA TRANQUILITY	1.8 ns	52.1 a	77.1 ns	32.4 a
SYN A2025**9** + AGRAL 90	1.4	48.1 ab	82.8	35.0 ab
SYN A1933**4** + AGRAL 90	1.8	46.8 abc	87.1	35.4 ab
QUADRIS TOP	1.9	42.2 abc	83.7	36.7 ab
SYN A2025**9**	1.7	41.5 abc	84.0	39.8 ab
SYN A1933**4**	1.8	36.8 bcd	89.5	41.3 b
SYN A1964**9**	1.6	34.6 cd	91.8	42.5 b
CHECK	2.3	24.6 d	90.7	53.1 c

[1]The three oldest leaves/plant on 20 onions were rated on a 0-2 scale where 0 = no stemphylium, 1 = <50% leaf with stemphylium, 2 => 50% of leaf diseased. The sum of the 3-leaf ratings for each plant was recorded (6 max. rating).
[2] On 22 Aug, leaves of 20 plants/replicate were removed and sorted into the following classes: 0 = 0 stemphylium, 1 = 1-4%, 2 = 5-10%, 3 = 11-25%, 4 = 26-50%, 5 =51-75%, 6 = >75% of the leaf area diseased.
[3] ns indicates no significant differences were found among the treatments.
[4] Numbers in a column followed by the same letter are not significantly different at P=0.05 Fisher's Protected LSD test.

Table 2. Yield data for onions, cv. La Salle, treated with experimental fungicides and grown at Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Treatment	Size Distribution (%)[1]			% Mkb	Yield (t/ha)
	Jumbo (>76 mm)	Can No. 1 (45-76 mm)	Small (<45 mm)		
LUNA TRANQUILITY	24.8 ns[2]	73.7 ns	1.5 ns	98.5 ns	78.7 ns
SYN A2025**9** + AGRAL 90	25.7	73.5	0.8	99.2	74.5
SYN A1933**4** + AGRAL 90	22.3	76.7	1.0	99.0	70.8
QUADRIS TOP	18.6	80.3	1.1	98.9	78.6
SYN A2025**9**	27.7	70.7	1.6	98.4	72.9
SYN A1933**4**	27.6	71.3	1.1	98.9	76.1
SYN A1964**9**	20.6	77.8	1.6	98.4	79.0
CHECK	13.3	84.5	2.2	97.8	64.6

[1] Percentage was determined by weight.
[2] ns = no significant differences were found among the treatments

2017 PMR REPORT # 19 **SECTION L: VEGETABLES and SPECIAL CROPS Diseases**

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

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TITLE: EVALUATION OF SOIL FUMIGANTS FOR CLUBROOT CONTROL ON SHANGHAI PAK CHOI, 2017

MATERIALS: PIC PLUS (85.5% chloropicrin), BUSAN 1236 (metam sodium 42.5%)

METHODS: The trial was conducted at the University of Guelph Muck Crops Research Station, Holland Marsh, Ontario on a muck soil (pH ≈ 6.0, organic matter ≈ 66%) naturally infested with *Plasmodiophora brassicae*. A randomized complete block design with five replicates per treatment was used. Each experimental unit (plot) was 1.75 m × 12 m. Treatments were: PIC PLUS at 164 & 280 kg/ha and BUSAN 1236 at 150 & 300 kg/ha. On 11 July, PIC PLUS was applied using a 2 m wide tractor-mounted PIC PLUS fumigator equipped with shanks to inject the product 25-30 cm into the soil. BUSAN 1236 was applied using a separate 2 m wide custom tractor-mounted fumigator with shanks spaced 17 cm apart applying the product 25-30 into the soil. After the treatments were applied, each plot was rolled and sealed with totally impermeable film (TIF) (Raven Industries, Sioux Falls, South Dakota. An untreated, (UNCOVERED CHECK) was included in addition to an untreated check covered with the totally impermeable film (TIF CHECK). HOBO pendent dataloggers were placed 5cm below the soil surface in both TIF CHECK and UNCOVERED CHECK treatments. After 14 days, on 25 July, the TIF was removed. On 28 July, each plot was seeded with four rows of Shanghai pak choi, cv. Mei Qing Choi, with 40 cm between rows using a Stanhay precision seeder. On 21 August, a 30 cm x 30 cm frame was randomly placed on the soil (twice) in each replicate and the number of weeds within the frame was counted and recorded to determine the number of weeds/m^2. On 5 September, 50 plants per replicate were removed and tops were weighed. Clubroot incidence was examined on these roots and 50 additional plants for a total of 100 roots and grouped by severity using a scale of 0 to 3: 0 = no clubbing, 1 = <1/4 of root clubbed, 2 = 1/4 – 1/2 of roots clubbed and 3 = > 1/2 of roots clubbed. Disease severity index (DSI) was determined using the following equation:

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

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

RESULTS: as presented in Tables 1 & 2

CONCLUSIONS: Clubroot incidence and severity throughout the trial was high. All treatments provided statistically significant control of clubroot compared to the UNCOVERED CHECK (Table 1). However, both rates of PIC PLUS provided a significant increase in fresh top weight per plant compared to the TIF CHECK.

Plant fresh weight significantly decreased as disease severity increased (P=0.03, r^2=0.71, Towt = 260.89–1.69*DSI). Clubroot was reduced in the TIF CHECK due to the solarization of the soil since disease incidence was similar compared to the chemical fumigants. Soil temperatures were on average 7°C higher under the TIF compared to the UNCOVERED CHECK (Table 2). PIC PLUS at 280 kg/ha and BUSAN 1236 at 300 kg/ha also provided control of weeds.

The efficacy of the fumigant treatments and TIF CHECK was assessed. The results of this study indicate that lower rates of PIC PLUS and BUSAN 1236 can be used to successfully control clubroot as well as higher rates. However, higher rates offer the advantage of improved weed control. Solarization from TIF may also be used successfully to suppress clubroot without chemical fumigants.

ACKNOWLEDGEMENTS: Funding was provided by the Clubroot Mitigation Initiative of Agriculture and Agri-Food Canada and the Canola Council of Canada. We wish to thank Douglas Ag Inc. and TriEst Ag Group Inc, Simcoe, Ontario.

Table 1. Clubroot incidence and severity for pak choy grown in muck soil naturally infested with *P. brassicae* , treated with fumigants at the Muck Crops Research Station, Ontario, 2017.

Treatment	Rate (kg/ha)	Incidence (%)	DSI[1]	Fresh Top Wgt/Plant (g)	# Weeds/m^2
PIC PLUS	280	62.8 a[2]	29.1 a	234.6 a	74.0 a
PIC PLUS	164	73.0 a	34.2 a	221.6 a	113.7 ab
BUSAN 1236	300	65.6 a	28.3 a	214.8 ab	70.3 a
BUSAN 1236	150	76.8 a	35.2 a	197.2 ab	123.0 b
TIF CHECK	--	66.8 a	30.3 a	171.0 b	124.0 b
UNCOVERED CHECK	--	100.0 b	81.1 b	122.7 c	153.7 b

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

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

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

Table 2. Average daily soil temperatures 5 cm below totally impermeable film (TIF) and bare soil compared to air temperatures at the Muck Crops Research Station, Ontario, 11-24 July, 2017.

Date	TIF CHECK		UNCOVERED CHECK		Air	
	Max Temp °C	Min Temp °C	Max Temp °C	Min Temp °C	Max Temp °C	Min Temp °C
July 11	32.6[1]	26.9	28.4	23.6	29.2	15.0
July 12	34.5	23.3	25.4	20.4	28.6	16.6
July 13	27.5	22.0	22.6	18.8	21.4	15.2
July 14	29.8	20.7	22.1	18.4	26.3	17.2
July 15	37.5	22.8	24.2	18.7	27.4	17.0
July 16	32.9	25.6	23.2	18.4	26.2	15.2
July 17	36.9	24.7	25.6	19.8	27.0	18.1
July 18	39.8	26.1	26.5	19.5	29.0	15.9
July 19	38.7	27.8	25.9	20.0	30.8	17.2
July 20	34.9	26.9	23.7	18.9	24.8	13.5
July 21	38.8	26.2	24.6	19.0	28.4	15.7
July 22	33.4	28.2	23.3	19.9	25.4	17.7
July 23	31.8	26.3	23.2	20.2	25.0	17.9
July 24	28.8	23.2	22.0	19.3	21.8	15.7
Average	**34.1**	**25.0**	**24.3**	**19.6**	**26.3**	**16.3**

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

2017 PMR REPORT # 20 **SECTION Q: GREENHOUSE CROPS, ORNAMENTALS AND TURF – Diseases**

CROP: Weigela (*Weigela florida* Thunb.) cv. 'Red Prince'
PEST: Foliar nematode (*Aphelenchoides* sp.)

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TITLE: **HYPOASPIS (*Stratiolaelaps scimitus*) PREDATORY MITES AND LUNA PRIVILEGE (fluopyram) FUNGICIDE FOR CONTROL OF FOLIAR NEMATODES ON AN ORNAMENTAL NURSERY CROP, 2017**

MATERIALS: LUNA PRIVILEGE (fluopyram 500g/L), HYPOASPIS-SYSTEM BIOBEST (*Stratiolaelaps scimitus = Hypoaspis miles*), STRATIOLAELAPS-APPLIED BIONOMICS (*Stratiolaelaps scimitus = Hypoaspis miles)*

METHODS: The trial was conducted in June-July 2017 on a highly susceptible, nematode-infested crop of *Weigela florida* cv. 'Red Prince' at a commercial nursery in the BC Fraser Valley, using natural inoculum. Each plant was in a 4inch (10cm) pot in a commercial growth medium (65%, 5% sawdust,10% perlite, 5% rice hulls, 15% coir) with a rice-hull surface mulch. Each plot consisted of 12 x 4inch (10cm) potted plants per flat, with one flat per replicate and 4 replicates per treatment arranged in a randomized complete block (RCB) design. On May 31, one week prior to the first application, the plant foliage was pruned back and all leaves with nematode lesions were removed and placed on the surface of the potting mix under the plants, to ensure high pest pressure. Flowers and leaves with lesions were removed again just before the first application on June 7 and plants without leaves or leaf buds were replaced.

LUNA PRIVILEGE (fluopyram) was applied as a foliar spray at 250 and 500mL/ha in 1000L solution/ha (100mL/m^2), twice at a 14-day interval on June 7 and June 22. LUNA PRIVILEGE was applied using a CO_2 back-pack sprayer at 20psi (138kPa) equipped with a double nozzle boom and Teejet 8002VS nozzles. For each application, the four flats in each treatment were placed in a 1m^2 area for spraying then returned to the randomized plot design. The check was sprayed with water alone. STRATIOLAELAPS-APPLIED BIONOMICS (SAB) was supplied by the manufacturer (Applied Bionomics Ltd., North Saanich, BC) in the commercial 1L container. SAB contains 15,000-20,000 *S. scimitus*/L in a pasteurized peat/bran mixture, or about 15-20 mites per cc.[1] HYPOASPIS-SYSTEM BIOBEST (HSB) is said to contain 25,000 mites/L.[2] Each predatory mite medium was mixed thoroughly and a quantity of media containing the required number of predatory mites, as per the concentration on the product label, was applied by teaspoon (1tsp = 5cc) to the surface of the potting mix in each flat. SAB was applied on June 7 as a single application in an amount equivalent to 125, 250, 500, 1000 and 2000 mites/m^2, or in two applications at 125, 250 and 500 mites/m^2 on June 7 and June 22. HYPOASPIS-SYSTEM BIOBEST (HSB) was applied at 250 mites/m^2 on June 7 and June 22. All plants were drenched with SUBDUE MAXX (metalaxyl-m, 240g/L) on June 16 at 0.08ml/L in 20ml per plant, to prevent root rot. A foliar fertilizer (Plant Products Ltd. 20-20-20 plus micronutrients) was

applied on June 16 and July 6 at a rate of 10g/L in a solution of 10L using a pump-action backpack sprayer. The plants were overhead-irrigated by the grower, as needed, and no other pesticides or fertilizers were applied.

Assessments: The percentage of leaf area with nematode lesions was assessed weekly on the Horsfall-Barratt visual scale of 0-11, where 0=no lesions, 1=1-3% leaf area affected; 2=3-6%; 3=6-12%; 4=12-25%; 5=25-50%; 6=50-75%; 7=75-88%; 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 (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%. The area under the disease progress curve (AUDPC) was calculated for the mean percentage of leaf area covered with nematode lesions using the standard formula $\sum ((x_i+x_{ii})/2 \text{ X } (t_i-t_{ii}))$ where x= % diseased, *i*= date and t= time (in this trial, t= one week for all assessments).

RESULTS: As in Table 1 and Figure 1. Extremely hot, dry weather impeded both the foliar nematodes and the predatory mites, resulting in few statistical differences among treatments.

CONCLUSIONS: In June-July 2017, in a controlled, replicated trial at a commercial nursery in British Columbia, Canada, the predatory mite, *Stratiolaelaps scimitus* (*Hypoaspis miles*), at 500-1000 mites/m^2 controlled foliar nematode damage on *Weigela florida* cv. 'Red Prince' as well as two applications of the fungicide LUNA PRIVILEGE (fluopyram) at 500mL/ha, and significantly better, in Duncan's MRT at P=0.05, than LUNA PRIVILEGE at 250mL/ha. Two applications of *S. scimitus*, each at 250-500 mites per m^2 (10-20mL or 2-4 tsp of product mix/m^2) reduced the percentage of leaf area affected by foliar nematodes by 50-70% compared to the check, for up to five weeks after the last application. Two applications of *S. scimitus* at 250-500 mites/m^2 tended to be more effective than one, but a single application at 1000 mites/m^2 was similarly effective. There was no significant difference between the APPLIED BIONOMICS and BIOBEST products, applied twice at 250 mites/m^2. The lowest rate of *Stratiolaelaps*, 125 mites/m^2 was less effective. Plots treated with the half-rate of LUNA PRIVILEGE (250mL/ha) were significantly poorer than the 500mL/ha rate one week after the second application, and had consistently higher nematode damage than the check, or the predatory mite treatments, throughout the trial. No phytotoxicity was observed in any treatment. In summary, the results of this trial suggest that the predatory mite, *Stratiolaelaps scimitus* (*Hypoaspis miles*) may be a cost-effective treatment for foliar nematodes in ornamental nursery crops, particularly on propagated cuttings in the greenhouse.

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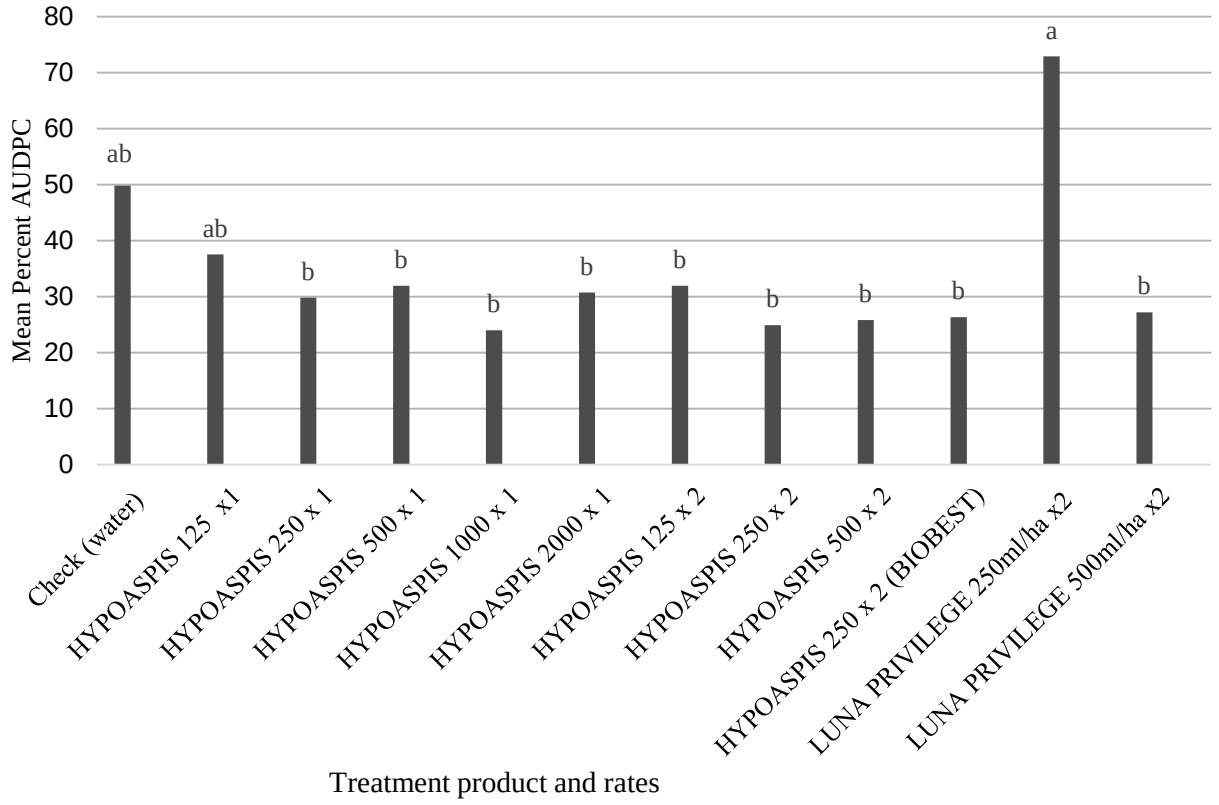
Table 1. Mean percentage of leaf area per plot with foliar nematode lesions: visual rating on the Horsfall-Barratt scale of 0-11, transformed to percentages.[1, 2]

Treatment	Rate /m^2 and # of Apps	14-June	22-June	28-June	05-July	12-July	19-July	25-July
Check (water)	-	2.3±0.0 a	2.3±0.0 b	10.0±6.7 a	11.1±8.9 ab	11.1±8.9 ab	9.4±6.6 a	9.4±6.6 ab
S. scimitus Applied Bionomics	125 x 1	2.3±0.0 a	2.3±0.0 b	4.7±3.3 ab	8.2±7.8 ab	10.5±9.5 ab	7.0±7.9 a	7.0±7.9 b
S. scimitus Applied Bionomics	250 x 1	2.9±1.2 a	2.3±0.0 b	4.7±3.3 ab	5.9±4.0 b	4.7±3.3 b	7.6±7.5 a	6.4±8.2 b
S. scimitus Applied Bionomics	500 x 1	2.3±0.0 a	2.3±0.0 b	3.5±1.4 ab	8.8±7.2 ab	6.4±3.5 b	7.0±7.9 a	5.3±2.9 b
S. scimitus Applied Bionomics	1000 x 1	2.3±0.0 a	2.3±0.0 b	4.1±3.5 ab	4.1±3.5 b	3.5±1.4 b	5.9±4.0 a	5.9±4.0 b
S. scimitus Applied Bionomics	2000 x 1	2.3±0.0 a	2.3±0.0 b	3.5±1.4 ab	6.4±3.5 b	5.3±2.9 b	7.6±7.5 a	8.8±7.3 ab
S. scimitus Applied Bionomics	125 x 2	2.3±0.0 a	2.3±0.0 b	4.7±3.3 ab	6.4±3.5 b	6.4±3.5 b	6.4±3.5 a	8.8±7.3 ab
S. scimitus Applied Bionomics	250 x 2	2.3±0.0 a	2.9±1.2 a	4.7±3.3 ab	4.7±3.3 b	3.5±1.4 b	5.3±2.9 a	5.3±2.9 b
S. scimitus Applied Bionomics	500 x 2	2.3±0.0 a	2.3±0.0 b	4.1±3.5 ab	4.7±3.3 b	4.7±3.3 b	5.8±4.0 a	5.9±4.0 b
S. scimitus BIOBEST	250 x 2	2.9±1.2 a	2.3±0.0 b	5.8±2.3 ab	5.3±2.9 b	4.1±1.2 b	5.3±2.9 a	4.1±1.2 b
LUNA PRIVILEGE	250mL/ha x 2	2.3±0.0 b	2.3±0.0 b	8.8±7.2 ab	17.6±14.5 a	17.6±14.5 a	15.8±16.2 a	19.3±14.4 a
LUNA PRIVILEGE	500mL/ha x 2	2.3±0.0 a	2.3±0.0 b	2.9±1.2 b	6.4±3.5 b	5.8±2.3 b	5.3±2.9 a	6.4±3.5 b

[1] Mean and standard deviation of 12 plants per plot; four replicates per treatment; RCB design.
[2] Numbers in the same column followed by the same letter are not significantly different in Duncan's MRT at P=0.05.

Figure. 1. Mean AUDPC for the percentage of leaf area with foliar nematode lesions.[1]



[1] Columns with the same letter are not significantly different in Duncan's MRT at P=0.05.