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Final Report: Integrated Pest Management Strategies for Powdery Mildew and Other Foliar Diseases of Wild Blueberries

Project Proponents: Wild Blueberry Producers Association of Nova Scotia and Bragg Lumber Company

SUMMARY: Field and laboratory studies have been completed examining the leaf spot diseases powdery mildew (caused by Microsphaera vaccinii), Septoria leaf spot (Septoria spp.) and rust leaf spot (Thekopsora minima). The epidemiology of powdery mildew was examined in the vegetative and cropping phases of production. Field trials examining the efficacy of various fungicides from various fungicide families and varying modes of action on powdery mildew, Septoria, rust and more recently Valdensinia (Valdensinia heterodoxa) have been completed. Working in collaboration with agrochemical companies (Bayer CropScience, Syngenta Canada, E.I. DuPont Canada, Valent BioSciences, BASF, DOW Agrosciences, Enage Agro and AgraQuest), Wild Blueberry Producer Associations in New Brunswick, Prince Edward Island and Nova Scotia, the Pest Management Center of Agriculture and Agri-Food Canada and the Pest Management Regulatory Agency of Health Canada has resulted in the registration of the fungicides Bravo® and Proline® for use in wild blueberries during the vegetative year of production. For the cropping phase of production, the label of the fungicide Pristine® has been expanded to include suppression of Septoria, rust and Valdensinia; the new fungicide Fontelis® has been registered for wild blueberry production with control of Septoria and rust expected to be included on the label for 2013, and it is also expected that a new strobiluron compound will be available in the near (i.e., 1 to 3) year period. Research has also commenced on examining the sensitivity of Septoria isolates to the fungicides presently being used in the wild blueberry industry, and a Septoria and rust disease management guide has been developed for the wild blueberry industry. The decision support mechanisms contained in this disease management guide continue to be tested, and the guide is presently undergoing review by extension specialists and fellow research scientists.

Final Report

PROJECT TITLE:
Integrated Pest Management Strategies for Powdery Mildew and Other Foliar Diseases of Wild Blueberries

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2. Organization(s) Profile

The **Wild Blueberry Producers Association of Nova Scotia (WBPANS)** represents over 1,100 wild blueberry growers in Nova Scotia. WBPANS serves the wild blueberry industry by acting as a liaison between the government and the general public. The Association is a leader in the areas of research, marketing and promotion of the wild blueberry, and provides services to its members through the sale of pest control equipment and supplies, newsletters, and fact sheets.

Oxford Frozen Foods Limited was formed in 1968 by John Bragg to establish a reliable processing facility for wild blueberries in NS and has grown to become the largest wild blueberry company in the world. The Company processes fruit from Nova Scotia, New Brunswick, PEI, Quebec, and the states of Maine and New Hampshire by purchasing blueberries from individual producers and their associated company **Bragg Lumber Company**. Oxford has contributed to research and development programs of specialists at the Nova Scotia Agricultural College and also through industry associations including the WBPANS and the Wild Blueberry Producer Association of North America. **Bragg Lumber Company** has agreed to be a co-applicant for this proposed R&D project.

3. Experience

WBPANS and **Oxford Frozen Foods Limited (Oxford)** have placed emphasis on developing a systematic agri-food production system that will ensure optimal plant growth, development, yield and composition, minimal use of agrochemicals, enhanced production efficiency and sustainability, and advancements in environmental stewardship, food safety and food traceability. The leaf disease research activities being conducted at the NSAC has been an important component striving to support the production system. Since the proposal was submitted, emphasis has been placed on surveying commercial fields to determine the incidence and severity of foliar leaf spot diseases, the associated causal organisms, the net impact on yield potential, and potential integrated pest management technique(s) to minimize the impact of these diseases.

WBPANS, **Bragg Lumber Co.** (sister company of Oxford), and the Nova Scotia Department of Agriculture initiated a **Wild Blueberry Research Program in 1996**. Dr. David Percival, Professor (**NSAC**, Department of Environmental Sciences) is the chair for the research program. The research activities of the program are focused on improving plant nutrition management practices, long-term sustainability, and the understanding of the fundamental biology of the lowbush (i.e., wild) blueberry. Drs. Lynda Stewart (2006-2007), Rishi Burlakoti (2008-2009) and Jyoti Kaur (2010 to present) have been the plant pathology postdoctoral research fellows working on the project. In addition, Dr. Paul Hildebrand (research scientist, AAFC Kentville) provided guidance in the initial stages of the project.

4. Project Title

Integrated Pest Management Strategies For Powdery Mildew and Other Leaf Spot Diseases of Wild Blueberries.

5. Project Overview

Once thought to be minor pests of blueberries, foliar fungal diseases including powdery mildew and *Septoria* leaf spot, and newly emerging diseases such as *Valdensia* leaf spot, have recently presented themselves as major pests to wild blueberry producers. Currently, the industry faces limitations in its choices for control of leaf spot diseases, with no registered fungicides for control of powdery mildew, and *Valdensinia*. This leaves the Canadian blueberry industry, valued at $270 million, vulnerable to significant losses. Research and new technology development are aimed at improving our understanding of the basic biology of the fungal pathogens, and providing producers with more options to control foliar pathogens efficiently and cost-effectively, while remaining competitive in foreign markets with stringent fungicide residue limits. The objectives of the research project have been to (i) identify foliar blueberry pathogens, (ii) monitor foliar disease incidence and severity, (iii) study the epidemiology of the powdery mildew pathogen *Microsphaera vaccinii*, and (iv) develop integrated pest management (IPM) practices involving chemical fungicides with alternate modes of action, reduced risk fungicides, and nutrient management practices. The impact of the IPM program will be evaluated on the growth, development and harvestable yield of the blueberry.

6. Progress With Research and Development Activities

Stage 1 – Powdery Mildew. Studies examining the epidemiology of the pathogen (*M. vaccinii)* causing powdery mildew commenced in 2006 at commercial fields situated in Ranous and Val Doucet, New Brunswick. These fields were known to have been severely effected by powdery mildew in previous years and had stem densities of approximately 560 and 710 stems·m^{-2} at the Ranous and Val Doucet sites respectively. The disease incidence was evaluated as the presence or absence of the pathogen on the blueberry foliage with fields in the vegetative (i.e., sprout) and cropping phases of production. Results from the two sites indicated that visible symptoms of powdery mildew were present in the wild blueberries by June 7 (Val Doucet) and June 13 (Renous). However, rapid progression of the disease did not occur until early to mid July at the two sites (Figure 1). This was coupled with increases in disease severity which resulted in substantial levels of premature leaf drop in late August and early September (data not shown).

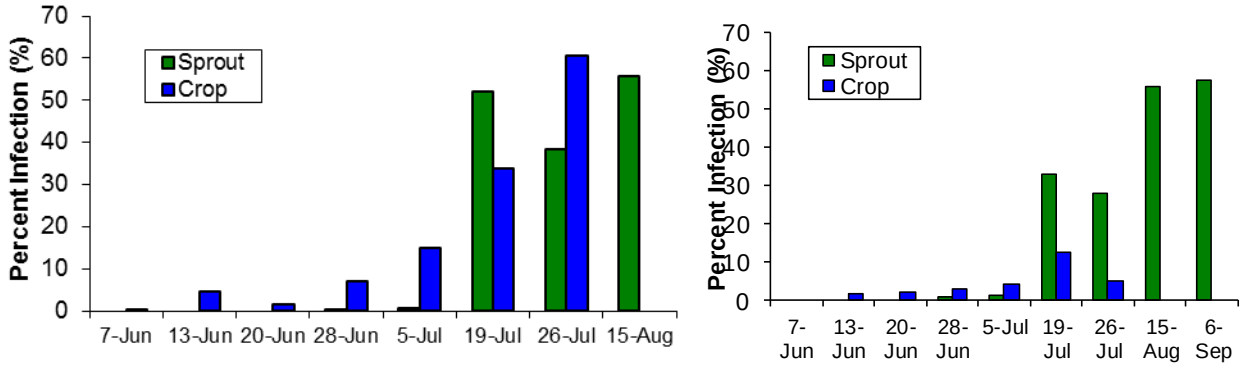

Figure 1. Incidence of powdery mildew (% stems examined with visual symptoms) located at Val Doucet and Renous, New Brunswick during the 2006 field season.

Upon examining potential products that were effective in reducing the incidence and severity of powdery mildew, emphasis was placed on (i) products that were either registered or could be registered in the near future in Canada, and (ii) reduced risk products including those that could be used in organic wild blueberry production. More specifically, the products that were examined included Permatrol® (extract from jojoba seeds that kills the fungus on contact by smothering powdery mildew mycelium and preventing spore formation and dispersal), Fungistop® (sulfur compound that inhibits cellular respiration, nucleic acid synthesis and protein formation in oidium), Cabrio® (active ingredient or a.i.: pyraclostrobin), Quintec® (a.i.: quinoxyfen), Bravo® (a.i.: chlorothalonil), Topas® (a.i.: propiconazole) and Kumulus® (a.i.: sulfur). Fungicides were applied using a 2 m, R&D sprayer equipped with 8003 TeeJet flat fan nozzles with a pressure of 221 kPa at a rate of 200 L solution·ha^{-1}.

Of the fungicides examined, Quintec® (a fungicide recently registered for powdery mildew control), Bravo® (chlorothalonil) and Topas® were all effective in reducing the incidence of powdery mildew at the two sites examined (Figure 2). Unfortunately the products that reduced risk products that were selected due to their ability to be used in organic production systems (Permatrol®, Fungistop® and Kumulus®) were not effective in suppressing powdery mildew and were subsequently discarded from further examination.

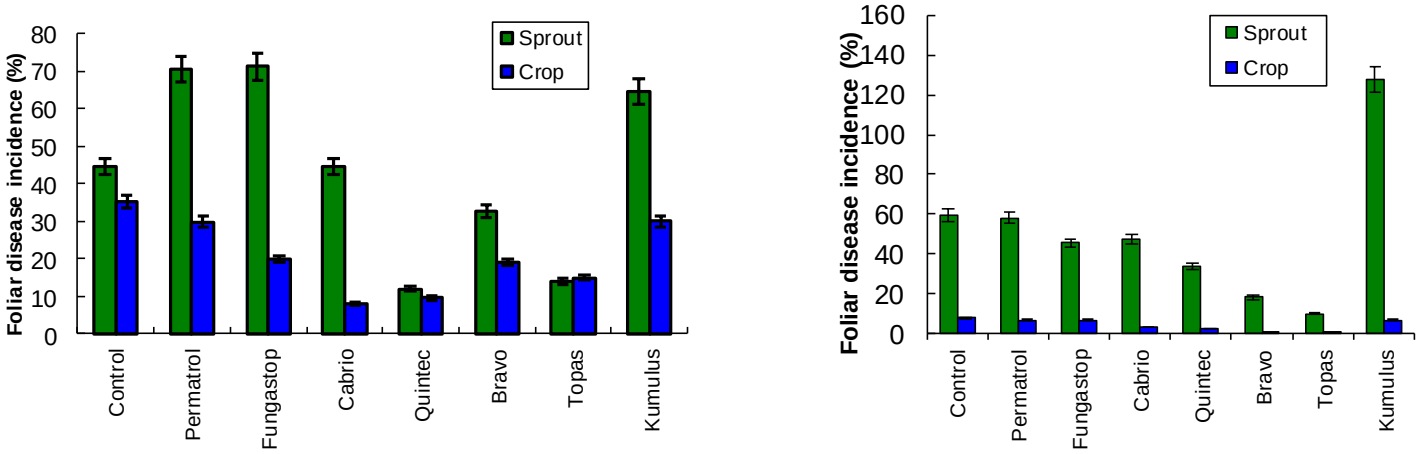

Figure 2. Efficacy of reduced risk and other known fungicides with known ability to suppress and/or control powdery mildew at two commercial blueberry fields in the sprout and cropping phases of production during the 2006 growing season.

Stage 2. Continuation With Examining the Efficacy of Various Fungicides on Powdery Mildew, Septoria and Rust.

Given the positive attributes encountered with the powdery mildew field trials, a further set of field trials were planned in 2007 and 2008 with emphasis on examining the ability to suppress the leaf diseases with other fungicides with emphasis on fungicides that posed less environmental (e.g., leaching or eroding into water supplies) and food risks (i.e. residue issues in processed foods) in export markets including the European Union and Japan. This resulted in the establishment of field trials located near Mount Vernon, PEI and Farmington, Nova Scotia. At these locations, a randomized complete block experimental design was used with a plot size of 6 x 8 m, a 2 m buffer between plots and 12 and 9 treatments at the Mount Vernon and Farmington sites respectively. Treatments included an untreated control, Bravo® (a.i. chlorothalonil), Bravo® + Topas®, Tourney® (also marketed as Quash® with an active ingredient of metconazole), Pristine® (a.i.'s pyraclostrobin and boscalid), Quadris® (a.i., axozystrobin), Switch® (a.i., cyprodonil and fludioxonil), Serenade Max® (a biopesticide containing strain QST 713 of *Bacillus subtilis*), an experimental fungicide belonging to the carboxamide family of fungicides (nondisclosure agreements are in place prohibiting naming the product), Flint® (a.i., trifloxystrobin), Folicur® (a.i., tebuconazole) and Proline® (a.i., prothioconazole). Treatments were applied at the first visual symptoms of the disease using recommended label rates on July 26 (Mount Vernon) and 27 (Farmington) respectively.

Results from these two field trials indicated that the Bravo®, Bravo® + Topas®, experimental fungicide and Proline® treatments improved leaf retention, reduced leaf disease incidence (i.e., presence of a leaf disease on a stem), Septoria severity (% leaf area with visual symptoms of the disease) and rust severity (also on a % leaf area with visual symptoms of the disease) (Tables 1 and 2). In addition, floral bud numbers were improved when the impact of the diseases on effective leaf area could be minimized (Tables 1 and 2).

Table 1. Impact of various treatments on leaf retention, disease incidence, *Septoria* severity, rust severity and floral bud number of wild blueberries at a field site located near Mount Vernon, Prince Edward Island at the conclusion of the 2007 growing season.

Product	Leaf retention (0 = no leaves, 1 = all leaves)	Leaf disease incidence (1.00 = 100%)	Severity of *Septoria* (% basis)	Severity of rust (% basis)	Floral bud number (# per stem)
Control	0.64bcd	1.00a	1.63a	18.2a	4.20bcd
Bravo®	0.99a	0.848c	0.66b	6.82d	4.42bcd
Bravo® + Topas®	0.96a	0.89c	0.63b	4.79de	6.32a
Tourney®	0.65bc	1.00a	1.74a	10.9c	3.74bcd
Pristine®	0.70b	1.00a	2.14a	11.3c	4.82abc
Quadris®	0.62bcd	1.00a	1.61a	13.3bc	2.92d
Switch®	0.64bcd	0.91bc	1.74a	10.5c	2.94d
Serenade™	0.56d	1.00a	1.66a	15.9ab	3.70bcd
Experimental	0.92a	0.91bc	0.90b	3.59e	5.16a
Flint®	0.62bcd	1.00a	1.98a	14.9b	3.22cd
Folicur®	0.57cd	1.00a	1.75a	14.8b	3.28cd
Proline®	0.99a	0.96ab	0.58b	7.22d	5.30ab

Table 2. Impact of various treatments on stem length, leaf disease incidence, leaf retention, *Septoria* severity, rust severity and floral bud number of wild blueberries at a field site located at Farmington, Nova Scotia at the conclusion of the 2007 growing season.

Product	Leaf retention	Leaf disease incidence (1.00 = 100%)	Severity of *Septoria* (% basis)	Severity of rust (% basis)	Floral bud number (# per stem)
Control	0.54b	1.00a	2.65b	7.61ab	6.42b
Bravo®	0.98a	0.94b	1.36c	3.16d	6.33b
Bravo®+Topas®	0.95a	0.99ab	1.36c	3.99cd	5.16b
Tourney®	0.43c	0.98ab	2.49b	9.80a	6.35b
Pristine®	0.53b	0.98ab	2.86b	7.30ab	6.4b
Quadris®	0.55b	1.00a	3.20b	6.69cb	6.28b
Switch®	0.44bc	0.98ab	3.12b	7.59ab	6.93b
Serenade®	0.45bc	1.00a	4.18a	7.90ab	6.30b
Experimental	0.40c	1.00a	3.28ab	5.62bcd	8.67a

An important observation that was also made during this second phase of fungicide efficacy (i.e., screening) trials was the absence of powdery mildew with those blueberry plants that had fungicides applied in the vegetative (i.e., sprout) phase of production. This coincided with producers beginning to use Bravo® applications as part of their integrated disease management practices. Although possibly also linked to weather conditions (the Maritimes has not had as dry a growing season since) and improvements in plant nutrition, utilization of this canopy management technique has resulted in the large scale absence of this disease since 2008.

An important commercialization achievement occurred in autumn of 2007 with the expansion of the Bravo® fungicide label to include the suppression of leaf diseases (e.g., Septoria and rust) in the

sprout phase of production. Data from the previously mentioned trials was included in the submission package which was assembled by the Pest Management Center of Agriculture and Agri-Food Canada and submitted to the Pest Management Regulatory Agency of Health Canada. This achievement provided wild blueberry growers with the ability to legally use Bravo® as part of a leaf spot disease management program. Prior to this, blueberry growers could only legally use this fungicide for the control of anthracnose and phomopsis in blueberry production.

As part of the due diligence approach to research and development activities, a small research trial was also conducted in the late summer and autumn of 2007 examining the impact of sprout year and cropping year use of the fungicide Bravo® on the occurrence of chlorothalonil residues (the active ingredient in the fungicide Bravo®). The experiment consisted of applying Bravo® to fields either in the sprout (i.e., late July) or cropping years of production (i.e., applied in late May and early July) at full and part of the approved label rate of 7.2 $L \cdot ha^{-1}$, harvesting the berries, thoroughly washing a subsample of the berries (i.e., to see if the chlorothalonil residue could be removed during processing the berries) and sending berry samples to a certified laboratory for chlorothalonil residue analysis. Results from this small experiment indicated that even at reduced application rates, Bravo® cannot be used in the crop year of production due to residue limitations in the European Union (i.e., residues in berries were above the allowable limit of 0.05 ppm). In addition, there was no consistent effect of reducing the chlorothalonil residue with thoroughly washing the blueberries prior to processing (i.e., turning into IQF blueberries).

With concerns existing regarding the optimum timing of fungicide application, research trials were also implemented in 2008 examining the impact of fungicide and frequency of application on the incidence and severity of the leaf spot diseases Septoria and rust. The field trials were located near East River and Earltown, Nova Scotia. A split plot experimental design was used with the whole plot factor consisting of 12 fungicide treatments and the split plot factor consisting of frequency of application (i.e., once or twice in a growing season). More specifically, the whole plot treatments consisted of untreated control, Bravo® (a.i. chlorothalonil), Pristine® (a.i.'s pyraclostrobin and boscalid), Quadris® (a.i., axozystrobin), Switch® (a.i.: cyprodonil and fludioxonil), an experimental fungicide belonging to the carboxamide family, Folicur® (a.i.: tebuconazole), Proline® (a.i.: prothioconazole), Tanos® (a.i.'s: famoxadone and cymoxanil), experimental + Nustar® (a.i.: flusilazole), Nustar® + Mancozeb® (a.i.: mancozeb) and Nustar® + Mancozeb®. The rates used were in accordance to the fungicide label recommendations and the application timings consisted of Septoria sporulation (early application in mid June) and rust sporulation (late July).

Results from these fungicide trials again illustrated the ability of the Bravo®, Folicur®, Quadris® and Nustar® and Bravo® treatments to significantly reduce the incidence and severity of Septoria and rust leaf spot diseases and improve leaf retention (Tables 2 and 3). The Proline® treatment did not lower the incidence of leaf spot disease nor effect the severity of these leaf spot diseases at the Tina Carr site (Table 3). However, this may have been due to not adding a surfactant to the Proline® solution prior to spraying the research plots. Although the Quadris® treatment had significantly fewer stems with the presence of leaf spot diseases and the severity of Septoria and rust were also significantly less, this treatment had mild phytotoxicity symptoms on some of the wild blueberry phenotypes present in the plots (i.e., the phenotypes with pale green foliage and white bloom). Given that these phytotoxicity symptoms also occurred in field trials located in New Brunswick and Prince Edward Island, no further assessments occurred with this fungicide.

Therefore, results from these trials conducted in the sprout year of production indicated that the triazole fungicides Folicur®, Proline® and Nustar® had potential for use as a means of suppressing Septoria and rust leaf spot diseases. In proposing Septoria and rust leaf spot solutions to the Pest Management Center's Minor Use Workshop in March 2008, consideration had to be given to the efficacy of these products, residue concerns and the likelihood of some of these fungicides being phased out in export markets including the European Union. With Proline® being one of the most recent products to be registered and having very good leaf spot suppression characteristics, it was proposed that this fungicide be put forward as the preferred solution. This option was subsequently supported by the Pesticide Minor Use Coordinators in the Maritimes and given priority at the Minor Use Workshop. Results from the leaf spot disease trials was subsequently passed along to the Pest Management Center, a dossier for using this fungicide in wild blueberry production was assembled and submitted to the PMRA and approval for the use of this of the Proline® fungicide was obtained in May 2011.

However, in addition to having the fungicide Proline® registered for use in the sprout year of production, the carboxamide fungicide Fontelis® (a.i.: penthiopyrad) has been registered for use in wild blueberry production for Monilinia blight control, and it expected that the label will be expanded soon for Septoria, rust and Valdensinia leaf spot control (data submission packages have been submitted to E.I. DuPont Canada). In addition, the registration of the fungicide Acapela® (a.i. picoxystrobin) for use in the vegetative phase of production for Septoria and rust control is expected in 2012/2013 (Rene Petroski, personal communication, E.I. DuPont Canada).

Lastly, with new fungicides with varying modes of action being introduced to the wild blueberry industry, a leaf spot disease decision support system was developed for use in wild blueberry production based on an approach similar to the decision support system that has been developed for Canadian pulse growers and the control of Ascochyta blight of chickpea (http://www.saskpulse.com/media/pdfs/100705__Chickpea_Booklet__2nd_edition__FINAL.pdf). The components of this include an overview of the diseases, integrated pest management, importance of scouting, infection process, scouting techniques, disease identification, disease risk rating, additional criteria that have to be considered (pollination considerations, destination of harvested crop - export market considerations, etc.) and resulting development of a management protocol for the vegetative (sprout) and cropping years of production.

Although developed in 2009, the leaf spot disease support system that was developed using the results associated with this project could not be published and distributed to the wild blueberry industry due to the new fungicides not being registered for use in Canada. Although Proline® was evaluated on a semi-commercial scale in 2010 (3 sites and applications to 40 ha of wild blueberries), received registration for use on wild blueberries in the vegetative (sprout) phase of production in Canada in May 2011, and was evaluated on a commercial scale throughout the summer of 2011, it wasn't until the fields had been harvested in 2012 that the management approaches used in the disease support system were completely verified and ready to be distributed to the wild blueberry industry. This has resulted in the preparation of a factsheet for leaf spot disease control in wild blueberries and also a more detailed overview of the leaf spot disease support system.

Table 3. Influence of fungicide application on incidence and severity of leaf diseases, leaf retention and stem lengths of wild blueberries in the vegetative (sprout) phase of production during the 2008 growing season at the "Tina Carr" commercial wild blueberry field located near East River, Nova Scotia.

Treatment	Application frequency	Disease incidence (stems with visible symptoms of infection)	Septoria severity (% leaf area basis)	Rust severity (% leaf area basis)	Leaf retention (leaves per stem)	Stem length (cm)
Control	Early	1.00	22.5	16.2	3.73	18.0
	Early + Late	1.00	18.6	8.88	5.50	16.3
Bravo®	Early	0.999	***5.37***	***2.74***	***11.2***	18.8
	Early + Late	1.00	***5.68***	***4.71***	***19.5***	19.6
Pristine®	Early	1.00	19.7	15.1	5.07	16.7
	Early + Late	1.00	12.9	6.64	***11.6***	18.6
Quadris®	Early	0.983	9.43	***5.41***	***13.3***	20.5
	Early + Late	***0.932***	***5.17***	***3.32***	***14.3***	15.9
Switch®	Early	1.00	23.8	22.2	2.80	18.3
	Early + Late	0.999	23.8	22.4	4.57	17.7
Experimental	Early	1.00	26.6	14.6	3.80	17.0
	Early + Late	0.999	27.4	14.9	3.40	16.0
Folicur®	Early	1.00	***6.96***	***3.92***	***11.5***	17.3
	Early + Late	***0.964***	***6.22***	***1.66***	***13.9***	16.5
Proline®	Early	1.00	15.3	11.5	***10.8***	17.2
	Early + Late	1.00	17.4	***4.65***	7.23	***14.9***
Tanos®	Early	1.00	22.3	19.9	3.30	16.9
	Early + Late	1.00	18.6	10.0	7.37	16.1
Experimental + Mancozeb®	Early	1.00	16.2	11.2	7.73	17.1
	Early + Late	0.999	16.1	9.39	9.33	16.4
Nustar® + Mancozeb®	Early	1.00	20.6	13.3	5.77	16.1
	Early + Late	1.00	14.2	9.50	6.53	16.7
Nustar® + Bravo®	Early	***0.982***	***7.66***	***4.40***	***10.3***	18.7
	Early + Late	***0.948***	***6.73***	***3.10***	***17.3***	17.8
ANOVA Results		Trt (<0.0001), Trt*Freq. (0.0575)	Trt (<0.0001), Freq. (0.0082)	Trt (<0.0001), Freq. (<0.0001), Trt*Freq.(0.0072)	Trt (<0.0001), Freq. (<0.0001), Trt*Freq(0.0072)	Trt (<0.0025), Freq. (<0.0122), Trt*Freq(0.0343)

[1.] Application frequency consisted of fungicides that were applied either once or twice during the growing season
[2.] Disease incidence was recorded as presence of visual symptoms of *Septoria* or rust of the stem (0 = none, 1.0 = 100%).

Table 4. Influence of fungicide application on incidence and severity of leaf diseases, leaf retention and stem lengths of wild blueberries in the vegetative (sprout) phase of production during the 2008 growing season at the "Big Scott" commercial wild blueberry field located near Earltown, Nova Scotia.

Treatment	Application frequency	Disease incidence (stems with visible symptoms of infection)	Septoria severity (% leaf area basis)	Rust severity (% leaf area basis)	Leaf retention (leaves per stem)	Stem length (cm)
Control	Early	0.995	20.6	9.71	7.95	17.0
	Early + Late			10.5	11.9	
Bravo®	Early	0.950	**10.2**	**3.54**	**17.6**	17.8
	Early + Late			**4.58**	**15.4**	
Pristine®	Early	0.997	20.4	8.67	11.6	18.0
	Early + Late			9.29	13.0	
Quadris®	Early	0.995	12.5	7.75	**14.7**	18.3
	Early + Late			**2.80**	**19.7**	
Switch®	Early	0.973	21.6	11.4	9.10	17.8
	Early + Late			8.37	8.30	
Experimental	Early	0.971	22.0	6.10	5.83	17.8
	Early + Late			10.8	8.90	
Folicur®	Early	0.961	**6.05**	**1.43**	**16.6**	16.9
	Early + Late			**1.72**	**17.3**	
Proline®	Early	0.996	**6.64**	5.99	**17.0**	18.4
	Early + Late			**0.893**	**18.5**	
Tanos®	Early	0.978	14.0	9.91	6.63	16.9
	Early + Late			10.3	9.25	
Experimental + Mancozeb	Early	0.995	15.2	9.58	7.93	17.7
	Early + Late			14.8	9.53	
Nustar® + Mancozeb®	Early	0.995	14.6	5.90	11.9	18.5
	Early + Late			10.8	10.8	
Nustar® + Bravo®	Early	**0.933**	**5.24**	**3.18**	**16.7**	18.5
	Early + Late			**4.39**	**21.1**	
ANOVA Results		Trt (<0.05)	Trt (<0.0001)	Trt (<0.0001), Trt*Freq.(0.011)	Trt (<0.0001), Freq. (<0.0071)	Trt (<0.0375)

[1.] Application frequency consisted of fungicides that were applied either once or twice during the growing season
[2.] Disease incidence was recorded as presence of visual symptoms of Septoria or rust of the stem (0 = none, 1.0 = 100%)

With widespread use of the fungicide chlorothalonil (marked under the trade names Bravo® 500, Bravo® Zn 500 and Echo® 720 and new fungicides being available for assessment, research trials were conducted during the 2012 growing season to evaluate the impact of these products on the incidence and severity of the leaf spot diseases Septoria, blueberry rust and Valensinia. The field trials were located near Benvie Hill and Earltown, Nova Scotia. A randomized complete block experimental design was used with five replications, seven treatments, a plot size of 4 x 6 m and 2 m buffers existing between plots. Treatments consisted of untreated control, a new experimental carboxamide fungicide, Inspire™ (a.i., difenoconazole), Quilt® (a.i.'s azoxystrobin and propiconazole), Bravo® 500 (a.i. chlorothalonil), Bravo® Zn 500 (a.i. chlorothalonil) and Echo® 720 (a.i. chlorothalonil). Treatments were applied using the previously described techniques during the first week of July and August which corresponded with the initial visual symptoms of Septoria and rust leaf spots at the field sites. Treatments were applied as previously cited and the rates used were in accordance to the fungicide label recommendations.

Results from the 2012 trials indicated that significant differences existed with respect to the ability to control Septoria, rust and Valdensinia leaf spot diseases. After the first fungicide treatment had been applied, the new experimental carboxamide fungicide had 20 and 20.8% fewer stems and 21.6 and 24.0% less leaf area infected with Septoria leaf spot than the untreated control at the Benvie Hill and Earltown sites respectively (Table 5). Similarly, Inspire™ treatment had 26.3 and 28.6% fewer stems and 29.1% less and 14.5% more leaf area with visual symptoms of Septoria leaf spot than the untreated control at the Benvie Hill and Earltown sites respectively (Table 5). Similarly, the fungicide Quilt® did not provide consistent control against Septoria leaf spot at either the Benvie Hill or Earltown sites(Tables 5 and 6). Therefore, given the inconsistency in results obtained with Inspire™ and Quilt®, these fungicides should not be evaluated further with respect to their ability to control Septoria leaf spot.

Interesting differences with respect to the three forms of the fungicide chlorothalonil in their ability to control Septoria, blueberry rust and Valdensinia leaf spots were present in this project. The Bravo® 500, Bravo® Zn 500 and Echo® had statistically similar incidences of Septoria leaf spot at the Benvie Hill site (Table 4), and the Bravo® 500 and Bravo® Zn 500 treatments had a lower severity of Septoria leaf spot at both the Benvie Hill and Earltown sites (Tables 5 and 6). All three treatments however, were very effective in reducing the incidence and severity of blueberry rust at the Benvie Hill and Earltown sites (Tables 7 and 8). Despite of this effectiveness in using chlorothalonil to control rust, the ability to use it alone in wild blueberry fields appears to be limited as a result of the inability of the three chlorothalonil treatments to control Valdensinia leaf spot. For this reason, it is recommended that chlorothalonil not be used alone in fields where Valdensinia leaf spot persists. In other leaf disease trials conducted from 2008 to 2012, effective control of Valdensinia leaf spot has been attained with the use of the fungicides Proline® and Allegro® (data not reported), and the simultaneous control of rust and Valdensinia leaf spot has been attained for the remainder of the growing season when a combination of chlorothalonil and Proline® was applied in July.

Table 5. Incidence and Severity of blueberry leaf spot diseases on July 26th, 2012 (after 1st fungicide application) at a commercial field located in Benvie Hill, Nova Scotia

Treatment	Stem length (cm)	*Septoria* incidence% (stem basis)	*Septoria* severity % (leaf area basis)	*Rust* incidence % (stem basis)	*Rust* severity % (leaf area basis)	*Valdensinia* incidence % (stem basis)	*Valdensinia* severity% (leaf area basis)	Presence of canker on stem[1]
Control (untreated)	15.0*bc*	19.8*a*	0.0960*b*	0	0	0.827*ab*	0.136	0.627
Experimental	16.2*b*	15.8*ab*	0.0753*b*	0.0400	0	0.107*bc*	0.00667	0.653
Inspire	15.1*bc*	14.6*b*	0.110*ab*	0	0	0c	0	0.587
Quilt	14.4*c*	14.9*b*	0.181*a*	0	0	0.0667*bc*	0.0200	0.653
Bravo	15.3*bc*	11.9*b*	0.0520*b*	0	0	0.253*bc*	0.0367	0.533
Bravo Zn	14.2*c*	13.2*b*	0.0700*b*	0	0	0c	0	0.627
Echo	17.7*a*	14.4*b*	0.135*ab*	0.0400	0.00133	0.213*bc*	0.0453	0.480
ANOVA Results	**Sig. (p<0.0001)**	**Sig. (p=0.0286)**	**Sig. (p=0.0202)**	**NS**	**NS**	**Sig. (p<0.0001)**	**NS**	**NS**

1 Presence of canker on stem: Yes=1, No=0

2 Analysis of variance (ANOVA) results refer to treatment effects that were either not significant (NS) or significant at p<0.05. Mean separation was completed using Duncan's multiple means comparison test procedure (*ά*=0.05).

Table 6. Incidence and Severity of blueberry leaf spot diseases on July 26th, 2012 (after 1st fungicide application) at a commercial field located in Earltown, Nova Scotia

Treatment	Stem length (cm)	*Septoria* incidence% (stem basis)	*Septoria* severity % (leaf area basis)	*Rust* incidence % (stem basis)	*Rust* severity % (leaf area basis)	*Valdensinia* incidence % (stem basis)	*Valdensinia* severity% (leaf area basis)	Presence of canker on stem[1]
Control (untreated)	18.0*bc*	12.5*abc*	0.0780*b*	0.413*a*	0.00267	2.49	0.763*a*	0.720*a*
Experimental	16.9*cd*	11.9*bc*	0.0593*b*	0*b*	0	1.85	0.235*b*	0.680*ab*
Inspire	17.7*bcd*	8.92*c*	0.0553*b*	0*b*	0	2.48	0.401*ab*	0.600*abc*
Quilt	18.7*ab*	16.4*a*	0.0740*b*	0*b*	0	0.840	0.0940*b*	0.480*cd*
Bravo	19.6*a*	11.0*bc*	0.0667*b*	0*b*	0	0.680	0.102*b*	0.613*abc*
Bravo Zn	19.4*a*	8.87*c*	0.0693*b*	0.147*b*	0.000667	1.12	0.265*b*	0.440*d*
Echo	17.5*bcd*	14.5*ab*	0.1533*a*	0*b*	0	2.85	0.471*ab*	0.547*bcd*
ANOVA Results	**Sig. (p<0.0001)**	**Sig. (p=0.0016)**	**Sig. (p=0.0019)**	**Sig. (p=0.0015)**	**NS**	**NS**	**Sig. (p=0.0041)**	**Sig. (p=0.0007)**

1 Presence of canker on stem: Yes=1, No=0

2 Analysis of variance (ANOVA) results refer to treatment effects that were either not significant (NS) or significant at p<0.05. Mean separation was completed using Duncan's multiple means comparison test procedure (*ά*=0.05).

Table 7. Incidence and Severity of blueberry leaf spot diseases on August 29th, 2012 (after 2nd fungicide application) at a commercial field located in Benvie Hill, Nova Scotia

Treatment	Stem length (cm)	Leaf retention	*Septoria* incidence% (stem basis)	*Septoria* severity % (leaf area basis)	*Rust* incidence % (stem basis)	*Rust* severity % (leaf area basis)	*Valdensinia* incidence % (stem basis)	*Valdensinia* severity% (leaf area basis)	Presence of canker on stem[1]
Control (untreated)	16.8*b*	25.4	26.8*ab*	0.959	31.9*a*	2.47*a*	1.17*b*	0.0700	0.627
Experimental	18.2*a*	22.2	24.2*ab*	0.385	1.40*c*	0.181*b*	5.00*a*	0.453	0.613
Inspire	16.7*b*	24.5	20.2*b*	0.649	7.37*b*	0.345*b*	2.65*b*	0.520	0.640
Quilt	16.8*b*	24.7	20.9*ab*	0.902	1.52*c*	0.352*b*	1.36*b*	0.360	0.747
Bravo	16.6*b*	25.2	18.6*b*	0.748	2.29*c*	0.703*b*	0.893*b*	0.327	0.560
Bravo Zn	16.9*b*	25.4	29.0*a*	0.503	2.25*c*	0.195*b*	1.20*b*	0.133	0.667
Echo	18.5*a*	27.3	20.2*b*	0.916	1.92*c*	0.103*b*	1.59*b*	0.280	0.640
ANOVA Results	**Sig. (p=0.001)**	**NS**	**Sig. (p=0.0188)**	**NS**	**Sig. (p<0.0001)**	**Sig. (p<0.0001)**	**Sig. (p=0.0016)**	**NS**	**NS**

1 Presence of canker on stem: Yes=1, No=0

2 Analysis of variance (ANOVA) results refer to treatment effects that were either not significant (NS) or significant at p<0.05. Mean separation was completed using Duncan's multiple means comparison test procedure (ά=0.05).

Table 8. Incidence and Severity of blueberry leaf spot diseases on August 24th, 2012 (after 2nd fungicide application) at a commercial field located in Earltown, Nova Scotia

Treatment	Stem length (cm)	Leaf retention	*Septoria* incidence% (stem basis)	*Septoria* severity % (leaf area basis)	*Rust* incidence % (stem basis)	*Rust* severity % (leaf area basis)	*Valdensinia* incidence % (stem basis)	*Valdensinia* severity% (leaf area basis)	Presence of canker on stem[1]
Control (untreated)	21.3*a*	24.5*b*	5.87*c*	0.0167*b*	17.1*a*	1.19*a*	12.2*a*	1.24*ab*	0.680*a*
Experimental	18.3*b*	22.7*b*	7.93*c*	0.0320*b*	0.800*c*	0.0867*b*	3.47*bc*	0.323*cd*	0.720*a*
Inspire	22.0*a*	33.6*a*	12.3*b*	0.0553*b*	8.04*b*	1.11*a*	3.85*bc*	0.760*abcd*	0.627*ab*
Quilt	21.4*a*	33.0*a*	4.64*c*	0.0393*b*	0.507*c*	0.474*ab*	1.07*c*	0.720*abcd*	0.467*b*
Bravo	21.5*a*	35.7*a*	6.63*c*	0.368*a*	0.467*c*	0.268*b*	2.60*bc*	0.540*bcd*	0.720*a*
Bravo Zn	22.0*a*	34.8*a*	5.43*c*	0.0647*b*	0.840*c*	0.626*ab*	5.44*b*	1.41*a*	0.573*ab*
Echo	19.7*b*	23.4*b*	7.52*c*	0.349*a*	1.31*c*	0.181*b*	3.49*bc*	0.985*abc*	0.640*a*
ANOVA Results	**Sig. (p<0.0001)**	**Sig. (p<0.0001)**	**Sig. (p<0.0001)**	**Sig. (p=0.0087)**	**Sig. (p<0.0001)**	**Sig. (p=0.0019)**	**Sig. (p<0.0001)**	**Sig. (p=0.0013)**	**Sig. (p=0.0133)**

1 Presence of canker on stem: Yes=1, No=0

2 Analysis of variance (ANOVA) results refer to treatment effects that were either not significant (NS) or significant at p<0.05. Mean separation was completed using Duncan's multiple means comparison test procedure (ά=0.05).

Stage 3. Leaf Spot Disease Management Techniques for the Cropping Phase of Production. Concerns were raised in 2007 and 2008 with leaf disease management techniques as a result of: (i) substantial Septoria pressures in the cropping year of production, (ii) residue issues encountered with the cropping year use of the fungicide Bravo® and pre-harvest applications of Pristine®, (iii) an apparent lack of efficacy associated with one application of the fungicide Pristine®, and (iv) the cost of this fungicide. Given this, trials were initiated in 2008 at commercial fields located in Diligent River (NS) and Val Doucet (NB) focusing on combinations of active ingredients that could potential offer adequate control of Septoria, minimal likelihood of residue issues in processed berries, multiple modes of action (minimal likelihood of resistance accumulation) and cost effectiveness. The specific treatments examined included an untreated control, Lance® (a.i.: boscalid) + Indar® (fenbuconazole), Lance® + Aliette® (fosetyl Al), Macozeb® (a.i.: mancozeb) + Indar®, Mancozeb® + Quadris® (a.i.: axozystrobin) and Pristine® (a.i.'s: boscalid and pyraclostrobin). The fungicides were applied using label rates in late June of the cropping year of production (i.e., at the first visual symptoms of the disease).

Results from the cropping year fungicide trials indicated that all of the applied fungicides reduced the proportion of stems with leaf spot disease symptoms at the Val Doucet site (Table 9). Although the proportion of stems with leaf disease symptoms was slightly lower at the Diligent River site, there was no effect of the fungicide treatments on the stems with symptoms of leaf spot diseases (Table 11). However, a significant effect of the fungicide treatments on Septoria severity was present at both sites with the Lance® (a.i.: boscalid) + Indar® (fenbuconazole), Lance® + Aliette® (fosetyl Al) and Pristine® (a.i.'s: boscalid and pyraclostrobin) treatments all substantially reducing the severity of Septoria leaf spot (Tables 9 and 11). Symptoms of rust symptoms were minimal at both sites.

Upon examining the effect of the treatments on the yield components of the wild blueberries, there was no significant effect on set fruit (i.e., viable berry number per stem). The number of "pinhead" berries (i.e., small berry number per stem) was significantly greater with the Lance® + Aliette® (fosetyl Al) treatment at the Val Doucet site only (Table 10). Harvestable yields were significantly effected at both sites with the fungicide treatments with harvestable berry yields of the Lance® + Indar® and Pristine® treatments being 44.7 and 54.1% greater than the untreated control at the Val Doucet site and 17.3 and 32.0% greater than the untreated control at the Diligent River site (Tables 10 and 12).

Therefore, results from the crop year studies indicated that effective Septoria leaf spot control can be obtained in the cropping year of production with the use of fungicide treatments including Pristine®. Concerns of fungicide residues in wild blueberries treated with Pristine® have been negated with more cautious usage (i.e., do not apply 1 month prior to harvest versus to the 1 day preharvest interval presently on the Canadian label). However, the feasibility of using alternative fungicides has not materialized as originally planned with Indar® not being registered for use in wild blueberries (an emergency use registration was granted for 1 year only), concerns in the European Union with respect to the use of Mancozeb® and Aliette® not providing adequate leaf spot control (studies conducted in south-eastern USA indicated that it could be used to control Septoria leaf spot of highbush blueberries). However, the upcoming registration of the pyrazole carboxamide fungicide Fontelis® will eventually provide blueberry producers with an alternative fungicide for use in the cropping year of production.

Table 9. Influence of fungicide application on incidence and severity of leaf diseases of wild blueberries in the cropping phase of production during the 2008 growing season at a commercial wild blueberry field located near Val Doucet, New Brunswick.

Treatment	Disease incidence (stems with visible symptoms of infection)	Septoria severity (% leaf area basis)	Rust severity (% leaf area basis)
Control	0.918a	0.776a	0.00271
Lance® + Indar®	0.652c	0.103b	0.00141
Lance® + Aliette®	0.752bc	0.320b	0
Mancozeb® + Indar®	0.660c	0.191b	0
Mancozeb® + Quadris®	0.788b	0.387b	0
Pristine®	0.675c	0.111b	0
ANOVA Results	Trt (<0.0001)	Trt (<0.0001)	NS

Disease incidence was recorded as presence of visual symptoms of *Septoria* or rust of the stem (0 = none, 1.0 = 100%)

Table 10. Influence of fungicide application in the cropping phase of production on wild blueberry yield components during the 2008 growing season at a commercial field located near Val Doucet, New Brunswick.

	Stem length (cm)	Side branch number per stem	Set fruit (berries per stem)	Pinheads (small malformed berries per stem)	Harvestable yield ($g \cdot m^{-2}$)
Control	14.1b	0.633a	10.1a	0.764b	418b
Lance® + Indar®	16.2a	0.673a	11.3a	0.953b	605a
Lance® + Aliette®	15.0ab	0.484a	10.9a	1.55a	637a
Mancozeb® + Indar®	16.3a	0.677a	12.2a	0.602b	546a
Mancozeb® + Quadris®	14.6ab	0.863a	12.0a	0.554b	635a
Pristine®	16.2a	0.432a	12.5a	0.812b	644a
ANOVA Results	Trt (p=0.0095)	NS	NS	Trt (p=0.0073)	Trt (p=0.0005)

Table 11. Influence of fungicide application on incidence and severity of leaf diseases of wild blueberries in the cropping phase of production during the 2008 growing season at a commercial wild blueberry field located near Diligent River, Nova Scotia.

Treatment	Disease incidence (stems with visible symptoms of infection)	Septoria severity (% leaf area basis)	Rust severity (% leaf area basis)
Control	0.739	0.542a	0a
Lance® + Indar®	0.680	0.294b	0a
Lance® + Aliette®	0.801	0.205b	0a
Mancozeb® + Indar®	0.752	0.321b	0a
Mancozeb® + Quadris®	0.779	0.544b	0a
Pristine®	0.736	0.213b	0.00690a
ANOVA Results	NS	Trt (p=0.0005)	NS

Disease incidence was recorded as presence of visual symptoms of *Septoria* or rust of the stem (0 = none, 1.0 = 100%)

Table 12. Influence of fungicide application in the cropping phase of production on wild blueberry yield components during the 2008 growing season at a commercial field located near Diligent River, Nova Scotia.

	Stem length (cm)	Side branch number per stem	Set fruit (berries per stem)	Pinheads (small malformed berries per stem)	Harvestable yield ($g \cdot m^{-2}$)
Control	14.5	0.375	4.09	0.160	294ab
Lance® + Indar®	15.1	0.529	4.57	0.241	345a
Lance® + Aliette®	14.8	0.588	6.00	0.163	308ab
Mancozeb® + Indar®	15.1	0.778	3.29	0.112	220b
Mancozeb® + Quadris®	15.5	0.635	3.03	0.202	207b
Pristine®	15.1	0.733	4.20	0.293	388a
ANOVA Results	NS	NS	NS	NS	Trt (p=0.0011)

Stage 4. Laboratory Studies Examining the Sensitivity of Septoria Isolates to Fungicides

With substantial levels of variability being noticed between researchers and extension specialists with respect Septoria leaf spot control, it was decided in 2009 that emphasis should be placed on collecting Septoria isolates from wild blueberry fields throughout Nova Scotia and determining their sensitivity to the active ingredients contained in fungicides. The active ingredients included those that were presently being commercially used when Septoria sporulation is occurring (propiconazole, chlorothalonil, pyraclostrobin and boscalid) and prothioconazole (the active ingredient in Proline®). Septoria cultures were established by bring leaf tissue samples containing visual samples back to the laboratory, isolating the various Septoria isolated in agar

media, re-infecting blueberry plants in controlled chambers with the various Septoria isolates to verify that these isolates were the causal organisms causing Septoria leaf spot, and then proceeding with a dose response study.

A significant challenge was encountered with the Septoria isolates due to this organism initially growing like yeast (i.e., producing a mass of undifferentiated cells) and not readily producing mycelium. To alleviate this problem, microtitre plates were inoculated with *Septoria* spore suspension and liquid media amended with different concentration of the active ingredients that were used. After incubation of the culture at room temperature in dark for 7-10 days, fungal growth (optical density) was measured with a spectrophotometer at 405 nm. The EC_{50} value of fungicide was estimated by comparing the relative growth of fungal culture in different concentrations of fungicides compared to fungal growth in fungicide non-amended liquid media.

Results from laboratory sensitivity studies indicated that there is no evidence of resistance by any of the active ingredients examined with the Mean EC_{50} values of the tolerant subgroups all being substantially less than the concentration typically being applied to control Septoria (Table 9). However, evidence of selection pressures were present with the triazole active ingredients propiconazole and prothioconazole havingthe highest EC_{50} values of all the active ingredients obtained. Given that triazole fungicides have been in use for over 20 years for the control of *Monilinia* blight in wild blueberry production, these results suggest that the management practices used for the control of *Monilinia* blight may have been a contributing factor in the emergence of Septoria leaf spot as a debilitating disease in wild blueberry production. Interestingly, there was no significant correlation between the isolates that were sensitive to the propiconazole and prothioconazole, suggesting that fungicides used prior to Topas® (the fungicide containing the active ingredient propiconazole) may have also been responsible for the tolerance of some of the Septoria isolates to prothioconazole (e.g., Funginex® which contains the active ingredient triforine).

Therefore, results from this laboratory study provide valuable insight into the response of the various Septoria isolates collected to the active ingredients presently being used in the wild blueberry industry. With active ingredients such as pyraclostrobin having a very narrow mode of action, ongoing assessments (i.e., every 5 to 10 years) should occur to determine if shifts in sensitivity have occurred resulting in increased tolerance or resistance to a particular active ingredient. This is particularly importantly with many of the newer fungicides (e.g., pyraclostrobin) having a narrow mode of action and high risk to resistance by organisms including Septoria. In the shorter term, this study also illustrates the importance of taking measures to minimize the likelihood of resistance to the new active ingredient prothioconazole. Although the results observed in this study may have been due to not using the proper metabolite that is active within the leaf tissue (prothioconazole-desthio), it does provide sufficient interest to warrant further investigation. Until these studies are completed, it is being recommended on a go-forward basis that Proline® always be combined with another fungicide to minimize the likelihood of resistance from occurring. Given that the wild blueberry industry is presently using Bravo® (a.i.: chlorothalonil) in the sprout year for the control of leaf spot diseases, combining Proline® with the Bravo® has the added benefit of not only inhibiting spore germination (which the Bravo® is responsible or), but also having the curative attributes of a triazole fungicide.

Table 13. Sensitivity of Septoria isolates to the various active ingredients contained in fungicides being used in the wild blueberry industry.

Treatment	Concentration Typically Applied With Fungicide Application (ppm or µg/ml)	Mean EC_{50} of the Sensitive Subgroup (µg/ml)	Overall Mean EC_{50} (µg/ml)	Mean EC_{50} of the Tolerant Subgroup (µg/ml)
Topas™ (a.i.: propiconazole)	**568**	**0.547**	**2.21**	**89.2**
Proline® (a.i.: prothioconazole)	**873**	**0.638**	**4.39**	**134**
Bravo® (a.i.: chlorothalonil)	**16,364**	**0.563**	**2.75**	**4.59**
Cabrio™* (a.i.: pyraclostrobin)	**931**	**0.0118**	**0.0372**	**0.0573**
Lance™* (a.i.: boscalid)	**1,832**	**0.283**	**0.732**	**2.06**

Technology Transfer Activities Associated With the Project

A. Peer Reviewed Publications Associated With the Project

1. Percival, D.C. and J.K. Dawson. 2009. Foliar disease impact and possible control strategies in wild blueberry production. ActaHort. 810:345-354.

2. Dawson, J.K., D.C. Percival, N.L. Pitts and P.D. Hildebrand. 2012. Foliar diseases hinder the photosynthetic processes of the lowbush blueberry (*Vaccinium angustifolium* Ait.). Plant Disease (In review).

B. Producer Related Functions

(i) 2012:

3. Percival, D. and Y. Chen. 2012. Canopy and Integrated Disease Management Practices For Wild Blueberry Production. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 16 and 17, 2012, Truro, Nova Scotia.

Number of people anticipated to attend the function: 400

Number of persons associated with the project contributing to the function: 3

4. Percival, D. and Y. Chen. 2012. Main and Interactive Effects of Canopy Management Practices, Yield Components and Harvestable Berry Yields of Wild Blueberries. North American Wild Blueberry Research and Extension Workers' Meeting. October 26 and 27, 2012, Fredericton, New Brunswick.

Number of people anticipated to attend the function: 400

Number of persons associated with the project contributing to the function: 4

5. Annual Field Day of the Wild Blueberry Producers Association of Nova Scotia. July 21, 2012. Debert, Nova Scotia. Oral Contribution: Wild Blueberry Leaf Spot Disease Update (see attached bulletin).

Number of persons attending the function: 300

Number of persons associated with the project contributing to the function: 7

6. Annual Field Day of the Prince Edward Island Wild Blueberry Growers Association. July 7, 2012. Mount Stewart, Prince Edward Island. Oral Contribution: Wild Blueberry Leaf Spot Disease Update (see attached bulletin).

Number of persons attending the function: 90

Number of persons associated with the project contributing to the function: 4

7. Annual Twilight Meetings of the Wild Blueberry Producers Association of Nova Scotia. Locations: Kempville (May 29), Debert (June 4), East River/Saint Mary's (June 5) and Parrsboro (June 7). Oral Contribution: Wild Blueberry Leaf Spot Disease Update (see enclosed bulletin)

Number of persons attending the function: 35 (Kempville), 120 (Debert), East River/Saint Mary's (30) and 60 (Parrsboro).

Number of persons associated with the project contributing to the functions: 4

8. Annual Winter Meeting of the Wild Blueberry Producers Association of Nova Scotia. March 24, 2012. Oral contribution (see enclosed PowerPoint Presentation)

Number of persons attending the function: 230

Number of persons associated with the project contributing to the functions: 1

9. Annual Field Management Meeting of the Bragg Group of Food Companies. February 15, 2012. Oral contribution: Wild Blueberry Leaf Spot Disease Update

Number of persons attending the function: 32

Number of persons associated with the project contributing to the function: 1

(ii) 2011:

10. Percival, D. and G. Dias. 2011. Energy consumption and greenhouse gas production associated with the primary production of wild blueberries and Leaf Spot Diseases and Monilinia Blight Updates. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 18 and 19, 2011, Truro, Nova Scotia (see enclosed PowerPoint presentation).

Number of people attending the event: 420

Number of persons associated with the project contributing to the function: 3

11. Percival, D. and G. Dias. 2011. Energy Consumption and Greenhouse Gas Production Associated With the Primary Production of Wild Blueberries and Leaf Spot Diseases and Monilinia Blight Updates. North American Wild Blueberry Research and Extension Workers' Meeting. October 27 and 28, 2011, Bangor, Maine.

Number of people anticipated to attend the function: 350

Number of persons associated with the project contributing to the function: 2

12. Annual Field Day of the Wild Blueberry Producers Association of Nova Scotia. July 23, 2011. Debert, Nova Scotia. Oral Contribution: Wild Blueberry Leaf Spot Disease Update. Also included were demonstration plots for viewing.

Number of persons attending the function: 325

Number of persons associated with the project contributing to the function: 7

13. Annual Field Day of the Prince Edward Island Wild Blueberry Growers Association. July 9, 2011. Mount Stewart, Prince Edward Island. Oral Contribution: Wild Blueberry Leaf Spot Disease Update.

Number of persons attending the function: 100

Number of persons associated with the project contributing to the function: 3

14. Annual Twilight Meetings of the Wild Blueberry Producers Association of Nova Scotia. Locations: Debert (June 2), East River/Saint Mary's (June 7) and Parrsboro (June 9). Oral Contribution: Wild Blueberry Leaf Spot Disease Update.

Number of persons attending the function: 160 (Debert), East River/Saint Mary's (50) and 70 (Parrsboro).

Number of persons associated with the project contributing to the functions: 3

15. Annual Winter Meeting of the Wild Blueberry Producers Association of Nova Scotia. March 19, 2011. Truro, Nova Scotia. Oral contribution (see enclosed PowerPoint Presentation)

Number of persons attending the function: 270

Number of persons associated with the project contributing to the functions: 1

(iii) 2010:

16. Percival, D. 2010. Leaf Diseases: What and How Much to Use, When to Apply It and Why You Should Apply It. Annual Meeting of the Prince Edward Island Wild Blueberry Growers Association. November 26, 2010, Truro, Nova Scotia (see enclosed PowerPoint presentation).

Number of people attending the event: 90

Number of persons associated with the project contributing to the function: 1

17. Percival, D. 2010. Wild Blueberry Research Program Update: Impact of Septoria Leaf Spot and Rust on the Growth, Development and Yield of Wild Blueberries. Leaf Spot Diseases, Monilinia Blight, and Nutrient Management. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 19 and 20, 2010, Truro, Nova Scotia (see enclosed PowerPoint presentation).

Number of people attending the event: 400

Number of persons associated with the project contributing to the function: 3

18. Percival, D. and E. Beaton. 2010. Impact of Leaf Spot Diseases and Potential Mitigation Technologies. North American Wild Blueberry Research and Extension Workers' Meeting. October 15 and 16, 2010, Quebec City, Quebec.

Number of people anticipated to attend the function: 375

Number of persons associated with the project contributing to the function: 3

19. Annual Field Day of the Wild Blueberry Producers Association of Nova Scotia. July 23, 2010. Debert, Nova Scotia. Oral Contribution and Field Demonstration: Wild Blueberry Leaf Spot Diseases: Causes, effects on plant growth, development and yield and mitigation technologies.

Number of persons attending the function: 350

Number of persons associated with the project contributing to the function: 8

20. Annual Field Day of the Prince Edward Island Wild Blueberry Growers Association. July 3, 2010. Mount Vernon, Prince Edward Island. Oral Contribution: Wild Blueberry Leaf Spot Disease Update.

Number of persons attending the function: 75

Number of persons associated with the project contributing to the function: 2

21. Annual Twilight Meetings of the Wild Blueberry Producers Association of Nova Scotia. 2010. Locations: Debert (June 4), East River/Saint Mary's (June 8) and Parrsboro (June 10). Oral Contribution: Soil Fertility, Plant Nutrition and Leaf Spot Disease Update.

Number of persons attending the function: 150 (Debert), East River/Saint Mary's (45) and 65 (Parrsboro).

Number of persons associated with the project contributing to the functions: 4

22. Percival, D. 2010. Annual Winter Meeting of the Wild Blueberry Producers Association of Nova Scotia. March 13. Wild Blueberry Research Program Update: Mosses and Leaf Spot Diseases. Truro, Nova Scotia. Oral contribution.

Number of persons attending the function: 210

Number of persons associated with the project contributing to the functions: 1

23. Percival, D. Annual Field Management Meeting of the Bragg Group of Food Companies. January 25, 2010. Leaf Diseases: What, Where, When and Why. Oral contribution: Wild Blueberry Leaf Spot Disease Update. Amherst, Nova Scotia.

Number of persons attending the function: 54

Number of persons associated with the project contributing to the function: 1

(iv) 2009:

24. Percival, D., H. Hines and R. Burlakotti. 2009. Valdensinia Leaf Spot Suppression Research Update. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. Oral Contribution. November 20 and 21, 2009 (see attached file).

Number of persons attending the function: 215

Number of persons associated with the project contributing to the function: 2

25. Percival, D., H. Hines and R. Burlakotti. 2009. Valdensinia Leaf Spot Suppression in Wild Blueberry Fields. North American Wild Blueberry Research and Extension Workers' Meeting. October 30 and 31, 2009. Moncton, New Brunswick.

Number of people anticipated to attend the function: 150

Number of persons associated with the project contributing to the function: 2

26. Annual Field Day of the Wild Blueberry Producers Association of Nova Scotia. July 18, 2009. Debert, Nova Scotia. Oral Contribution and Field Demonstrations: Wild Blueberry Leaf Spot Diseases: Impacts on Plant Growth, Development and Yield and Mitigation Technologies.
Number of persons attending the function: 350
Number of persons associated with the project contributing to the function: 5

27. Annual Twilight Meetings of the Wild Blueberry Producers Association of Nova Scotia. 2009. Locations: Debert (June 4), East River/Saint Mary's (June 9) and Parrsboro (June 11). Oral Contribution: Soil Fertility, Plant Nutrition and Leaf Spot Disease Update.
Number of persons attending the function: 180 (Debert), East River/Saint Mary's (40) and 60 (Parrsboro).
Number of persons associated with the project contributing to the functions: 3

28. Percival, D. 2009. Wild Blueberry Research Program Update: Mosses, Soil Fertility, Leaf Spot Diseases and MRL's. Annual Management Meeting of the Prince Edward Island Blueberry Growers Association. Oral Contribution. April 7.
Number of persons attending the function: 75
Number of persons associated with the project contributing to the functions: 1

29. Percival, D. 2009. Wild Blueberry Research Program Update: Mosses, Soil Fertility, Leaf Spot Diseases and MRL's. Annual Management Meeting of the Crossroads Blueberry Cooperative (co-sponsored by Cavendish Agri-Services). Wild Blueberry Research Update. April 3.
Number of persons attending the function: 110
Number of persons associated with the project contributing to the functions: 1

30. Percival, D. 2009. Wild Blueberry Research Program Update: Soil Fertility, Plant Nutrition and Leaf Spot Diseases. Annual Winter Meeting of the Wild Blueberry Producers Association of Nova Scotia. March 13. Truro, Nova Scotia. Oral contribution.
Number of persons attending the function: 210
Number of persons associated with the project contributing to the functions: 1

(v) 2008:

31. Percival, D. 2008. Wild Blueberry Leaf Diseases: Sprout and Crop Phase of Production Leaf Spot Disease Suppression Techniques. Annual Meeting of the Prince Edward Island Blueberry Growers' Association. November 29, Charlottetown, Prince Edward Island (see enclosed PowerPoint presentation).
Number of people attending the event: 60
Number of persons associated with the project contributing to the function: 1

32. Percival, D. 2008. Wild Blueberry Research Report (Sprout and Crop Phase of Production Leaf Disease Suppression Techniques). Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 21 and 22, Truro, Nova Scotia (see enclosed PowerPoint presentation).
Number of people attending the event: 400
Number of persons associated with the project contributing to the function: 3

33. Percival, D. 2008. Foliar and Floral Diseases: Production Calendar (in collaboration with Syngenta Canada) (see attached file)

34. Percival, D. 2008. Sprout and Crop Phase of Production Leaf Spot Disease Suppression Techniques. North American Wild Blueberry Research and Extension Workers' Annual Meeting. October 23 and 24, Bangor Maine (see enclosed PowerPoint presentation).
Number of people attending the event: 110
Number of persons associated with the project contributing to the function: 2

35. Annual Field Day of the Wild Blueberry Producers Association of Nova Scotia. July 19, 2008. Debert, Nova Scotia. Oral Contribution and Field Demonstration: Wild Blueberry Leaf Spot Diseases: Identification, Impacts and Mitigation Technologies.
Number of persons attending the function: 220
Number of persons associated with the project contributing to the function: 6

(vi) 2007:
36. Dawson, J., D. Percival, B. Gray and P. Hildebrand. 2007. Foliar Diseases: Impact on Photochemistry and Leaf Retention. Oral Contribution. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 16 and 17, 2007 (see attached file).
Number of persons attending the function: 230
Number of persons associated with the project contributing to the function: 4

37. Stewart, L., D. Percival and P. Hildebrand. 2007. Leaf Spot Diseases. Challenges and Potential Control Strategies. Oral Contribution. Annual Meeting of the Wild Blueberry Producers Association of Nova Scotia. November 16 and 17, 2007 (see attached file).
Number of persons attending the function: 230
Number of persons associated with the project contributing to the function: 4

38. Percival, D., H. Hines, G. Thyssen and L. Stewart. 2007. Wild Blueberry Research Program Update. Annual Oral Contribution. Annual Meeting of the New Brunswick Wild Blueberry Producers Association. April 25, 2007.
Number of persons attending the function: 120
Number of persons associated with the project contributing to the function: 1

Project Leader Assessment

Overall, the project has been very successful in (i) developing an improved understanding of the basic biology and life cycles associated with the fungal organisms causing the Septoria, blueberry rust, powdery mildew and Valdensinia leaf spot diseases of wild blueberries; (ii) assessing under laboratory and field conditions the efficacy and phytotoxicity of various biological and agrochemical products for controlling these fungal diseases; (iii) providing critical data and recommendations for the control of these leaf spot diseases to government agencies including the various provincial departments of agriculture in the maritime provinces, Agriculture and Agri-Food Canada (Pest Management Center) and Health Canada (Pest Management Regulatory Agency); (iv) fostering new international research and development linkages with organizations including Michigan State University and Rothamsted Research

(http://www.rothamsted.ac.uk/) (Harpenden, England); (v) provide the resources to assist with the training of highly qualified personnel including postdoctoral research fellows, undergraduate students and producers and most importantly, (v) providing Canadian wild blueberry producers with the required technologies to minimize the impact of these leaf spot diseases, greatly improve plant growth, development and yield and ultimately remain competitive in an increasingly competitive global economy. The impact of these new technologies was particularly evident in 2012 with numerous producers using these technologies having wild blueberry yields that were far above the 5 year, Nova Scotia average of 1,85 kg berries·ha^{-1}. In conjunction with providing adequate pollination, appropriate fertilization and minimizing the impact of other pest pressures (e.g., weeds), numerous wild blueberry producers attained yields in excess of 10,000 kg·ha^{-1}. Despite these successes, work is still required to ensure that producers have the information and knowledge required to make appropriate management decisions regarding these leaf spot diseases. In address this need, work will continue with the wild blueberry producers in Canada and the various technology transfer mechanisms.