Five Needle Pines in British Columbia, Canada: Past, Present and Future

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Abstract—In British Columbia (BC), Canada, we have been involved with white pine and blister rust since the rust's discovery on imported infected pines through the port of Vancouver in 1910. Just after the rust's introduction, the USDA Forest Service established monitoring plots and species trials in BC, but these were abandoned when the rust became well established in the USA. Resistance research began again in 1946 with a collection of western white pine (*Pinus monticola* Dougl. ex D.Don) seed that was sent to Ontario for testing. In about 1950 grafted plus trees were inoculated in a disease garden, but this work was also abandoned in 1960 when it was demonstrated that seedlings from such selections could be susceptible. Parent tree selection and seedling inoculation of open-pollinated families of western white pine began again in earnest in 1987. From this material we have the basis of a breeding and seed orchard program based on partial resistance mechanisms. An F_1 generation is being produced for future research. Additionally, we are considering single gene resistance traits, such as MGR, which can be pyramided onto the partial resistance of our breeding population. Efforts, particularly for conservation interests, are also being started for whitebark pine (*P. albicaulis* Engel.).

Key words: genetic resistance, western white pine, whitebark pine, limber pine

Five Needle Pines in British Columbia

Both western white pine (*Pinus monticola* Dougl. ex D.Don) and whitebark pine (*P. albicaulis* Engel.) achieve the northern extent of their distributions in British Columbia (BC), Canada, while limber pine (*P. flexilis* James) achieves the limit of its distribution in the Canadian Rockies in both Alberta and BC. The two alpine species, whitebark and limber pine, provide valuable tree cover for wildlife in exposed alpine country, food for birds and small mammals, stabilizing elements for snow packs and soils in these steep and fragile environments, and are an important feature of the aesthetics of the high mountains. Western white pine, besides providing many of these features, is also a fast growing and highly valuable component of BC's timber industry. Although these species may suffer from the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), and *P. albicaulis* relies on Clark's nutcracker (*Nucifraga columbiana* Wilson) for regeneration, their most serious threat has been the introduction of blister rust (*Cronartium ribicola* J.C. Fischer) in the early part of the 1900s. So great was the damage due to blister rust, that it was felt that these species might be lost completely. The major research effort with the white pines has therefore been an intensive search for resistance to blister rust. To this end, the USDA Forest Service established rust resistance programs in Idaho, Oregon, and California. The Canadian and BC Forest Services also established rust screening programs in BC. The prognosis for western white pine is now considerably better – although some of the other species such as whitebark pine are still at a risk. We outline below the events and the progress made to date and strategies we are hoping to develop to protect this valuable natural resource.

Past—Introduction of *Cronartium ribicola*

In 1911 British Columbia (BC) was experiencing a boom with a population of 392,500, more than double the previous 10-year census. The population was largely farmers, loggers, and coal miners with little education. Quite likely Tom Newman planned to take advantage of the boom when he imported 1,000 exotic *P. strobus* L. seedlings from France for resale in 1910. However, most of the recent immigrants were from Britain, and in 1914 many of the men returned to Europe to fight in World War I. Before the war, Newman and others sold some imported pines, but sales crashed with the outbreak of the war, and the remaining plants seem to have been abandoned (Gussow 1923). Perhaps Newman never returned from the European conflict; certainly many did not, and the war had effectively put an end to the boom. Under these circumstances it is amazing that blister rust was first identified in BC only 3 years after the war, in the fall of 1921 (Gussow 1923). Although the potential value of the white pines was understood, in those years in BC there was a stronger commercial interest in currants (*Ribes* spp), the alternate host of blister rust (Eastham 1922; 1922/3). However, the U.S. Forest Service was worried about the threat to western white pines, particularly *P. monticola*, and they dispatched field personnel to BC as early as 1922.

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From the Portland, OR, office researchers came to Vancouver, BC, then north via train to near present day Whistler, BC. Here they established a species susceptibility trial (Childs and Bedwell 1948) and various research plots (Lachmund 1934; Childs and Kimmey 1938). Once it was clear that the rust was well established in the United States, no new plots were established in BC. About that time (1927) the lone collaborating Canadian scientist was killed in a car crash (Estey 1994), and Canadian rust research stopped until 1946.

In 1946 the provincial chief forester had *P. monticola* seed collected from the BC interior and sent to Heimburger in Ontario for resistance testing. Both Heimburger and Riker in Wisconsin were doing resistance testing in *P. strobus*. In 1948 the Canadian government hired Porter to do resistance testing in BC. Porter followed Riker's protocol of grafting plus-trees and placing them in a ribes (disease) garden (fig. 1). He obtained scions from survivors in the old U.S. Forest Service plots near Whistler, trees in similar plots that he had established, and a few trees recommended by the BC Forest Service. He rated clones by percentage of ramets cankered after 5 or 7 years in a disease garden. These were also placed in three forest sites and subjected to natural infection. The most promising *P. strobus* and *P. monticola* from Heimburger and *P. strobus* from Riker were also placed at these sites. When it was discovered that grafts from old trees can produce susceptible offspring (Patton 1967), the program ended, and Porter left to become a school teacher. All the material from one field site was transferred to the University of BC experimental forest, and the other sites were abandoned. These sites were revisited in the 1980s, and the cankering of the clones tended to follow Porter's (1960) original ranks (Hunt and Meagher 1989).

The success of Bingham's resistance work in Idaho (Bingham 1983) and the need for *P. monticola* for reforesting laminated-root-rot (*Phellinus weirii* (Murr.) Gilb.) sites was the catalyst for the BC Forest Service and Canadian Forest Service (CFS) to sign a cooperative memorandum of understanding on blister rust resistance in 1983. Disease free plus-trees were selected for both Interior and Coastal populations. Open-pollinated (OP) cones were collected from the selected trees, and the resulting progeny seedlings were exposed to blister rust in inoculation chambers. The first successful inoculation occurred in 1987 and was repeated annually to 1995. This material is now the basis for white pine seed orchards and resistance breeding programs in BC.

Present

The resistance program continues in BC primarily through the continuing cooperative relationship between the provincial government, the CFS, which provides pathology research and screening, and increasingly the Forest Industries, which provide technical support through their seed orchard programs. The efforts of the past have allowed us, at this stage, to assess the resistance found to date, not just in the populations screened in BC, but also in other jurisdictions in Western North America. We can also assess the transferability of seed sources of western white pine and are looking at the most appropriate strategy of seed deployment from our seed orchards in order to use the best available resistance with well-adapted seed sources. Not all of these questions can be answered at present, but current research should answer them in the near future.

Figure 1—Porter's screening for blister rust resistance by growing grafted *Pinus monticola* ramets from blister rust resistant candidates in a disease (ribes) garden at Duncan BC in 1955.

Resistance Story to Date

Most of the resistance programs in Western North America to date have concentrated on selections and screening of open-pollinated families from surviving canker-free parent trees. The strong selection pressure, first in the natural stands and then in inoculation chambers, almost assures that these are not mere "escapes" but that there is a genetic basis to this resistance. However, as with the original Riker method of screening grafts, it has been difficult to determine the basis of resistance and how the resistance is inherited. The exception is the case of the hypersensitive response (HR), a major gene resistance (MGR) found in sugar pine (*P. lambertiana* Dougl.) and some populations of *P. monticola* (for example, Champion Mine) (Kinloch and others 1970, Kinloch and others 2003). Although there are some complexities to MGR (Kinloch and Dupper 1998, Kinloch and others 1999), it is relatively simple and easily understood because it is a classical vertical resistance controlled by a single dominant gene. More complex resistances, falling under the headings of "partial resistance" and "tolerance", are more difficult to characterize, and we have a much poorer understanding of their genetic basis.

In BC we have now made a series of nearly 600 selections from the CFS screening program. This included a fairly intensive parent tree selection from both the Interior and Coastal BC (about 300 from each population) and rust screening of the OP progeny for what may be considered two "partial resistance" mechanisms: "slow-canker growth" (Hunt 1997) and "difficult-to-infect seedlings" (Hunt and others 1998). We have also selected a set of trees from established plantation trials and from Texada Island where a stand was characterized with "tolerance" and trees were selected for their marked "bark reaction" response.

Although the first orchard selections were based on forward selection of the progeny from the screening trials, lately, where it is feasible, we have switched to collecting scion from the original selected parents. Selection of parent material, rather than progeny, has allowed us to proceed much faster with our breeding program, as seed cones can be produced on ramets in as little as 2 years. Also the hypothesis presented that some of the resistance found in the Idaho populations may be controlled by recessive genes (McDonald and Hoff 1971; Hoff 1988) has encouraged us to use parents rather than OP progeny and concentrate future screening on a F_1 population constructed from the best parents. Crossing for this breeding program consists of crosses between parents of similar putative mechanisms, crosses with susceptible parents and selfs. Selfs, where they can be made, will be particularly valuable if recessive genes are involved. The construction of this F_1 breeding population is now well under way (fig. 2), making use of structured mating designs that will help in future genetic interpretations.

Transferability and Adaptability of White Pine Seed Sources

Seed transfer guidelines have been, and continue to be, developed from three series of trials that test most of the

Figure 2—Pollination bags for breeding program crosses on top-pruned young grafts of western white pine at CanFor Seed Orchard, Sechelt BC (photo courtesy R. Sniezko).

range of western white pine on 24 sites throughout BC (fig. 3). The first series contrasted the R.T. Bingham (Moscow, ID) arboretum seed source with a local BC source. Trials were established within and north of the species range. The second was established in nine root disease sites and included 14 provenances covering the range limits of the species (Hunt 1987). The third had 12 provenances with family structure on six sites. These trials have been described in detail (Hunt 1987, Hunt 1994, Hunt and Meagher 1989, Meagher and Hunt 1998, Meagher and Hunt 1999), and these results are summarized below. We also report results from recent assessments from two of the family/provenance trials.

Results from these series show that western white pine does not show a strong clinal response to growth or disease resistance, but rather there are abrupt changes. Most striking are the southern populations from the Sierras, Klamath, and Warner Mountains that grow poorly and are generally highly susceptible to rust, even more so than the northern populations (perhaps as a result of physiological opportunities that the rust can exploit) (Hunt 1994; Meagher and Hunt 1998). Rehfeldt and others (1984) also showed this absence of a strong geographic pattern of variation except in these southern populations. Sources north of these (especially north of the Columbia River) and extending east as far as Montana are less dramatic in their differences. Interior sources, including Idaho, grow well at the coast (Bower 1987; Meagher and Hunt 1998). Coastal sources tended to be slightly inferior for growth (Meagher and Hunt 1998) and less hardy (Thomas and Lester 1992) than interior sources on the interior sites. Some of our more northerly populations do well for juvenile vigour on our interior sites (Meagher and Hunt 1998). The Idaho material was more winter-damaged than BC sources in the trials north of the species range. The resistance of the Moscow, ID, arboretum material held up well in BC's interior but was lower on coastal sites (Hunt and Meagher 1989; Meagher and Hunt 1999). Thus, the Idaho material is not recommended for the northern part of the range nor at the coast but is recommended for the southern Interior. At 5 years, the Champion Mine (MGR) source from southern Oregon showed poor vigour as did the more northern Oregon sources (Mt. Hood and Willamette; fig. 3, sources 29 and 30). Based on this it was recommended that the Columbia River should be a southern transfer boundary and that sources from Oregon should not be used in BC (Meagher and Hunt 1998).

Recent, 2001, Reassessment of Coastal Family/Provenance Trials

In 2001 12-year assessments were made on the two coastal family/provenance trial sites (Ladysmith and Sechelt, fig. 3, locations close to sources 24 and 26) for growth and survival. We present here some preliminary results that allow a reflection on the above recommendations after rust has greatly affected these two coastal sites. Details of the Provenance Plantations experiments are provided in Meagher and Hunt (1998). But briefly this included 12 provenances with four to five cone-parents per provenance with an additional five more bulked provenances. Figure 3 shows the

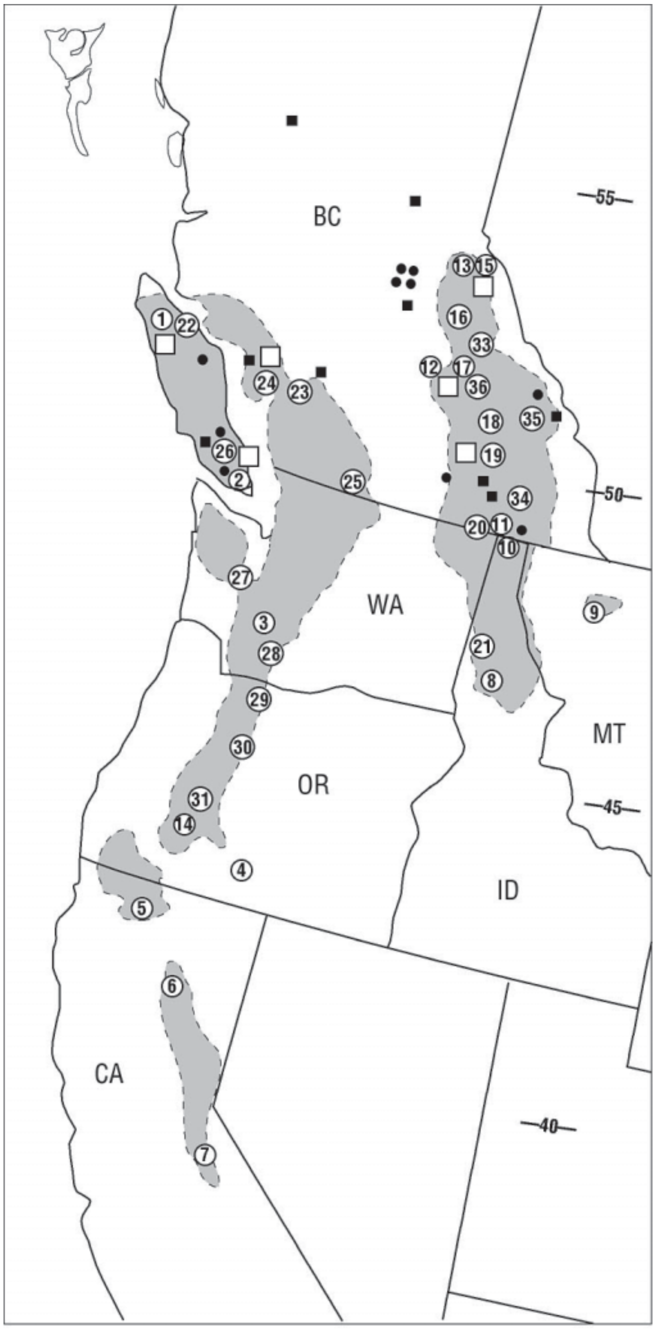

Figure 3—Distribution of western white pine (shaded area), provenance origins (circled numbers) and plantations. Solid circles indicate plantations using R.T. Bingham (Moscow) arboretum seed source contrasted to local sources. Solid squares indicate plantations in the root-rot disease experiment sites with provenances 1 through 14. Open squares indicate plantations that have some or all of provenances 15 through 35. The Ladysmith and Sechelt site are these latter open squares near provenaces 26 and 24, respectively.

provenance collections site (numbers 15 through 31) and the trial locations. Six plantations (3 Coastal and 3 Interior) were established with 25 replicates per plantation. The measurements reported here include height, rust and overall survival on two of the Coastal sites (fig. 3, trial sites close to origin sources, 24 (Sechelt) and 26 (Ladysmith)). In terms of survival, rust has not been the only mortality agent although it is by far the most causative agent. Both sites have been damaged by bough pickers (white pine is highly desirable for Christmas decorations), but this was not deemed to hinder our results and interpretations.

Anova models were run on each of these sites for the following effects: replicates, geographic origin and families within geographic origin. Means analysis – Student-Newman-Keuls (SNK) were also conducted on the geographic origin groupings (Steel and Torrie 1980). Geographic origin groups included: Northern Interior BC (Valemont, Raft River, Barriere and Mt. Revelstoke, fig. 3, sources 15, 16, 17, and 18); Southern Interior BC (Arrow and Trail, fig. 3, sources 19 and 20); Idaho (bulk unselected collections not F_2, fig. 3, source 21); Vancouver Island (includes low elevation Sunshine Coast) (fig. 3, sources 22, 24 and 26); Lower Mainland High Elevation (Cascade) BC (Whistler and Manning Park, fig. 3, sources 23 and 25); Washington Olympic Peninsula (fig. 3, source 27); Northern Oregon Cascade (Mt Hood and Willamette, fig. 3, sources 29 and 30); Southern Washington Cascade (White River, fig. 3, source 28) and Dorena Oregon – "Champion Mine" (fig. 3, source 31). Also included were some selected seedlots. These include the Westar selections – Southern Interior BC but selected as clean parent trees; the Dorena "Champion Mine" MGR selections; and the Porter selections as described above; and at the Ladysmith site, only exotics (mainly *P. strobus* but also *P. koraiensis* Sieb. and Zucc.).

Results are presented for: the percentage canker-free stems in 1995 assessment (CF95); the percentage canker-free stems in 2001 (CF01); mean height and standard errors (in cm) and finally - percent likely crop tree survivors (CT) - those trees, both tall and healthy either canker-free or just minor infections (table 1). Although survival in this last measure reflects other factors such as vigour (height growth), frost survival, and other factors, blister rust escape was by far the major factor.

Ladysmith, although showing the results of blister rust ahead of Sechelt, has now grown beyond the worst of the infection, and 30 percent of the original healthy trees are alive and likely to remain so (some as tall as 12m at age 12). On this site three sources were significantly less infected than the rest. One of the exotic species, *P. koraiensis*, showed markedly less infections in the 1995 assessment (only 9 percent), but this species quickly fell behind for growth rate and had faded from the planting by 2001. Although *P. strobus* has continued to show good survival, it has also shown signs of frost damage and poor overall vigour (table 1; fig. 4). The Dorena seedlot did the best for rust survival (as expected) but was lower ranked for growth (reflecting the earlier assessment) (table 1; fig. 4). One of the more impressive lots was the Porter families, which were second only to the Dorena source for both clean trees in 2001 (CF01) and potential crop trees (CT). The Porter families were also the tallest and were significantly different from the Dorena lot for vigour (height growth) (table 1; fig. 4). This selected lot screened for early survival, using Riker's *P. strobus* protocols, appears to have been effective on a site such as Ladysmith.

The Vancouver Island, Washington, and northern Oregon sources performed quite similarly. The Idaho lots as a whole, as in the earlier analysis, were poor on these coastal sites for survival (mainly blister rust) but were good for growth; these, however, were nonselected Idaho material. The Northern Interior BC source and the high elevation Lower Mainland BC were poor for both growth and survival. Although geographic origins were significant in our model (P<0.0001) so were families within origin. The Southern Interior BC origin, which had the largest number of families, showed up

Table 1—Results showing : % clean trees 1995 – CF95, % clean trees 2001 – CF01, mean height and standard error, and % crop trees (CT), which are defined as those trees that are alive and healthy (either canker free, branch canker, or tolerant stem reaction) and greater than 3 m at Ladysmith or greater than 2 m at Sechelt.

	Trial Sites							
	Ladysmith				Sechelt			
Seedlots	CF95	CF01	HT01 ± se	CT	CF95	CF01	HT01 ± se	CT
Overall plantation	56	30	610 ± 4	27	65	20	461 ± 4	18
Northern Interior BC	46	15	576 ± 15	26	62	14	399 ± 12	12
Southern Interior BC	53	25	639 ± 24	36	73	20	467 ± 24	21
Westar S. Interior BC	52	27	627 ± 5	35	66	23	484 ± 7	21
Idaho	51	22	603 ± 12	29	56	9	460 ± 11	9
Coastal BC, High Elevation	44	10	551 ± 22	15	59	10	455 ± 17	8
Vancouver Island BC	46	20	614 ± 15	28	60	16	470 ± 14	17
Porter families BC	68	52	679 ± 13	55	78	25	510 ± 20	27
Olympic Peninsula WA	51	29	619 ± 31	37	70	22	452 ± 24	21
Southern Cascade WA	62	40	605 ± 25	42	72	33	426 ± 23	23
Northern Cascade OR	54	29	585 ± 20	35	64	17	457 ± 17	15
Dorena OR Champion Mine	74	65	573 ± 20	65	84	49	494 ± 17	40
Exotics (*P strobus*)	73	48	534 ± 15	46				

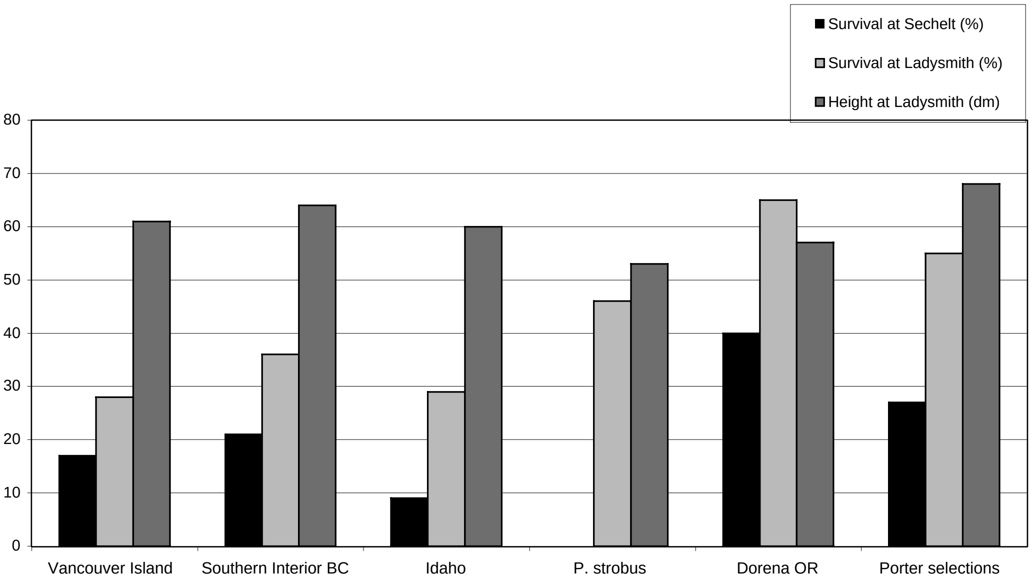

Figure 4—Height (dm) at Ladysmith plantation and Survival (%) at Sechelt and Ladysmith plantations for five *P. monticola* sources and the *P. strobus* source in 2001 at age 12. (Survival refers to crop tree survival as discussed in the text.)

well for growth but not survival; however; several families showed consistently better survival over both sites.

Although the Porter families, screened for phenotypic survival in ribes gardens (fig. 1), did well on such sites as Ladysmith, on higher rust hazard sites such as Sechelt heavy mortality continues (overall plantation infections going from 35 percent to 80 percent in 5 years; table 1). The phenotypic survival selection as conducted by Porter is likely equivalent to the partial resistance screening of the current programs. This indicates to us that on severe rust sites, MGR, such as in the Dorena "Champion Mine" source, will need to be combined with the partial resistances in order to have any trees survive.

Future

The future prospect for western white pine against blister rust is hopeful. Certainly compared to other exotic pathosystems, such as chestnut blight (1904 introduction) caused by *Cryphonectria parasitic* (Murrill) Barr. on American chestnut (*Castenea dentata* Marsh. Borkh.) or to Dutch elm disease caused by *Ophiostoma ulmi* (Buism.) Nannf. (1920's introduction) and *O. novo-ulmi* Brasier (1940's introduction) on elm species (*Ulmus* spp.), there does appear to be a reasonable degree of native resistance. Confirmation of this resistance from the inoculations to field trials is under way through a series of excess stock trials (Hunt 2002). Investigation of these trials together with continued measurements of the provenance trials will help us to establish deployment guidelines for the orchard seed which will soon be available.

Deployment Potential for Western White Pine in BC

Orchards in the interior BC have a predominant element of material from the Idaho program. The emphasis here will be to incorporate our own selections and compare them to Idaho material.

On the coast, three seed orchards will soon be producing seed. Earlier use of seedling progeny for orchard establishment has now given way to the use of selected parents based on results of the inoculation of their progeny. New material, primarily selections from heavily infected trials, is also being added. All of these selections fall under the general categories of "partial resistance" or "tolerance". In addition to this, we have been encouraged to use "total resistance" pollen based on the performance of "Champion Mine" and "Champion Mine" pollinated seedlots in the "root disease" trials (Hunt 1987, Hunt these proceedings) and shown here (table 1; fig. 4). These seedlots (Dorena in table 1) have the Cr2 gene which conditions a hypersensitive response (HR) in western white pine. The strategy of pyramiding HR can be implemented in seed orchards by either supplemental mass pollination or mass control pollination. Both of these methods have found practical use in BC (Webber 1995).

While Cr2 is a powerful form of resistance (the Dorena seedlot, table 1), a pathotype of rust that overcomes it does exist (vcr2), and Cr2 cannot be seen as an ultimate solution (Kinloch and others 2003). Although there are few examples of "total" or "vertical resistance" pathosystems being durable (Leach and others 2001), a completely durable resistance may not be required. Because most cankering occurs close to the ground in BC (Hunt 1991), resistance may therefore only be needed during the plantation's early years. How fast and far vcr2 will spread and its durability are the more relevant questions. If vcr2 becomes widely distributed, it would negate any further planting of single gene resistance solely based on Cr2. Investigations of Cr2 material in the BC root disease trials have failed to show any virulent pathotypes up to 15 years (Hunt and others these proceedings), and in a Bear Pass, OR, plantation some resistant Cr2 trees are still canker-free after more than 60 years (Sniezko, pers. comm). However, the observation of vcr2, the virulent strain, in a relatively small population (hence small selection pressure) of *P. monticola* with Cr2 at the Happy Camp field station in northern California (Sniezko and others these proceedings) is most certainly disturbing. Some encouragement for using the strategy of pyramiding HR has come from observations made in the long-term deployment and monitoring of sugar pine with the Cr1 hypersensitive response gene. As in western white pine, a pathotype of blister rust virulent to Cr1 exists (Kinloch and Comstock 1980). Data indicate that the virulent strain of the rust (vcr1) does not always arise quickly or spread rapidly (Kinloch and Dupper 1998). This has encouraged us to develop a deployment strategy that attempts to manage the Cr2/vcr2 pathosystem by integrating it into a silvicultural option that would incorporate hazard assessment area to be planted and distance from other plantations.

Future Research Directions

Further investigation of the Cr2 gene and its potential durability is needed. This will include: careful investigation of all plots in which it has been deployed in BC, follow up of the material that the Dorena program has deployed, and continued interaction with the Region 5 sugar pine program which has provided a model for this deployment. Besides Cr2, other "total resistant" genes may exist and be made available. The Dorena Genetic Resource Center is investigating other potential dominant gene resistances in western white pine (Sniezko pers. comm). Although *P. monticola* and *P. lambertiana* do not naturally hybridize (Bingham 1972), there are now *in vitro* fertilization methods (Fernando and others 1997) which may permit such a cross, and thus add Cr1 as a resistance gene in *P. monticola*. The multiplicity of these "total resistance" genes should add to their durability and strategies to use multiple "total resistance" genes need developing.

The pyramiding of several race-specific resistances into a single plant genotype theoretically has the ability to greatly reduce the probability of a mutation to multiple virulence (Wheeler and Diachun 1983). However, this assumes that the mutations to virulence are independent of each other. Empirical evidence from crop literature, however, points to the fact that there is no clear association between the number of resistance genes in cultivars and their durability (Mundt 1990). Some single resistances have proven highly durable while others have been highly ephemeral, and combinations are not necessarily more durable unless specific resistances are included (Johnson 2000). It has been hypothesized that the quality and durability of a plant resistance gene is a function of the fitness penalty of virulence. Even where genes fail, they may be beneficial through a residual effect because they may add a cost to the pathogen of not having the avirulence (Leach and others 2001). The advent of molecular genetics technology to investigate gene function has offered some insights into the potential relationships between viurlence/avirulence and durability. Although avirulence can confer a high degree of fitness in some cases (resulting in durability of HR), in others this does not appear to be so, and these relationships can be complex (Leach and others 2001). Bacterial blight resistance in rice has shown such a positive functional relationship between the avirulence gene in the pathogen and fitness through its aggressiveness (rate a virulent isolate produces an amount of disease) (Vera Cruz and others 2000). The study of gene function and the protein – ligand relationships between resistance, virulence/avirulence in HR pathosystems in the white pines are being investigated by the CFS (Ekramodddoullah and Tan 1998, Yu and others 2002) and may lead to some insights and potential indicators of durability.

HR total resistance is only one component of our resistant breeding program. We will continue to rely on partial resistances and tolerances for the major part of our effort, and the breeding program is directed to families and individuals selected for this type of resistance. By using a structured mating design and cloning of individuals we can begin to construct pedigreed lines to more carefully observe the partial resistances and be in a position to start to understand some of the underlying genetics.

Another part of the investigation of resistance will be the observation of blister rust as an endemic pathosystem with Asian white pines. Some early work with Asian hybrids was conducted by Heimberger in Ontario, and some of this material may still be available (G. Daoust pers. comm). Unlike the other two exotic pathosystems mentioned earlier (chestnut blight and Dutch elm disease), we are not obliged to use species hybrids and backcrossing to save our native gene pool as there does appear to be ample resistance in our native populations. However, the observation of the endemic pathosystem in Asian species and their hybrids with North American white pines should help us greatly in understanding resistance and identifying which resistances are likely to be the most durable.

Biotechnology can help in our efforts. This will include in-vitro fertilization (Fernando and others 1997) to help in hybrid crosses; embryogenesis to clone lines for the pedigreed breeding program (some successful lines have already been produced); molecular biology to detect the protein precursors of HR; and molecular genetic techniques to help in understanding the genetic basis of resistance. A lot of classical breeding and pathological research will need to be continued to realize this effort.

Although a lot of effort has been spent on western white pine to the point where we can start to see the results and envision its return as an important species to our landscape (Fins and others 2001), other species are still in danger. Whitebark pine, *P. albicaulus*, is considered an endangered species in BC and the U.S. Pacific Northwest (Krakowski 2001, Mahalovich, these proceedings). To this end we have initiated a large-scale seed collection. This is both to preserve important gene pools that are under threat and to start some initial screening in this species. The successes we have had to date should encourage us to keep up the effort in reestablishing these species and continue the co-operative atmosphere of this effort throughout the regions where the white pines grow.

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