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RESEARCH
AT THE LAURENTIAN FORESTRY CENTRE
OF NATURAL RESOURCES CANADA

ANNOSUS ROOT AND BUTT ROT

CAUSED BY *HETEROBASIDION IRREGULARE* IN PINES

Canada

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INTRODUCTION

Annosus root and butt rot appeared in Quebec relatively recently and its progression still seems to be fairly limited. However, the capacity of this disease to spread over long distances and the value of the species it attacks or could attack justify the need for a synthesis of the scientific knowledge that currently exists regarding this disease. Detection methods and recommendations for limiting the spread of the disease will also be discussed.

Pathogenic fungus *Heterobasidion irregulare.*

HISTORY

Annosus root and butt rot in North American pines is caused by the pathogenic fungus *Heterobasidion irregulare* (Underw.) Garbel. & Otrosina. In Europe, a similar disease in pines caused by *Heterobasidion annosum* (Fr.) Bref. *sensu stricto* has been known since 1874. Given the significant damage that can be caused by fungi of the *Heterobasidion* genus in the Northern Hemisphere, they have been categorized among the most devastating pathogens in coniferous forests.

The disease spreads from one tree to another through root contact, which results in mortality rings, hence the French name given to the disease (*maladie du rond*, or "ring disease"). It was only in 1951 that English pathologist John Rishbeth discovered that the fungus infiltrates a stand through its spores, which colonize the stumps of freshly-cut pines. This discovery shone a light on the main mode of propagation of the fungus, leading to the development of control methods to prevent the introduction of the disease by treating freshly-cut stumps.

In eastern Canada, annosus root and butt rot was first reported in Ontario in 1955 in two red pine plantations that had been thinned in 1929. The disease was then observed in several areas in Ontario, including Larose Forest (located near the Quebec border) in 1968.

Given the proximity to Quebec and the spread of the fungus, in 1982, the *Comité de pathologie forestière du Québec* started recommending that forest managers treat red pine stumps with borax after thinning operations, a product that was then approved for this use in Canada. In 1985, the Laurentian Forestry Centre of Natural Resources Canada's Canadian Forest Service implemented a plan to monitor the disease in Quebec. In September 1989, the disease was identified for the first time in Quebec in a red pine plantation located near Lac La Blanche, north of Buckingham, approximately 40 km from Larose Forest.

Mortality ring in a red pine plantation.

Map of the disease's progression in eastern Canada.

Regeneration colonized by *Heterobasidion irregulare.*

BIOLOGY

The hosts

In eastern Canada, red pine is the most affected tree species for the moment. Indeed, red pine has been a species of choice for tree plantations in Ontario and Quebec since the 1940s. Thinning operations in these plantations began some 20 years after planting, thus creating a suitable environment for the spread of the disease in this species. It should be noted that the disease was also reported in white pine and jack pine in Ontario (Myren 1973). Experiments in Ontario plantations revealed that the stumps of jack pine could be colonized by *Heterobasidion irregulare*. Since jack pine has been significantly replanted in Quebec, and given its vast natural range, managers should take this risk into account when harvesting. In addition to pine, it has been observed that other species such as balsam fir and young white spruces located near pines infected by *H. irregulare* have been attacked. However, these species did not generally act as entry points for the disease into a plantation. Therefore, there is no need to treat them on a preventive basis.

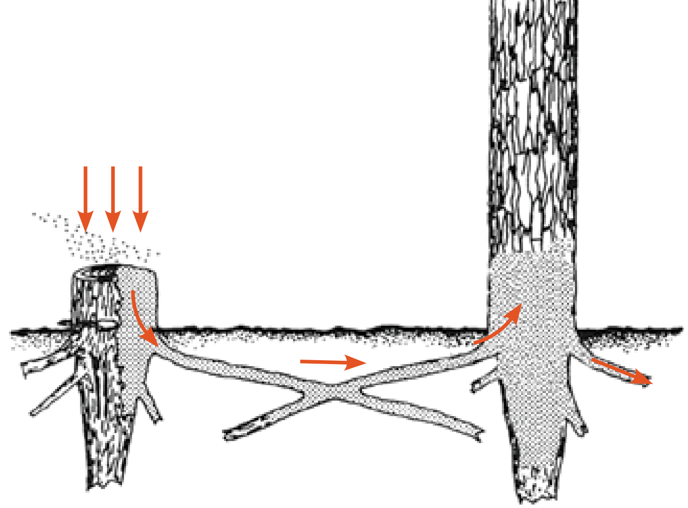
The fungus

The fungus known under the name *Heterobasidion annosum sensu lato* in fact represents several species. Fungus taxonomists have recently described new species. The only species that can be found in pines of northeastern North America is now called *H. irregulare*. This fungus reproduces sexually by forming sporophores. In turn, they produce spores that spread the fungus and with it, the disease. The fungus can also reproduce asexually and is then known under the name *Spiniger meineckella* (Olson) Stalpers. It has mostly been observed on isolates in pure culture in the laboratory.

Heterobasidion irregulare sporophores made visible after removing the layer of organic matter hiding the base of the trunk.

The sporophore makes it possible to identify the disease. Its upper surface is bumpy, it is fawn-coloured and progressively turns black near the point where it attaches to the wood. One distinctive trait is the white band around its edge. Its lower surface (hymenaphore), where the spores are produced, is white and porous. The sporophore is approximately 10 cm wide, but it can reach up to 20 cm. When it begins to form, the sporophore is minuscule, measuring approximately 1 to 2 cm. It appears as a white and porous formation on the bark of trees at the root collar level and sometimes on the litter. The sporophore develops from July until late in the fall. In northern zones, the sporophore darkens and decays the following year. In more southern regions, such as the Niagara Peninsula in Ontario, the sporophore can survive longer given the more favourable climatic conditions.

***Heterobasidion irregulare* sporophores at the beginning of their development.**



Development of *Heterobasidion irregulare*, from the colonization of a stump to the invasion of neighbouring trees.

Detecting the disease

In order to detect the disease in a red pine plantation where thinning operations have been conducted a few years before, the first step consists in looking for dead trees or trees whose crown shows symptoms of decline, such as reddened needles, shorter needles or sparse foliage. Detection should preferably be done from September to November.

A search must then be conducted at the base of these dead or decaying trees as well as on stumps located in the immediate vicinity of these trees to look for signs of the disease, which are the sporophores of the fungus. They can be seen easily, but usually the litter must be removed with a hand weeder to uncover them. At the beginning of its development, the sporophore is white and porous. In order to properly identify the fungi found, especially in a stand where the disease has never been reported, it is recommended that samples be sent to a diagnostic laboratory.

The disease

The spores of the fungus can cover long distances. In 1968, for example, phytopathologists collected viable *Heterobasidion irregulare* spores in New Brunswick, more than 110 km from the nearest source of infection. In the UK, Rishbeth caught viable spores at sea, more than 300 km from the nearest potential infection source. Thus, after being transported by the wind, *H. irregulare* spores can colonize freshly-cut stumps.

The surface of a freshly-cut stump is also favourable to colonization by other microorganisms. Therefore, to successfully colonize the stump, *H. irregulare* must invade the surface before these other microorganisms. In the literature, the duration of this period of stump vulnerability to *H. irregulare* can vary quite a bit, ranging from a few days to three or four weeks. Usually, few infections occur more than two weeks after a tree is cut or when the temperature is too high.

The mycelium of *H. irregulare* develops in the stump and gradually participates in its decomposition. The fungus does not infect the trunk much because of the inhibitive substances, such as resin, that are present within it. It progresses into the roots, thus extending its area of infection. The fungus then comes into contact with the roots of neighbouring conifers, infects them, and migrates towards the foot of these trees, eventually causing tree death. The fungus will then continue its progress, extending out to other adjacent trees. This progression, starting from a central point and extending outwards, creates rings of diseased and dead trees in a forest stand. The speed of this radial progress is estimated at less than 1 m per year.

The disease therefore progresses slowly from a central point. However, since the number of infection points can be high after thinning operations in a plantation, the disease can spread very quickly. Its most pernicious characteristic is that the fungus can survive for a very long time in the stumps and roots, more than 50 years in some cases. This situation jeopardizes the reforestation of infested areas since the regeneration of conifers is quickly killed off by the disease.

Hand weeder used to uncover *Heterobasidion irregulare* sporophores hidden by the organic matter.

CONTROL METHODS

Prevention

Given the nature of annosus root and butt rot, which attacks a part of the tree that is not very accessible, i.e. the roots, it is strongly recommended to prevent its introduction in a stand. The current prevention method used in several countries consists in treating the stumps after felling. No chemical product is approved in Canada for this purpose. However, a biological product was approved in 2014: Rotstop® C. It is prepared using an isolate from the saprophyte fungus *Phlebiopsis gigantea* (Fr.) Jül. found in Quebec. Rotstop® C comes in the form of a wettable powder and, according to the manufacturer's instructions, the mash produced must be applied on the stumps within 24 hours of its preparation. Adding dye to the mash makes it possible to control the quality of the application.

All pesticides must be applied in compliance with provincial regulations and the instructions that appear on the product label in accordance with the *Pest Control Products Act.* In Quebec, users must respect the *Pesticides Act, Chapter P-9.3*, and in Ontario, they must respect the *Pesticides Act, R.S.O. 1990, Chapter P.11.*

The product must be applied immediately after the trees have been felled, using a manual sprayer in small plantations. For mechanized operations, multifunctional harvesters can be equipped with automatic sprayers, making it possible to automatically inoculate the stumps with the *P. gigantea* fungus. Whether the disease is present or not, all pines must be treated in latitudes where the disease has been reported.

This preventive treatment is applied as soon as average daily temperature is higher than 5°C. In winter, when the average daily temperature is below 5°C, the conditions are not conducive to new infections by the disease, making it possible to cut pines without having to apply the product. Climate change could modify the period when it is necessary to apply the treatment.

John Rishbeth was the first to have a certain level of success in experimenting with biological treatments for *Heterobasidion annosum* in 1963, in the UK. He observed that untreated stumps were often colonized by the saprophyte fungus *Phlebiopsis gigantea* (Fr.) Jül. Once established, this saprophyte prevented colonization by *H. annosum*. Another benefit of this fungus is that it produces a large quantity of spores when grown in an artificial laboratory environment. *Phlebiopsis gigantea* forms a very thin sporophore on the surface of the substrate it decomposes. Since the initial tests, *P. gigantea* has been tested on various species and in various conditions. To optimize its efficiency, it is preferable to use an indigenous isolate of *P. gigantea* instead of an isolate from another country where the ecological conditions can be different.

Multifunctional harvester equipped with an automatic sprayer.

Manual spraying.

Eradication

Once *H. irregulare* has established itself in a stand, it is very difficult to get rid of it since the fungus can survive for decades in the stumps and roots left after harvesting. The ideal solution is to decontaminate these islands of infection to stop them from spreading. One way of eliminating the disease is to remove the infected stumps and destroy them. Heavy machinery is therefore needed to extract all the stumps and roots and to dispose of them. However, the larger the infected zone, the more difficult it becomes to apply this method since two rows of seemingly healthy pines must also be removed at the edge of the contaminated surface area. Some authors suggest a buffer zone of 5 to 10 m.

Isolating the mortality rings

Isolating mortality rings is applicable in stands where only a few trees are affected or when the expansion of the mortality ring is very limited. A zone that includes the mortality ring and two rows of seemingly healthy trees must be delimited, and then a trench that is as deep as the pines' root system must be dug around this zone. The rows of additional trees are necessary since the disease may already be present in trees that show no apparent symptoms.

Substitution

Another way of reclaiming sites infected with *Heterobasidion irregulare* is to replant them with species that are less sensitive to the disease, such as deciduous species.

RECOMMENDATIONS

Given the current state of knowledge on annosus root and butt rot and eastern Canada's climatic conditions, the following recommendations would help reduce the risks of infection as much as possible, at a minimal cost.

1. Treatment with Rotstop® C, the only product currently approved in Canada for the treatment of stumps against *Heterobasidion irregulare*, must be applied immediately after the trees have been felled when average daily temperature is above 5°C (manufacturer's recommendation). The stumps of all pine species must be treated in latitudes where the disease has been reported, whether the site is infected or not.

2. It is necessary to make sure the work is properly done. Tests conducted in Ontario have revealed that treatment failures are not attributable to the product used, but to a certain percentage of stumps that have not been treated, often because they were covered by branches. This is why it is recommended to add dye to the Rotstop® C solution.

3. Harvesting work can be undertaken without the need for Rotstop® C when average daily temperature is below 5°C or when the sporophores present on old stumps or standing trees are covered with snow in winter. Below 0°C, the risk of infection is nearly absent, and it is very low when average daily temperature is between 1 and 5°C.

4. For newly-infected sites, it is recommended to eradicate the disease or to isolate the small centres of infection.

CONCLUSION

It has been over a century since annosus root and butt rot was described by the German forest pathologist Robert Hartig, who had also recognized that the disease was transmitted from one tree to another through root contact. However, it would take another 50 years for the Englishman Rishbeth to make the connection between the introduction of the disease into a plantation and the colonization of freshly-cut stumps by *H. annosum*. The disease was thus able to invade several plantations that had undergone thinning operations, mainly in Europe.

Forest managers in eastern Canada are currently facing the same problem as European foresters at the turn of the 19th century. A large number of pine plantations are being thinned and the pathogenic fungus is present in that environment. However, forest managers benefit from the epidemiological knowledge regarding annosus root and butt rot that was acquired by European foresters. The development of means of control and the approval of a biological product, Rotstop® C, make it possible to prevent the contamination of forest lands which, once infected, are very hard to treat. Prevention is without a doubt the best solution.

Useful links

Ministère des Forêts, de la Faune et des Parcs du Québec. La maladie du rond. http://mffp.gouv.qc.ca/forets/fimaq/insectes/fimaq-insectes-maladies-rond.jsp (Available in French only).

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Pest Control Products Act http://laws-lois.justice.gc.ca/eng/acts/P-9.01/

Pesticides Act, Chapter P-9.3 http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/P-9.3

Pesticides Act, R.S.O. 1990, Chapter P.11 https://www.ontario.ca/laws/statute/90p11

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