BLISTER RUST RESISTANCE IN WHITE PINE

C. Heimburger

Division of Research
Ontario Department of Lands and Forests
Maple, Ontario, Canada

The work on blister rust resista nce in white nine can be divided into 2 phases. The first phase started about 1937. At that time cooperation in forest tree breeding was establish ed between the Dominion Forest Service, the Department of Agriculture and the National Research Council of Canada who employed Dr. L.P.V. Johnson as forest geneticist. At about that time we received a letter from Dr. C. Schenk in Germany, asking for seeds of white pine of different geographic origin, in order to test the strains for resist ance to blister rust and, if possible, to find a resistant strain. Dr. Gast started a collection of white pine seeds of different origins, for some physiological work at Harvard Forest, and we received seed samples from him in exchange for samples we collected. Dr. P. J. Riker, of Wisconsin, also started his work on resistance to blister rust at that time, and we received some seeds from his supposedly resistant trees for our tests. Our attention was also directed towards a plantation of white pine at the Seigniory of Mr.Joly de Lotbiniere at Pointe Pinion in Quebec. Forest pathologists of the Department of Agriculture had discovered a heavy attack of blister rust in this planttion in 1921. The plantation had been established in 1908 with about 400 plants imported from a nursery in Germany and soon showed heavy infection. The plants were probably of Lake States origin. In 1921 there were 372 living pines and of these 66 percent had infections in the aecial stage. There were also 20 dead standing trees and 13 of these had been killed by the rust. A single tree often had 10-20 separate infections, and one tree had 35. The plantation is situated on a low, north-facing terrace on the south shore of the St. Lawrence River, and a high escarpment imm ed-lately to the south of the plantation has a garden with ribes. In 1921 there were about 150 ribes bushes in the garden. In 19141 there were 72 ribes less than 200 feet from the plantation and only 46 white pine were left of which one showed an infection with blister rust (McCallum, A. W., 1941: Report on examination of the white pine plantation on the Seigniory of Mr. Joly de Lotbiniere at Pointe Flaton, Quebec; unpublished). Since then. 10 trees with cankers on the main stem and one with a branch canker have been removed, leaving 35 trees completely free from any sign of blister rust. No new infections have been noticed during the last 10 years. It was be lieved that these remaining trees might have inherent resistance to the rust and several seed collections were made in this plantation. Later, some of the trees were used for pollen collection and for hybridization work on a limited scale. The seedlings were raised at the Peta.wawa Forest Experiment Station and at the Annex of the National Research Council near Ottawa. Seeds of Ribes cynosbati were collected and the resulting plants set out in mixture with the white pine materials at the Annex. The Annex is situated near the Ottawa River on a low-lying area that gets night fogs from the river in the fall and is a good place for natural infection with blister rust. Nothing much happened at first, but after about 6 years infection followed by heavy mortality was quite noticeable. Some seedling lots were eliminated altogether at this time. The Pointe Platon origins and some lots from

Harvard Forest showed much less damage than the others. Unfortunately, the tallies made at that time by the forest pathologists can not be located. In 1947 and 1948 the white pine and ribes materials were moved to a new area at the Connaught Rifle Ranges near Ottawa. During this operation the plants were culled for poor form, rust infection and slow growth. In 1947, several white pine lots were moved from the Petawawa F.E.S. and planted together with the selected plants from the Annex. Also from this operation, the tallies, if made, are not available. In the new plantation every 2 rows of white pine were alternated with a row of ribes. The plantation was inspected and a tally was made in the spring of 1952, 1953, and again in the summer of 1954. We now have data on the original number of plants set out there of each surviving lot, as well as on mortality and infection by blister rust since the establishment of this plantation. As some of the larger lots are replicated within the planting area it is possible to obtain fairly good average figures for the proportion of healthy plants, without any outward signs of blister rust. These are as follows:

Lot no.	Total no. of plants	Number healthy	Percent healthy	Origin
127	74	23	31.1	Pack Forest
128	73	31	42.5	Harvard Forest
278	145	113	78.1	Pte. Platon (several trees)

These lots were grown at the Petawawa F.E.S. without being subjected to infection by blister rust previous to 1947. The Pointe Platon origin stands out with its large proportion of healthy plants as compared with the other two lots. Of the lots grown at the Annex, unfortunately, none is directly comparable with the Petawawa lots. The figures from many small lots are too variable for direct comparison.

The first phase of the work indicates that one seed lot from Pte. Flaton, collected from trees free from blister rust after at least 33 years of heavy infection, shows a greater proportion of healthy plants than comparable lots from unselected trees. All the materials have been subjected to natural infection only and undoubtedly include a large proportion of escapes. We have recently selected 200 of the best trees in the Connaught Range plantation and started scion collection and grafting for further testing under more intensive artificial inoculation with blister rust.

The second phase of the work started in 1946 at Maple, Ont. The breeding of white pine was established by the Research Division of the Ontario Department of Lands and Forests as a major research project and more funds became available for this than previously. Most of the work with white pine has been concerned with acquisition of new materials and with their testing and evaluation. Grafting was used as an importart tool in this. At first Scotch pine was used as stock for grafting, but soon we found, heavy summer mortality of grafts on this stock and have used white pine since. Grafts from all Pointe Piaton trees were made, as well as from seemingly resistant white pine in Denmark, British Columbia, Wisconsin, Idaho an d Washington. Scions were obtained from several arboretums in North America and Europe of exotic white pines, collected from trees of flowering age. Plus-trees of native white pine were selected in several localities and included in

the tests. Hybridization has been carried out on trees at Maple, Ont., and the seemingly resistant trees at Pointe Platon, with pollen of native and exotic species. Since 1950, the breeding for resistance to blister rust is being coordinated and kept up-to-date bythe U.S. Forest Service, which receives and distributes reports from workers on blister runt in white pines in the United States end Canada.

A plantation of black currents was established to produce material for blister rust inoculations, and white pine seedlings were raised of native and exotic species. A search of the literature revealed that white pine seedlings could be infected with blister rust during their first year in the seed bed and this was amply confirmed in our tests. We have in some years obtained quite heavy inflection after our inoculations, probably supplemented to a considerable degree with natural infection from the abundant black currant bushes nearby. Through cooperation with the British Columbia Forest Service, cones were obtained from several areas in the Interior and the seedlings were subjected to heavy artificial (plus some natural) infection at Wane since their first year in the seed beds. This resulted in very heavy infection and mortality at first, gradually tapering off until we now have some transplants that have not shown new signs of infection for the last 3 years. Several populations of western write pine were eliminated in this process. If it were possible to grow white pine like potatoes, from vegetative cuttings, we could now supply British Columbia with initial growing stock of western white pine, possibly carrying a reasonable degree of resistance to blister rust and adapted to a rather wide range of climatic and soil conditions. Pinus flexilis also lends itself very well to this "boiling down" but is often entirely eliminated. The following seedling inoculation technique has been used:

The seed bed in surrounded by a frame of lumber, the soil if moistened, and ribes leaves with telial columns are planted in the soil rather densely among the seedlings, with their petioles about 1/2 inch in the soil, and watered down. The bed is covered with a lath screen and double thickness of wet burlap which is held down by another lath screen. The whole is kept moist for about a week by watering and recently by plastic hose sprinklers. We have tried to grow Ribes Cynosbati and some other ribes species also, but found black currants much superior in producing abundant telial columns on their leaves. The black currants often get so hea vily infected by the rust that many leaves drop off and very few are available at the time of inoculation, in September-October. We now grow the hushes in a lath house. This is quite satisfactory but the construction of a lath house is very expensive and we are looking for a better way to grow ribes. Black currant seedlings show great variation in degree of infection with rust and retention of leaves after being inflected. It might, perhaps, be possible to select a few bushes that could be grown inn the open with us and still retain their leaves after being heavily rusted. As they can easily be propagated by cuttings, this should be a relavively easy procedure. None of the standard named varieties seem as satisfactory in this respect as some of the seedlings. The cross, susceptible black x red current, was made a few years ago by Dr. A.W.S. Hunter of the Division of Horticulure, Control Experimental Farm, Ottawa. The hybrids are said to be sterile, which should be helpful if control of ribes spread by birds were necessary. In recent years all our currant bushes are cut down to the ground in the fall, at the time of leaf collection. This produces strong shoots with good lea ves and eliminates berry production. Older white

pine seedlings and all grafts have been, until very recently, inoculated with blister rust according to the method used by Dr. A.J. Riker and his assistants in Wisconsin. Instead of attaching the currant leaves to the white Pine materials with wire clips, we soon changed to tooth picks. In this process we soon found out that seedlings were much easier to inoculate with blister rust than grafts, i.e. they showed much heavier and more rapid infection. This might be due to their more compact growth form, in compari son with the grafts, which often look somewhat like skinny chickens with bare bottoms, while the seedlings offer a more favorable microclimate to the germinating blister rust spores. There may also be a difference in susceptibility caused by differences in the growth phases of the materials, i.e. the juvenile seedling growth could be more susceptible than the mature growth of the grafts. After 3-4 years in the inoculation beds, the healthy see dlings and grafts are set out into a nursery compartment at a rather wide spacing, where many grafts are now flowering and are being used in hybridization work. It has occurred repeatedly that materials remaining healthy in the inoculation beds sowed blister rust infection in the breeding compartment. This indicates that the inoculation method used has been insufficient for the proper evaluation of resistance and a more intensive method for infection with blister rust is needed.

In the fall of 1954 we used a modification of the inoculation method used by R. T. Bingham of the Spokane Blister Rust Control Unit. Shoots of black currants with green leaves carrying abundant telial columns were stuck into the soil close to the white pine grafts and seedlings in the inoculation beds, and the soil was thoroughly watered. The beds were covered with lath screens, etc., as described in young seedling inoculation. In this manner it was possible to maintain the leaves in a fresh condition during several days, which had not been possible formerly by using detached currant leaves as inoculum. At that time 1086 grafts belonging to 64 clones, and 5385 seedlings and 129 grafts belonging to h3 populations, were inoculated. The currant shoots were left in the beds through the winter and most of these began to produce new leaves in the spring as they had rooted in the meantime. They were then removed. A heavy spotting of the pine needles, characteristic of early infection with blister rust, soon became quite apparent. Some of the needles with heavy spotting were sectioned by the forest pathologists stationed at Maple and showed the presence of blister rust hyphae. A detailed tally of the various degrees of spotting was made in early July of this year, as more pressing work in grafting and hybridization precluded an earlier tally. The spotting was tallied for each plant 0=no spots, 1=weak spotting, 2=medium spotting and 3=heavy spotting. The results undoubtedly show a much heavier infection than has taken place, as many other kinds of spots than those caused by blister rust were tallied at this late date. The final evaluation will be possible as cankers appear. The results of the tally are as follows:

Clones(C) or populations(P)	No. of plants	Plants with spots	Total spot score	Percent with spots	Ave. spotting
strobus grafts (scions from trees)					
48 C	858	748	934	87.2	1.09
strobus grafts (scions from seedlings)					
3 P	128	118	184	92.1	1.48
monticola grafts (scions from trees)					
5 C	66	55	107	83.3	1.62
peuce grafts (scions from trees)					
7 C	120	97	107	80.7	0.89
griffithii grafts (scions from trees)					
3 C	22	22	23	100	1.04
strobus seedlings					
34 P	2911	2903	6882	100	2.36
monticola seedlings					
4 P	93	93	155	100	1.67
peuce seedlings					
1 P	9	6	6	66.7	0.7
griffithii seedlings					
8 P	1050	1029	2479	98	2.36
strobus x pentaphylla seedlings					
1 P	32	32	79	100	2.5
strobus x peuce seedlings					
1 P	123	109	152	88.6	1.3

The data show that strobus seedlings probably are more susceptible to blister rust than grafts. The old findings of the pathologists that monticola is more susceptible than strobus, and the other species are less susceptible, seem to be borne out by the grafts but not by the seedlings. Peuce stands out in yielding less susceptible grafts and seedlings.

The grafts and seedlings of supposedly resistant strobus materials have yielded the following results:

Clones(C) or populations(P)	No. of plants	Plants with spots	Total spot score	Percent with spots	Ave. spotting
Wisconsin grafts					
8 C	135	92	98	68.1	0.72
Wisconsin seedlings					
9 P	499	498	1285	100	2.58
Pte. Platon seedlings					
13 P	1929	1924	4377	100	2.27

While the Wisconsin grafts score a little better than the average strobus grafts, the Wisconsin and Pte. Platon seedlings are not superior to the average strobus seedlings. This is in line with recent findings in Wisconsin and Spokane. The results are discouraging and indicate that there is much room for further improvement of the inoculation technique and in the selection of seemingly resistant individuals as a basis for breeding. I believe that the experience obtained thus far with white pine and related species, indicates that resistance to blister rust is inherited as a polygenic character and that breeding for resistance should be carried out with this as a working hypothesis, unless definite results to the contrary are obtained. Better inoculation of grafts is necessary. To that end the grafts should be made as low as possible, as long as this does not interfere with the quality of the grafting. In a report to the Lake States Forest Tree Improvement Conference this year, I have presented results obtained with bare root grafting of white pine, using a modification of the Mississippi method. The results are quite encouraging,, but the method requires good scions. The Spokane method of inoculation seems superior to the Wisconsin method and could be improved further by using the best possible inoculum obtained from selected black currant materials. Large seedling populations could be "boiled down" to a few selected seedlings surviving several intensive artificial inoculations and then propagated vegetatively. Propagation by means of rooted stem cuttings of juvenile materials could probably be carried out at 'a cost of 10 cents per plant. Such plants, preferably seedling progenies of plus or elite trees, should. be acceptable for setting out in relatively small numbers in white pine plantations, using ordinary unselected nursery stock as fillers. This may be an insurance against too great losses from blister rust in the present generation and probably also in the next, if the selected plants otherwise remain superior and resistant and are retained as seed trees. The breeding of strains of white pine containing a satisfactory proportion of resistant individuals will probably require more than one generation of intensive selection, inoculation and hybridization. To obtain results in this within a reasonable length of time, a shortening of the breeding cycle of white pine is necessary. This appears to be the main bottleneck at the present time and any efforts to overcome it should be given high priority in any white pine breeding project.

DISCUSSION

Bramble Just what is this bare root grafting that you mentioned?

Heimburger It was developed in Mississippi. You take nursery stock in the spring and select the plants for reasonable size of the stem just above the ground and trim up a little bit, lift and heel-in in a moist place. In Mississippi they used southern pines and put them in the greenhouse at over 90° F. We used white pine and put them in sand in a cold frame covered the frame with sash and then with light screens and let the sun gradually bring them to growth. Then we investigated the roots. When the roots start growing we take them out and into the lab and put them between wet burlap and we bench graft right in the lab. Then we put them back into inoculation beds. The roots are bare while we are grafting, but we try to keep them as short a time as possible in a bare condition.

Question Is this a root graft?

Heimburger No, the graft is on the stem; it is a regular side graft, as low as possible. When we plant them outside in the bed, the place of grafting is in the ground and they are then low and branching out near the ground and resemble seedlings in morphology.

Schreiner How successful is your grafting?

Heimburger So far we got over 80 percent this year on about 20 clones of which some are poor grafters and some are good grafters, but we can increase that by selecting for graftability because the clones we worked with have not been grafted before they are raw material.

Schreiner Have you given up trying to root cuttings?

Heimburger We have not given up rooting but grafting is so much quicker and more certain. On seedling stock using juvenile scions it is probably quite possible on a large scale. In nursery production we can do just as well with grafting at 10 cents a piece.

Schreiner Are you working on inducing early flowering in trees?

Heimburger This is a very complicated problem. We can induce flowering as you know, by girdling, strangulation, root pruning and perhaps phloem inversion. They've done that at Ely in Minnesota and got very good results there. We tried it this year but have not results to publish. The best results we got is with partial girdling of red pine. The grafting of young seedlings into the crown of an old tree has riot induced flowering in white pine. The grafts are quite successful and they have been there for about 4 or 5 years and just sit there, look very nice but don't flower. We need more research.

Gabriel When do you collect your scionwood and do you use polyethylene bags for storage?

Heimburger No, we use a mixture of sedge peat and coarse sand and we keep them in cold frames. Formerly we used to set them in the fall and that caused a lot of heaving. Now we can collect them in the fall, put them up into small bundles with rubber bands, heel them in and set them in the spring. Now we are too busy with other things in the spring. We like to do it in the fall, at least the collecting part if we have time.

Question Why have you given up grafting on scotch pine?

Heimburger Because the grafts die, the roots die sooner or later. Probably the scotch pine root cannot live on white pine hormones but we have tried the other way around and have scotch pine growing on white pine roots quite successfully. This is probably because white pine is a more primitive species and the root can live on a wider variety of hormones than Scotch pine which is more advanced from an evolutionary standpoint and its roots are

more restricted in their diet. Take a scotch pine in a plantation about 4 or 5 feet tall and stick a. white pine on top of it. The grafts will live very nicely as long as there are scotch pine side branches which supply the scotch pine roots with scotch pine hormones. As soon as you remove the scotch pine branches the grafts usually die. We tried this on low grafts and they died.

Ehrhart Is black spruce being rooted in Canada?

Heimburger There is a chap in Quebec who has reported that black spruce can be propagated from root suckers. I would like to see it first.

Ashworth Do you really think that the white pine seedlings that are resistant develop more resistance as they grow older?

Heimburger Well, the oldest material is now about 6 or 7 years old and of course all the susceptible ones are immediately destroyed, as we don't want to carry them any more than we can help it because of lack of space. The resistant ones apparently gradually get less and less affected. This is probably connected with the morphology of the plants as they get up in the air. The susceptibility is usually better when they are small, compact and surrounded by grass, and when they get more air, at least in eastern white pine, they gradually get more resistant which is probably due to their morphology and to their environment which changes. I suppose if you enclosed the whole pine into a gunny sack and kept it sprinkled you would get infection all right.