The Susceptibility of *Populus trichocarpa* Provenances in the Pacific Northwest to *Septoria musiva* and *Septoria populicola*

by

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Contents

Abstract

A *Populus trichocarpa* provenance trial in Harrison Mills had tested positive in 2009 and 2010 for *Septoria musiva,* a pathogen that reduces the photosynthetic activity of its host through necrotic spots on the leaf surface and has the potential to girdle and kill the host through cankers that develop on the branches and main stem. A closely related pathogen, *Septoria populicola,* has also been reported in the provenance trial; this particular pathogen is native to British Columbia and causes only non-lethal minor leaf lesions, but is impossible to distinguish from *Septoria musiva* without conducting DNA-based analyses*.* This study is aimed to assess the frequency of *S. musiva* and *S. populicola* infections on provenances of *P. trichocarpa* to determine if there is a pattern of differential susceptibility. The provenances of the *P. trichocarpa* extend from Alaska, through British Columbia and down into Oregon; these were grouped into two categories: a North and South population. The proportions of *Septoria musiva* and *Septoria populicola* infections were compared between the north and south populations to determine if there is a difference in infection proportions between the regions. The north and south proportions were also compared between 2010 and 2011. Although the number of infections were always higher in northern than in southern provenances, no significant differences were found between northern and southern infection proportions for *Septoria musiva* or *Septoria populicola* in 2010 or 2011. A comparison between regional infections in 2010 and 2011 was also not significantly different from one another for *Septoria musiva.* Although no significant differences was observed in the infection proportions of *Septoria populicola* between the southern populations over 2010 and 2011, a significant difference was observed in the infection proportions between northern regions in 2010 and 2011.

Keywords: Septoria musiva, Septoria populicola, Populus trichocarpa, black cottonwood, Mycosphaerella populorum, Mycosphaerella populicola

Introduction

Poplars are integral in Canada due to their vast abundance and potential in the country's forest industry; in addition, poplars have several desirable biological characteristics such as rapid, indeterminate growth, hybridization characteristics that make them ideal for culturing (Feau, Mottet, Perinet, Hamelin, & Bernier, 2010). As the demand for energy increases, and the limits of the fossil fuel economy projected to peak within the next several decades, the demand for renewable energy is rapidly increasing (McPhail, Cigolotti, & Moreno, 2012).

Black cottonwood (*Populus trichocarpa* Torr. & A. Gray) is native to British Columbia and is also distributed along the northwestern coast of North America from California to Alaska; the poplar embodies all the characteristics that make them ideal for cultivation. In BC, black cottonwood has already been utilized for lumber harvest, pulping and riparian restoration; its role in the future biofuel endeavors is also met with high expectations. As such, several plantations across the province have been cultivating the tree for the economical applications listed.

As with all other poplars, *P. trichocarpa* is host to many diseases and other biotic stress factors, especially in areas of intensive culturing, as the selection of cottonwood by breeders if often placed on wood quality and growth characteristics (Ostry & Mcnabb Jr., Susceptibility of Populus species and hybrids to disease in the North central United States, 1985). Two such diseases include *Septoria musiva* Peck. (telomorph: *Mycosphaerella populorum* Thomps.) and *Septoria populicola* (telomorph: *Mycosphaerella populicola*). *Septoria populicola* is native to British Columbia, while *Septoria musiva* has historically been localized in eastern North America

(Ostry, 1987; Krupinsky, 1989). The injury symptoms of the two pathogens are indentical in which they cause circular, necrotic spots on the foliage, which leads to reduced photosynethic leaf area, as well as premature scenscence of leaves (Bier, 1939). However, a key difference in the injury symptoms is that *S. musiva* has been associated with canker development in the main stem and branches, which can potentially girdle and kill the tree (Bier, 1939; Ostry, 1987; Newcombe & Ostry, 2001; Callan, Leal, Foord, Dennis, & van Oosten, 2007; Feau, Mottet, Perinet, Hamelin, & Bernier, 2010). The canker causing ability of *S. musiva* has is detrimental and can lead to plantation failure (Bier, 1939; Ostry, 1987). *S. musiva,* despite being native to eastern Canada, has recently been reported and isolated from several poplar plantations within Fraser Valley, British Columbia (Callan, Leal, Foord, Dennis, & van Oosten, 2007); as *P. trichocarpa* has never been exposed to *S. musiva* in western Canada, the pathogen's establishment in the province could be detrimental to local *P. trichocarpa* populations.

A black cottonwood plantation comprised of *P. trichocarpa* from 35 different drainages was established in Harrison Mills, BC in 2007. Several trees in that plantation have tested positive for *S. musiva* and *S. populicola*. Currently, the *S. musiva* disease outbreak is localized within the plantation and black cottonwood adjacent to the plantation has not shown any symptoms of infection. As the two pathogens are morphologically identical with overlapping characteristics, and have injury symptoms that are virtually indistinguishable, the two pathogens must be identified and distinguished at the genetic level through the use of *ITS* (Internal Transcribed Spacer) primers developed by Feau et al. (2005).

The threat of *S. musiva* has now reached the Pacific Northwest; it is important to determine if there are patterns in the *P. trichocarpa* provenances in their susceptibility to the two pathogens and whether or not some provenances display less susceptibility. A field study was conducted at the plantation in Harrison Mills with the objective to determine if any *P. trichocarpa* within the plantation exhibit any resistance to *S. musiva and S. populicola*; the plantation had been sampled by Beauseigle et al. (2010) many elements of this study have been drawn on their work with various changes to sampling methodology, laboratory protocol, and statistical analyses. This study divides the 7 geographical regions delineated by Beauseigle et al. 2010 into a northern and southern population and uses a subsample of 306 trees out of over 3000 trees within the plantation to gain a coarse scale analyses.

Methods and Materials

Description of the Plantation

Established in 2007, provenance trial EP1123.02 is a *Populus trichocarpa* plantation located in the Fraser Valley at Harrison Mills, B.C. (49^{o} 13’42.00 N, 121^{o}54’51.30). It is comprised of 516 clones from 35 different drainage regions and distributed within the plantation in a randomized complete block design; each individual tree plot had a spacing of approximately 2.5m x 2.5m. Eight repetitions for each block was planted with each clone is represented 4-8 times within the block, depending on the availability of clonal material. Fertilizers were not applied to the plantation.

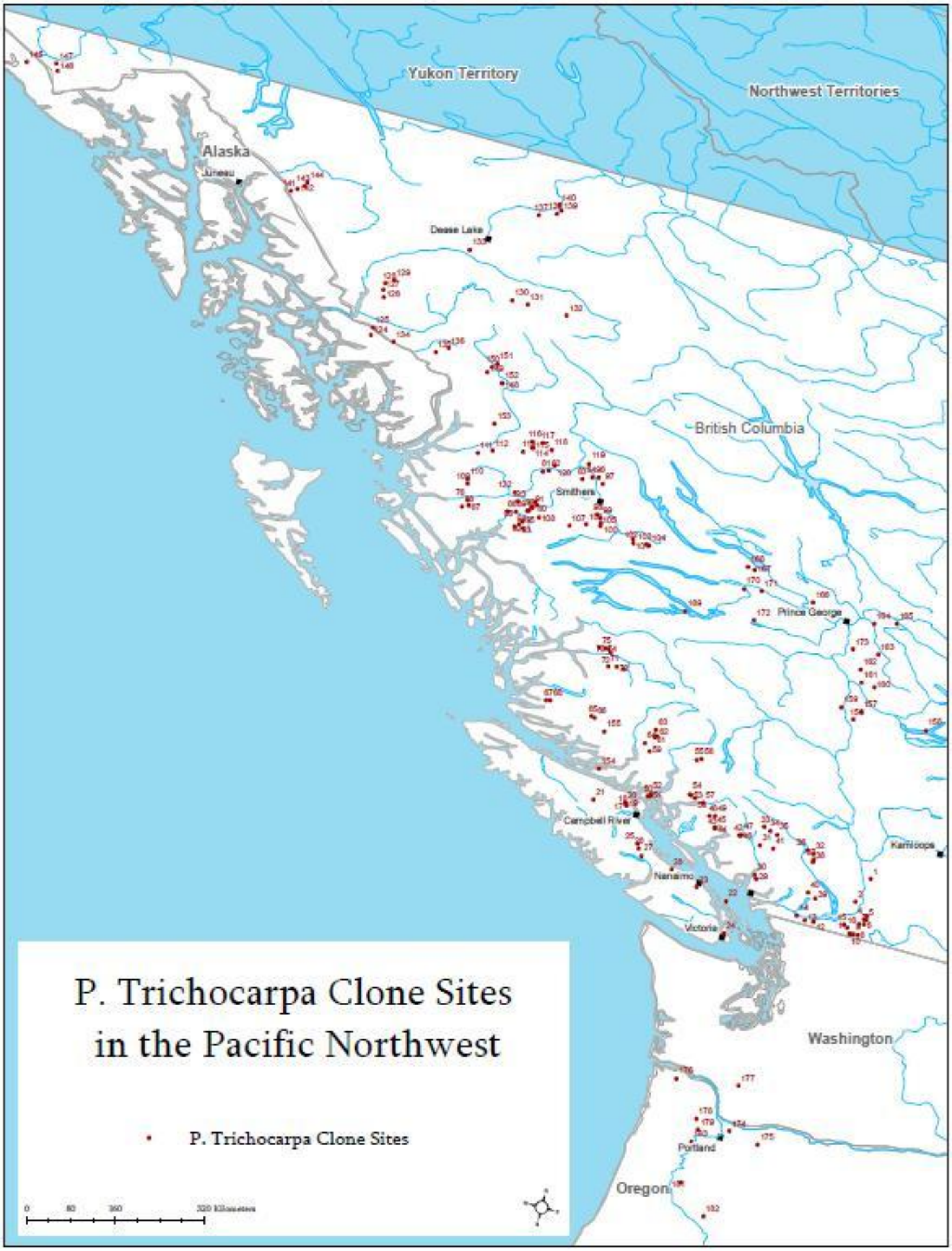

Figure 1 **– A map of the origins of each *P. trichocarpa* within the plantation at Harrison Mills. Obtained from Dr. Harry H. Kope, Forest Practices and Investment Branch, British Columbia, Ministry of Forests, Lands, and Natural Resource Operations, Victoria, British Columbia)**

Septoria spp. Identification

Identification of leaf spots that were potential *Septoria* spp. lesions was based on characterization in literature (Bier, 1939; Ostry & Mcnabb, 1985; Sinclair and Lyon, 2005). Lesions on the leaves are generally localized in the lower branches and are characterized as circular necrotic spots that are black in colour. Pycnidia can sometimes be seen within the center of the lesions. Cankers are also characterized as dark, necrotic protrusions from the stem or branches. The figures below illustrate features that are generally associated with *Septoria musiva* and *Septoria populicola*; cankers in the figures belong exclusively to *Septoria musiva*:

Figure 2 **– (On left) Photograph of *P. trichocarpa* that has been infected with multiple *Septoria musiva* cankers around the stem (Photograph by Fung, 2012). (On top right) Example of *Septoria musiva* leaf spots on hybrid poplar (Photograph from Sinclair & Lyon, 2005). (On bottom right) Juvenile tree showing symptoms of *Septoria* spp. leaf spot injury. (Photograph from Ostry et al., 1989)**

Leaf Sample Collection

Each tree was screened for leaf spots originating from the lower branches that resembled *S. musiva* or *S. populicola*; 3-5 leaves with *Septoria*-like leaf spots were collected from each individual, with each leaf originating from a different side of the tree. Leaves containing *Septoria* and other foliage diseases which had been found in Beauseigle et al. 2010*,* were omitted to avoid contamination of other leaf samples and complications during the DNA amplification. The collected leaves were placed in a brown paper lunch bag and stored in 4^{o}C while awaiting leaf spot extraction. Trees were also inspected for branch or stem cankers that resemble *S. musiva* infection symptoms. Cankers were also collected to extract *S. musiva* isolates, which would support the samples identified in the leaves. However, the cankers, although extracted for *S. musiva* isolates, were not cross-referenced in this study.

Leaf Spot Extraction

The leaf spot extraction protocol from Beauseigle et al. 2010 was modified from selecting one leaf of the three leaves and selecting a single leaf spot from the leaf to extracting three leaf spots per leaf for each of the leaves collected from the plantation and pooling the spots into a microcentrifuge tube. The leaf spots were excised using a cork borer due to its circular shape, which allowed a more accurate excision while reducing the amount of uninfected plant tissue. All extraction tools were sterilized under a flame torch and 100% ethanol after each sample was processed to avoid cross sample contamination.

DNA Extraction

For each sample, 3-5 leaf spots were selected from and pooled into a new microcentrifuge tube for DNA extraction; this was another change from the protocol used by Beauseigle et al. 2010, where several leaf spots are pooled together for DNA extraction, as opposed to one leaf spot selected from the sample. Several DNA pooling experiments were conducted by spiking *S. musiva* DNA from petri dish cultures with plant and *S. populicola* DNA to determine the maximum number of leaf spots that could be pooled with distinctively observable *S. musiva* readings. This pooling of several leaf spots from one individual tree increases the chance of detecting *S. musiva* by obtaining a broader representation of all the leaf spots on an infected tree.

Metal beads were added to each microcentrifuge tubes and submerged in liquid nitrogen to weaken the cell membranes and allow the extraction of high quality DNA required for the real-time PCR. The microcentrifuge tubes were then placed in a mechanical shaker and ground up into a fine powder. The DNA from the grounded leaf spot samples were then extracted using the DNeasy Plant Mini Kit from Qiagen Company); the protocol (http://www.qiagen.com/literature/render.aspx?id=201167) enclosed with the extraction kit was used with the following amendments:

11. Add 100µl **autoclaved water** for elution. Incubate for 5 min at room temperature (15–25°C). Centrifuge for 1 min at ≥6000 x *g*.

12. Repeat step 11 - this step was omitted from the extraction protocol.

Extracted DNA samples were then stored in -20^{o}C conditions until the RT-PCR is conducted.

Real-time Polymerase Chain Reaction (RT-PCR)

The efficacy of real-time polymerase chain reaction (RT-PCR) has seen a high degree of success in fungal pathogen detection (Gottsberger, 2010; Qu, Wanner, & Christ, 2011; Schaad, et al., 2003; Callan, Leal, Foord, Dennis, & van Oosten, 2007). RT-PCR also allows for a large number of samples to be processed with the possibility of a quantitative analysis DNA within each sample. The *ITS* sequence showed distinct polymorphisms between *S. musiva* and *S. populicola* (Feau, Weiland, Stanosz, & Bernier, 2005), and as such, *ITS* was targeted using sequence specific oligonucleotides and probes were used to amplify the region. Such methods were also used in Beauseigle, et al. (2010) to detect and differentiate between *S. musiva* and *S. populicola* DNA. An RT-PCR procedure based on the TaqMan probe was used; the primers and probes used is summarized below:

Table 1 - **Summary of *S. musiva* and *S. populicola* primers and probes used in RT-PCR to detect and differentiate between the pathogens' DNA. (Beauseigle, Feau, & Hamelin, 2010)**

Primer Name	**Specificity**	**Sequence 5'-3'**
Smus_SSU193F	*S. musiva*	CGGTATTTTCAGCCTGCAG
Smus_SSU_288R	*S. musiva*	GCC GTT ATC CGT ACA ACT GA
Smus_SSU243F_probe	*S. musiva*	AGGTAGATATTAGGACAATTGGTGTAAAGA TGAT
Spopulicola_SSU193F	*S. populicola*	CGGTATTTTCAGCCTGCAC
Spopulicola_SSU288R	*S. populicola*	GCCGTTATCCGTACAACTAG
Spopulicola_SSU243F_probe	*S. populicola*	AGGAAGATATTAGGACGATGGGTGTAAAGATGAAA

The primers and probes were designed based on the small subunit (SSU) gene using IDT Sci Tools Oligo Analyzer 3.1 software and were custom ordered from Biosearch Technologies (Novato, CA, USA). The probe FAM-BHQ 1 was an oligonucleotide containing fluorescent dye 6-carboxyfluorescein (FAM) as a reporter at the 5' end, and a non-fluorescent quencher dye at the 3' end.

Real-time PCR reactions were performed in MicroAmp Optical 96-well plates using a Bio-rad CFX96TM thermal cycler system (Bio-Rad. Hercules, CA, USA). Each reaction contained 3.6µl of sample DNA, 10µl of 1X SsoFast probes supermix (Bio-Rad. Hercules, CA, USA), with 0.7µl of each forward and reverse primer, 5µl of probe for a total volume of 20µl. Each primer and probe was used at 350nM and 250nM final concentration, respectively. Each sample was duplicated on the same plate.

The thermal cycling parameters used were 2 min at 95°C for enzyme activation followed by 40 cycles of denaturation at 95°C for 5s and 5s of annealing/extension at 60°C. The threshold cycles (CT) were determined by plotting the relative fluorescence Units (RFU) against the cycle number. The results of the amplifications were analyzed using the CFX Manager software (version 1.0, Bio-Rad. Hercules, CA., USA).

Statistical Analysis

Two-tailed Z-test comparisons of the difference between two proportions were conducted on the 2011 and 2010 dataset, using the formulae:

(1.1)

$$Z_{test} = \frac{(\hat{p}_1 - \hat{p}_2)}{S_{\hat{p}1-\hat{p}2}}$$

(1.2)

$$S_{\hat{p}1-\hat{p}2} = \sqrt{\frac{(\hat{p}_1\hat{q}_1)}{n_1} + \frac{(\hat{p}_2\hat{q}_2)}{n_2}}$$

The Z-test was set at an alpha level of 0.05, where the $Z_{0.05}$ value = ±1.96; P-values for $Z_{0.05}$ = 0.256. $\hat{p}$ = proportion of trees infected with a specific pathogen over the total number of trees uninfected by the pathogen; the pathogen could be *Septoria musiva* or *Septoria populicola.* $\hat{q}$= number of uninfected trees/total number of trees in region. n_1 and n_2 are the total number of uninfected individuals, which includes samples that were positive for *S. populicola* and samples that were negative for both diseases. Using these formulae, the proportions of infected trees/uninfected trees from the Northern provenances were compared against the Southern populations for separately for both 2010 and 2011 datasets; a summary of the values used listed in the results section below:

Table 2 **– Summary of disease infection substituted into equations 1.1 and 1.2. The total number of trees uninfected by either *Septoria musiva* or *Septoria populicola* is excluded from this table.**

	2010				2011			
	North		South		North		South	
	S.musiva	***S. populicola***	***S.musiva***	***S. populicola***	***S.musiva***	***S. populicola***	***S.musiva***	***S. populicola***
# Infected	**11**	**92**	**9**	**118**	**9**	**104**	**6**	**106**
Total #(trees)	**115**		**155**		**149**		**157**	
$\hat{p}$	**0.096**	**0.800**	**0.058**	**0.761**	**0.047**	**0.685**	**0.0385**	**0.679**
$\hat{q}$	**0.904**	**0.200**	**0.942**	**0.239**	**0.953**	**0.315**	**0.962**	**0.321**

Results

Results Overview

The 2010 data set was collected by Beauseigle et al. (2010) and is summarized below in table 3, along with the 2011 results. Beauseigle et al. (2010) had grouped the 35 regions into 7 locations; in this study, the 7 locations (Dease Lake, Far North, Midcoast, Prince George, Smithers, South Coast and USA) were divided into a Northern and Southern population. The north consists of: Dease Lake, Far North, Midcoast, Prince George and Smithers, while the south is composed of South Coast and USA. The division of these two groups is illustrated in table 3 where the non-shaded regions represent the north, while the shaded cells represent the south. A total of 940 trees were sampled in 2010, but only 270 samples representing 100 families had been analyzed (Beauseigle et al. 2010).

In 2011, trees from all 8 repetitions were sampled from provenance trial EP1123.02, with a total sample size of over 3000 trees; however, a sub-sample of 306 trees were processed, with 149 samples from the north and 157 samples representing the south. A summary of the data collected in 2011 and 2010 are shown in table 3 below; the *S. musiva* infected trees in 2011 are summarized in table 4.

Table 3 - **Summary of *Septoria spp.* infection from 2011 and 2010. The pink shaded rows are collectively the Northern region, while the blue shaded rows represent the Southern region. Trees that were positive for both *Septoria* species are not counted in the "*S. musiva only" and "S. populicola only"* columns.2010 data from Beauseigle et al. (2010)**

2011					
Area	**Number of trees sampled**	***S.musiva* only**	***S.populicola* only**	***S. musiva + S. populicola***	**Negative for Both *Septoria spp.***
Dease Lake	7	2	3	0	2
Far North	3	0	3	0	0
Midcoast	40	0	31	2	7
Prince George	41	2	28	0	11
Smithers	58	1	35	0	22
South Coast	135	4	100	2	29
USA	22	0	4	0	18
Total	306	9	204	4	89
2010					
Dease Lake	11	2	9	-	0
Far North	3	1	2	-	0
Midcoast	46	5	35	-	5
Prince George	22	1	17	-	4
Smithers	33	2	29	-	2
South Coast	136	7	101	-	28
USA	19	2	17	-	1
Total	270	20	210	-	40

Table 4 – **Summary of trees that tested positive for *S. musiva* in 2011. The grey shaded rows indicate trees that were also positive for *S. musiva* infection in 2010. The green shaded rows indicate *S. musiva* infected trees in 2011 that were directly adjacent or in close proximity to *S. musiva* positive trees in 2010. Un-shaded rows indicate newly infected trees that are spatially segregated from *S. musiva* infected trees in 2010. The tree tag refers to the actual label of the tree within the plantation, while the tree number denotes the geographical origin and replicate number. Lat = Latitude, Long = Longitude, Elev = Elevation.**

Tree Tag	Tree Number	Area	Main Drainage	Lat	Long	Elev	Identification
311	A150-3	Dease Lake	Bell-Irving	5644	12944	579	S.musiva
570	A150-3	Dease Lake	Bell-Irving	5644	12944	579	S.musiva
1020	A56-3	Mid Coast	Homathko	5117	12450	152	S.musiva and S.populicola
1249	A75-4	Mid Coast	Dean	5249	12657	27	S.musiva and S.populicola
901	A165-7	Prince George	McGregor	5411	12200	579	S.musiva
1398	A171-5	Prince George	Nechako R.	5406	12426	655	S.musiva
618	A93-4	Smithers	Kitimat	5409	12835	61	S.musiva
52	A7-5	South Coast	Fraser R.	4924	12133	500	S.musiva
599	ATXD 15-29	South Coast	-	-	-	-	S.musiva
724	A25-3	South Coast	EVIC	4957	12515	76	S.musiva
735	A23-2	South Coast	EVIS	4914	12404	60	S.musiva and S.populicola
958	A17-3	South Coast	EVIN	5013	12548	30	S.musiva
1212	ADTAC 7	South Coast	-	-	-	-	S.musiva and S.populicola

Septoria musiva and Septoria populicola infection in 2010

The proportion of infected individuals in Beauseigle et al. (2010) was not divided between north and south populations, but rather a total number of infected individuals across the entire plantation. When divided into north and south, the north had 11 *S.musiva* infected individuals out of a 115 leaf samples (9.6%), while the south had 9 trees that tested positive for *S.musiva* out of 155 trees (5.8%). With *S. populicola* infected individuals, the north had 92 infected trees out of 115 (80.0%) and the south 118 out of 155 (76.1%) that tested positive. The number of trees infected with both diseases is unknown, as it was not reported in Beauseigle et al. (2010). 40 trees tested negative for either *Septoria* species; however, it should be noted that these 40 individuals were not free of lesions, but simply did not test positive for either disease under the identification protocol.

Z-test comparison of proportions between the number of trees infected with *S. musiva* in the northern population was not significantly different from the number of individuals infected with *S. musiva* in southern populations [Two-tailed Z-test, $Z_{0.05} = \pm 1.96 > Z_{test} = 1.353$; P-value = 0.256]. Similarly, the proportion of trees infected with *S. populicola* from the north was not significantly different from proportion of infected trees in the south [Two-tailed Z-test, $Z_{0.05} = \pm 1.96 > Z_{test} = 0.946$; P-value = 0.256].

Septoria musiva and Septoria populicola infection in 2011

Analogous to the 2010 analyses, the 7 geographical regions from Beauseigle et al. 2010 were separated into a north and south population and tested for proportion of infected trees over the total number of trees. The samples analyzed in 2011 contained a total of 13 individuals infected with *Septoria musiva* out of 306 processed trees (4.2%). *Septoria populicola* had a higher disease incidence of 210 infected individuals out of 306. Of the infected individuals, 4 trees were positive for both *Septoria musiva* and *Septoria populicola*. 89 trees were negative for infection of either *Septoria* species on leafs with lesions on it.

As in 2010, the proportion of trees infected with *S. musiva* in the north was not significantly different from the proportion of trees infected with *S. musiva* in the south [Two-tailed Z-test, $Z_{0.05} = \pm 1.96 > Z_{test} = 0.499$; P-value = 0.256]. The proportion of trees infected with

S. populicola in the north was also statistically the same as the proportion of *S. populicola* infected trees in the south. [Two-tailed Z-test, $Z_{0.05} = \pm 1.96 > Z_{test} = 0.237$; P-value = 0.256].

Septoria spp. infection in 2010 vs. 2011

Trees 570, 901 and 1020 had tested positive in 2010 for *S. musiva* infection; these same three trees have once again tested positive for *S. musiva* in 2011. In addition, trees: 311, 736 and 1398 have tested positive in 2011 and are situated directly adjacent to trees (tree 310 735 and 1400 respectively) that had tested positive in the previous year. Generally, trees that tested positive for *S. musiva* in 2011 are in close proximity to trees that were positive for *S. musiva* in 2010. The exceptions to this are trees 618, 1212 and 1249, which are confirmed for *S. musiva* infection in 2011, but are spatially segregated from previously infected trees in 2010.

A Z-test comparison of proportions was also conducted to compare the proportion of infected of individuals in 2010 versus 2011 for each *Septoria* disease, with 2010 infection in the north compared with 2011 infection in the north. In 2010, 9.6% of the 115 samples from the north were infected with *S. musiva,* compared to the 4.7% of the 149 samples in 2011. However, the proportion of *S. musiva* infected trees in the north in 2011 did not statistically differ from the trees that were positive for *S. musiva* in 2010 [Two-tailed Z-test, $Z_{0.05} = -1.96 < Z_{test} = -1.500$; P-value = 0.256]. *S. musiva* infection was present in 3.8% of the 157 leaf samples from southern trees that were processed in 2011; however, this did not differ significantly from the 5.8% of *S. musiva* infection reported in the south in 2010 [Two-tailed Z-test, $Z_{0.05} = -1.96 < Z_{test} = -0.739$; P-value = 0.256].

76.1% of the 149 trees sampled from the southern population in 2010 were positive for *S. populicola,* compared to the 67.9% of the 157 trees southern trees in 2011; these proportions were not statistically different [Two-tailed Z-test, $Z_{0.05} = -1.96 < Z_{test} = -1.660$; P-value = 0.256]. However, the proportion of northern trees infected with *S. populicola* in 2010 (80.0%) did differ significantly from the proportion of infected individuals in 2011 (68.5%) [Two-tailed Z-test, $Z_{0.05} = -1.96 > Z_{test} = -2.166$; P-value = 0.256].

Discussion

Sampling in 2010 vs. 2011- Methods and Protocol Differences

Although nearly 3000 trees are present within the 8 repetitions at Harrison Mills, leaf samples and statistical analyses were only conducted on a subset of 306 trees located within repetitions 1-3. The purpose of analyzing a subsample of tree leaves is to detect any trends that could be observable at a coarse level scale and reduce the time and effort required to process over 3000 leaf spot samples. In addition, data from the previous year was available for repetitions 1-3 from Beauseigle et al. (2010); this allowed a temporal comparison of available data to detect any apparent trends in *S. musiva* and *S. populicola* infection within the plantation. Tree mortality was also a concern with respect to resampling trees from 2010, more specifically, the trees along the southern edge of replicates 2 and 3, where most of the trees had died, possibility due to maladaptation to the local environment. Trees such as tree 929, which was positive for a *S. musiva* canker in 2010 (Beauseigle et al. 2010), could not be resampled as it was one of the trees along the southeastern edge that had been removed. The 2010 data set from Beauseigle et al. (2010) also represented 100 families within the provenance trial with a total sample size of 269 individual trees. In the 2011 data set, 107 families are represented over 306 tree samples; however, as the 2011 samples were randomly selected, there is no direct overlap between the families analyzed in 2010 versus those analyzed in 2011. The plantation contains families from 138 provenances; although not all of these families are represented in the 2011 data, a large proportion of the families are covered (107 out of 138). The time of sampling in 2011 was also slightly earlier in the year compared to the collection time of the 2010 dataset. The 2011 leaf samples, more specifically, replicates 1 – 3, were collected in August, while the samples collected by Beauseigle et al. (2010) were collected in the latter half of September. Initial lesions usually appear 3 – 4 weeks after bud burst (Feau, Mottet, Perinet, Hamelin, & Bernier, 2010), which would have been the optimal time to collect samples before other diseases propagate within the plantation. However, flooding from the adjacent river restricted the accessibility of the site and thus, leaf collection was delayed to August.

A key difference between the 2010 and the 2011 dataset is the protocol in the DNA extraction protocol. In Beauseigle et al. (2010), only 1 leaf spot from a single leaf was excised from the infected leaves and extracted. This method was changed to extracting 3 leaf spots from at least 3 leaves per tree, for a total of 9 leaf spots; from these leaf spots, 3-5 are randomly selected and pooled during the DNA extraction and RT-PCR. The detectability *S. musiva and S. populicola* using the pooled leaf spot protocol were tested using known isolates of *S. populicola* and *S. musiva* and the primers and probes from table 1. After several pooling and detection experiments, it was determined that 3-5 leaf spots was the optimal number to use. In addition, a portion of the samples in 2010 were processed using a modified Zolan and

Pukkila (1986) extraction protocol; although this protocol allowed more flexibility and controlling DNA purity, the DNA yield is lower than the DNeasy Plant Mini Kit extraction protocol (Beauseigle et al. 2010). The data set from 2011 also contained more than two times the samples that were negative for *Septoria* spp. (40 negatives in 2010 vs. 89 negatives in 2011), which could have been the result of standardizing the extraction protocol that favors the DNA quantity over DNA quality.

Septoria spp. infected trees in 2011

Previous studies have suggested that the primary inoculum for *S. musiva* originates from the leaf litter (Luley & McNabb Jr., 1989; Ostry, 1987). This is reflected in the 2010/2011 data, as the trees that were previously infected in 2010 were once again infected in 2011; trees 570, 901 and 1020 are all positive for *Septoria musiva* in both years of data (table 4). Of the 13 *S. musiva* positive trees identified in 2011, 7 of the infected trees are directly adjacent or in close proximity to trees that were previously infected in 2010 (table 4). However, trees 618, 1212 and 1249 had no prior history of *S. musiva* infection. In addition, these three trees were at least 3 tree rows and columns away from the closest *S. musiva* positive tree in 2010. It is uncertain if the flood from the Fraser River contributed to the spread of the disease, as the extent of the flooding is unknown. However, the three newly infected trees are relatively distant from the riverbank itself. Nonetheless, the infection of *S. musiva* within the plantation appears to have become self-propagating by infecting previously uninfected areas. It is worth noting that tree family A150-3, which originates from the Dease Lake geographical region, appears to be the most highly susceptible to *S. musiva*. Trees 311, 570, 1443 are all within the A150-3 family with tree 570 testing positive for *S. musiva* infection in 2010 and 2011. Tree 311, although negative for *S. musiva* in 2010, was directly adjacent to tree *S. musiva* positive tree 310 and has been tested positive in 2011. Tree 1443 was not included in the 2011 subsampled data from this study. Beauseigle et al. (2010) had attributed this infection of two trees within the same provenance to a 1) chance event or 2) local inoculum concentrated in the area or 3) they are more susceptible to *S. musiva* than other provenances. The reinfection of tree 570, along with the newly affected tree 311 suggests the infection could be more than a chance event. Trees 291 and 350, similar to tree 311, are also directly adjacent to tree 310; neither of the two trees tested positive for *S. musiva,* suggesting a relatively higher resistance compared to 311. However, the absence of *S. musiva* on 291 and 350 could simply be due to sampling error, where despite increasing the number and pooling the collected leaf spots, the true *S. musiva* infected spots are missed. The susceptibility of northern geographical regions cannot be statistically shown however, as low representation Dease Lake and Far North provenances and tree mortality have drastically reduced the number of available samples from the northern geographical regions and limiting statistical analyses.

Unlike *S. musiva,* the infection of *S. populicola* within the plantation is well established and has infected the majority of the trees in the plantation, infecting 208 out of the total 306 samples collected in 2011. There are no apparent trends with respect to *S. populicola* infection within the plantation, as the disease is native to British Columbia and is distributed wherever susceptible hosts are present (Newcombe, Ostry, Hubbes, Perinet, & Mottet, 2001).

Z-test Results Interpretation

Analyses of the proportion of infected individuals within each geographical region would be the most ideal way of identifying resistant provenances; however, processing over 3000 leaf samples representing all 7 geographical demands a vast amount of time and resources. By using a subset of data, coarse scale analyses can be conducted; the results of such analyses could dictate if the additional 2700 samples would need to be processed. Furthermore, there was an unequal representation of each provenance from when the provenance trial was established due to the availability of clonal material; the mortality of numerous trees have also contributed to the low representation of each geographical region, as reflected in table 3. In response to these limiting factors, the regions were divided into a northern and southern population where the north includes: Dease Lake, Far North, Smithers, Prince George and Midcoast, while the south includes: Southcoast and USA.

In the 2010-northern population, 11/115 (9.6%) of the total samples were positive for *S. musiva* infection, compared to the 9/155 (5.8%) infected in the southern region. Although the north has a greater proportion of individuals infected, this was not statistically different from the proportion of infected individuals found in the southern population. Similarly, in 2011, the 7/149 (4.7%) of *S. musiva* infected trees in the north was not statistically different from the 6/157 (3.8%) infected trees in the south. It is interesting to note that the total number of *S. musiva* infected individuals is approximately an even split between the north and south, with 11 and 9 respectively in 2010, and 7 and 6 respectively in 2011. A comparison between proportion of infected individuals in 2010-north and 2011-north, as well as 2010-south and 2011-south also indicates that the proportions are not statistically different. This could be interpreted as a stable rate of infection within the plantation between 2010 and 2011. The non-significant variation in *S. musiva* infection between the north and the south interesting, as one would expect a degree of resistance in one region over another, given the large amount of diversity within natural populations of poplars (Newcombe & Bradshaw, Quantitative trait loci conferring resistance in hybrid poplar to Septoria Populicola, the cause of leaf spot, 1996). However, as *S. musiva* had never been reported in the Pacific Northwest until 2006 (Callan, Leal, Foord, Dennis, & van Oosten, 2007), it is unlikely that *P. trichocarpa* has coevolved with *S. musiva* to generate some level of adaptive resistance (Clay & Kover, 1996). This is also reflected in *Populus deltoides* exhibiting some degree of resistances to *S. musiva* cankers, as the two have coevolved together and selective pressures place on one another have yielded resistance and increased virulence to one another (Newcombe & Ostry, 2001). Given total number of trees within the provenance trial, the frequency of cankers on the poplar clones was low. Cankers from branches that were found during the sampling were negative for *S. musiva* and were attributed to other injury causal agents. Several trees appeared to have cankers in the main stem; however, extracting the canker for *S. musiva* was not possible without killing the tree and was thus avoided. Variability in *S. musiva* aggressiveness has been documented given different isolates of the pathogen (Krupinsky, 1989); as the plantation is infected by a newly colonized pathogen that is subjected to population bottlenecks, it is possible that the *S. musiva* present within the plantation is one of mild aggressiveness. However, as LeBoldus et al. (2007) reports that host genotype variability had a bigger influence on disease severity than pathogen genotype variability, the founder's effect the newly colonized *S. musiva* might not be restricting the aggressiveness and disease severity within the plantation. Analyses of neutral molecular markers within the *S. musiva* genome have suggested that *S. musiva* has a high potential for local adaptation to sudden environmental changes (Feau, Hamelin, Vandecasteele, Stanosz, & Bernier, 2005). Furthermore, LeBoldus et al. (2010) found a significant clone-isolate interaction when conducting spray inoculations on *Populus* clones and *S. musiva* isolates to induce cankers. This clone-isolate interaction could account for the low frequency of cankers within the plantation, as the newly colonized population of *S. musiva* is unable to bypass the tree's natural defense systems to generate cankers without infection through tissue wounds (LeBoldus & Blenis, 2010). Although the aggressiveness and disease severity in the plantation appear to be rare events, overtime, the infection of *S. musiva* in the Fraser Valley could be much more detrimental.

S. populicola infection also showed no significant differences between the north and south population in 2010 and 2011. This result is expected, as *S. populicola* is native to British Columbia; as such, the pathogen and the host have coevolved together through the selective pressure they exert on one another (Clay & Kover, 1996). However, as pathogens have a higher generation turnover, any resistance to *S. populicola* could be by *P. trichocarpa* can be rapidly negated through several generations of genetic recombination. Finally, a significant difference was found in between the *S. populicola* infection in the 2011-north infection and the 2010-north infection. The same significance was not detected in the comparison between 2011-south and 2010-south populations. This year over year difference could be attributed to *S. populicola* being epidemic in some years and not epidemic in others (Newcombe & Bradshaw, 1996).

Experimental Improvements and Future Research

Although north and south populations showed no significant differences in *S. musiva* infection proportions, the apparent trend in the reinfection of the provenances in Dease Lake suggests that the region is relatively more susceptible to *S. musiva* than the geographical regions to the south. However, given the limited dataset, statistically analyses could not be conducted on each geographical region alone. As such, a better representation of each individual region, specifically from the northern provenances could strengthen this apparent relationship. As samples from the other 5 repetitions are available, it may be beneficial to process the samples to detect for the presence or absence of *S. musiva.* In addition, repeating the experiment for an additional year may be helpful in determining if the reinfections of specific regions are due to chance and high inoculum concentrations, or if there is a difference in quantitative resistance to *S. musiva.*

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Appendices

Tree No.	Tree ID	Area	Main Drainage	Location	Map #	Lat	Long	Elev	Pathogen Identity
40	A80-2	Smithers	Skeena	Skeena RID. SKN	80	5451	12820	140	S.populicola
44	A165-6	Prince George	McGregor	McGregorR. MCG	165	5411	12200	579	S.populicola
45	A105-5	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R./	105	5440	12707	567	S.populicola
52	A7-5	South Coast	Fraser R.			4924	12133	500	S.musiva
55	A146-7	Far North	Aisek	Tatshenshini	146	5926	13750	34	S.populicola
95	A162-1	Prince George	Fraser R.	Hixon HIXN 1	162	5324	12238	518	S.populicola
109	A158-3	Prince George	Cunningham R.	16 Kimball Cr.	158	5256	12110	823	S.populicola
115	A158-4	Prince George	Cunningham R.	16 Kimball Cr.	158	5256	12110	823	S.populicola
168	A55-4	Mid Coast	Homathko	Homathko R.lC.	55	5114	12 457	88	S.populicola
169	A12-4	South Coast	Fraser	Vender Cana1IL.	12	4909	12206	20	negative for both Septoria species
176	A178-4	USA	GS033	Pittsburg, W A. P	178	4550	12307	900	S.populicola
177	A1-5	South Coast	Fraser	Nahatlatch R./A.	1	5000	12134	213	S.populicola
184	A87-4	Smithers	Skeena	Skeena R.IN. SK	87	5417	12922	30	S.populicola
185	A153-3	Smithers	U. Nass	White RIA. WHTA	153	5556	12916	366	S.populicola
190	A27-3	South Coast	EVIC	Courtenay/H. CNYH	27	4940	12504	76	S.populicola
192	A161-3	Prince George	Fraser R.	Fraser R. QFRS	161	5304	12231	472	S.populicola
231	A158-2	Prince George	Cunningham R.	16 Kimball Cr.	158	5256	12110	823	S.populicola
257	A163-7	Prince George	Fraser R.	WillowR. WLOW	163	5355	12217	640	negative for both Septoria species
274	A88-2	Smithers	Skeena	Skeena R.IO. SK	88	5413	12932	21	S.populicola
281	A164-6	Prince George	Fraser R.	5 Shelley SHEL	164	5402	12236	564	negative for both Septoria species
282	A156-7	Prince George	Quesnel R.	6 Australian QA	156	5243	12228	442	S.populicola
285	A94-4	Smithers	Kitimat	Kitimat R.lC. K	94	5403	12841	18	negative for both Septoria species
291	A164-1	Prince George	Fraser R.	5 Shelley SHEL	164	5402	12236	564	S.populicola
311	A150-3	Dease Lake	Bell-Irving	7 Bell-Irving/C.	150	5644	12944	579	S.musiva

321	A92-1	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	S.populicola
323	A82-2	Smithers	Skeena	KitwangaIF . KT	82	5505	12811	177	S.populicola
325	A156-6	Prince George	Quesnel R.	6 Australian QA	156	5243	12228	442	S.populicola
326	A161-3	Prince George	Fraser R.	Fraser R. QFRS	161	5304	12231	472	S.populicola
331	A160-4	Prince George	Fraser R.	6 Cottonwood QC	160	5302	12209	823	S.populicola
337	A94-2	Smithers	Kitimat	Kitimat R.lC. K	94	5403	12841	18	S.populicola
348	A88-2	Smithers	Skeena	Skeena R.lO. SK	88	5413	12932	21	negative for both Septoria species
349	A87-2	Smithers	Skeena	Skeena R.IN. SK	87	5417	12922	30	negative for both Septoria species
350	A95-4	Smithers	Kitimat	Hirsch Cr.lD. H	95	5404	12827	335	negative for both Septoria species
356	A159-5	Prince George	Fraser R.	Baker Cr. QBKR	159	5257	12252	823	S.populicola
367	A116-5	Smithers	U. Nass	NassRtH. NASH	116	5543	12849	183	S.populicola
410	A156-7	Prince George	Quesnel R.	6 Australian QA	156	5243	12228	442	S.populicola
424	A76-5	Smithers	Skeena	Exehamsiks RIP	76	5425	12926	46	negative for both Septoria species
448	A171-4	Prince George	Nechako R.	14 Redmond Cr. A.	171	5406	12426	655	negative for both Septoria species
453	A153-3	Smithers	U. Nass	White RIA. WHTA	153	5556	12916	366	S.populicola
468	A98-4	Smithers	Bulkley	Bulkley R.lC. B	98	5457	12717	451	negative for both Septoria species
475	A162-1	Prince George	Fraser R.	Hixon HIXN 1	162	5324	12238	518	negative for both Septoria species
505	A95-2	Smithers	Kitimat	Hirsch Cr.lD. H	95	5404	12827	335	negative for both Septoria species
506	A136-2	Dease Lake	L. Stikine	6 Iskut R.lC. I	136	5656	13020	317	negative for both Septoria species
519	A96-4	Smithers	Bulkley	Bulkley R./ A.	96	5515	12730	311	negative for both Septoria species
522	A41-3	South Coast	Squamish	GlacierlB Aha L.	41	5006	12300	579	negative for both Septoria species
531	A163-4	Prince George	Fraser R.	WillowR. WLOW	163	5355	12217	640	negative for both Septoria species
570	A150-3	Dease Lake	Bell-Irving	7 Bell-Irving/C.	150	5644	12944	579	S.musiva
571	A22-4	South Coast	EVIS	Cassigy/J. CSYJ	22	4904	12352	20	S.populicola
573	A33-3	South Coast	Lillooet	a Lillooet R./ A.	33	5037	12323	411	S.populicola

574	A89-8	Smithers	Skeena	Skeena R.IP. SK	89	5433	12828	61	S.populicola
576	A9-2	South Coast	Fraser	Chilliwack R.#2/I.	9	4906	12138	360	S.populicola
577	A105-1	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R./	105	5440	12707	567	S.populicola
578	A179-2	USA	GS031	North Plains, OR.	179	4534	12300	100	S.populicola
579	A35-4	South Coast	Lillooet	a Lillooet R.lC.	35	5030	12300	271	S.populicola
580	A25-2	South Coast	EVIC	Campbell R.IF. CM	25	4957	12515	76	negative for both Septoria species
581	A57-5	South Coast	Southgate	1 Southgate R./ A	57	5049	12429	239	S.populicola
583	A171-1	Prince George	Nechako R.	14 Redmond Cr. A.	171	5406	12426	655	S.populicola
584	A67-1	Mid Coast	Rivers	Chuckwalla R.lC.	67	5144	12719	67	S.populicola
585	A87-4	Smithers	Skeena	Skeena R.IN. SK	87	5417	12922	30	S.populicola
586	A179-5	USA	GS031	North Plains, OR.	179	4534	12300	100	S.populicola
587	A71-2	Mid Coast	Burke	Bella Coola R.lC.	71	5223	12636	135	S.populicola
588	A174-3	USA	GS001	Carson, WA. CARS	174	4545	12250	650	negative for both Septoria species
590	A47-5	South Coast	Jervis	Skwawka R.IF. SK	47	5015	12356	244	S.populicola
591	A74-1	Mid Coast	Dean	eanR./C. DENC 7	74	5250	12648	91	S.populicola
592	A1-1	South Coast	Fraser	Nahatlatch R./A.	1	5000	12134	213	negative for both Septoria species
593	A154-4	Mid Coast	KingcomeR.	20a Atlatzi R.lA.	154	5059	12607	0	S.populicola
594	A13-5	South Coast	Fraser	MatsQui Is.IM. M	13	4907	12220	8	S.populicola
596	A19-3	South Coast	EVIN	Salmon R. #2/C SL	19	5016	12550	30	S.populicola
598	A72-4	Mid Coast	Dean	eanR./A. DENA 7	72	5246	12637	213	S.populicola
599	ATXD 15-29	South Coast							S.musiva
615	A79-4	Smithers	Skeena	Skeena R/e. SKN	79	5446	12816	122	negative for both Septoria species
616	A84-5	Smithers	Skeena	HazeltonIH. HAZ	84	5513	12740	238	negative for both Septoria species
618	A93-4	Smithers	Kitimat	Kitimat R.IB. K	93	5409	12835	61	S.musiva
619	A106-2	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R.I	106	5437	12730	735	S.populicola

624	A163-3	Prince George	Fraser R.	WillowR. WLOW	163	5355	12217	640	S.populicola
627	A151-1	Dease Lake	Bell-Irving	7 Bell-Irving/D.	151	5651	12937	677	S.populicola
631	A95-4	Smithers	Kitimat	Hirsch Cr.lD. H	95	5404	12827	335	S.populicola
636	A76-5	Smithers	Skeena	Exehamsiks RIP	76	5425	12926	46	negative for both Septoria species
644	A156-1	Prince George	Quesnel R.	6 Australian QA	156	5243	12228	442	negative for both Septoria species
645	A123-3	Smithers	Skeena	Kitsumkalum R.IB.	123	5444	12847	155	negative for both Septoria species
661	A93-4	Smithers	Kitimat	Kitimat R.IB. K	93	5409	12835	61	negative for both Septoria species
663	A106-1	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R.I	106	5437	12730	735	S.populicola
667	A164-3	Prince George	Fraser R.	5 Shelley SHEL	164	5402	12236	564	S.populicola
685	A113-1	Smithers	U. Nass	Nass RIE. NASE	113	5524	12859	207	negative for both Septoria species
702	A163-4	Prince George	Fraser R.	WillowR. WLOW	163	5355	12217	640	negative for both Septoria species
705	A53-1	South Coast	Homathko	Homathko R./ A.	53	5056	12451	46	negative for both Septoria species
706	A92-1	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	S.populicola
709	A37-2	South Coast	Harrison	Lillooet R./ A.	37	5007	12232	314	S.populicola
711	A94-3	Smithers	Kitimat	Kitimat R.lC. K	94	5403	12841	18	S.populicola
713	A183-1	USA	GS056	Lafayette, OR. LA	183	4512	12305	100	S.populicola
714	A157-3	Prince George	Quesnel R.	6 Quesnel L. QL	157	5258	12219	488	S.populicola
715	A36-1	South Coast	Lillooet	Lillooet R.ID.	36	5018	12245	222	S.populicola
716	A44-3	South Coast	Jervis	Skwawka R.lC. SK	44	5015	12400	152	S.populicola
717	A123-3	Smithers	Skeena	Kitsumkalum R.IB.	123	5444	12847	155	S.populicola
718	A177-1	USA	GS024	Castle Rock, W A.	177	4620	12255	100	negative for both Septoria species
719	A182-2	USA	GS051	Jasper, OR. JASP	182	4400	12255	150	S.populicola
720	A8-3	South Coast	Fraser	Chilliwack R.#l/H.	8	4906	12131	480	S.populicola
721	A3-3	South Coast	Fraser	Wellington Bar/C.	3	4940	12125	91	S.populicola
722	A39-3	South Coast	Harrison	Lillooet R.lC.	39	4946	12213	64	S.populicola
723	A64-3	Mid Coast	Knight	0 W.Klinaklini R.	64	5118	12546	546	S.populicola
724	A25-3	South Coast	EVIC	Campbell R.IF. CM	25	4957	12515	76	S.musiva

726	A72-1	Mid Coast	Dean	eanR./A. DENA 7	72	5246	12637	213	S.populicola
727	A9-2	South Coast	Fraser	Chilliwack R.#2/I.	9	4906	12138	360	S.populicola
729	A45-4	South Coast	Jervis	Skwawka R.ID. SK	45	5015	12401	323	S.populicola
730	A53-1	South Coast	Homathko	Homathko R./ A.	53	5056	12451	46	S.populicola
732	A4-2	South Coast	Fraser	Yale West/D. YA	4	4934	12128	549	S.populicola
733	A17-2	South Coast	EVIN	Memekav R./ A. ME	17	5013	12548	30	S.populicola
735	A23-2	South Coast	EVIS	Lantzville/K. LNZ	23	4914	12404	60	S.musiva and S.populicola
736	A69-5	Mid Coast	Burke	Bella Coola R./ A.	69	5225	12610	152	S.populicola
737	A13-2	South Coast	Fraser	MatsQui Is.IM. M	13	4907	12220	8	S.populicola
738	A27-2	South Coast	EVIC	Courtenay/H. CNYH	27	4940	12504	76	S.populicola
740	A172-6	Prince George	Nechako R.	14 Diamond Is. B.	172	5357	12426	671	S.populicola
741	A39-2	South Coast	Harrison	Lillooet R.lC.	39	4946	12213	64	S.populicola
742	A59-4	Mid Coast	Knight	W.Klinaklini R./ A	59	5107	12535	30	negative for both Septoria species
743	A64-1	Mid Coast	Knight	0 W.Klinaklini R.	64	5118	12546	546	negative for both Septoria species
748	A23-4	South Coast	EVIS	Lantzville/K. LNZ	23	4914	12404	60	negative for both Septoria species
756	A18-2	South Coast	EVIN	Salmon R. #IIB. S	18	5013	12549	30	S.populicola
757	A28-5	South Coast	EVIC	Fanny Bayll. FNYI	28	4931	12451	46	S.populicola
758	A26-5	South Coast	EVIC	Black Creek/G. BL	26	4950	12511	91	negative for both Septoria species
759	A5-5	South Coast	Fraser	Yale East/E. YA	5	4934	12124	61	negative for both Septoria species
760	A52-1	South Coast	Phillips	Phillips R.lC.	52	5041	12515	58	S.populicola
761	A46-1	South Coast	Jervis	Skwawka R.IE. S	46	5013	12357	231	negative for both Septoria species
762	A9-4	South Coast	Fraser	Chilliwack R.#2/I.	9	4906	12138	360	negative for both Septoria species
764	A161-4	Prince George	Fraser R.	Fraser R. QFRS	161	5304	12231	472	negative for both Septoria species
765	A66-4	Mid Coast	Machmell	Machmell R.IB	66	5137	12635	122	negative for both Septoria species
768	A12-2	South Coast	Fraser	Vender Cana1IL.	12	4909	12206	20	negative for both Septoria species
770	A74-4	Mid Coast	Dean	eanR./C. DENC 7	74	5250	12648	91	negative for both Septoria species

771	A19-5	South Coast	EVIN	Salmon R. #2/C SL	19	5016	12550	30	S.populicola
772	A33-5	South Coast	Lillooet	a Lillooet R./ A.	33	5037	12323	411	S.populicola
774	A32-2	South Coast	Squamish	Elaho R.ID. EL	32	5015	12235	305	S.populicola
778	A128-1	Dease Lake	L. Stikine	L. Stikine	128	5731	13147	61	S.populicola
779	A32-3	South Coast	Squamish	Elaho R.ID. EL	32	5015	12235	305	S.populicola
781	A50-1	South Coast	Phillips	Phillips R./ A.	50	5036	12519	5	S.populicola
782	A48-2	South Coast	Toba Inlet	23 Toba R./A. T	48	5031	12414	67	negative for both Septoria species
833	A29-2	South Coast	Squamish	Squamish R./ A.	29	4952	12314	61	S.populicola
835	A66-5	Mid Coast	Machmell	Machmell R.IB	66	5137	12635	122	S.populicola
837	A50-4	South Coast	Phillips	Phillips R./ A.	50	5036	12519	5	S.populicola
838	A39-5	South Coast	Harrison	Lillooet R.lC.	39	4946	12213	64	S.populicola
840	A75-2	Mid Coast	Dean	eanR.lD. DEND 7	75	5249	12657	27	S.populicola
841	A105-5	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R./	105	5440	12707	567	S.populicola
842	A14-3	South Coast	Fraser	McMillan Is.IN.	14	4911	12235	15	negative for both Septoria species
844	A177-5	USA	GS024	Castle Rock, W A.	177	4620	12255	100	S.populicola
845	A92-4	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	negative for both Septoria species
846	A15-2	South Coast	Fraser	Harrison R./O. H	15	4917	12157	40	S.populicola
848	A19-4	South Coast	EVIN	Salmon R. #2/C SL	19	5016	12550	30	S.populicola
849	A159-2	Prince George	Fraser R.	Baker Cr. QBKR	159	5257	12252	823	S.populicola
851	A100-4	Smithers	Bulkley	Bulkley R.IE. B	100	5445	12707	494	negative for both Septoria species
852	A92-3	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	S.populicola
854	A43-4	South Coast	Jervis	Skwawka R.IB. SK	43	5014	12400	115	S.populicola
856	A45-4	South Coast	Jervis	Skwawka R.ID. SK	45	5015	12401	323	S.populicola
857	A92-2	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	negative for both Septoria species
858	A41-5	South Coast	Squamish	GlacierlB Aha L.	41	5006	12300	579	S.populicola
860	A49-5	South Coast	Toba Inlet	23 TobaR.IB. TO	49	5034	12405	73	S.populicola
861	A58-2	South Coast	Southgate	1 Southgate R.IB.	58	5053	12444	91	negative for both Septoria species

862	A174-3	USA	GS001	Carson, WA. CARS	174	4545	12250	650	S.populicola
863	A37-2	South Coast	Harrison	Lillooet R./ A.	37	5007	12232	314	S.populicola
880	A17-2	South Coast	EVIN	Memekav R./ A. ME	17	5013	12548	30	S.populicola
881	A73-4	Mid Coast	Dean	eanR.IB. DENB 7	73	5250	12642	152	S.populicola
882	A32-5	South Coast	Squamish	Elaho R.ID. EL	32	5015	12235	305	S.populicola
883	A49-2	South Coast	Toba Inlet	23 TobaR.IB. TO	49	5034	12405	73	S.populicola
884	A181-5	USA	GS048	Halsey, OR. HALS	181	4425	12320	300	S.populicola
886	A4-5	South Coast	Fraser	Yale West/D. YA	4	4934	12128	549	S.populicola
888	A53-2	South Coast	Homathko	Homathko R./ A.	53	5056	12451	46	S.populicola
889	A24-2	South Coast	EVIS	Chemainus R.IL. C	24	4853	12342	5	S.populicola
890	A15-5	South Coast	Fraser	Harrison R./O. H	15	4917	12157	40	negative for both Septoria species
892	A23-4	South Coast	EVIS	Lantzville/K. LNZ	23	4914	12404	60	S.populicola
893	A133-1	Dease Lake	U. Stikine	Tanzilla R./A.	133	5818	13028	567	S.populicola
894	A15-3	South Coast	Fraser	Harrison R./O. H	15	4917	12157	40	S.populicola
896	A28-2	South Coast	EVIC	Fanny Bayll. FNYI	28	4931	12451	46	S.populicola
897	A58-2	South Coast	Southgate	1 Southgate R.IB.	58	5053	12444	91	negative for both Septoria species
898	A122-2	Smithers	Skeena	Cedar R./A (KITA)	122	5457	12855	274	S.populicola
899	A21-4	South Coast	EVIN	White R.IE. WHTE,	21	5008	12603	213	negative for both Septoria species
900	A177-2	USA	GS024	Castle Rock, W A.	177	4620	12255	100	S.populicola
901	A165-7	Prince George	McGregor	McGregorR. MCG	165	5411	12200	579	S.musiva
902	A6-1	South Coast	Fraser	Hope North/F. H	6	4926	12126	61	S.populicola
904	A78-3	Smithers	Skeena	Skeena RIB. SKN	78	5441	12823	122	negative for both Septoria species
905	A154-5	Mid Coast	KingcomeR.	20a Atlatzi R.lA.	154	5059	12607	0	S.populicola
906	A180-4	USA	GS041	Jefferson, OR. JE	180	4444	12305	100	negative for both Septoria species
907	A12-1	South Coast	Fraser	Vender Cana1IL.	12	4909	12206	20	negative for both Septoria species
909	A75-1	Mid Coast	Dean	eanR.ID. DEND 7	75	5249	12657	27	S.populicola

910	A32-4	South Coast	Squamish	Elaho R.ID. EL	32	5015	12235	305	negative for both Septoria species
911	A58-1	South Coast	Squamish	GlacierlB Aha L.	41	5006	12300	579	negative for both Septoria species
912	A67-4	Mid Coast	Southgate	1 Southgate R.IB.	58	5053	12444	91	negative for both Septoria species
916	A71-4	Mid Coast	Burke	Bella Coola R.lC.	71	5223	12636	135	negative for both Septoria species
917	A2-3	South Coast	Fraser	Nahatlatch L.IB.	2	4958	12149	335	S.populicola
918	A54-4	South Coast	Homathko	Homathko R.IB.	54	5057	12454	37	S.populicola
919	A7-1	South Coast	Fraser	Hope South/G. H	7	4924	12133	500	negative for both Septoria species
920	A106-2	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R.I	106	5437	12730	735	S.populicola
921	A154-2	Mid Coast	KingcomeR.	20a Atlatzi R.lA.	154	5059	12607	0	S.populicola
922	A178-2	USA	GS033	Pittsburg, W A. P	178	4550	12307	900	S.populicola
923	A52-2	South Coast	Phillips	Phillips R.lC.	52	5041	12515	58	negative for both Septoria species
937	A161-2	Prince George	Fraser R.	Fraser R. QFRS	161	5304	12231	472	negative for both Septoria species
938	A15-3	South Coast	Fraser	Harrison R./O. H	15	4917	12157	40	negative for both Septoria species
939	A54-3	South Coast	Homathko	Homathko R.IB.	54	5057	12454	37	S.populicola
940	A122-2	Smithers	Skeena	Cedar R./A (KITA)	122	5457	12855	274	negative for both Septoria species
942	A72-1	Mid Coast	Dean	eanR./A. DENA 7	72	5246	12637	213	negative for both Septoria species
943	A38-2	South Coast	Harrison	Lillooet R.IB.	38	5002	12232	213	S.populicola
944	A54-2	South Coast	Homathko	Homathko R.IB.	54	5057	12454	37	negative for both Septoria species
946	A53-4	South Coast	Homathko	Homathko R./ A.	53	5056	12451	46	S.populicola
948	A20-2	South Coast	EVIN	Salmon R. #3ID. S	20	5017	12552	30	S.populicola
949	A175-5	USA	GS009	N. Bonneville WA.	175	4535	12200	300	S.populicola
950	A171-1	Prince George	Nechako R.	14 Redmond Cr. A.	171	5406	12426	655	S.populicola
951	A22-3	South Coast	EVIS	Cassigy/J. CSYJ	22	4904	12352	20	S.populicola
953	A11-2	South Coast	Fraser	Chilliwack R.#4/K.	11	4905	12144	280	negative for both Septoria species
957	A50-5	South Coast	Phillips	Phillips R./ A.	50	5036	12519	5	negative for both Septoria species

958	A17-3	South Coast	EVIN	Memekav R./ A. ME	17	5013	12548	30	S.musiva
959	A42-4	South Coast	Jervis	Skwawka R./ A. S	42	5013	12359	61	negative for both Septoria species
960	A183-4	USA	GS056	Lafayette, OR. LA	183	4512	12305	100	S.populicola
961	A158-6	Prince George	Cunningham R.	16 Kimball Cr.	158	5256	12110	823	S.populicola
962	A80-2	Smithers	Skeena	Skeena RID. SKN	80	5451	12820	140	negative for both Septoria species
963	A46-5	South Coast	Jervis	Skwawka R.IE. S	46	5013	12357	231	S.populicola
964	A1-2	South Coast	Fraser	Nahatlatch R./A.	1	5000	12134	213	S.populicola
966	A75-5	Mid Coast	Dean	eanR.ID. DEND 7	75	5249	12657	27	S.populicola
967	A28-3	South Coast	EVIC	Fanny Bayll. FNYI	28	4931	12451	46	S.populicola
968	A41-3	South Coast	Squamish	GlacierlB Aha L.	41	5006	12300	579	S.populicola
969	A36-2	South Coast	Lillooet	Lillooet R.ID.	36	5018	12245	222	S.populicola
970	A180-3	USA	GS041	Jefferson, OR. JE	180	4444	12305	100	S.populicola
983	A87-2	Smithers	Skeena	Skeena R.IN. SK	87	5417	12922	30	S.populicola
998	A165-7	Prince George	McGregor	McGregorR. MCG	165	5411	12200	579	S.populicola
1020	A56-3	Mid Coast	Homathko	Homathko R.ID.	56	5117	12450	152	S.musiva and S.populicola
1049	A178-3	USA	GS033	Pittsburg, W A. P	178	4550	12307	900	S.populicola
1068	A128-3	Dease Lake	L. Stikine	L. Stikine	128	5731	13147	61	negative for both Septoria species
1200	A7-3	South Coast	Fraser	Hope South/G. H	7	4924	12133	500	S.populicola
1212	ADTAC 7	South Coast							S.musiva and S.populicola
1216	A45-5	South Coast	Jervis	Skwawka R.ID. SK	45	5015	12401	323	S.populicola
1217	A158-5	Prince George	Cunningham R.	16 Kimball Cr.	158	5256	12110	823	S.populicola
1218	A105-5	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R./	105	5440	12707	567	S.populicola
1225	A23-5	South Coast	EVIS	Lantzville/K. LNZ	23	4914	12404	60	S.populicola
1230	A15-4	South Coast	Fraser	Harrison R./O. H	15	4917	12157	40	negative for both Septoria species
1233	A7-4	South Coast	Fraser	Hope South/G. H	7	4924	12133	500	S.populicola
1235	A55-3	Mid Coast	Homathko	Homathko R.lC.	55	5114	12 457	88	S.populicola

1245	A79-4	Smithers	Skeena	Skeena R/e. SKN	79	5446	12816	122	S.populicola
1247	A35-1	South Coast	Lillooet	a Lillooet R.lC.	35	5030	12300	271	S.populicola
1249	A75-4	Mid Coast	Dean	eanR.lD. DEND 7	75	5249	12657	27	S.musiva and S.populicola
1254	A173-2	Prince George	Nechako R.	14 Chilako R. C	173	5353	12259	183	S.populicola
1261	A64-2	Mid Coast	Knight	0 W.Klinaklini R.	64	5118	12546	546	S.populicola
1272	A28-4	South Coast	EVIC	Fanny Bayll. FNYI	28	4931	12451	46	S.populicola
1277	A50-2	South Coast	Phillips	Phillips R./ A.	50	5036	12519	5	S.populicola
1278	A11-1	South Coast	Fraser	Chilliwack R.#4/K.	11	4905	12144	280	S.populicola
1279	A178-1	USA	GS033	Pittsburg, W A. P	178	4550	12307	900	negative for both Septoria species
1298	A182-3	USA	GS051	Jasper, OR. JASP	182	4400	12255	150	S.populicola
1302	A10-1	South Coast	Fraser	Chilliwack R.#3/J.	10	4905	12143	280	S.populicola
1303	A164-2	Prince George	Fraser R.	5 Shelley SHEL	164	5402	12236	564	negative for both Septoria species
1304	A17-2	South Coast	EVIN	Memekav R./ A. ME	17	5013	12548	30	S.populicola
1307	A53-1	South Coast	Homathko	Homathko R./ A.	53	5056	12451	46	S.populicola
1308	A32-4	South Coast	Squamish	Elaho R.ID. EL	32	5015	12235	305	S.populicola
1309	A26-2	South Coast	EVIC	Black Creek/G. BL	26	4950	12511	91	S.populicola
1313	A165-6	Prince George	McGregor	McGregorR. MCG	165	5411	12200	579	S.populicola
1314	A25-1	South Coast	EVIC	Campbell R.IF. CM	25	4957	12515	76	S.populicola
1316	A142-5	Far North	Taku	Taku River/B	142	5842	13324	49	S.populicola
1317	A54-3	South Coast	Homathko	Homathko R.IB.	54	5057	12454	37	S.populicola
1319	A181-1	USA	GS048	Halsey, OR. HALS	181	4425	12320	300	S.populicola
1323	A16-2	South Coast	Fraser	Harrison Mill/P.	16	4914	12151	30	negative for both Septoria species
1324	A92-3	Smithers	Kitimat	Kitimat R./ A.	92	5415	12831	122	negative for both Septoria species
1326	A45-4	South Coast	Jervis	Skwawka R.ID. SK	45	5015	12401	323	S.populicola
1327	A154-5	Mid Coast	KingcomeR.	20a Atlatzi R.lA.	154	5059	12607	0	S.populicola
1328	A76-5	Smithers	Skeena	Exehamsiks RIP	76	5425	12926	46	S.populicola

1329	A154-2	Mid Coast	KingcomeR.	20a Atlatzi R.IA.	154	5059	12607	0	S.populicola
1330	A68-3	Mid Coast	Rivers	Chuckwalla R.ID.	68	5146	12712	79	S.populicola
1331	A9-5	South Coast	Fraser	Chilliwack R.#2/I.	9	4906	12138	360	S.populicola
1332	A4-2	South Coast	Fraser	Yale West/D. YA	4	4934	12128	549	S.populicola
1333	A27-3	South Coast	EVIC	Courtenay/H. CNYH	27	4940	12504	76	S.populicola
1336	A43-3	South Coast	Jervis	Skwawka R.IB. SK	43	5014	12400	115	S.populicola
1337	A36-3	South Coast	Lillooet	Lillooet R.ID.	36	5018	12245	222	S.populicola
1338	A22-4	South Coast	EVIS	Cassigy/J. CSYJ	22	4904	12352	20	S.populicola
1339	A46-1	South Coast	Jervis	Skwawka R.IE. S	46	5013	12357	231	S.populicola
1340	A181-5	USA	GS048	Halsey, OR. HALS	181	4425	12320	300	S.populicola
1341	A19-2	South Coast	EVIN	Salmon R. #2/C SL	19	5016	12550	30	S.populicola
1342	A16-5	South Coast	Fraser	Harrison Mill/P.	16	4914	12151	30	S.populicola
1343	A31-3	South Coast	Squamish	Squamish R.lC.	31	5006	12322	177	S.populicola
1344	A165-8	Prince George	McGregor	McGregorR. MCG	165	5411	12200	579	S.populicola
1345	A69-3	Mid Coast	Burke	Bella Coola R./ A.	69	5225	12610	152	S.populicola
1346	A3-1	South Coast	Fraser	Wellington Bar/C.	3	4940	12125	91	S.populicola
1347	A69-4	Mid Coast	Burke	Bella Coola R./ A.	69	5225	12610	152	S.populicola
1348	A48-2	South Coast	Toba Inlet	23 Toba R./A. T	48	5031	12414	67	S.populicola
1349	A142-3	Far North	Taku	Taku River/B	142	5842	13324	49	S.populicola
1350	A38-4	South Coast	Harrison	Lillooet R.IB.	38	5002	12232	213	S.populicola
1352	A38-4	South Coast	Harrison	Lillooet R.IB.	38	5002	12232	213	S.populicola
1353	A106-2	Smithers	Bulkley (Telkwa)	wa)lla Telkwa R.I	106	5437	12730	735	S.populicola
1354	A89-8	Smithers	Skeena	Skeena R.IP. SK	89	5433	12828	61	S.populicola
1355	A13-3	South Coast	Fraser	MatsQui Is.IM. M	13	4907	12220	8	S.populicola
1356	A64-1	Mid Coast	Knight	0 W.Klinaklini R.	64	5118	12546	546	S.populicola
1357	A50-4	South Coast	Phillips	Phillips R./ A.	50	5036	12519	5	S.populicola
1360	A56-4	Mid Coast	Homathko	Homathko R.ID.	56	5117	12450	152	S.populicola

1362	A41-5	South Coast	Squamish	GlacierIB Aha L.	41	5006	12300	579	S.populicola
1380	A156-1	Prince George	Quesnel R.	6 Australian QA	156	5243	12228	442	S.populicola
1382	A18-4	South Coast	EVIN	Salmon R. #IIB. S	18	5013	12549	30	S.populicola
1383	A62-1	Mid Coast	Knight	Klinaklini R.ID.	62	5134	12530	427	S.populicola
1384	A72-1	Mid Coast	Dean	eanR./A. DENA 7	72	5246	12637	213	S.populicola
1386	A62-3	Mid Coast	Knight	Klinaklini R.ID.	62	5134	12530	427	S.populicola
1387	A22-5	South Coast	EVIS	Cassigy/J. CSYJ	22	4904	12352	20	S.populicola
1388	A114-2	Smithers	U. Nass	Nass RIF. NASF	114	5534	12847	152	S.populicola
1389	A67-1	Mid Coast	Rivers	Chuckwalla R.lC.	67	5144	12719	67	S.populicola
1390	A8-4	South Coast	Fraser	Chilliwack R.#l/H.	8	4906	12131	480	S.populicola
1391	A183-1	USA	GS056	Lafayette, OR. LA	183	4512	12305	100	S.populicola
1392	A75-2	Mid Coast	Dean	eanR.lD. DEND 7	75	5249	12657	27	S.populicola
1397	A154-3	Mid Coast	KingcomeR.	20a Atlatzi R.lA.	154	5059	12607	0	S.populicola
1398	A171-5	Prince George	Nechako R.	14 Redmond Cr. A.	171	5406	12426	655	S.musiva
1437	A163-1	Prince George	Fraser R.	WillowR. WLOW	163	5355	12217	640	negative for both Septoria species
1440	A164-1	Prince George	Fraser R.	5 Shelley SHEL	164	5402	12236	564	S.populicola
1442	A87-5	Smithers	Skeena	Skeena R.IN. SK	87	5417	12922	30	S.populicola
1462	A88-2	Smithers	Skeena	Skeena R.lO. SK	88	5413	12932	21	S.populicola
1490	A94-3	Smithers	Kitimat	Kitimat R.lC. K	94	5403	12841	18	S.populicola
1491	A89-4	Smithers	Skeena	Skeena R.IP. SK	89	5433	12828	61	S.populicola
1493	A82-6	Smithers	Skeena	KitwangaIF . KT	82	5505	12811	177	S.populicola
1495	A94-4	Smithers	Kitimat	Kitimat R.lC. K	94	5403	12841	18	negative for both Septoria species

Provenance Trial EP.1123.02.05 Layout

Kilby - Harrison Mills Ct

Fraser River — Fraser Riv

- trees in subsample of Fung, 2012
- trees positive for S. musiva leafspot in 2010 and 2011
- trees positive for S. musiva leafspot in 2011
- trees positive for S. musiva leafspot in 2010
- trees with S. musiva canker in 2010 (isolated by culture)

Spur Road

rep 2 (c36, r29)

	c55	c54	c53	c52	c51	c50	c49	c48	c47	c46	c45	c44	c43	c42	c41	c40	c39	c38	c37	c36
r30																				
r29																				rep 2
r28																				
r27																				
r26								rep 3								1130	1129	X	1079	X
r25	1514	1467	1466	X	1418	1371	1370	1323	1322	1275	X	1227	X	1179	1178	1131	1128	1081	1078	1031
r24	1513	1468	1465	1420	X	X	X	1324	1321	X	1273	1228	1225	1180	1177	1132	X	1082	1077	1032
r23	1512	X	X	1421	1416	1373	1368	1325	X	1277	1272	1229	1224	X	1176	1133	1126	1083	1076	1033
r22	X	1470	1463	1422	X	1374	1367	1326	1319	1278	1271	1230	1223	1182	1175	1134	1125	1084	1075	1034
r21	1510	1471	1462	1423	1414	1375	1366	1327	1318	1279	1270	1231	1222	1183	X	1135	1124	1085	1074	1035
r20	1509	1472	1461	1424	1413	X	1365	1328	1317	1280	1269	1232	X	1184	X	1136	1123	1086	1073	1036
r19	1508	1473	X	X	X	1377	1364	1329	1316	1281	1268	1233	X	X	1172	1137	1122	X	1072	X
r18	1507	1474	1459	1426	1411	1378	1363	1330	X	1282	1267	X	1219	1186	1171	1138	1121	X	X	1038
r17	1506	1475	1458	1427	1410	1379	1362	1331	1314	1283	X	1235	1218	1187	X	1139	X	1089	1070	1039
r16	1505	1476	1457	1428	1409	1380	X	1332	1313	1284	1265	1236	1217	1188	X	X	1119	1090	1069	1040
r15	1504	X	1456	1429	1408	X	1360	1333	1312	1285	1264	1237	1216	1189	1168	1141	1118	1091	1068	1041
r14	1503	X	X	1430	X	1382	1359	X	X	1286	1263	1238	1215	1190	1167	1142	X	1092	X	1042
r13	1502	1479	1454	1431	X	1383	X	X	X	1287	1262	1239	1214	1191	1166	1143	1116	1093	1066	X
r12	1501	1480	1453	1432	1405	1384	1357	1336	1309	1288	1261	1240	1213	1192	1165	1144	1115	1094	1065	1044
r11	1500	1481	X	1433	1404	1385	1356	1337	1308	1289	X	1241	1212	1193	1164	1145	1114	1095	1064	X
r10	1499	1482	X	1434	1403	1386	1355	1338	1307	1290	1259	1242	1211	1194	1163	1146	X	1096	1063	1046
r9	X	X	1450	X	1402	1387	1354	1339	X	1291	1258	1243	1210	1195	1162	1147	1112	1097	1062	1047
r8	X	1484	1449	1436	1401	1388	1353	1340	X	1292	1257	1244	1209	1196	1161	1148	1111	1098	1061	1048
r7	X	1485	1448	1437	1400	1389	1352	1341	1304	1293	1256	1245	1208	1197	1160	1149	1110	1099	1060	1049
r6	1495	1486	X	X	1399	1390	X	1342	1303	X	X	1246	1207	1198	1159	1150	1109	1100	1059	1050
r5	1494	1487	1446	1439	1398	1391	1350	1343	1302	X	1254	1247	X	1199	1158	1151	1108	1101	1058	1051
r4	1493	1488	1445	1440	1397	1392	1349	1344	1301	1296	X	1248	1205	1200	1157	1152	1107	1102	1057	X
r3	1492	1489	1444	X	1396	1393	1348	1345	X	1297	X	1249	1204	1201	1156	1153	1106	1103	X	1053
r2	1491	1490	1443	1442	1395	1394	1347	1346	1299	1298	1251	1250	1203	1202	1155	1154	1105	X	1055	1054
r1								rep 3												
	c55	c54	c53	c52	c51	c50	c49	c48	c47	c46	c45	c44	c43	c42	c41	c40	c39	c38	c37	c36

rep 2 (above c21)

	c35	c34	c33	c32	c31	c30	c29	c28	c27	c26	c25	c24	c23	c22	c21	c20	c19	c18	c17
r30		991	990	931	X	871	870	811	810	751	750	X	X	631	630	571	570	511	510
r29		992	989	932	929	872	869	812	809	752	749	692	689	632	629	X	569	512	509
r28		993	988	933	X	X	868	X	808	753	748	693	X	633	628	573	568	X	508
r27		994	987	934	927	874	867	814	807	754	747	694	687	634	627	574	567	514	507
r26		995	986	935	926	X	866	X	X	X	X	695	686	635	626	X	X	515	506
r25		996	985	X	925	876	865	X	805	756	745	696	685	636	X	576	565	516	505
r24		997	984	937	924	877	864	817	804	757	744	697	684	637	624	577	564	517	X
r23		998	983	938	923	878	863	818	803	758	743	698	683	638	623	578	X	518	503
r22		999	982	939	922	879	862	819	802	759	742	699	682	639	622	579	562	519	502
r21		X	981	940	921	880	861	820	801	760	741	700	681	640	621	580	561	520	501
r20		1001	980	X	920	881	860	821	800	761	740	701	680	X	620	581	560	521	500
r19	1029	X	X	942	919	882	X	822	799	762	X	702	679	642	619	582	X	522	X
r18	X	1003	978	943	918	883	858	823	798	X	738	703	678	X	618	583	X	523	X
r17	1027	1004	X	944	917	884	857	824	797	764	737	704	677	644	617	584	557	524	497
r16	1026	X	976	X	916	X	856	X	796	765	736	705	676	645	616	585	556	X	X
r15		1006	975	946	X	886	855	X	X	X	735	706	675	646	615	586	555	526	495
r14		1007	974	X	X	X	854	827	794	X	X	X	674	647	614	587	554	527	494
r13		X	973	948	913	888	853	828	793	768	733	X	673	648	613	588	553	528	493
r12		X	972	949	912	889	852	829	X	X	732	709	672	649	612	X	552	529	X
r11		1010	971	950	911	890	851	830	791	770	X	X	X	X	X	590	X	530	491
r10		1011	970	951	910	X	850	831	790	771	730	711	670	651	610	591	550	531	490
r9		1012	969	952	909	892	849	832	789	772	729	X	669	652	609	592	549	532	489
r8		1013	968	953	908	893	848	833	788	773	X	713	668	653	X	593	548	533	488
r7		1014	967	954	907	894	X	X	787	774	727	714	667	654	607	594	547	534	487
r6		1015	966	955	906	X	846	835	786	775	726	715	666	655	X	X	546	535	486
r5	X	1016	965	X	905	896	845	836	785	776	X	716	665	656	605	596	545	536	485
r4	1024	1017	964	957	904	897	844	837	784	X	724	717	664	X	604	X	544	X	X
r3	1023	1018	963	958	903	898	843	838	783	778	723	718	663	658	603	598	543	X	483
r2	1022	1019	962	959	902	899	842	839	782	779	722	719	662	659	602	599	542	X	482
r1	1021	1020	961	960	901	900	841	840	781	780	721	720	661	660	601	X	541	X	481
	c35	c34	c33	c32	c31	c30	c29	c28	c27	c26	c25	c24	c23	c22	c21	c20	c19	c18	c17

rep 1 (below c21)

EP.1123.02.05

Kilby - Harrison Mills Ct

er **Fraser River**

Spur Road

c16	c15	c14	c13	c12	c11	c10	c9	c8	c7	c6	c5	c4	c3	c2	c1	
451	450	391	390	331	330	271	270	211	210	151	150	91	90	31	30	r30
452	449	392	389	332	329	272	X	X	209	152	149	92	89	32	29	r29
453	448	393	388	X	328	273	268	213	208	X	X	93	88	33	28	r28
X	X	X	387	334	327	274	X	214	207	X	X	94	X	X	27	r27
455	446	395	386	335	326	275	266	215	206	155	146	95	X	35	26	r26
456	445	396	385	336	325	276	265	216	205	X	145	96	85	36	25	r25
457	444	397	384	337	324	277	264	217	204	157	144	97	84	X	X	r24
458	443	398	X	338	323	278	263	X	X	158	143	98	X	X	23	r23
459	442	399	382	X	322	279	X	219	202	X	142	99	X	39	22	r22
X	441	400	381	340	321	280	261	220	201	X	X	X	81	40	21	r21
461	X	401	380	341	320	281	260	221	200	X	X	X	X	X	20	r20
X	439	402	X	342	319	282	259	222	199	X	X	102	79	42	19	r19
X	X	X	X	343	X	283	X	223	X	163	X	X	78	43	18	r18
464	X	404	377	344	317	284	257	224	197	164	X	104	77	44	X	r17
X	X	405	376	345	316	285	X	225	196	X	136	105	76	45	16	r16
X	435	406	375	346	315	286	255	226	195	166	135	106	75	46	15	r15
467	434	407	374	347	314	287	254	X	194	167	134	107	74	47	14	r14
468	433	408	373	348	313	288	253	228	193	168	133	108	73	48	13	r13
469	432	409	372	349	X	X	252	229	192	169	132	109	72	49	12	r12
470	431	410	X	350	311	290	251	230	X	170	131	110	71	50	11	r11
471	430	411	370	351	310	291	250	231	190	X	130	111	70	51	10	r10
X	429	X	369	X	309	292	X	X	189	X	129	112	X	52	9	r9
473	428	X	368	353	308	293	X	X	188	173	X	113	68	53	8	r8
474	X	414	367	354	307	294	X	234	187	X	X	114	67	54	7	r7
475	X	X	X	X	X	295	X	235	186	175	126	115	66	55	X	r6
476	425	X	365	356	305	X	245	236	185	176	X	116	65	56	X	r5
X	424	X	364	357	304	297	X	237	184	177	124	117	X	57	4	r4
478	X	418	363	X	303	X	243	238	183	X	123	118	63	58	X	r3
479	X	419	362	X	302	299	X	239	182	X	122	X	X	59	2	r2
480	421	420	361	360	301	X	241	X	181	180	121	120	61	60	1	r1
c16	c15	c14	c13	c12	c11	c10	c9	c8	c7	c6	c5	c4	c3	c2	c1	

Spur Road

rep 6

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20	c21	c22
r37											1883	X	1957	X	X	2032	2495	2496	X	X	2531	2532
r36					X	1663	1734	1735	1808	X	X	1885	1956	X	2030	2033	2494	2497	X	2515	2530	2533
r35					1661	1664	1733	1736	1807	1810	X	X	1955	1960	2029	X	2493	2498	2511	X	2529	X
r34					1660	X	X	1737	X	1811	X	1887	1954	1961	2028	X	X	X	X	X	2528	X
r33					1659	1666	1731	1738	1805	1812	1879	1888	1953	1962	2027	X	X	2500	X	X	2527	2536
r32					1658	X	1730	1739	1804	1813	1878	X	1952	1963	2026	2037	X	X	X	X	2526	2537
r31					1657	1668	1729	X	X	X	1877	1890	1951	1964	2025	2038	X	2502	X	2520	X	X
r30					1656	1669	1728	1741	1802	X	1876	X	1950	X	2024	X	2488	2503	2506	2521	2524	X
r29					1655	1670	X	X	X	1816	1875	1892	1949	1966	2023	2040	2487	X	X	X	X	2540
r28	X	1543	1598	1599	1654	1671	1726	1743	1800	1817	1874	1893	1948	1967	X	2041	r28					
r27	1541	X	1597	1600	1653	1672	1725	X	1799	X	1873	X	1947	X	X	2042	r27					
r26	1540	X	1596	1601	1652	1673	X	1745	1798	1819	1872	X	1946	X	2020	X	r26					
r25	1539	X	1595	X	1651	1674	1723	1746	1797	1820	1871	1896	1945	1970	2019	X	r25					
r24	1538	X	X	X	1650	1675	1722	1747	X	X	1870	1897	1944	1971	2018	X	r24					
r23	1537	X	1593	1604	X	1676	1721	X	1795	1822	1869	1898	X	1972	X	X	r23					
r22	1536	1549	1592	1605	X	1677	X	1749	1794	X	1868	1899	X	1973	2016	2047	2090	2091	r22			
r21	1535	1550	X	1606	1647	1678	1719	1750	1793	1824	X	1900	1941	1974	2015	2048	X	2092	r21			
r20	1534	X	1590	1607	1646	1679	1718	1751	X	1825	1866	X	1940	X	2014	2049	2088	2093	r20			
r19	1533	1552	1589	X	1645	X	1717	X	1791	1826	1865	X	X	1976	2013	2050	2087	2094	r19			
r18	X	1553	1588	1609	X	1681	1716	1753	1790	1827	1864	1903	1938	1977	2012	2051	2086	2095	r18			rep 5
r17	1531	1554	X	1610	1643	1682	X	1754	1789	1828	1863	X	1937	1978	2011	2052	2085	2096	r17			
r16	X	1555	1586	1611	1642	X	1714	1755	1788	1829	1862	1905	X	1979	2010	X	2084	2097	2128	X	2160	2161
r15	1529	1556	1585	1612	1641	1684	1713	1756	1787	1830	X	1906	1935	1980	2009	2054	2083	2098	2127	2130	2159	2162
r14	1528	X	1584	1613	1640	1685	1712	1757	1786	X	1860	1907	1934	1981	2008	X	2082	X	2126	2131	2158	2163
r13	X	1558	1583	1614	X	1686	1711	1758	1785	1832	1859	1908	1933	1982	2007	X	2081	X	2125	2132	2157	X
r12	1526	1559	1582	1615	1638	X	1710	1759	1784	1833	1858	X	1932	1983	2006	2057	2080	2101	2124	2133	X	2165
r11	X	1560	1581	1616	1637	X	1709	X	1783	1834	1857	X	1931	1984	2005	2058	2079	2102	2123	2134	2155	2166
r10	1524	1561	1580	1617	1636	X	X	1761	X	1835	1856	1911	X	1985	2004	2059	2078	2103	2122	2135	2154	2167
r9	X	1562	1579	1618	1635	X	1707	1762	X	X	1855	1912	1929	X	X	X	X	X	2121	2136	2153	X
r8	1522	1563	1578	X	1634	X	1706	1763	X	X	1854	1913	1928	X	2002	2061	X	X	X	2137	X	2169
r7	1521	1564	1577	X	X	X	1705	1764	1779	1838	1853	1914	1927	X	2001	X	2075	2106	2119	2138	X	2170
r6	1520	1565	1576	1621	1632	X	1704	1765	1778	1839	1852	1915	1926	1989	X	2063	2074	X	2118	X	X	X
r5	X	1566	1575	X	1631	X	1703	X	1777	1840	X	1916	1925	1990	1999	2064	2073	2108	X	X	2149	2172
r4	1518	1567	1574	1623	1630	1695	1702	X	1776	1841	1850	1917	1924	X	1998	2065	2072	X	2116	2141	2148	X
r3	1517	X	1573	1624	1629	X	1701	X	1775	1842	X	1918	1923	1992	X	2066	X	2110	2115	2142	2147	2174
r2	1516	X	1572	1625	1628	1697	X	1769	1774	1843	X	X	1922	1993	X	2067	X	2111	X	X	X	X
r1	X	X	X	X	1627	1698	X	1770	X	X	1847	1920	X	1994	1995	2068	2069	2112	2113	2144	X	X
	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20	c21	c22

rep 4

Fraser River | **Fraser River**

c23	c24	c25	c26	c27	c28	c29	c30	c31	c32	c33	c34	c35	c36	c37	c38	c39	c40	c41	c42	c43	c44
X	2550	2567	2568	2585	2586	2603	X	2621	2622	2639	2640	2657	2658	2675	X	2693	2694	2711	2712	2729	2730
2548	2551	2566	X	X	X	2602	2605	X	2623	2638	X	2656	X	2674	X	2692	2695	2710	2713	X	2731
2547	X	X	2570	X	2588	2601	2606	2619	2624	2637	2642	2655	2660	2673	2678	X	X	X	2714	X	2732
2546	X	2564	2571	2582	2589	2600	2607	2618	2625	2636	X	2654	2661	X	X	X	X	X	X	2726	2733
2545	X	X	2572	X	2590	2599	2608	2617	X	X	X	X	2662	2671	2680	2689	X	2707	2716	2725	2734
2544	X	X	X	2580	2591	2598	2609	2616	X	2634	2645	2652	X	X	X	2688	2699	2706	X	2724	2735
X	X	X	2574	X	2592	2597	2610	X	2628	2633	2646	2651	X	X	2682	X	X	2705	2718	X	X
2542	2557	2560	2575	2578	X	2596	X	2614	X	2632	X	2650	2665	2668	2683	X	X	2704	2719	X	2737
2541	X	2559	X	2577	2594	2595	2612	2613	2630	2631	2648	X	2666	X	2684	2685	X	2703	X	X	X

rep 6

rep 7

c45	c46	c47	c48	c49	c50	c51	c52	c53	c54	c55	c56	c57	c58	c59	c60	c61	c62	c63
X	X	2768	2769	X	X	X	2817	X	X	2864	2865	2888	2889	2912	X	2936	X	X
X	2749	2767	2770	X	X	X	X	X	X	X	2866	2887	X	X	2914	X	X	X
X	2750	2766	X	2790	X	2814	2819	X	X	2862	X	X	X	X	X	2934	X	2958
X	X	2765	X	2789	X	2813	2820	X	2844	X	X	2885	X	2909	X	2933	X	2957
2743	2752	2764	X	X	2797	2812	2821	X	X	2860	X	X	2893	2908	2917	X	X	X
X	2753	X	2774	X	X	X	2822	X	X	2859	2870	2883	2894	X	2918	X	X	X
X	2754	X	X	X	X	X	X	2834	2847	X	2871	X	X	2906	X	2930	X	X
2740	2755	2761	X	X	X	X	X	2833	2848	2857	X	2881	2896	2905	2920	X	X	2953
X	X	X	2777	2784	2801	2808	X	X	2849	2856	2873	2880	2897	2904	X	X	2945	2952
		X	2778	2783	2802	2807	X	2831	2850	X	2874	X	2898	2903	2922	2927	X	X
		2758	2779	X	2803	X	2827	2830	2851	2854	2875	2878	2899	2902	2923	2926	X	X
		2757	2780	X	2804	X	2828	2829	2852	2853	2876	X	2900	X	2924	2925	2948	2949

rep 7

rep 4

	c23	c24	c25	c26	c27	c28	c29	c30	c31	c32	c33	c34	c35
r16	2192	2193	2224	2225	2256	2257	2288	2289	2320	2321	X	X	X
r15	2191	2194	2223	2226	2255	X	2287	2290	2319	2322	2351	2354	2383
r14	2190	X	2222	2227	2254	X	X	2291	2318	2323	2350	2355	2382
r13	2189	X	2221	2228	2253	2260	X	2292	2317	2324	2349	2356	2381
r12	2188	2197	2220	2229	2252	2261	2284	2293	2316	2325	2348	2357	2380
r11	X	2198	2219	2230	2251	2262	2283	2294	2315	2326	2347	2358	X
r10	X	2199	2218	2231	X	2263	2282	2295	X	X	2346	2359	2378
r9	2185	2200	2217	X	2249	2264	2281	2296	X	2328	2345	2360	2377
r8	2184	2201	2216	2233	2248	2265	2280	X	X	2329	2344	2361	X
r7	2183	2202	2215	2234	2247	X	X	X	2311	X	2343	X	X
r6	2182	2203	2214	2235	2246	2267	2278	2299	2310	X	2342	2363	2374
r5	X	2204	2213	2236	X	X	2277	2300	2309	2332	X	X	2373
r4	2180	2205	2212	2237	2244	2269	2276	2301	2308	X	X	2365	2372
r3	2179	2206	X	X	2243	2270	2275	X	X	X	2339	X	2371
r2	X	X	2210	X	X	X	2274	X	X	X	X	X	2370
r1	2177	2208	2209	X	2241	2272	2273	X	X	2336	2337	2368	X

	c36	c37	c38	c39	c40	c41	c42	c43	c44	c45	c46
r10	2385	2404	2405	2424	X	2444	2445	2464	2465	2484	
r9	2386	2403	2406	2423	2426	2443	2446	2463	2466	X	
r8	2387	X	2407	X	2427	2442	2447	2462	X	X	
r7	2388	2401	2408	2421	2428	X	2448	2461	2468	2481	
r6	2389	2400	X	2420	2429	2440	2449	2460	X	2480	
r5	2390	2399	2410	X	2430	2439	2450	2459	X	2479	
r4	2391	2398	2411	2418	2431	2438	2451	2458	2471	2478	
r3	2392	X	2412	2417	2432	2437	2452	2457	2472	2477	
r2	2393	2396	2413	2416	2433	2436	X	2456	X	X	X
r1	2394	2395	2414	X	2434	2435	2454	2455	2474	X	2486

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c64	c65	c66	c67	c68	c69	c70	c71	c72	c73	c74	c75	c76	c77	c78	c79	c80	c81	c82	c83	c84	c85	c86	c87	c88	c89	
X	X	X	X	X	3032	X	X	X	X	X	3104	X	X	X	X	X	3176	X	X	X	3224	X	X	X	X	r37
X	X	X	3007	3010	X	X	X	3058	X	X	X	X	X	X	X	X	X	X	X	3202	X	X	3247	X	X	r36
X	X	2987	X	X	3030	X	X	X	X	X	X	X	X	X	X	3155	X	X	X	X	X	X	X	X	X	r35
X	X	X	X	3012	X	3036	X	X	X	X	X	X	X	X	X	X	X	X	3197	3204	X	3228	X	X	X	r34
X	X	2989	X	X	X	3037	3052	X	3076	X	3100	3109	X	X	X	X	X	3181	X	3205	X	3229	3244	X	X	r33
X	X	2990	X	X	X	X	X	X	3075	X	X	3110	3123	3134	3147	X	X	X	3195	X	X	3230	X	3254	X	r32
X	X	X	X	3015	X	X	3050	X	X	3087	X	X	X	3135	X	X	3170	X	3194	3207	X	3231	3242	X		r31
X	X	X	3001	3016	X	X	X	X	X	X	X	X	X	X	X	X	3169	X	X	X	3217	X	X	X		r30
X	2976	X	3000	3017	3024	3041	X	3065	X	X	3096	X	X	X	X	3161	3168	X	X	3209	3216	X	X	X		r29
X	2975	2994	2999	X	3023	X	X	3066	X	X	X	X	3119	3138	X	3162	X	X	3191	3210	X	3234	3239	X		r28
2971	2974	2995	2998	3019	X	3043	X	X	X	X	X	3115	3118	3139	3142	3163	3166	X	3190	X	3214	3235	X	X		r27
2972	X	2996	2997	3020	X	3044	X	3068	3069	3092	X	3116	3117	X	3141	X	3165	3188	3189	X	3213	3236	X	3260		r26

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