AN INVESTIGATION ON THE OCCURRENCE OF THE PATHOGEN *SIROCOCCUS CONIGENUS* INFECTING NATURAL AND PLANTED RED PINE AT THE HOGARTH PLANTATION

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An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Science in Forestry

Faculty of Natural Resources Management

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ABSTRACT

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Sirococcus conigenus is a pathogen common in forests of the northern temperate zone and is the causal agent of deertail disease or *Sirococcus* shoot blight on red pine. This disease has been present on red pine at the Hogarth Plantation in Thunder Bay, Ontario for several years in an area of natural regeneration parallel to the 8-year old planted red pine. Red pine is a commercially important species and holds educational value for Lakehead University so this investigation took place to assess if the disease had spread or has the potential to significantly spread into the planted stock. The investigation confirmed that the natural red pine is being heavily impacted by the disease, most likely due to their location under overstory red pines that are suspected to be infected with *S. conigenus*. It was revealed that there was no major spread into the planted stock, other than a few planted pines that were infected because they were close enough or intermingled with infected trees.

CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

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INTRODUCTION AND OBJECTIVES

Sirococcus conigenus (DC.) P.F. Cannon & Minter, formerly known as *Sirococcus stobilinus* Preuss, causal agent of deertail disease/*Sirococcus* shoot blight on red pine (*Pinus resinosa* Aiton) is a relatively common disease of red pine, and other conifers (Sinclair *et al.,* 1987; Myren, 1994; Hansen & Lewis, 1997). An image of the disease on red pine at the Hogarth Plantation is seen below in Figure 1.

Figure 1. Red pine shoot at the Hogarth Plantation infected by *S. conigenus*

It can be a significant issue in young plantations or during seedling production. Infection on red pine results in the death of current-year shoots, ultimately leading to less vigorous pines and severe disfigurement to tree form. Lakehead University's Hogarth Plantation is the area where the research for this thesis was conducted. The plantation is a 44-hectare parcel of land gifted to the university in 2003 from Dr. Walter Hogarth. This is an excellent site that the university's Natural Resources Management faculty utilizes for a number of educational purposes. Unfortunately, in 2009 a fire burned a majority of the plantation and new red pine seedlings were planted in the burned area. The natural regeneration of red pine near the fence line, adjacent to the planted stock are all quite heavily infected with the disease. Most of these saplings are all growing along the fence line in very close proximity to the planted red pine, that replaced the older forest that grew before it.

The disease can be easily spread through young plantations and significant damages can be incurred after repeated years of infection on current year shoots (Sinclair *et al.,* 1987). It is always in the best interests of woodlot managers to have healthy, disease-free forests and it would be no exception for Lakehead University to want to preserve the economic, educational and ecological value of the trees at the Hogarth Plantation. The main concern was that the planted stock would become heavily infected with the disease rendering the plantation economically worthless.

The research and data collection for this thesis will revolve around studying the presence of *S. conigenus* and its degree of severity at the Hogarth Plantation and if the disease has spread from where it is known to be (on the naturally regenerated red pine) to the planted red pine. A discussion will revolve around the factors that contribute to the basic spread of forest pathogens and specifics on the spread of *S. conigenus* itself and how factors at the Hogarth Plantation influence the spread. The literature will be used to come to conclusions that outline why the pathogen has or has not infected the new plantation. The conclusions drawn from this thesis will be significant in furthering the understanding of the dynamics and effects of this disease on its hosts. Findings will be valuable to those who manage the Hogarth Plantation and similar plantations/forests to make decisions regarding disease control and vegetation management. It can be predicted that *S. conigenus* has most likely spread into the planted stock in areas where crowns of infected trees are intermingled or in close proximity.

REVIEW OF THE LITERATURE

Pathogen Description and Taxonomy

The pathogen *Sirococcus conigenus* (Deuteromycota, Coelomycetes) was first described in the mid-1800s and named *S. strobilinus* (Sinclair *et. al.,* 1987). Species within the genus *Sirococcus* are classified within a large group called the Fungi Imperfecti, in which reproduction occurs asexually while sexual reproduction is unknown (Schlarbaum *et al,* 1998). Over 30 species of *Sirococcus* have been described from across the world, although many of these have not been described in-depth in recent literature (Rossman *et al.,* 2007). *Sirococcus conigenus* however, is a pathogen that has been studied and described extensively by researchers throughout North America and Europe, due to the damaging shoot blight it induces on ornamental and commercially desired tree species.

Pathogen Hosts and Range

Sirococcus conigenus has a wide host range of conifers across the temperate northern hemisphere where it is most prolific on species of *Pinus, Tsuga*, *Picea* and *Calocedrus* (Farr *et. al.*, 1989). Other literature states it also infects species of *Abies, Larix* and *Pseudotsuga* (Rossman *et al*., 2007). The pathogen is also said to occur locally in some regions of Africa and Asia (Kowalski, 2010). Studies have shown that red pine (*Pinus resinosa*) is one of the most highly susceptible species to *S. conigenus* (Ostry *et. al*. 1990). Other species that are high on the scale of susceptibility to the pathogen include western hemlock, Jeffery pine, ponderosa pine, blue spruce and sitka spruce (Sinclair *et. al.,* 1987).

Signs and Symptoms of Disease

On pine shoots, the first symptoms of infection from this pathogen occur on or adjacent to needle bases on new shoots, where small purplish lesions develop with a drop of resin at the point of inoculation about 2 weeks after the initial infection (Sinclair *et. al.,* 1987). New infections are primarily confined to the area of shoot elongation, which results in growth stoppage on the infected shoots (Sinclair *et. al.,* 1987). This halt in growth causes the infected shoot to bend conspicuously in a downwards direction, resembling that of a deer tail, shepherd's crook or lion's tail (Sinclair *et. al.,* 1987, Myren, 1994; Hansen & Lewis, 1997; Maine Forest Service, 2018). Shoot death and needle droop become most noticeable in June and continue into August (Sinclair *et. al.,* 1987). On 1st-year seedlings, symptoms become apparent in late summer and autumn, and in a matter of several days to a few weeks the infection girdles the shoot causing the tip to die and appear brown in colour (Sinclair *et. al.,* 1987). Red pine seedlings in their 1st-year of growth are highly susceptible to mortality from this pathogen (Sinclair *et. al.,* 1987).

As the shoots become infected, asexual fruiting bodies called pycnidia develop on the bases of killed needles and along the stem of infected shoots, most commonly found in abundance on red pine beneath the basal sheaths of drooping needles (Sinclair *et. al.,* 1987). The colour of the pycnidia first appear brown and blacken with age (Sinclair *et. al.,* 1987). Pycnidia average size is 100 µm in diameter, and are often much larger when found on the bases of red pine needles (Sinclair *et. al.,* 1987).

Pathogen Mechanisms of Infection

Understanding the biology and life cycle of *Sirococcus conigenus* is paramount to making connections between disease severity on its hosts. The pathogen survives and overwinters on ground debris such as needles and stems, and on cones on infected trees (Cram *et. al*, 2012). Spores are most abundant in the spring, coinciding with bud break on host species (Cram *et. al*, 2012). The pathogen thrives in higher moisture conditions that are required for spores to emerge from fruiting bodies and be distributed primarily by rain splash or sometimes by wind (Government of Canada, 2020). Infections develop readily when conidia are deposited on susceptible vegetation that remains wet for at least 24 hours in temperatures between 10 degrees to 25 degrees Celsius, with the most favourable temperatures for the disease between 16 degrees to 20 degrees Celsius. It has also been noted that lower light conditions do favour the development of this pathogen, as light-stressed trees are more susceptible to inoculation (Wall and Magasi, 1976; NRCAN, 2011)

In a study conducted by Ostry *et. al* (1990), *S. conigenus* impacts were observed among three different sites with similar climate. The study areas were in Wisconsin's Highland State Forest, Nicolet National Forest and Minnesota's Superior National Forest, all of which have a very similar climate to Thunder Bay. Their study aimed to analyze the susceptibility of the host trees to this pathogen by tracking information regarding how many spores of the pathogen were present in certain areas at a certain time with regards to shoot development on host trees. By trapping spores on microscope slides placed in various locations and different proximities to infected trees and later counting the number of *S. conigenus* spores present, they were able to track and determine when the spores were being released and how far the pathogen's spores travel at these locations. The research found that majority of the spore release occurred in May and June and peaked well before the maturation of current year shoots, which occurred in late June to early July across all three locations (Ostry *et. al*, 1990). This is a function of the pathogen that allows for it to have the most profound effect on its hosts, as it can only infect succulent, barely lignified current year shoots (NRCAN, 2015).

The effects of this pathogen have been described as cumulative, as current year shoots are killed, however, not all in the same year, giving opportunity for further infection in future years (O'Brien, 1973). The research by Ostry *et al.,* (1990) also showed how much the pathogen relies on rain splash for dispersal of its spores. The experiment utilized four hundred 8-year-old red pine saplings at the Nicolet National Forest where the spore traps were placed at a variety of distances from an infected tree and were used to track spore dispersal. It was shown that 40% of the spores travelled within 0 to 3.0 metres from the infected tree, 50% travelled 3.1 to 6.0 metres from the infected tree and at 6.1 to 9.0 metres feet, 6% of the spores were found. All remaining distances up to 21 metres made up the remaining 4% of spore dispersal. This showed how wet weather contributes to the release of spores because only on the traps exposed during rainfall were spores found, and the small amount dispersed between 9 metres to 21 metres can be attributed to strong winds (Ostry *et al*, 1990).

Disease severity is also highly dependent upon stand structure and host surroundings (*i.e.* even/uneven-aged, open-grown). The study by Ostry *et al.,* (1990) showed that younger red pine growing under an infected canopy (uneven-aged) at one of the sites displayed a 48% mortality, while open-grown pines were not impacted whatsoever by the pathogen. At the other site, only 5 of the 200 marked open-grown pines were infected while 140 of 200 pines in the understory of an infected stand were infected with *S. conigenus* (Ostry *et. al.,* 1990). This showed an obvious link between high mortality rates of younger trees in uneven aged stands. Another study done in Wisconsin's Highland State National Forest by Bronson and Stanosz (2006) involved planting red pine beneath an infected overstory. Results of this experiment confirmed the conclusions made by the Ostry *et. al*. (1990) study that drew parallel conclusions stating that *S. conigenus* poses a significant threat to pine regeneration growing in an infected multicohort stand (Bronson and Stanosz, 2006).

It has also been discovered that *S. conigenus* is a seed-borne pathogen (Stanosz, n.d.). This means that seeds may contain spores on the surface of the seed coat or internally which can contaminate and destroy the endosperm and the embryo of seeds, which can lead to significant stunting or a complete halt in seedling germination and development (Cram and Fraedrich, 2010). Seedborne pathogenicity is said to be responsible for most of the losses to *S. conigenus* in container nurseries (Cram and Fraedrich, 2010). During cone harvests, too many older cones, which have a higher chance of containing seedborne pathogens, can be inadvertently collected leading to post-germination infection (Sutherland *et. al.*, 1981). Disease incidence may also be related to seed source. In a Canadian lodgepole pine nursery infected with *S. conigenus*, the seedlings that were most commonly blighted were grown from seeds sourced from Washington and southern British Columbia (Sinclair *et. al.*, 1987). This suggests that some seeds may show resistance to the pathogen pre and post-germination.

Control

With it being confirmed that *Sirococcus conigenus* can pose a risk to regeneration efforts under certain conditions, it is important for forest managers to know what can be done to assist regeneration. Two main methods of control were described in the literature that involve the physical removal of infected vegetation and chemical control. The Ostry *et. al.* (1990) study tested some fungicides and it was shown that chlorothalonil and folpet provided the best chemical control when applied in late May (Ostry *et al*., 1990). The same study tested the removal of infected shoots in an open area and also tested removing overstory red pine in another area while also removing infected shoots on understory trees. Both of these tests displayed how it is an effective way to significantly reduce the spread and cumulative effects of the disease, however, it is rather labour intensive (Ostry *et. al.,* 1990). The common themes described in the literature with regards to management and control state that regeneration success is hindered if host species are regenerating close in proximity to other infected host species, specifically in the understory (Haugen and Ostry, 2013).

Preventative Measures

The best way to combat the fungus is to create conditions in which it can not thrive. As mentioned in sections above, the fungus takes advantage of cool, damp, low light conditions, so if one is given the opportunity to establish a plantation from the ground-up, when it comes time to plant the trees, ensure that they are planted at spacings according to the mature size. This is to allow the most possible sunlight and air movement through a plantation, which circulates possibly contaminated air but dries out susceptible plant material (Koetter and Grabowski, 2019). Frequent and regular monitoring is critical in the prevention of infection to allow flexibility in developing a suitable management strategy (Maine Forest Service, 2018). Stands should be adequately thinned even in stands with trees that would not be considered large enough for thinning treatments. The Maine Forest Service states that thinning treatments to prevent *S. conigenus* infection should be limited to stands with an average live crown ratio greater than 40% (Maine Forest Service, 2018). In some high-value plantations with a history of *S. conigenus* infections, if there is a period of prolonged wet and humid weather in the forecast, then a preventative fungicide application is recommended in some cases to get a proverbial head start on mitigating disease impacts (Koetter and Grabowski, 2019). To prevent any chance of infection in a plantation from the pathogen a viable option would be to plant conifer species that have shown resistance to *S. conigenus*. Austrian pine, white pine and balsam fir have all remained healthy when exposed to spores from infected red pines (Sinclair *et. al.*, 1987).

MATERIALS AND METHODS

The research for this project involved documenting a variety of parameters on

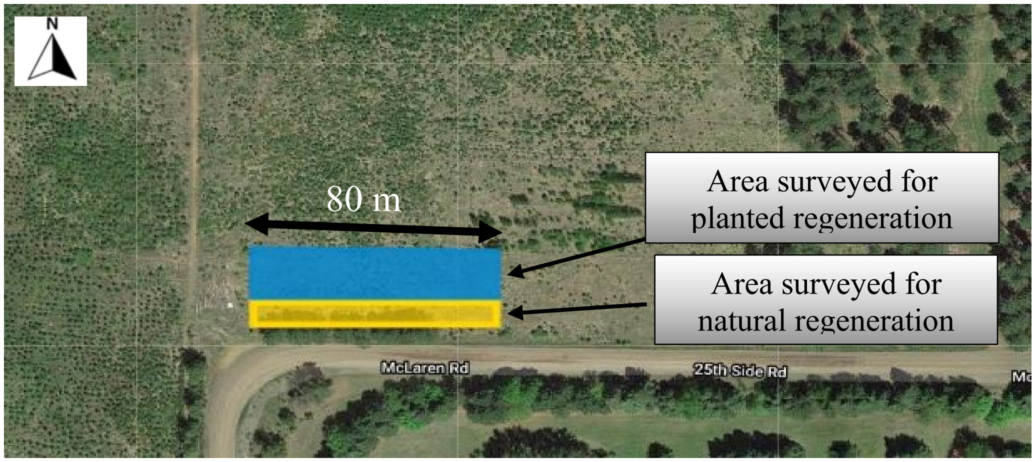


Figure 2. Aerial satellite view of section of Hogarth Plantation with study areas highlighted

Map Source: Google MyMaps

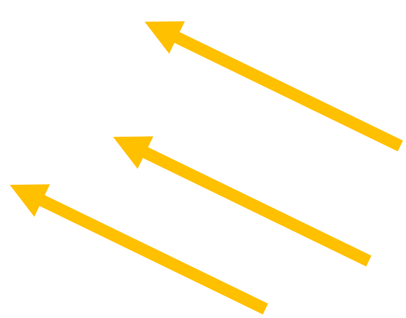
sampled *Pinus resinosa* saplings in the Hogarth Plantation in October of 2019. An aerial satellite view of the study area is seen in Figure 2. The first step of the data collection involved marking the infected trees within the area of natural regeneration. Determining if the red pines were infected with *Sirococcus conigenus* involved examining each tree for common symptoms of the disease such as the characteristic wilted needles with visible pycnidia located on the abaxial side. The area of natural regeneration that was studied covers approximately 0.1 hectares and is located along the southern fence line in the eastern portion of the plantation, just to the north of McLaren Road/25th Side Road.

The area of natural regeneration under study highlighted by the line in Figure 2. Trees were marked with flagging tape (as seen in Figure 3.) and another pass through the walked line was carried out to ensure that the minimal number of seedlings were not missed, so that all infected seedlings were marked for assessment of disease severity.

Disease severity was classified as a percent value of coverage, 0% being no presence of

Figure 3. Some infected naturally regenerated saplings flagged along fence line (yellow arrows pointing to some visible infected shoots)

disease on any shoots and 100% meaning all shoots are infected with *S. conigenus*.



Each infected tree's age was also determined through counting the whorls, which each represent one year's growth on young conifer saplings. After the data was collected for the section of infected natural regeneration along the fence, trees inside the area of planted red pine were sampled for the same parameters (degree of infection and tree age). The area studied within the planted stock covers approximately 0.15 hectares and is highlighted on the map in Figure 1. The inspection of the planted stock was mostly limited to the planted trees within an approximate 3-metre radius from the nearest infected trees located in the area of natural regeneration. However, the rest of the trees approximately up to 20 metres into the planted area were inspected for signs of disease. This was performed to assess if wind-dispersed spores of *S. conigenus* were causing disease further into the planted stock, further away from the area of natural regeneration where the disease appeared to be most rampant. All data was compiled into a spreadsheet for further statistical analysis to show the relationship between the presence of *S. conigenus* in the area of known infection to the presence of the disease, or lack thereof in the planted stock, adjacent to the fence line.

RESULTS

After observation and data collection at the Hogarth Plantation, the evidence confirms the preconceived notion that *Sirococcus conigenus* has heavily impacted the area of naturally regenerating red pine parallel to the fence line along the 25th Sideroad. From the collected sample of 108 naturally regenerated red pine, 54% of the observed trees exhibited characteristics of deertail disease caused by *Sirococcus conigenus*. This distribution is illustrated in the chart seen in Figure 4. See raw data in Appendix I.

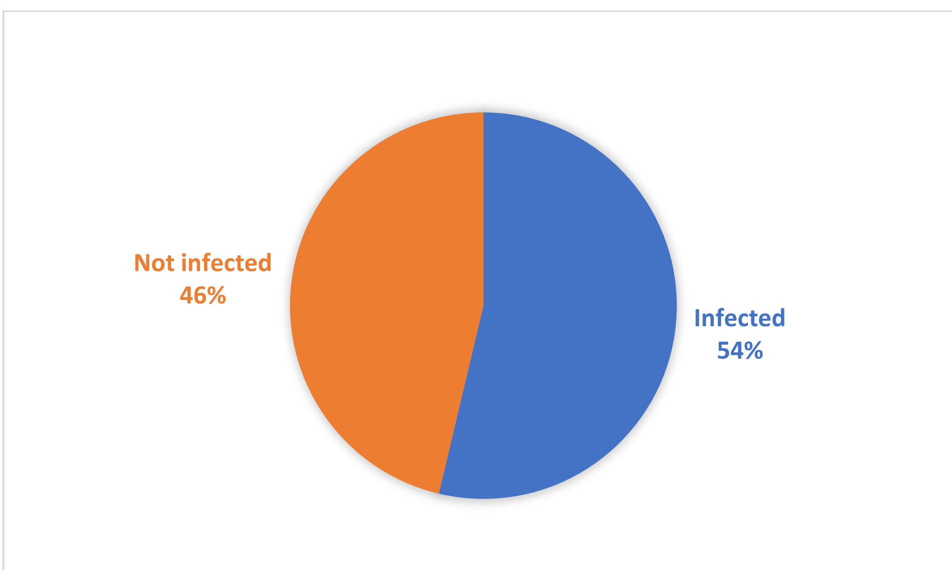


Figure 4. The sampled amount of naturally regenerated red pine infected and not infected with *S. conigenus* at the Hogarth Plantation

From the sample of naturally regenerated red pines that showed signs of infection, there was a variation of disease severities, with some trees only having a small coverage of the disease, while others were fully covered with the disease. Majority of the infected cohort exhibited a low to moderate degree of disease severity. Of the 58 sampled trees showing signs of infection, 35 of them (60%) showed 10-30 percent coverage, 15 trees (26%) showed 40 – 90 percent coverage, and 8 trees (14%) were 100 percent covered with the disease. These findings are illustrated in the graph in Figure 5.

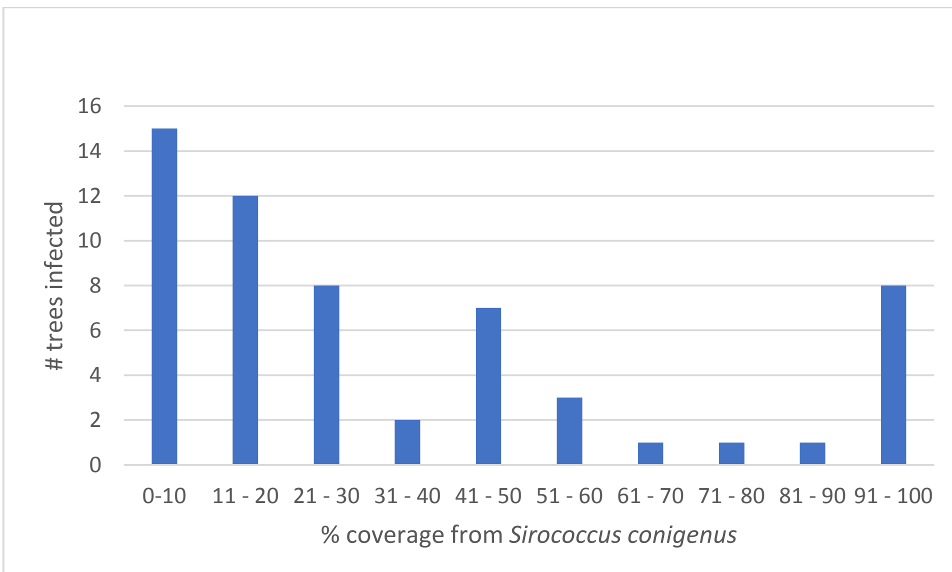


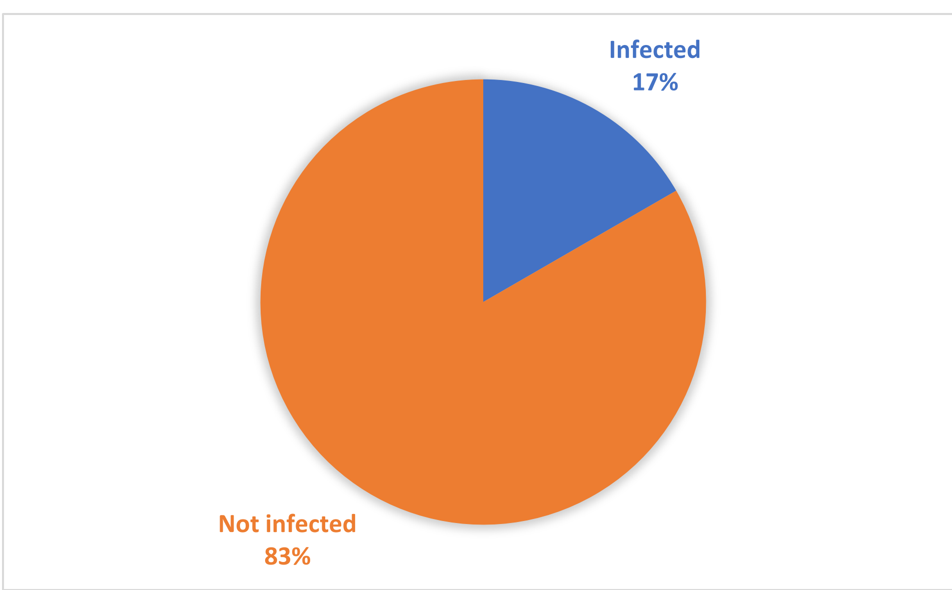
Figure 5. The number of natural red pines infected with *S. conigenus* at the Hogarth Plantation categorized by exhibited degrees of severity

The averages from the sample for tree age and disease coverage were 4.7 years in age and 40%, respectively. Red pines aged four to six years displayed the highest incidence of infection, containing 74.1 percent, accounting for approximately three-quarters of the infected trees. The infected trees within this age group averaged 32.8 percent disease coverage. There were many 1-year-old seedlings in the naturally regenerated area, however, only three (5.17% of total infected trees) displayed disease symptoms; all of which exhibited 100 percent disease coverage. It appeared as though there was a high mortality rate of year-old seedlings, but it was inconclusive if whether or not the mortality was attributed to *S. conigenus* or some other factors due to the lack of needles to observe the pycnidia. Ages 2, 3, 7 and 8 made up only a small portion of the total infected trees, containing only 12 of the 58, approximately 21% of the total infected stock. These findings are summarized below in Table 1.

Table 1. Data summary of *Sirococcus. conigenus* infection in natural red pine at the Hogarth Plantation

Age (years)	#of infected trees	Average cover (%)	Portion of all infected trees (%)
1	3	100.00	5.17
2	5	32.00	8.62
3	3	30.00	5.17
4	12	40.00	20.69
5	18	28.33	31.03
6	13	39.23	22.41
7	3	40.00	5.17
8	1	10.00	1.72

With regard to the planted stock of red pine, it appears as though the impacts from *S. conigenus* have been far less significant compared to the extent of the disease in the



natural regeneration. There were very few individual trees within the planted stock that exhibited any sign of infection. From 48 sampled planted trees, it was shown that 83% did not display any signs of infection and only 17% showed symptoms of infection. This is illustrated below in Figure 6.

Figure 6. The sampled amount of planted red pine infected and not infected with *S. conigenus* at the Hogarth Plantation

Planted trees with signs of infection only exhibited minor coverage averaging 11.2% between 8 infected trees; all of which were 8 years old. A visual representation showing the number of trees within the varying degrees of infection is shown below in Figure 7.

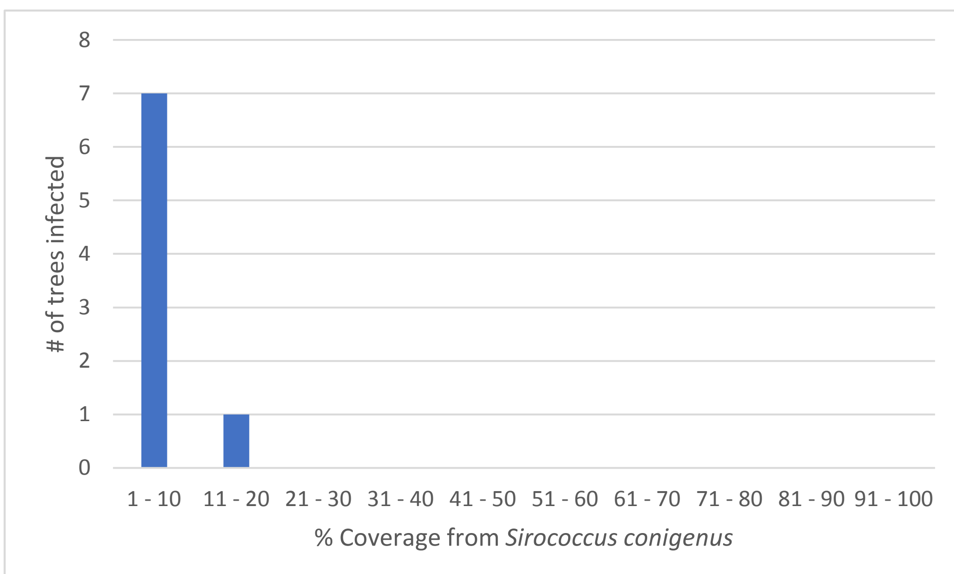


Figure 7. The number of planted red pines infected with *S. conigenus* at the Hogarth Plantation categorized by exhibited degrees of severity

The location of infection on the planted trees was limited to a few lower branches that were facing towards, or intermingled with infected natural regeneration. After observation of the planted area immediately next to the naturally regenerating area, it became apparent that the disease was not spreading much further than approximately 3 metres into the planted stock, impacting some lower branches only slightly. A further look into the planted area occurred up until there was approximately 20 metres between the planted trees and the infected trees on the outside. There was no incidence of disease observed greater than approximately 3 metres from infected natural trees.

DISCUSSION

The focus of this study was to provide a glimpse into the interaction of the pathogen *S. conigenus* on naturally regenerated saplings and planted saplings of red pine at the Hogarth Plantation. This study looked at a small section within the plantation, and compared to other studies that investigated *S. conigenus* interactions, this study was on a much smaller scale. For example, Ostry *et. al.* (1990) observed the impacts of the pathogen across a broad area at 3 separate study sites. There have been numerous studies on this topic due to red pine being an important commercial species in North America, and with *S. conigenus* being a harmful and relatively abundant pathogen. Despite this present study being on a smaller scale compared to other studies of a similar nature, the findings reflected those found in the other studies.

Before this study took place, it was known that the specified area of natural red pine was infected but no studies had ever taken place to quantify and describe the current state of infection. The research showed that over half of the natural cohort was infected. It is important to note that this natural cohort is growing beneath mature red pine that grows along the roadside. It was unclear if whether or not the overstory red pines were infected with *S. conigenus* because only a basic visual assessment from the ground could be performed. From the ground, it appeared as though some shoots were drooping, but without being able to look closely at the needles to see if pycnidia were present the observation was inconclusive. However, it is possible that these overstory pines are infected and spores that are dispersed land directly below on the naturally regenerated pines. As the natural regeneration directly below the overstory became infected, the pathogen was able to spread in the area at an increasing rate through rain splash. Infections most likely began on the lower branches and then after several years, the cumulative impacts lead to more infections on new shoots. This is shown through most infected trees being between 4-6 years in age with approximately 75% of their shoots killed by the disease. As demonstrated by Ostry *et al.,* (1990), the overstory red pines reduce the amount of light reaching the ground and also plays a role in increasing the relative humidity in the understorey which no doubt would aid spore germination and fungal growth.

The main driver behind this study was to see if the infection in the natural regeneration had or is threatening to spread significantly into the planted stock of red pine. The research revealed that the planted stock is not showing any significant signs of infection. Seventeen percent of the sample showed signs of infection, with infections being limited up to 10% of the shoots on the lower branches of planted trees that were very close or intermingled with infected natural regeneration. When the rest of the planted area was observed it was shown that there were no signs of infection on planted trees that were greater than 3 meters away from the nearest infected trees. This showed that any spread of the pathogen at this site is attributed to mostly rain splash and not wind dispersal. It also displays that when the plantation was established, the seeds in which the seedlings were grown from were not infected with *S. conigenus*, as it is also a seedborne pathogen. It can be assumed that, like the area of natural regeneration, if there were overstory red pines scattered throughout the plantation then there would be a much higher incidence of infection in the planted stock. Being in the open results in lower humidity, a drier situation due to sun exposure, and overall, a less conducive environment for fungal infection.

The overall risk of a major infection from *S. conigenus* within the plantation is low, however, preventative measures can still be taken. The branches of the very few infected planted trees can be pruned off to prevent the cumulative impacts this pathogen exhibits. Beyond the basic pruning of infected shoots, the best course of action would be to regularly monitor the situation to be able to quickly assess the best course of action if the infections are spreading noticeably. Another factor to consider is that the climate is changing and this impacts the dynamics between pathogens and their hosts. As the climate changes in the Thunder Bay District, there may be increases in significant rain events, temperatures and humidity. Nothing can be said with certainty but changing climatic conditions may end up favouring the spread of the pathogen in the plantation which could require intervention, such as fungicide applications or thinnings to encourage airflow and to prevent spread through rain splash.

CONCLUSION

The Hogarth Plantation is an area rich in educational, economical and ecological value and through conducting this study it became evident that those values are not being significantly degraded, which is good news for Lakehead University. This study was effective in quantitatively and qualitatively showing the impact of *S. conigenus* has on natural and planted trees. The plantation appears to be healthy and there is a low risk of a significant infection in the near future. There is no intensive intervention required at this time but it is still important to monitor the situation to mitigate future issues. This monitoring can be performed very simply by periodically walking through the planted area and assessing for signs of disease. This was an interesting study to pursue and it would be interesting to see future studies that employ more intensive sampling techniques that cover a larger area of the plantation. In future studies there should also be some repetitions of the sampling procedures to give some statistical rigour to the conclusions. Also, procedures that involve assessing the overstory trees that are suspected to be infected will be useful as well as getting a more effective quantification of spore counts at certain distances from infected trees.

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APPENDIX

APPENDIX I – RAW DATA

Natural Regeneration – Fenceline

Tree	Disease	Age	Coverage (%)
1	No	N/A	N/A
2	Yes	8	10
3	Yes	6	100
4	No	N/A	N/A
5	No	N/A	N/A
6	No	N/A	N/A
7	No	N/A	N/A
8	Yes	7	60
9	Yes	6	20
10	Yes	6	20
11	Yes	4	10
12	Yes	3	20
13	Yes	4	10
14	Yes	2	100
15	No	N/A	N/A
16	No	N/A	N/A
17	No	N/A	N/A
18	No	N/A	N/A
19	No	N/A	N/A
20	No	N/A	N/A
21	No	N/A	N/A
22	Yes	4	20
23	Yes	5	20
24	Yes	3	10
25	No	N/A	N/A
26	No	N/A	N/A
27	Yes	6	20
28	No	N/A	N/A
29	Yes	5	10
30	No	N/A	N/A
31	No	N/A	N/A
32	Yes	4	50
33	No	N/A	N/A
34	Yes	2	50
35	Yes	2	10
36	Yes	5	10
37	Yes	4	25
38	No	N/A	N/A
39	No	N/A	N/A
40	Yes	5	10

41	Yes	5	30
42	Yes	6	20
43	No	N/A	N/A
44	Yes	4	80
45	Yes	7	30
46	No	N/A	N/A
47	Yes	7	30
48	Yes	6	40
49	No	N/A	N/A
50	Yes	6	10
51	Yes	5	50
52	No	N/A	N/A
53	No	N/A	N/A
54	Yes	6	90
55	No	N/A	N/A
56	No	N/A	N/A
57	Yes	5	20
58	Yes	6	40
59	No	N/A	N/A
60	Yes	5	100
61	Yes	5	50
62	No	N/A	N/A
63	Yes	5	30
64	Yes	6	10
65	No	N/A	N/A
66	No	N/A	N/A
67	Yes	1	100
68	Yes	2	50
69	Yes	4	20
70	Yes	5	10
71	No	N/A	N/A
72	No	N/A	N/A
73	No	N/A	N/A
74	Yes	2	50
75	No	N/A	N/A
76	No	N/A	N/A
77	Yes	6	70
78	Yes	1	100
79	Yes	5	10
80	No	N/A	N/A
81	No	N/A	N/A
82	Yes	5	30
83	No	N/A	N/A
84	No	N/A	N/A

85	No	N/A	N/A
86	Yes	4	10
87	Yes	4	30
88	No	N/A	N/A
89	Yes	6	20
90	No	N/A	N/A
91	Yes	4	20
92	Yes	1	100
93	Yes	4	100
94	No	N/A	N/A
95	Yes	5	10
96	Yes	5	30
97	No	N/A	N/A
98	No	N/A	N/A
99	Yes	3	60
100	Yes	4	100
101	No	N/A	N/A
102	Yes	5	20
103	No	N/A	N/A
104	No	N/A	N/A
105	Yes	5	10
106	Yes	6	50
107	No	N/A	N/A
108	Yes	5	60

Planted area			
Tree	Disease	Age	Coverage (%)
1	No	N/A	
2	No	N/A	
3	No	N/A	
4	No	8	10
5	No	N/A	
6	No	N/A	
7	No	8	10
8	No	8	10
9	No	N/A	
10	No	N/A	
11	No	N/A	
12	No	N/A	
13	No	N/A	
14	No	N/A	
15	No	N/A	
16	No	N/A	
17	No	8	20
18	No	N/A	
19	No	N/A	
20	No	N/A	
21	No	N/A	
22	No	N/A	
23	No	N/A	
24	No	N/A	
25	No	N/A	
26	No	N/A	
27	No	N/A	
28	No	8	10
29	No	8	10
30	No	N/A	
31	No	N/A	
32	No	N/A	
33	No	N/A	
34	No	N/A	
35	No	8	10
36	No	N/A	
37	No	N/A	
38	No	N/A	
39	No	N/A	
40	No	N/A	

41	Yes	8	10
42	Yes	N/A	
43	Yes	N/A	
44	Yes	N/A	
45	Yes	N/A	
46	Yes	N/A	
47	Yes	N/A	
48	Yes	N/A	