RESEARCH REPORT

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Fruit Rot Pathogens and their Impact on Cranberry Production in British Columbia:
Efficacy of potential fungicides against cranberry fruit-rot pathogens

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APPROACH

A four-year research study initiated in 2013 identified *Allantophomopsis lycopodina* (black rot), *Phyllosticta elongata* (early rot/berry speckle), *Physalospora vaccinii* (blotch rot), *Phomopsis vaccinii* (viscid rot), *Coleophoma empetri* (ripe or white rot), *Colletotrichum acutatum*, *Colletotrichum gloeosporioides* and *Glomerella cingulata* (bitter rot), *Botrytis cinerea* (yellow rot), and *Fusicoccum putrefaciens* (end Rot) as the major pathogens responsible for cranberry fruit-rot in British Columbia. Amongst the pathogens, *Allantophomopsis lycopodina* (being the predominant pathogen), *Phyllosticta elongata* and *Physalospora vaccinii* accounted for the majority of fruit rot estimated in 2014 and 2015 growing seasons. The studies further confirmed that the cranberry fruit rot pathogens were present at all phenological (developmental) stages of cranberries, i.e. from flowering to fruit ripening, and were prevalent in all cranberry producing regions. Besides the major fruit-rot pathogens, *Alternaria, Aspergillus*, *Cladosporium*, *Epicoccum*, *Fusarium*, *Mucor*, *Penicillium*, *Pestalotiopsis* and yeasts were also recovered from the cranberry samples. This wide range of fungal pathogens both major ones and others, as identified on cranberries in BC fields can collectively contribute to both pre- and post-harvest fruit-rot, depending on their prevalence and distribution, climatic conditions, or when harvest is delayed and with poor handling and storage conditions.

From these studies, it is apparent that at least eight to ten major fungal pathogens are responsible for fruit-rot complex in BC cranberries. Due to the complicity of multiple pathogens involved in pre- and post-harvest fruit-rot, fungicides that are currently registered for cranberries may or may not have the required efficacy to control the wide range of pathogens involved in cranberry fruit-rot. These pathogens also vary in their biology, virulence, time of infection and spread dictated by climatic conditions, and their population, distribution and contribution to fruit-rot complex vary from year to year, or field to field. Therefore, the overall objective of the study was to assess the levels of efficacy of registered and other potential fungicides to each of the major fruit-rot pathogens and, thereby, choose the most effective fungicides having broader spectrum of activity to manage fruit-rot complex on cranberries.

METHODOLOGY

A total of 26 chemical fungicides, belonging to 9 different classes of compounds (FRAC Groups), and 2 biological fungicides were selected for this study (Annexure 1). All 28 fungicides were evaluated for efficacy to inhibit the mycelial growth and spore germination of ten major cranberry fruit rot pathogens at both minimum and maximum application rates as per the manufactures' label recommendations. In order to avoid discrepancy in the recommended application rates (i.e. by weight or by volume per spray volume or hectare) amongst different fungicides, the minimum and maximum application rates of each fungicide were made in 500 L volume of water as a standard spray volume. In order to measure the actual inhibitory (efficacy) effect of the fungicides, fungicides were also tested at the maximum recommended rates in 200 L water; a standard volume used in a foliar boom-spray application. Since the nature of a fungicide can be preventative and/or curative the experiments were designed to assess the ability of fungicides to inhibit both the germination of spores (as preventative action) and growth of mycelium (as curative action) of the major fruit-rot pathogens. For each pathogen, at least 2 to 3 representative isolates, obtained from cranberry fields at different geographical locations, were included; i.e. a total of 23 isolates of ten major pathogens were included in the study (Annexure 2). For genus *Colletotrichum*, 3 isolates of each of the three groups, *C. acutatum C. gloeosporioides*, and their teleomorph (sexual stage) *Glomerella cingulate*, were included. For *Physalospora vaccinii*, two isolates of its dark and light coloured phenotypes were included.

Inhibition of mycelial growth: Petri plates containing a bioassay medium, ¼-strength potato dextrose agar (¼PDA), amended with the minimum and maximum rates of each fungicide were prepared for the assays. Similarly prepared assay plates without the fungicides were used as controls. To assess the efficacy of fungicides to each of the pathogen, two similarly prepared assay plates of both minimum and maximum rates of each fungicide were used as replicates. For the assessment of inhibition of mycelial growth of the pathogens by fungicides, 4 mm diameter mycelial plugs taken from an actively growing culture of the pathogen, previously grown on a PDA medium, were placed in the centre of each fungicide amended and non-amended assay plates, and the plates were incubated in the dark at 24°C for at least 5 to 7 days. Depending on the growth of the pathogen on the control plates, at the end of either 5th or 7th day of incubation two measurements of the mycelial growth, i.e. colony diameter, of the pathogen were measured and the average mycelial colony growth of each pathogen was calculated for both fungicide amended (at minimum and maximum rates) and non-amended control plates (Figure 1). The degrees of inhibition of mycelial growth of each pathogen by the fungicides were assessed based on the percentage reduction in the mycelial growth of the pathogen by the fungicides at both minimum and maximum rates, based on the mycelial growth of the pathogen in the absence fungicides.

Inhibition of spore germination: A similar methodology was followed for evaluating the efficacy of fungicides to inhibit the germination of spores of the major fruit-rot pathogens. Spores, either conidia or ascospores, were harvested from pure cultures of the pathogens, previously grown on PDA, and 20 µl aliquots of spore suspensions at a concentration of 1×10^4 spores ml^{-1} were placed onto fungicide amended (at both minimum and maximum recommended label rates in 200 L volume) and non-amended assay medium prepared in multi-well microtiter plates;

two similarly prepared micro-wells of both minimum and maximum rates of each fungicide were used as replicates. The assay plates were incubated in the dark at 18°C for at least 5 to 7 days until growth of the pathogens was visible on fungicide non-amended control plates. Inhibition of spore germination of the pathogens by each fungicide was assessed based on the absence or presence of growth of the pathogen on fungicide-amended assay wells versus presence of growth of the pathogen on fungicide non-amended assay wells in the plates (Figure 2).

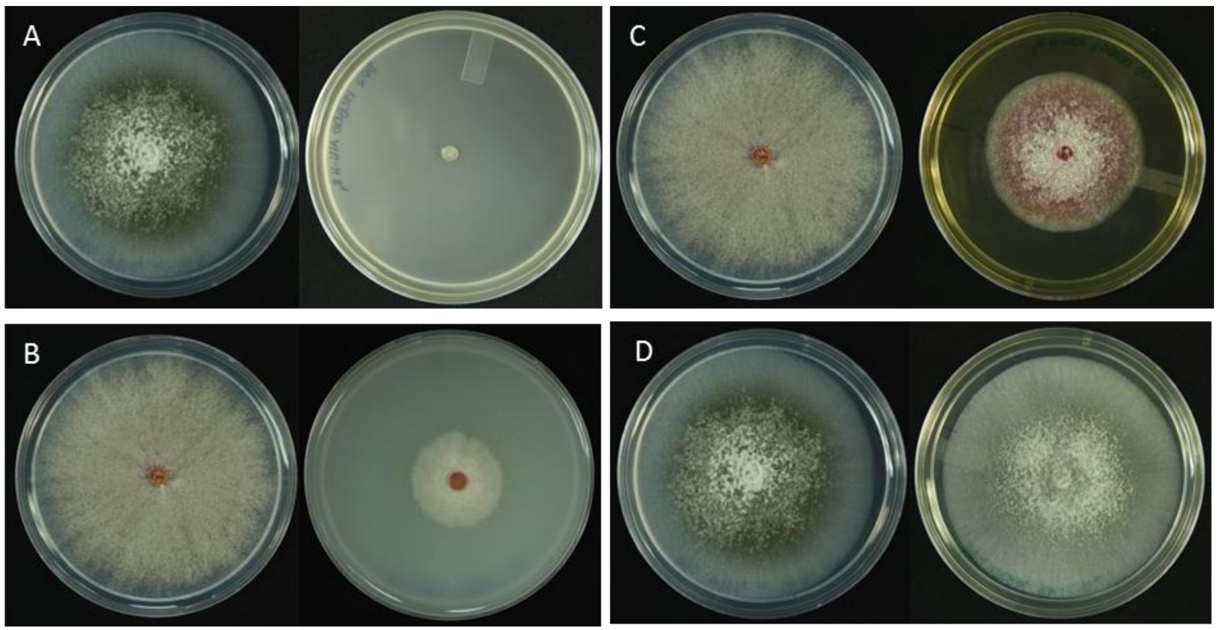

Figure 1. Efficacy of inhibition of mycelial growth of cranberry fruit-rot pathogens by fungicides on fungicide-amended and non-amended, i.e. control, assay plates; A) highly effective inhibition of scale 8-10, right, vs. control, left, B) moderately effective inhibition of scale 5-7, right, vs. control, left, C) less effective inhibition of scale 2-4, right, vs. control, left, and D) no inhibition, right, vs. control, left.

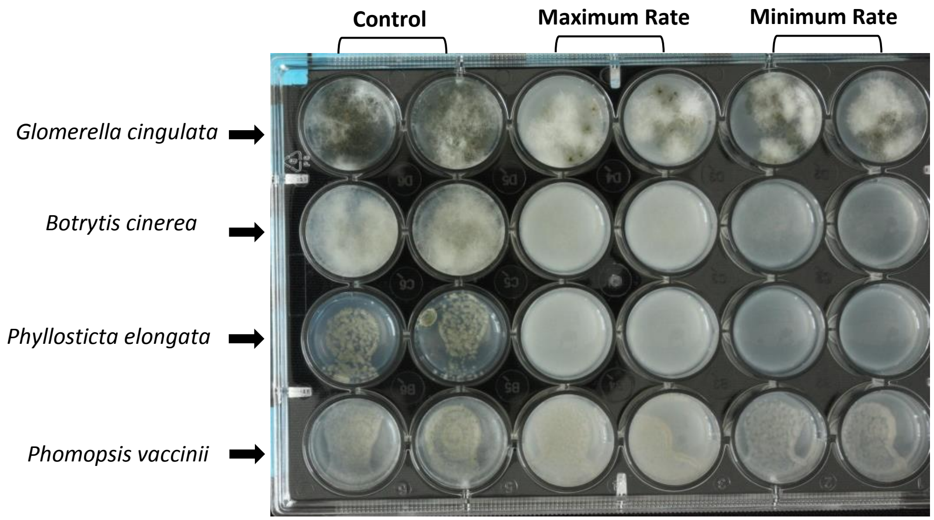

Figure 2. Efficacy of inhibition of germination of spores of four different cranberry fruit-rot pathogens by the fungicide Sercadis (FRAC group 7) on a multiwall microtiter assay plate. Assay plate was prepared with the minimum and maximum label rates of the fungicide-amended and non-amended fungal growth medium in replicate wells.

RESULTS & DISCUSSION

Group M Fungicides

Group M fungicides are considered broad spectrum, i.e. active against a wide range of pathogens. They have both preventative and curative activities against cranberry fruit-rot pathogens. However, since Group M fungicides are non-systemic in nature, they are suited for preventative use, prior to infection by pathogens. Group M chemicals interfere with multiple genes of the target pathogen and, therefore, considered **low risk.** Repeated use of Group M chemicals does not or seldom result in resistance development in fungal pathogens. Group M chemicals are highly recommended for preventive use and in rotation with other medium to high risk fungicides.

- **Inhibition of mycelial growth (Table 1):**
  - The fungicides of **FRAC group M** were highly effective (scale 8 to 10) at inhibiting the mycelial growth of all cranberry fruit rot pathogens, with the exception of:

- **Bravo** was moderately effective (scale 5 to 7) at inhibiting the growth of *Botrytis cinerea* (yellow rot), *Coleophoma empetri* (ripe/white rot) and less effective at inhibiting the growth of *Fusicoccum putrefaciens* (leaf drop/canker) at concentrations in 500 L , and
- **Guardsman** was moderately effective (scale 5 to 7) at inhibiting *Botrytis cinerea* (yellow rot) and less effective (scale 2 to 4) at inhibiting *Fusicoccum putrefaciens* (leaf drop/canker).

- **Inhibition of spore germination (Table 1):**
  - **Bravo** was effective at inhibiting the germination of spores of cranberry fruit rot pathogens, except *Botrytis cinerea* (yellow Rot).
  - **Cueva** was effective at inhibiting the germination of spores cranberry fruit rot pathogens, with the exception of *Allantophomopsis lycopodina* (black rot) and *Phyllosticta elongata* (early rot) at the minimum label rate in 200L water.
  - **Copper 53W** was effective at inhibiting the germination of spores of cranberry fruit rot pathogens.
  - **Maestro** inhibited the germination of spores of cranberry fruit rot pathogens, except *Glomerella cingulata* (bitter rot) at the minimum label rate in 200L water.
  - **Kocide** inhibited the germination of spores of cranberry fruit rot pathogens, with the exceptions of *Botrytis cinerea* (yellow rot), *Colletotrichum acutatum* and *Glomerella cingulata* (bitter rot) at the label rates in 200L water.
  - **Guardsman** did not inhibit the germination of spores of cranberry fruit rot pathogens, with the exception of *Colletotrichum gloeosporioides* (bitter rot) at the maximum label rate in 200L water.

Group 3 Fungicides

Group 3 fungicides can be considered broad spectrum, active against most of the cranberry fruit-rot pathogens. They act both preventatively and curatively against pathogens. Since Group 3 chemicals are systemic they are more suited for curative than preventative use. In general, Group 3 chemicals are considered **high risk** since they interfere with a single or a couple of genes of the target pathogen. Repeated use of these chemicals leads to resistance development in fungal pathogens. Group 3 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 2):**
  - **Fullback**, **Funginex**, **Proline**, **Inspire** and **Tilt** were highly effective (scale 8 to 10) at inhibiting the mycelial growth of cranberry fruit rot pathogens tested, with the exception of **Inspire**, which was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Fusicoccum putrefaciens* (end rot) at the minimum rate in 500L of water.

- **Indar** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of most of the cranberry fruit rot pathogens, but was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Colletotrichum gloeosporioides* (bitter rot) and *Glomerella cingulata* (bitter rot).

- **Inhibition of spore germination (Table 2):**
  - **Funginex** and **Inspire** were effective at inhibiting the germination of spores of the cranberry fruit rot pathogens.
  - **Fullback** was effective at inhibiting the germination of spores of most of the cranberry fruit rot pathogens, but was ineffective at inhibiting the germination of *Botrytis cinerea* (yellow rot).
  - **Indar** was effective at inhibiting the germination of spores of most of the cranberry fruit rot pathogens, but was ineffective at inhibiting the germination of *Botrytis cinerea* (yellow rot) and *Phyllosticta elongata* (early rot) spores at the minimum rate in 200L water, and was ineffective at inhibiting the germination of *Colletotrichum* spp. (bitter rot), *Glomerella cingulata* (bitter rot), and *Phomopsis vaccinii* (viscid rot) at both rates in 200L water.
  - **Proline** was effective at inhibiting the germination of spores of most of the cranberry fruit rot pathogens, but was ineffective at inhibiting the germination of *Botrytis cinerea* (yellow rot), *Phomopsis vaccinii* (viscid rot), and *Phyllosticta elongata* (early rot) at the minimum concentration in 200L water.
  - **Tilt** was effective at inhibiting the germination of spores of most of the cranberry fruit rot pathogens, but was ineffective at inhibiting the germination of *Botrytis cinerea* (yellow rot).

Group 7 Fungicides

Group 7 fungicides are not active against most cranberry fruit-rot pathogens. They do not have preventive action, but can be used curatively due to their systemic activity. Group 7 chemicals are considered **medium** to **high risk**, depending on the chemistry, since they interfere with a single or a few genes of the target pathogen. Repeated use of these chemicals leads to resistance development in fungal pathogens. Group 7 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 3):**
  - **Aprovia** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of cranberry fruit rot pathogens.
  - **Adepidyn** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or moderately (scale 5 to 7) effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Fontelis** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of *Glomerella cingulata* (bitter rot), but it was less (scale 2 to 4) or moderately (scale 5 to 7) effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.
- **Kenja** was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Phyllosticta elongata* (early rot), but was less effective (scale 2 to 4) at inhibiting the mycelial growth of all other cranberry fruit rot pathogen.
- **Sercadis** was moderately (scale 5 to 7) effective at inhibiting the mycelial growth of *Botrytis cinerea* (yellow rot) and *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or not effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 3):**
  - **Aprovia** was effective at inhibiting the germination of spores of cranberry fruit rot pathogens.
  - **Sercadis** was ineffective at inhibiting the germination of spores of cranberry fruit rot pathogens.
  - **Adepidyn** was effective at inhibiting the germination of spores of *Phyllosticta elongata* (early rot), but was ineffective at inhibiting the germination of spores of all other cranberry fruit rot pathogens tested.
  - **Kenja** was effective at inhibiting the germination of spores of *Phyllosticta elongata* (early rot) at the maximum rate in 200L water, but was ineffective at inhibiting the germination of spores of all other fruit rot pathogens tested.
  - **Fontelis** was ineffective at inhibiting the germination of spores of cranberry fruit rot pathogens, with the exception of *Colletotrichum gloeosporioides* (bitter rot) and *Phyllosticta elongata* (early rot).

Group 9 Fungicides

Group 9 fungicides are active against most cranberry fruit-rot pathogens. They are curative, but have limited preventative activity against certain pathogens. Since Group 9 fungicides are systemic they are more suited for curative than preventative use. In general, Group 9 chemicals are considered **medium risk** since they interfere with a few genes of the target pathogen. Repeated use of these chemicals often can lead to resistance development in fungal pathogens. Group 9 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 5):**
  - **Scala** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of most of the cranberry fruit rot pathogens, but was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Colletotrichum acutatum* and *Colletotrichum gloeosporioides* (bitter rot).

- **Vangard** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of *Allantophomopsis lycopodina* (black rot), *Botrytis cinerea* (yellow rot), *Fusicoccum putrefaciens* (end rot), *Phomopsis vaccinii* (viscid rot), *Phyllosticta elongata* (early rot) and *Physalospora vaccinii* (blotch rot), but was less (scale 2 to 4) or moderately (scale 5 to 7) effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 5):**
  - **Scala** was effective at inhibiting the germination of spores of cranberry fruit rot pathogens, but was ineffective at inhibiting the germination of spores of *Colletotrichum acutatum* (bitter rot), *Colletotrichum gloeosporioides* (bitter rot) and *Phomopsis vaccinii* (viscid rot).
  - **Vangard** was effective at inhibiting the germination of spores of *Allantophomopsis lycopodina* (black rot), *Fusicoccum putrefaciens* (end rot), and *Phyllosticta elongata* (early rot), but was ineffective at inhibiting the germination of spores of all other cranberry fruit rot pathogens.

Group 11 Fungicides

Group 11 fungicides are low to moderately active against cranberry fruit-rot pathogens. They are mostly curative rather than preventative, and have systemic activity. In general, Group 11 chemicals are considered **high risk** since they interfere with a single or a couple of genes of the target pathogen. Repeated use of Group 11 chemicals leads to resistance development in fungal pathogens. Group 11 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 4):**
  - **Quadris** was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Allantophomopsis lycopodin*a (back rot), *Colletotrichum gloeosporioides* (bitter rot), *Phyllosticta elongata* (early rot) and *Physalospora vaccinii* (blotch rot), but was less effective (scale 2 to 4) at inhibiting the mycelial growth of all other cranberry fruit rot pathogens tested.
  - **Flint** was moderately effective (scale 5 to 7) at inhibiting *Colletotrichum gloeosporioides* (bitter rot), but was less (scale 2 to 4) or not effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.
  - **Evito** was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or not effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 4):**
    - **Evito** and **Quadris** were ineffective at inhibiting the germination of spore of cranberry fruit rot pathogens.
    - **Flint** was effective at inhibiting the germination of spores of *Allantophomopsis lycopodina* (black rot), but was ineffective at inhibiting the germination of spores of all other cranberry fruit rot pathogens.

Group 12 Fungicides

Group 12 fungicide, Medallion (Scholar), has curative activity against cranberry fruit-rot pathogens, but has limited preventative activity against certain pathogens. They are systemic and, therefore, more suited for curative than preventative use. In general, Group 12 chemicals are **low** to **medium risk**; interfere with a few genes of the target pathogen. Repeated use of these chemicals can lead to resistance development in fungal pathogens. Group 12 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 6):**
    - **Medallion** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of cranberry fruit rot pathogens, except *Allantophomopsis lycopodina* (black Rot) and *Coleophoma empetri* (ripe rot).

- **Inhibition of spore germination (Table 6):**
    - **Medallion** was effective at inhibiting the germination of spores of *Allantophomopsis lycopodina* (black rot) and *Phyllosticta elongata* (early rot), but was ineffective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

Group 17 Fungicides

Group 17 fungicide, Elevate, is curative against cranberry fruit-rot pathogens, with systemic activity. Group 17 chemicals are **low** to **medium risk**, since they interfere with a few genes of the target pathogen. Repeated use of these chemicals can lead to resistance development in fungal pathogens. Group 17 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 7):**
    - **Elevate** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of *Allantophomopsis lycopodina* (black rot) and *Fusicoccum putrefaciens* (end rot), but was less (scale 2 to 4) or moderately (scale 5 to 7) effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 7):**
    - **Elevate** was ineffective at inhibiting the mycelial growth of cranberry fruit rot pathogens.

Group 19 Fungicides

Group 19 fungicide OSO (Polyoxin-D) has **low** to **moderate** activity against cranberry fruit-rot pathogens. In general, Group 19 chemicals are **medium risk**, and they interfere with chitin synthesis of fungal cell wall. Repeated use of Group 19 chemicals can lead to resistance development in pathogens. Group 19 chemicals should not be used consecutively and be rotated with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 8):**
    - **OSO (Polyoxin D)** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of *Botrytis cinerea* (yellow rot) and *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or moderately (scale 5 to 7) effective at inhibiting the mycelial growth of all other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 8):**
    - **OSO (Polyoxin D)** was ineffective at inhibiting the germination of spores of cranberry fruit rot pathogens.

Group 33 Fungicides

Group 33 fungicide, Aliette has both preventative and curative activity against cranberry fruit-rot pathogens. In general, Group 33 chemicals are true systemic, and are considered **low risk;** they interfere with a few or more genes of the targeted pathogen. Repeated use of Group 33 chemicals may lead to resistance development in pathogens. Group 33 chemicals are good candidates for use in rotation with Group M and other classes of chemicals.

- **Inhibition of mycelial growth (Table 9):**
    - **Aliette** was highly effective (scale 8 to 10) at inhibiting the mycelial growth of cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 9):**
    - **Aliette** was effective at inhibiting the germination of spores of all cranberry fruit rot pathogens, except *Allantophomopsis lycopodina* (black rot) at the minimum label rate in 200L water.

Biological Fungicides

Biological fungicides are non-systemic in nature and have limited activity against plant pathogens, including cranberry fruit-rot pathogens. They can be preventative or curative, depending on the nature of the biocontrol product. They are considered **low risk** and can be used in conjunction/rotation with chemical fungicides. Biological fungicides can be "live" organisms or their metabolites (by-products), plant derivatives/extracts, etc.

- **Inhibition of mycelial growth (Table 10):**
    - **Regalia** was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Phomopsis vaccinii* (early rot) and *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or not effective at inhibiting the mycelial growth of other cranberry fruit rot pathogens.
    - **Timorex** was moderately effective (scale 5 to 7) at inhibiting the mycelial growth of *Phyllosticta elongata* (early rot), but was less (scale 2 to 4) or not effective at inhibiting the mycelial growth of other cranberry fruit rot pathogens.

- **Inhibition of spore germination (Table 10):**
    - **Regalia** was not effective at inhibiting the germination of spores of cranberry fruit rot pathogens, but was effective at inhibiting the germination of spores of *Glomerella cingulata* at the maximum label rate in 200L water.
    - **Timorex** was not effective at inhibiting the germination of spores of *Allantophomopsis lycopodina* (black rot), *Botrytis cinerea* (yellow rot), and, at the minimum label rate in 200L, *Glomerella cingulata* (bitter rot), but was effective at inhibiting the germination of spores of other cranberry fruit rot pathogens.

Table 1. Efficacy of FRAC group M fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group M fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth																		B. Inhibition of spore germination											
	Bravo			Copper			Cueva			Guardsman			Kocide			Maestro			Bravo		Copper		Cueva		Guardsman		Kocide		Maestro	
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	9	8+	9+	10	10	10	10	9+	N/A	8+	9	10	10	10	10	10	10	10	+	+	+	+	-	+	-	-	+	+	+	+
Botrytis cinerea **(Yellow rot)**	7+	7+	9+	10	9+	7	10	10	N/A	6	6+	7+	8	8	6	8+	9	10	-	-	+	+	+	+	-	-	-	-	+	+
Coleophoma empetri **(Ripe rot)**	6+	6	10	10	10	10	10	10	N/A	10	8+	10	10	10	10	8+	6+	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	8	8	8	10	10	10	10	10	N/A	8	8	10	10	10	10	8+	8+	10	+	+	+	+	+	+	-	-	-	+	+	+
Colletotrichum gloeosporioides **(Bitter rot)**	8	8	9+	10	10	10	10	10	N/A	8+	8+	10	9+	10	10	9	8+	10	+	+	+	+	+	+	-	+	+	+	+	+
Fusicoccum putrefaciens **(End rot)**	5+	3+	10	8+	10	9	8	9	N/A	3	3+	8	9	10	10	8	8	10	+	+	+	+	+	+	-	-	+	+	+	+
Glomerella cingulata **(Bitter rot)**	8+	8+	9+	10	10	10	10	10	N/A	8+	8+	10	8	9	10	9	9+	10	+	+	+	+	+	+	-	-	-	+	-	+
Phomopsis vaccinii **(Viscid rot)**	9	9	9+	10	10	10	10	10	N/A	8+	8+	8	10	10	10	9+	9	10	+	+	+	+	+	+	-	-	+	+	+	+
Phyllosticta elongata **(Early rot)**	8+	8	10	10	10	10	10	10	N/A	10	10	8+	10	10	10	10	10	10	+	+	+	+	-	+	-	-	+	+	+	+
Physalospora vaccinii **(Blotch rot)**	8+	8+	10	10	10	10	10	10	N/A	10	10	10	10	10	10	10	10	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 2. Efficacy of FRAC group 3 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 3 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth																		B. Inhibition of spore germination											
	Fullback			Funginex			Indar			Inspire			Proline			Tilt			Fullback		Funginex		Indar		Inspire		Proline		Tilt	
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	+	+	+	+	+	+	+	+	+	+	+	+
Botrytis cinerea **(Yellow rot)**	10	10	9	10	9+	10	9+	9	10	9+	9	9+	9+	10	10	9+	9+	10	-	-	+	+	-	+	+	+	-	+	-	-
Coleophoma empetri **(Ripe rot)**	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	9	9+	10	10	10	10	8+	8+	9	9	10	10	10	10	10	10	10	10	+	+	+	+	-	-	+	+	+	+	+	+
Colletotrichum gloeosporioides **(Bitter rot)**	10	10	10	10	10	10	7+	7+	7+	9	9+	10	10	10	10	10	10	10	+	+	+	+	-	-	+	+	+	+	+	+
Fusicoccum putrefaciens **(End rot)**	10	10	10	9	10	10	10	10	10	7+	10	10	10	10	10	10	10	10	+	+	+	+	+	+	+	+	+	+	+	+
Glomerella cingulata **(Bitter rot)**	10	10	10	10	10	10	6	6	5+	9+	10	10	10	10	10	10	10	10	+	+	+	+	-	-	+	+	+	+	+	+
Phomopsis vaccinii. **(Viscid rot)**	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	+	+	+	+	-	-	+	+	-	+	+	+
Phyllosticta elongata **(Early rot)**	10	10	10	10	10	10	9	9+	10	10	9+	10	10	10	8+	10	10	10	+	+	+	+	-	+	+	+	-	+	+	+
Physalospora vaccinii **(Blotch rot)**	10	10	10	10	10	10	7+	7+	10	10	10	10	10	10	10	10	10	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3. Efficacy of FRAC group 7 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 7 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available

A. Percentage inhibition of mycelial growth

	Adepidyn			Aprovia			Fontelis			Kenja 400 SC			Sercadis		
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L
***Allantophomopsis lycopodina* (Black Rot)**	4+	4	4+	9	10	10	3+	3+	7	3+	2+	6	2+	3+	8
***Botrytis cinerea* (Yellow rot)**	6	7	6	9+	9+	10	4	5+	5+	5	5+	6+	6	6	8
***Coleophoma empetri* (Ripe rot)**	6+	4+	3+	10	10	10	2+	3+	2+	1+	2	1	3	3	4
***Colletotrichum acutatum* (Bitter rot)**	4	4	3+	8+	9	10	7	7	8+	1+	1+	2+	0	0	3
***Colletotrichum gloeosporioides* (Bitter rot)**	3	3+	2+	8+	8+	10	7	7	6+	1	1+	1+	2+	3	2+
***Fusicoccum putrefaciens* (End rot)**	5	5	7+	10	10	10	2+	3	6	3	2	6	1+	1	6+
***Glomerella cingulata* (Bitter rot)**	5+	4+	4	9	10	10	9+	9+	8	4	4+	4	4+	4+	4
***Phomopsis vaccinii* (Viscid rot)**	5+	6	5+	10	9+	10	4	4	5	4	4	4	5	4+	5+
***Phyllosticta elongata* (Early rot)**	8	10	7+	10	10	10	7+	7+	8	7	7	8	6+	7+	8
***Physalospora vaccinii* (Blotch rot)**	4+	4	6	10	10	10	3+	3	4+	3	2+	3+	2+	2+	5

B. Inhibition of spore germination

	Adepidyn		Aprovia		Fontelis		Kenja 400 SC		Sercadis	
	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
***Allantophomopsis lycopodina* (Black Rot)**	-	-	+	+	-	-	-	-	-	-
***Botrytis cinerea* (Yellow rot)**	-	-	+	+	-	-	-	-	-	-
***Coleophoma empetri* (Ripe rot)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
***Colletotrichum acutatum* (Bitter rot)**	-	-	+	+	-	-	-	-	-	-
***Colletotrichum gloeosporioides* (Bitter rot)**	-	-	+	+	+	+	-	-	-	-
***Fusicoccum putrefaciens* (End rot)**	-	-	+	+	-	-	-	-	-	-
***Glomerella cingulata* (Bitter rot)**	-	-	+	+	-	-	-	-	-	-
***Phomopsis vaccinii* (Viscid rot)**	-	-	+	+	-	-	-	-	-	-
***Phyllosticta elongata* (Early rot)**	+	+	+	+	+	+	-	+	-	-
***Physalospora vaccinii* (Blotch rot)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4. Efficacy of FRAC group 11 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 11 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth									**B. Inhibition of spore germination**					
	Evito			**Flint**			**Quadris**			**Evito**		**Flint**		**Quadris**	
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
***Allantophomopsis lycopodina* (Black Rot)**	1+	1+	2+	2+	2+	9+	5	7+	5	-	-	**+**	**+**	-	-
***Botrytis cinerea* (Yellow rot)**	0	0	2	1	1+	9	3+	4	5+	-	-	-	-	-	-
***Coleophoma empetri* (Ripe rot)**	2	2+	3+	3+	4	8	2	2+	4	N/A	N/A	N/A	N/A	N/A	N/A
***Colletotrichum acutatum* (Bitter rot)**	1+	1	3+	1	1+	5+	4+	4	3+	-	-	-	-	-	-
***Colletotrichum gloeosporioides* (Bitter rot)**	4+	4	6	5+	5	6+	7+	7	7	-	-	-	-	-	-
***Fusicoccum putrefaciens* (End rot)**	3+	2+	4	2+	2+	8	3+	4	5	-	-	-	-	-	-
***Glomerella cingulata* (Bitter rot)**	2	2+	4+	2+	2+	7+	4+	5	4	-	-	-	-	-	-
***Phomopsis vaccinii* (Viscid rot)**	2+	3	4	1+	2	8	2+	2+	2+	-	-	-	-	-	-
***Phyllosticta elongata* (Early rot)**	6	6	8+	4+	5+	9+	6	6+	8+	-	-	-	-	-	-
***Physalospora vaccinii* (Blotch rot)**	4+	4+	8+	4	4+	10	6+	8	8+	N/A	N/A	N/A	N/A	N/A	N/A

Table 5. Efficacy of FRAC group 9 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (Scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 9 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth						B. Inhibition of spore germination			
	Scala			Vangard			Scala		Vangard	
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	8+	9	9+	8+	9	10	+	+	+	+
Botrytis cinerea **(Yellow rot)**	9+	10	9	9	9	9	+	+	-	-
Coleophoma empetri **(Ripe rot)**	10	10	8	6	6	10	N/A	N/A	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	6+	7	5+	4+	5	5+	-	-	-	-
Colletotrichum gloeosporioides **(Bitter rot)**	7+	7+	6+	5	5+	4+	-	-	-	-
Fusicoccum putrefaciens **(End rot)**	10	10	8	8+	8+	10	+	+	+	+
Glomerella cingulata **(Bitter rot)**	8	8+	7+	7	6+	7+	+	+	-	-
Phomopsis vaccinii **(Viscid rot)**	9	9+	8	8	7	8	-	-	-	-
Phyllosticta elongata **(Early rot)**	10	10	9+	9+	9+	10	+	+	+	+
Physalospora vaccinii **(Blotch rot)**	10	10	10	9+	10	10	N/A	N/A	N/A	N/A

Table 6. Efficacy of FRAC group 12 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 12 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available

	A. Percentage inhibition of mycelial growth			B. Inhibition of spore germination	
	Medallion			Medallion	
	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	7+	7+	8	+	+
Botrytis cinerea **(Yellow rot)**	8	9+	7	-	-
Coleophoma empetri **(Ripe rot)**	4+	5+	4+	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	7+	9	9	-	-
Colletotrichum gloeosporioides **(Bitter rot)**	8	7+	8	-	-
Fusicoccum putrefaciens **(End rot)**	8+	8+	8+	-	-
Glomerella cingulata **(Bitter rot)**	8	7	9	-	-
Phomopsis vaccinii **(Viscid rot)**	8	8	8	-	-
Phyllosticta elongata **(Early rot)**	9+	9+	10	+	+
Physalospora vaccinii **(Blotch rot)**	9	10	10	N/A	N/A

Table 7. Efficacy of FRAC group 17 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 17 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth			B. Inhibition of spore germination	
	Elevate			Elevate	
	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	8+	9	10	-	-
Botrytis cinerea **(Yellow rot)**	7+	7+	6	-	+
Coleophoma empetri **(Ripe rot)**	5	6	7	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	3	3	4	-	-
Colletotrichum gloeosporioides **(Bitter rot)**	3+	4+	4	-	-
Fusicoccum putrefaciens **(End rot)**	10	10	10	-	-
Glomerella cingulata **(Bitter rot)**	4+	5+	6+	-	-
Phomopsis vaccinii **(Viscid rot)**	5	6	7	-	-
Phyllosticta elongata **(Early rot)**	7	7+	8+	-	-
Physalospora vaccinii **(Blotch rot)**	3+	5	10	N/A	N/A

Table 8. Efficacy of FRAC group 19 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 19 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth			B. Inhibition of spore germination	
	OSO (Polyoxin D)			OSO (Polyoxin D)	
	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L
Allantophomopsis lycopodina **(Black Rot)**	5	5	7	-	-
Botrytis cinerea **(Yellow rot)**	9	9	9+	-	-
Coleophoma empetri **(Ripe rot)**	2+	2+	2	N/A	N/A
Colletotrichum acutatum **(Bitter rot)**	6+	7	8	-	-
Colletotrichum gloeosporioides **(Bitter rot)**	4+	5	8	-	-
Fusicoccum putrefaciens **(End rot)**	6+	10	8+	-	-
Glomerella cingulata **(Bitter rot)**	4+	3+	5+	-	-
Phomopsis vaccinii **(Viscid rot)**	2+	4+	6	-	-
Phyllosticta elongata **(Early rot)**	8+	9	10	-	-
Physalospora vaccinii **(Blotch rot)**	6+	6+	8+	N/A	N/A

Table 9. Efficacy of FRAC group 33 fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of FRAC group 33 fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	A. Percentage inhibition of mycelial growth			B. Inhibition of spore germination	
	Aliette			Aliette	
	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L
***Allantophomopsis lycopodina* (Black Rot)**	10	10	10	-	+
***Botrytis cinerea* (Yellow rot)**	10	10	10	+	+
***Coleophoma empetri* (Ripe rot)**	10	10	10	N/A	N/A
***Colletotrichum acutatum* (Bitter rot)**	10	10	10	+	+
***Colletotrichum gloeosporioides* (Bitter rot)**	10	10	10	+	+
***Fusicoccum putrefaciens* (End rot)**	10	10	10	+	+
***Glomerella cingulata* (Bitter rot)**	10	10	10	+	+
***Phomopsis vaccinii* (Viscid rot)**	10	10	10	+	+
***Phyllosticta elongata* (Early rot)**	10	10	10	+	+
***Physalospora vaccinii* (Blotch rot)**	10	10	10	N/A	N/A

Table 10. Efficacy of bio-fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens was presented as mean percentage reduction in the mycelial growth (scale of 0 to 10: 10 = 100%, 9 = ≥90%; 8 = ≥80%; 7 = ≥70%; 6 = ≥60%; 5 = ≥50%; 4 = ≥40%; 3 = ≥30%; 2 = ≥20%; 1 = ≥10%; 0 = 0%), in comparison to the growth of the pathogens in the absence of fungicides. Efficacy of bio-fungicides to inhibit the germination of spores of cranberry fruit rot pathogens was presented as (+) for positive inhibition and (-) for negative inhibition. N/A = data not available.

	C. Percentage inhibition of mycelial growth						D. Percentage inhibition of mycelial growth			
	Regalia			Timorex			Regalia		Timorex	
	Min 500L	Max 500L	Max 200L	Min 500L	Max 500L	Max 200L	Min 200L	Max 200L	Min 200L	Max 200L
***Allantophomopsis lycopodina* (Black Rot)**	3+	5+	N/A	0	1	8+	-	-	-	-
***Botrytis cinerea* (Yellow rot)**	2+	6+	N/A	0+	1+	10	-	-	-	-
***Coleophoma empetri* (Ripe rot)**	0	0+	N/A	1	1+	8+	N/A	N/A	N/A	N/A
***Colletotrichum acutatum* (Bitter rot)**	1+	4	N/A	3	4	6+	-	-	+	+
***Colletotrichum gloeosporioides* (Bitter rot)**	0	3	N/A	3	4	7	-	-	+	+
***Fusicoccum putrefaciens* (End rot)**	1+	6	N/A	2	3+	10	-	-	+	+
***Glomerella cingulata* (Bitter rot)**	1+	4	N/A	4	5	8+	-	+	-	+
***Phomopsis vaccinii* (Viscid rot)**	6	7	N/A	4+	5+	8+	-	-	+	+
***Phyllosticta elongata* (Early rot)**	5	6+	N/A	5	6+	10	-	-	+	+
***Physalospora vaccinii* (Blotch rot)**	4	6+	N/A	3	4+	10	N/A	N/A	N/A	N/A

CONCLUSIONS

Inhibition of mycelial growth (Table 11):

- Fungicides **Copper 53W**, **Cueva** and **Kocide** of group M, **Fullback**, **Funginex**, **Inspire**, **Proline** and **Tilt** of group 3, **Aprovia** of group 7, and **Aliette** of group 33 were highly effective at inhibiting the mycelial growth of fruit-rot pathogens.
- Fungicides **Bravo**, **Guardsman** and **Maestro** of group M, **Indar** of group 3, **Scala** and **Vangard** of group 9, and **Medallion** (**Scholar**) of group 12 were highly effective at inhibiting the mycelial growth of most cranberry fruit-rot pathogens, but were moderately to less effective at inhibiting the mycelial growth of one or a few cranberry fruit-rot pathogens, depending on the fungicide.
- Fungicides **Fontelis** of group 7, **A19649B** (**Adepidyn**) of group 7, **Elevate** of group 17, and **OSO** (**Polyoxin D**) of group 19 were highly effective at inhibiting the mycelial growth of a few cranberry fruit-rot pathogens, but moderately to less effective at inhibiting the mycelial growth of most cranberry fruit-rot pathogens.
- **Quadris** of group 11 was moderately to less effective at inhibiting the mycelial growth of all cranberry fruit rot pathogens.
- Fungicides **Kenja** and **Sercadis** (**Xemium**) of group 7, **Evito** and **Flint** of group 11, and the biological fungicides **Regalia Maxx** and **Timorex Gold** were less or not effective at inhibiting the mycelial growth of most cranberry fruit-rot pathogens, but moderately effective in inhibiting the mycelial growth of one or two cranberry fruit-rot pathogens.

Inhibition of spore germination (Table 11):

- Fungicides **Copper 53W** of group M, **Funginex** and **Inspire** of group 3, and **Aprovia** of group 7 were effective at inhibiting the germination of spores of fruit rot pathogens at both minimum and maximum rates.
- Fungicides **Bravo**, **Cueva**, **Kocide** and **Maestro** of group M, **Fullback**, **Proline**, and **Tilt** (**Topas**) of group 3, and the biological fungicide **Timorex Gold** were effective at inhibiting the germination of spores of most cranberry fruit-rot pathogens, but were only effective at the maximum rate for one or a few fruit-rot pathogens.
- **Scala** and **Vangard** of group 9 were effective at inhibiting the germination of spores of some cranberry fruit-rot pathogens, but not others.
- Fungicides **Guardsman** of group M, **Indar** of group 3, **Fontelis** of group 7, **A19649B** (**Adepidyn**), **Kenja**, and **Sercadis** (**Xemium**) of group 7, **Evito**, **Flint**, and **Quadris** of group 11, **Medallion** (**Scholar**) of group 12, **Elevate** of group 17, **OSO** (**Polyoxin D**) of group 19, and the biological fungicide **Regalia Maxx** were not effective at inhibiting the germination of spores of most or all cranberry fruit-rot pathogens.

Table 11. The efficacy of fungicides to inhibit the growth of mycelium of cranberry fruit-rot pathogens, at minimum and maximum recommended label rates in 500 L or maximum rate in 200 L, in comparison to the growth of the pathogens in the absence of fungicides; the results were presented in a colour coded scale, from highly effective to not effective. The efficacy of fungicides to inhibit the germination of spores of cranberry fruit-rot pathogens, at minimum and maximum recommended label rates in 200L water, was presented in a colour coded scale, from inhibition to no inhibition.

FRAC Group	Fungicide	Fruit Rot Pathogens																			
		Inhibition of Mycelial Growth										Inhibition of Spore Germination									
		Allantophomopsis lycopodina	*Botrytis cinerea*	*Coleophoma empetri*	*Colletotrichum acutatum*	*Colletotrichum gloeosporioides*	*Fusicoccum putrefaciens*	*Glomerella cingulata*	*Phomopsis vaccinii*	*Phyllosticta elongata*	*Physalospora vaccinii*	*Allantophomopsis lycopodina*	*Botrytis cinerea*	*Coleophoma empetri*	*Colletotrichum acutatum*	*Colletotrichum gloeosporioides*	*Fusicoccum putrefaciens*	*Glomerella cingulata*	*Phomopsis vaccinii*	*Phyllosticta elongata*	*Physalospora vaccinii*
Gp. M	**Bravo** (chlorothalonil)	highly effective	moderately effective	moderately effective	highly effective	highly effective	less effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Copper 53W (copper sulphate)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Cueva (copper octanoate)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at maximum rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at maximum rate	data not available
	Guardsman (copper oxychloride)	highly effective	moderately effective	highly effective	highly effective	highly effective	less effective	highly effective	highly effective	highly effective	highly effective	no inhibition	no inhibition	data not available	no inhibition	inhibition at maximum rate	no inhibition	no inhibition	no inhibition	no inhibition	data not available
	Kocide (copper hydroxide)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	inhibition at maximum rate	inhibition at either rate	inhibition at either rate	inhibition at maximum rate	inhibition at either rate	inhibition at either rate	data not available
	Maestro (captan)	highly effective	highly effective	moderately effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at maximum rate	inhibition at either rate	inhibition at either rate	data not available
Gp. 3	Fullback (flutriafol)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Funginex (triforine)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Indar (fenbuconazole)	highly effective	highly effective	highly effective	highly effective	moderately effective	highly effective	moderately effective	highly effective	highly effective	moderately effective	inhibition at either rate	inhibition at maximum rate	data not available	no inhibition	no inhibition	inhibition at either rate	no inhibition	no inhibition	inhibition at maximum rate	data not available
	Inspire (difenoconazole)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Proline (prothioconazole)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at maximum rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at maximum rate	inhibition at maximum rate	data not available
	Tilt / Topas (propiconazole)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
Gp.7	A19649B / Adepidyn (pydiflumetofen)	less effective	moderately effective	moderately effective	less effective	less effective	moderately effective	moderately effective	moderately effective	highly effective	less effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	inhibition at either rate	data not available
	Aprovia (benzovindiflupyr)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
	Fontelis (penthiopyrad)	less effective	less effective	less effective	moderately effective	moderately effective	less effective	highly effective	less effective	moderately effective	less effective	no inhibition	no inhibition	data not available	no inhibition	inhibition at either rate	no inhibition	no inhibition	no inhibition	inhibition at either rate	data not available
	Kenja (isofetamid)	less effective	moderately effective	not effective	not effective	not effective	less effective	less effective	less effective	moderately effective	less effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	inhibition at maximum rate	data not available
	Sercadis / Xemium (fluxapyroxad)	less effective	moderately effective	less effective	not effective	less effective	not effective	less effective	less effective	moderately effective	less effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
Gp. 9	Scala (pyrimethanil)	highly effective	highly effective	highly effective	moderately effective	moderately effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at either rate	inhibition at either rate	data not available	no inhibition	no inhibition	inhibition at either rate	inhibition at either rate	no inhibition	inhibition at either rate	data not available
	Vangard (cyprodinil)	highly effective	highly effective	moderately effective	moderately effective	moderately effective	highly effective	moderately effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	no inhibition	no inhibition	inhibition at either rate	no inhibition	no inhibition	inhibition at either rate	data not available
Gp. 11	Evito (fluoxastrobin)	not effective	not effective	less effective	not effective	less effective	less effective	less effective	less effective	moderately effective	less effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
	Flint (trifloxystrobin)	less effective	not effective	less effective	not effective	moderately effective	less effective	less effective	less effective	moderately effective	less effective	inhibition at either rate	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
	Quadris (azoxystrobin)	moderately effective	less effective	less effective	less effective	moderately effective	less effective	less effective	less effective	moderately effective	moderately effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
Gp. 12	Medallion / Scholar (fludioxonil)	moderately effective	highly effective	moderately effective	highly effective	highly effective	highly effective	moderately effective	highly effective	highly effective	highly effective	inhibition at either rate	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	inhibition at either rate	data not available
Gp. 17	Elevate (fenhexamid)	highly effective	moderately effective	moderately effective	less effective	less effective	highly effective	moderately effective	moderately effective	moderately effective	less effective	no inhibition	inhibition at maximum rate	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
Gp. 19	OSO (Polyoxin D)	moderately effective	highly effective	less effective	moderately effective	moderately effective	highly effective	less effective	less effective	highly effective	moderately effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	no inhibition	data not available
Gp. 33	**Aliette** (fosetyl-Al)	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	highly effective	inhibition at maximum rate	inhibition at either rate	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at either rate	data not available
Biological	Regalia Maxx (*Reynoutria* sp. extract)	less effective	less effective	not effective	less effective	not effective	less effective	less effective	moderately effective	moderately effective	moderately effective	no inhibition	no inhibition	data not available	no inhibition	no inhibition	no inhibition	inhibition at maximum rate	no inhibition	no inhibition	data not available
	Timorex Gold (Tea tree oil)	not effective	not effective	not effective	less effective	less effective	less effective	less effective	moderately effective	moderately effective	less effective	no inhibition	no inhibition	data not available	inhibition at either rate	inhibition at either rate	inhibition at either rate	inhibition at maximum rate	inhibition at either rate	inhibition at either rate	data not available

Mycelial growth legend	Spore germination legend
highly effective	inhibition at either rate
moderately effective	inhibition at maximum rate
less effective	no inhibition
not effective	data not available

Annexure 1

A total of twenty-six chemical fungicides, belonging to ten different chemical classes of compounds (FRAC Groups), and two biological fungicides were tested *in vitro* for their ability to inhibit the mycelial growth and spore germination of ten major fruit-rot pathogens in BC cranberry fields.

Note: Fungicides highlighted in blue-colour have been registered for the use on cranberry in Canada.

Chemical group		Active ingredient	Product Name
Gp. M	1	chlorothalonil	Bravo 500
	2	copper sulphate	Copper 53 WP
	3	copper octanoate	Cueva
	4	copper oxychloride	Guardsman
	5	copper hydroxide	Kocide
	6	captan	Maestro 80 DF (Captan)
Gp. 3	7	flutriafol	Fullback 125 SC
	8	triforine	Funginex DC
	9	fenbuconazole	Indar
	10	difenoconazole	Inspire
	11	prothioconazole	Proline 480 SC
	12	propiconazole	Tilt (Topas / Orbit)
Gp. 7	13	pydiflumetofen	A19649B (Adepidyn)
	14	solatenol (benzovindiflupyr)	Aprovia
	15	penthiopyrad	Fontelis
	16	isofetamid	Kenja (Isofetamid 400 SC)
	17	fluxapyroxad	Sercadis (Xemium)
Gp. 9	18	pyrimethanil	Scala
	19	cyprodinil	Vangard
Gp. 11	20	fluoxastrobin	Evito 480 SC
	21	trifloxystrobin	Flint 50 WG
	22	azoxystrobin	Quadris
Gp. 12	23	fludioxonil	Medallion (Scholar)
Gp. 17	24	fenhexamid	Elevate 50 WDG
Gp. 19	25	Polyoxin D	OSO 5% SC
Gp. 33	26	fosetyl-Al	Aliette
Biological	27	*Reynoutria sachalinensis* extract	Regalia Maxx
	28	*Melaleuca alternifolia* (tea-tree) extract	Timorex Gold

Annexure 2

At least two to three isolates of ten major fruit-rot pathogens from BC cranberry fields were included in the *in vitro* bioassay for the efficacy of fungicides to inhibit the mycelial growth and spore germination of cranberry fruit rot pathogens.

	Fruit rot	Pathogens	Isolate number	Field location
1	*Black rot*	*Allantophomopsis lycopodina* (dark strain)	15 CB 55	Pitt Meadows
2			15 CB 57	Surrey
3			15 CB 59	Surrey
4	*Yellow rot*	*Botrytis cinerea*	15 CB 29	Delta
5			15 CB 30	Langley
6			15 CB 31	Pitt Meadows
7	*Ripe rot*	*Coleophoma empetri*	15 CB 70	Richmond
8			15 CB 71	Delta
9			15 CB 72	Richmond
10	*Bitter rot*	*Colletotrichum acutatum*	15 CB 01	Richmond
11			15 CB 02	Langley
12			15 CB 03	Pitt Meadows
13		*Colletotrichum gloeosporioides*	15 CB 06	Richmond
14			15 CB 07	Langley
15			15 CB 08	Langley
16		*Glomerella cingulata*	15 CB 11	Delta
17			15 CB 12	Richmond
18			15 CB 13	Richmond
19	*End rot*	*Fusicoccum putrefaciens*	15 CB 39	Langley
20			15 CB 40	Richmond
21			15 CB 41	Delta
22	*Viscid rot*	*Phomopsis vaccinii*	07 CB 04	Richmond
23			15 CB 66	Delta
24			15 CB 67	Surrey
25	*Early rot*	*Phyllosticta elongata*	15 CB 60	Chilliwack
26			15 CB 61	Richmond
28			15 CB 62	Langley
29	*Blotch rot*	*Physalospora vaccinii* (dark strain)	15 CB 45	Langley
30			15 CB 47	Richmond
31		*Physalospora vaccinii* (light strain)	15 CB 49	Pitt Meadows
32			15 CB 50	Richmond