SURVEYS OF DAMAGE AGENTS AFFECTING YOUNG TREE GENETICS RESEARCH PLANTATIONS AND SEED ORCHARDS IN ALBERTA AND A SUMMARY OF CONTROL TREATMENTS

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ABSTRACT

A major program of forest genetics research and tree improvement was initiated in Alberta in 1976, and has involved the establishment of approximately 200 research and experimental tree plantings (during 1976 to 1994) of many tree species on over 33 sites across Alberta. The field headquarters where the genetic research trials and related plantings were initiated is located at the Alberta Tree Improvement and Seed Centre (ATISC, earlier known as Pine Ridge Forest Nursery) near Smoky Lake, Alberta. Subsequent surveys and assessments of seedlings and young trees indicated that several biotic (e.g., insects, diseases, rodents, etc.) and abiotic (e.g., frost, excess moisture, etc.) factors were contributing to tree injury and mortality, and thereby affecting growth and survival of trees. This injury and tree loss resulted in a request for systematic surveys of insect and disease pests and other damage agents to be undertaken by staff of the Forest Insect and Disease Survey unit of Natural Resources Canada. These surveys commenced in 1986 in several of the established tree genetic plantations and experimental sites and were continued more or less annually until 1994. The objectives of the surveys were to: (1) identify the insect, disease and other agents causing tree losses and damage; (2) assess the magnitude and damage characteristics of each damage agent; (3) make recommendations for follow up monitoring for potential pests and damages, and; (4) review and recommend appropriate control strategies where applicable.

The results of the surveys reported here provide a summary of the biotic and abiotic agents affecting cones, seedlings and trees, gives a distributional summary of damage agents according to plantation sites established within the province up to 1994, and indicates the relative importance of each agent. The report also provides a listing of unpublished technical reports that resulted from the work described here and can be referred to for further details where necessary.

During the period from 1986 to 1994, some preceding years and some subsequent years to 1999, a number of experimental and operational insect and disease control trials were conducted at the Pine Ridge Forest Nursery (Site 32), and at Sites 19 (Snuff Mountain) and 22 (Huallen). This report also presents a brief description of these control trials and gives an assessment of the effectiveness of treatments.

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1.0 INTRODUCTION

The province of Alberta commenced a major forest genetics research and tree improvement program in 1976. This program to date (2011) has involved the establishment of over 200 research and specialty tree plantations located at 71 experimental sites distributed throughout the province. As a basis for this program, twenty two, tree-breeding regions in the province have been delineated for the purpose of developing regionally adapted superior varieties of trees for economically important tree species, lodgepole pine (*Pinus contorta* var. *latifolia*), white spruce (*Picea glauca*), black spruce (*P. mariana*), jack pine (*P. banksiana)*, Douglas-fir (*Psuedotsuga menziesii*), tamarack (*Larix laricina*), western larch (*Larix occidentalis*), aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*). Other native and exotic tree species selections and provenance collections, including hardwoods, have been included in many of the experimental trials. The majority of these trials are maintained by the province or by the province and industry under cooperative agreements. These established plantations represent a significant long-term investment in genetic testing including progeny tests, species comparison tests, provenance tests, seed orchards, seedling and clonal germplasm banks, and arboreta. Because of their nature as experimental and research trials, and the fact that some plantings are regularly irrigated and fertilized, these plantations invariably require more intensive management than do operational field plantings. The plantations vary from 0.1 to 16 ha in area and are generally protected by chain-link or game fences.

During the surveys of early seedling growth and survival, tree injury and mortality caused by a variety of insects, diseases, and other biotic and abiotic agents were noted. This injury, in addition to planting and site-related mortality, prompted the need for additional intensive surveys to identify and quantify the impact of the various damage agents that may be affecting different tree species, different seedlot provenances and/or families and clones and different geographical locations. In some cases, there was also a need to assess for control applications to mitigate insect and disease damages. A variety of control trials were initiated, including some experimental as well as some operational, to deal with insect and disease problems as they arose. Some of these control trials were conducted prior to 1989, while others were carried out more routinely for management of pest organisms. Systematic surveys of the tree genetic plantations were commenced in 1986 by staff of the Forest Insect and Disease Survey unit of Natural Resources Canada in collaboration with the Alberta Forest Service (now Forestry Division, Alberta Sustainable Resource Development) and carried out annually until 1994 on genetic experimental plantation sites identified in Figure 1.

This report focuses on pest and damage impact surveys undertaken in Alberta since 1986 in established tree genetic installations and incorporates other related survey and control trial studies undertaken since 1976 (see reference list of published and unpublished reports). The report includes a summary of the tree damage agents identified during the surveys, identifies those causing important impact, reviews experimental and operational controls and provides base information for future reference.

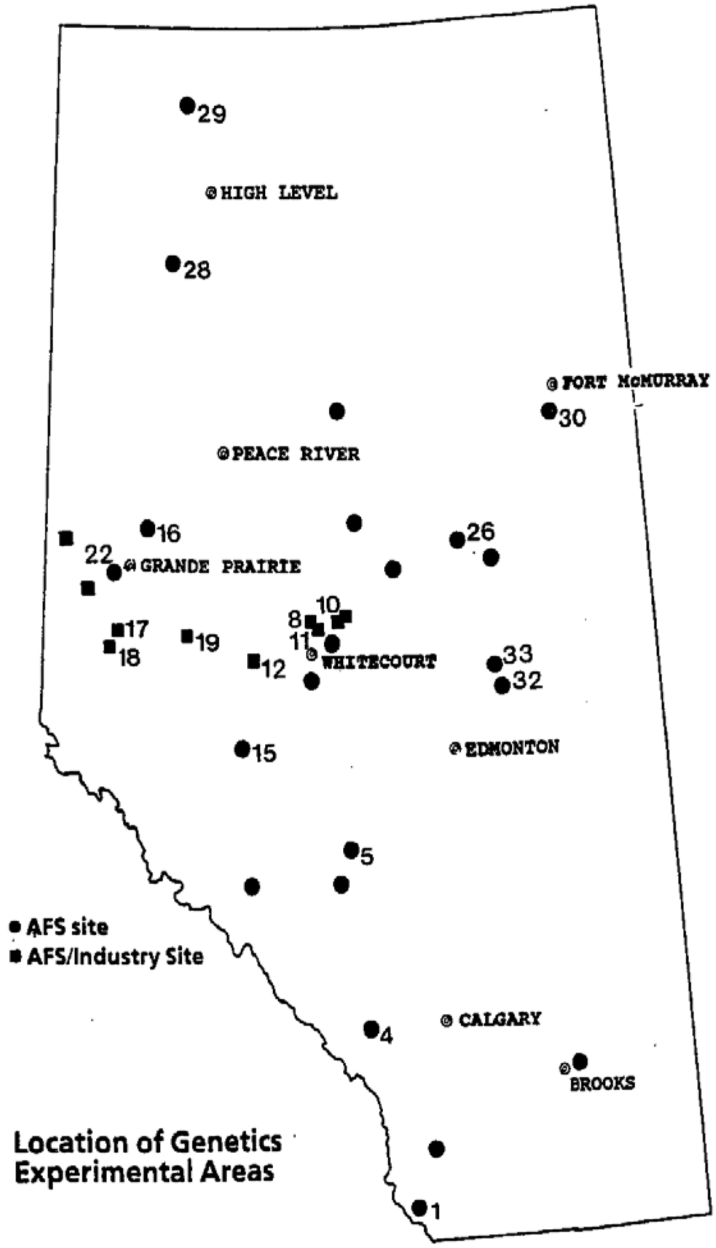

Fig. 1 Map of Alberta showing the locations of established genetic experimental sites to 1994. Sites designated with a number were surveyed during 1986 to 1994 for insect, disease and other damage agents and are identified as follows: 1-Castle; 4-Jumping Pound; 5-Prairie Creek; 8-Judy Creek; 10-Swan Hills, Blk. 26; 11-Virigina Hills; 12-Fox Creek; 15-Swartz Creek; 16-Sexsmith; 17-Nose Mountain, Blk. 32; 18-Nose Mountain, Blk. 11; 19-Snuff Mountain; 22-Huallen; 26-Calling Lake; 28-Chinchaga River; 29-Hay River; 30-Hangingstone; 32-Pine Ridge Forest Nursery; 33-Block H (see also Table 1 for a complete listing of experimental sites and forest district locations). Site locations without a number were not surveyed for damage agents.

2.0 METHODS AND MATERIALS

2.1 Survey and Tree Assessment Methods

Prior to 1986, various surveys and special studies were undertaken in Alberta to help resolve specific pest problems related to the production and growth of nursery-grown tree seedlings at the Pine Ridge Forest Nursery near Smoky Lake, Alberta. Methodologies deployed in these studies are referenced in several file reports (Petty *et al.* 1977; Hiratsuka and Allen 1980, 1981a, 1981b; Cerezke 1987). For surveys conducted after 1986, methods of plantation assessment were somewhat variable, depending upon the objectives of the survey, time and manpower available, size and age of trees and plantation area. For routine, systematic surveys of pests and damage, however, certain criteria were established as a guide. Initially, 33 genetic experimental sites were identified (Table 1) including two major sites (Pine Ridge Forest Nursery complex and Huallen Seed Orchard complex near Grande Prairie) that were to be assessed annually because of their importance. All other sites were to be assessed on a rotation basis; i.e., up to 7 sites per year and each re-surveyed once every 5 years, or as the need arose because of any special pest infestations. Plantation sites selected for each year's assessment were prioritized on the basis of provincial or industrial need and periodic pest concerns, were generally older than 5 years since establishment, were represented by several tree species, and were distributed widely in the province so as to provide a broad overview of annual pest and damage conditions. A Maximum of 1-2 days, usually with two observers, was suggested as a reasonable time to spend monitoring each plantation site.

Table 1. List of Forest Genetic Experimental sites established in Alberta 1976 to 1994.

Forest District	No.[a]	Experimental Site	Natural Subregion	Forest District & Agric. Zone	No.[a]	Experimental Site	Natural Subregion
Bow Crow	1[b]	Castle	Montane	Slave Lake	23[*]	Zeidler Mill	Central Mixedwood
	2[*]	Porcupine Hills	Montane		24[*]	South Mitsue	Central Mixedwood
	3[*]	Bateman Creek	Montane		25[*]	Red Earth	Central Mixedwood
	4	Jumping Pound	Montane				
				Lac la Biche	26	Calling Lake	Central Mixedwood
Clearwater	5	Prairie Creek	Upper Foothills		27[*]	Wandering River	Central Mixedwood
Rocky	6[*]	Tershishner Ck.	Montane				
	7[*]	Diamond Hill	Lower Foothills	Peace River	28	Chinchaga River	Central Mixedwood
Whitecourt	8	Judy Creek	Upper Foothills	Footner Lake	29	Hay River	Central Mixedwood
	9[*]	Swan Hlills, Bk 15	Upper Foothills				
	10	Swan Hiils, Bk 26	Upper Foothills	Athabasca	30	Hangingstone	Central Mixedwood
	11	Virginia Hills	Upper Foothills				
	12	Fox Creek	Lower Foothills				
	13[*]	Carson Lake	Lower Foothills	Agric. zone	31[*]	Brooks Horticultural	Dry Mixedgrass
	14[*]	WCT Mountain	Lower Foothills			Station	
Edson	15	Swartz Creek	Lower Foothills				
				Agric. zone	32	Pine Ridge Forest	Dry Mixedwood
Grande	16	Sexsmith	Lower Foothills			Nursery	
Prairie	17	Nose Mt, Bk 32	Upper Foothills			(Main Site)	
	18	Nose Mt, Bk 11	Upper Foothills	Agric. zone			
	19	Snuff Mt, Bk 37	Lower Foothills		33	Pine Ridge Forest	Dry Mixedwood
	20[*]	Forest HQ	Peace River Parkland			Nursery	
	21[*]	Saddle Hills	Lower Foothills			(Block H)	
	22	Huallen	Dry Mixedwood				

[a] All experimental sites are numbered for convenience and correspond to site locations shown in Fig. 1. Site locations that were not surveyed for damage agents are identified with an asterisk (*) and are not numbered in Fig. 1.
[b] Site 1 was visited in 1989 but a survey for damage agents was not undertaken, partly because the site was too poorly maintained. It was revisited in future years after site maintenance (weeding and ingress removal) was improved

2.1.1 Tree Selection:

The method of survey involving tree selection and health assessment was similar in most plantations, except that tree sampling intensity often varied depending upon size and importance of the plantation. In a few cases, all trees within a plantation were examined. Total number of trees in plantations assessed varied from approximately 100 to 16,000. For the most routine surveys, starting in the first row of a plantation and selecting an initial sample tree from a table of random numbers determined selection of sample trees. Subsequent sample trees followed in sequence as every fifth, tenth, or other number of trees decided at the beginning of the survey. The samplers progressed consecutively down each row until the entire plantation area was covered. Thus, in all cases, sample trees selected for examination and assessment were distributed evenly throughout each plantation. In large plantations, or where time was a prime limiting factor, sample trees were selected in every second, fourth, or fifth consecutive row. In some other situations where few trees were involved, or where pest and damage information were of a high priority, all trees within selected rows were sampled or all trees within a plantation. Plantation sites selected for surveys are listed in Table 1 and are cross-referenced by corresponding number in Fig. 1.

2.1.2 Tree Assessment:

Sample trees were systematically examined in the following way. Each tree or tree position selected for examination could be assigned one of five condition codes:

- 01-Healthy, with no apparent defects or injury;
- 02-Fairly vigorous, and may have minor injuries or defects but the tree is judged to be able to recover and is not declining in health;
- 03-Declining (in health) or dying, with one or more severe injury or defect symptoms that will ultimately lead to mortality;
- 04-Dead for one or more years; and
- 05-Tree not present and assumed to be missing.

To facilitate examination and assessment, each tree was divided into three structural components: root and root collar, stem, and crown (includes foliage, buds, twigs, and branches). Each tree component was visually inspected for physical signs and symptoms of injury, which were classified according to one or more of the following categories: browse, bud/shoot kill, cankers, climate induced, defoliation, deformity, galls, resinosis, girdling, chlorosis, top-kill, and other undefined injuries, which may include injuries due to air, water, and soil pollutants, competition, drowning, improper planting, etc. Causal agents affecting the various sign and symptom injury were identified according to specific biotic and abiotic agents and the severity of injury was estimated. On trees classed as declining or dying and dead one or more years, the causal agent(s) was identified where possible. In addition to the selected sample trees, other observations were noted on non sample trees. Samples of damage agents that could not be identified in the field were brought back to the laboratory for further examination.

Damage conditions were summarized by tree species, age of plantation, and by geographic location. In some instances damage conditions in plantations were further summarized by provenance or family category to facilitate genetic analyses for scientific studies.

2.2 Experimental and Operational Control Trials:

Trials conducted for control of insect and disease problems are described by target organism. Information is given on the method of control treatment, location of treatment, and an assessment of the results is provided where available.

3.0 RESULTS AND DISCUSSION

3.1 Survey Results

The surveys conducted over a 9-year period (1986 to 1994) identify important insect, disease, and other abiotic agents that cause defects and mortality of trees, and affect their early growth performance. Since the plantation sites and field trials contain a wide variety of genetic stock of different species and origins established at widely separated geographic locations, some generalizations about the incidence and impact of certain damage agents can be made. The data also provide Alberta an account of agents likely to be important to two promising non-native species, Siberian larch (*Larix siberica*) and Scots pine (*Pinus sylvestris*). All biotic and abiotic agents affecting plantation grown trees are listed by common name for each tree species in Tables 3, 5, 7, 9, 11, 13 and 14, and a combined listing of biotic agents with scientific names is given in Appendix A. The individual yearly survey results and related work have resulted in a large number of unpublished reports which are cited in the text where applicable and listed in Section 6.0 of this report. Published literature cited in the report is referenced separately in section 5.0.

The important agents affecting each major tree species are discussed below to indicate their incidence, distribution, impact, and some consequences that may relate to site, tree size and age.

3.1.1 White spruce:

A total of 12 Experimental Sites with planted white spruce were surveyed (Fig. 2; Tables 2, 3). Among the insect species causing important injury at widely separated locations were yellow-headed spruce sawfly (*Pikonema alaskensis*), spruce bud midge (*Rhabdophaga swainei*), and white pine weevil (*Pissodes strobi*) (Cerezke 1987, 1993b). The latter two, respectively cause bud and shoot kill of the leader and thus impact on height growth. Yellowheaded spruce sawfly primarily defoliates current-year needles but tends to concentrate its attacks on trees previously defoliated. Repeated attacks may severely retard height and radial growth, and cause tree mortality when defoliation is complete (Ives and Wong 1988; Martineau 1984; Wilson 1971). All three insect species are distributed widely, survive in a variety of sites, tend to re-infest annually at the same locations, and show a preference for open-grown trees (Cerezke 1972; Ives and Wong 1988; Martineau 1984; Wallace and Sullivan 1985; de Groot 1995; Retnakaran and Harris 1995). Incidence of their injury tends to decrease after about age 20 years. The incidence of attacked trees at sites by these three insects ranged from 0 to 10% for yellowheaded spruce sawfly, 0 to 6.9% for spruce bud midge, and 0 to 5.2% for white pine weevil. The incidence of killed leaders by the white pine weevil was probably much higher than 5.2% at Site 32 where control treatments have been applied for several consecutive years. It is noteworthy that in a separate survey conducted in 1993 on Sites 13, 24, 25 and 26, incidence of leader kill caused by the white pine weevil was, respectively, 5%, 6%, 27% and 33% (Hansen, 1995). Of these four sites, only Site 26 had been previously (1989) surveyed (Tables 1, 2). Over the four-year period (1989-1993), there has thus been an almost 6-fold increase in white pine weevil injury.

Of the diseases, Armillaria root disease (*Armillaria ostoyae*) was the most serious and caused tree mortality at four plantation sites (Cerezke 1987; Cerezke and Mallett 1991). Infection rate was low (<3%) at three sites but caused 8.7% mortality at Site 15. The impact of this disease will probably continue over time because of established infection centers (Mallett 1992; Morrison and Mallett 1996).

Three sites (11, 15, 30) had high infection rates (64 to 84% of trees) of spruce needle rust (*Chrysomyxa ledicola*) during 1989, probably as a result of high moisture conditions during the spring growth period and an abundant local source of its alternate plant host, Labrador-tea (*Ledum groenlandicum*). While infected needles drop off and tree vigour is reduced, a high infection rate usually does not persist in the same area during consecutive years (Ziller 1974; Hiratsuka 1987; Myren and Gross 1994).

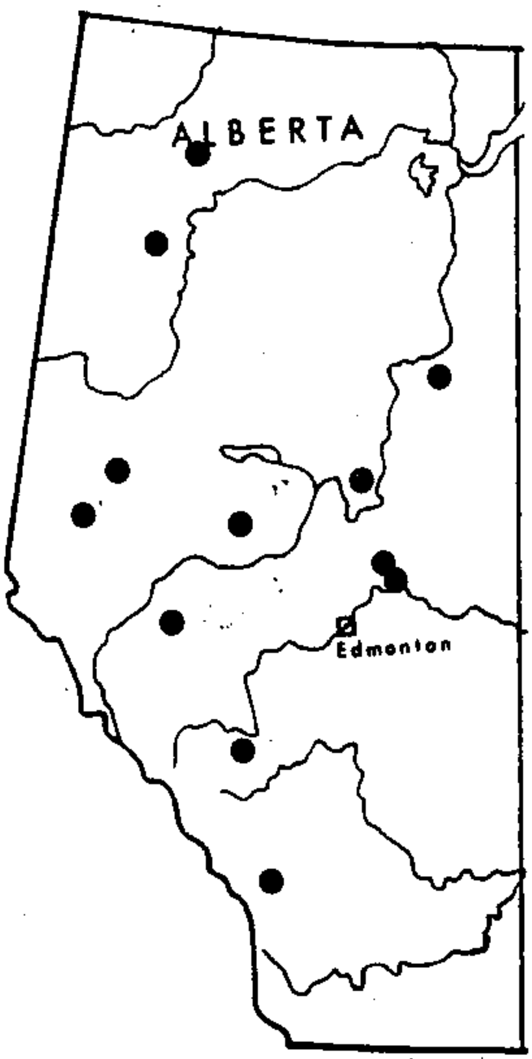

Fig. 2 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting white spruce.

Table 2. Genetics experimental sites surveyed for damage agents affecting white spruce (*Picea glauca*) from 1986 to 1994 (see Fig. 1 for site location designations).

Year	Sites surveyed
1986	32
1987	16
1988	16
1989	1,4,11,15,16,26,28,29,32
1990	5,11,12,30,32
1991	29,32,33
1992	29,32,33
1993	32
1994	32,33

A number of site factors, including competition with natural vegetation, desiccation, and excess moisture often influences early survival of seedlings. These factors were important at several sites (Table 3). Injury due to late spring frost, however, was the most important of the abiotic agents, causing injury in at least 8 Experimental Sites (Cerezke 1991a, 1993b; Cerezke and Mallett 1991). Most of the injury resulted in killed shoots and buds. The incidence of affected trees was occasionally prominent in localized "frost pockets". Trees tend to become more immune to frost injury as they develop beyond the seedling stage. Trees affected by late spring frosts may produce little shoot growth during the current year and a proliferation of new shoots in the following year (Boyce 1961). At the most northerly site (Site 29, Hay River), some mortality of 2-3 m tall trees resulted from late spring frosts during one or more years (Cerezke 1993b). Injury on these trees was confined to the lower stem and was characterized by necrosis and resinosis of the outer bark, dead cambium, and formation of a frost ring (Sinclair *et al.* 1987). The injury probably resulted from a combination of above normal temperatures in April, followed by a drop in temperature of several degrees below freezing in May, similarly as observed in Sitka spruce plantations in Finland (Yde-Andersen and Koch 1993).

Table 3. Summary of incidence of tree damage agents recorded on white spruce (*Picea glauca*) planted in experimental sites surveyed, 1986 – 1994.

Damage agent	4	5	11	15	16	22	26	28	29	30	32	33
An aphid sp.									+		+	
Cooley spruce gall adelgid											+	
Fir coneworm										+	+	
Ragged spruce gall adelgid											+	
Spruce bud midge					+				+	+		
Spruce bud moth					+							
Spruce budworm									+			
Spruce coneworm											+	+
Spruce gall adelgid					+				+	+	+	
Spruce spider mite											+	+
Yellowheaded spruce sawfly				+	+	+				+	+	+
A web-spinning sawfly									+		+	
White pine weevil				+	+		+	+	+	+	+	+
Armillaria root rot		+		+			+				+	
Spruce cone rust											+	
Spruce needle rust			+	+						+	+	
Competition				+	+		+	+				
Desiccation	+											
Excess moisture		+			+		+			+		
Hail											+	
J-root							+			+		
Late spring frost			+	+	+		+		+	+	+	+
Winter injury	+											
Undefined			+				+		+			

[a] Sites surveyed were as follows: 4-Jumping Pound; 5-Prairie Creek; 11-Virginia Hills; 15-Swartz Creek; 16-Sexsmith; 22-Huallen; 26-Calling Lake; 28-Chinchaga River; 29-Hay River; 30-Hangingstone; 32-Pine Ridge Forest Nursery; 33-Block H.

3.1.2 Lodgepole pine:

A total of 13 Experimental Sites with planted lodgepole pine were surveyed for damage agents from 1986 to 1994 (Fig. 3; Tables 4, 5) (Cerezke, 1987, 1991c, 1991d, 1993a, 1993b, 1996a, 1996b; Cerezke and Hoberg 1996; Cerezke and Mallett 1991). Significant insect species causing growth impact and mortality include northern pitch twig moth (*Petrova albicapitana*), lodgepole terminal weevil (*Pissodes terminalis*), white pine weevil (*P. strobi*), and Warren root collar weevil (*Hylobius warreni*). The northern pitch twig moth occurred at most sites, and was especially abundant at two sites (10 and 22) during 1992 when 60.8% and 71.0%, respectively, of trees were infested. Injury in the form of broken leaders, resulting from this insect's feeding was only minor (<1%), in spite of the high incidence rates.

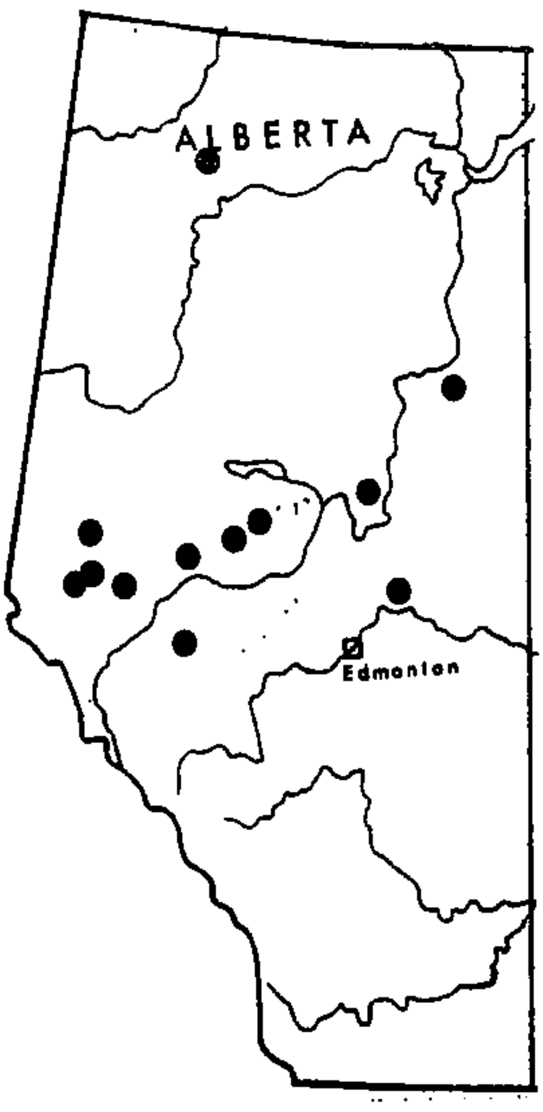

Fig. 3 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting lodgepole pine.

During any one year of survey, the lodgepole terminal weevil caused <1% leader kill, except at Site 32 where it was less than 5%. Somewhat rarer attacks, though more damaging, by the white pine weevil occurred at Sites 19 and 32.

Table 4. Genetics experimental sites surveyed for damage agents affecting lodgepole pine (*Pinus contorta* var. *latifolia*) from 1986 to 1994 (see Fig. 1 for site location designations).

Year	Sites surveyed
1986	32
1987	12,19
1988	17,18,19,22
1989	4,11,15,19,22,26,29,32
1990	4,11,12,17,22,30,32
1991	10,17,18,19,22,29,32
1992	22,32
1993	32
1994	19,32

Natural populations of Warren root collar weevil occurred at Sites 10, 11, 12, 17, 18, and 19 and have caused an estimated 7-10% mortality accumulated mostly during the first 6 to 15 years of growth (Cerezke 1990, 1991b, 1991d, 1993b). Tree mortality usually results when the roots or root collar circumference are girdled more than 90%. Trees with less than this amount of girdling, however, suffer reduced radial growth and height loss (Cerezke 1994). The incidence of new and old attacks on trees at all six sites continues to accumulate annually, and therefore some tree mortality can be expected to continue to at least ages 20 to 25 years, while some growth reduction may continue through to stand maturity (Cerezke 1994; Ives and Rentz 1993). The surveys at Sites 17 and 22 suggested there was a positive relationship of attack incidence by the northern pitch twig moth and Warren root collar weevil and tree growth and vigour (Cerezke 1989, 1990, 1991b, 1991c, 1991d, 1992, 1993a, 1993b).

Important diseases were western gall rust (*Endochronartium harknessii*), comandra blister rust (*Cronartium comandrae*), and Armillaria root disease (*Armillaria ostoyae*). Armillaria root disease was confirmed at four sites and caused mortality in the range of 0 to 1.2% of trees. Additional mortality at these sites is likely to continue as the stands develop. It is noteworthy that a low incidence of Armillaria infection was found at Site 12, and none was found at the other three sites (17, 18, 19), all in the Grande Prairie Forest District.

Table 5. Summary of incidence of tree damage agents recorded on lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Englemann) planted in experimental sites surveyed.

Damage agent	4	10	11	12	15	17	18	19	22	26	29	30	32
A pitch moth		+											+
A web-spinning sawfly									+				
A pyralid moth sp.		+									+		
A pyralid moth sp.									+				
Fir coneworm													+
Hard pine adelgid				+					+				
Lodgepole terminal weevil		+		+	+	+			+	+			+
A needle-feeding sawfly									+				
Northern pitch twig moth		+		+		+	+		+				+
Warren rootcollar weevil		+	+	+		+	+	+					
White pine weevil								+					+
Armillaria root rot		+		+	+								+
Comandra blister rust									+				
Pine needle cast		+											+
Western gall rust		+	+	+		+	+	+	+				+
Rodents (mice or voles)					+								
Yellow-bellied sapsucker													+
Competition				+	+	+			+				
Desiccation	+												
Excess moisture					+	+				+			
J-root		+		+	+	+	+				+	+	
Mechanical								+	+				+
Winter/spring frost	+								+				+
Winter drying	+												
Chemical	+												

[a] Sites surveyed were as follows: 4-Jumping Pound; 10-Swan Hills, Blk 26; 11-Virginia Hills; 12-Fox Creek; 15-Swartz Creek; 17-Nose Mountain, Blk 32; 18 Nose Mountain, Blk 11; 19-Snuff Mountain; 22-Hualien; 26-Calling Lake; 29-Hay River; 30-Hangingstone; 32-Pine Ridge Forest Nursery.

Western gall rust was present at 8 of the 13 sites surveyed and had infection rates as high as 33.9% (in Site 17) (Cerezke 1991b, 1991d). Some of the early tree mortality attributed to this rust (mostly of trees less than 10 years old) occurred at several sites as a result of galls near the stem base. These early infections are believed to be of nursery origin. Subsequent branch and stem infections have occurred especially during the years 1988 to 1990, and have generally resulted in a low incidence of injury. Data from four plantation sites, all with a high incidence of western gall rust infection, have indicated that less than 30% (range: 18.5% to 28.5%) of infected trees have galls formed on the main stem, while the remainder have only branch galls. The presence of branch galls is unlikely to result in measurable growth impact; however, they provide a continued source of inoculum for reinfection.

About 1% incidence of infection and tree mortality by comandra blister rust was present at Site 22 in 1992 (Cerezke 1993a; Cerezke and Hoberg 1996). The source of this infection is also believed to be of nursery origin. Seedlings for the plantation sites were grown at the Pine Ridge Forest Nursery (Site 32) where 0.03% and 1.13% infection, respectively by western gall rust and comandra blister rust, was found on 2-0 lodgepole pine seedlings during a survey in 1979 (Hiratsuka and Allen. 1980).

At one of the sites (Site 15, Swartz Creek), an 18% incidence of mortality resulted from the girdling by mice or voles in 1989 (Emond and Cerezke 1990). The injury occurred when the seedlings were only four years old and probably when mice/vole populations were high. Similar injury is not likely to occur as the trees become older.

Among the abiotic factors, injury associated with container-grown and field planting technique (identified as J-root defect) was the most serious, affecting root growth, tree stability, and tree mortality at 8 sites (Table 5). Weakly supported or leaning trees were common at Sites 12, 17, 18, and 19, where the incidence ranged from 3.6% to 32.8% (Cerezke 1990, 1991b, 1991d; Tidsbury 1990a, 1990b).

3.1.3 Siberian larch:

A total of 6 Experimental Sites with planted Siberian larch were surveyed for damage agents from 1986 to 1994 (Fig. 4; Tables 6, 7) (Cerezke 1991a, 1995; Cerezke and Mallett 1991). Minor defoliation by the larch sawfly (*Pristiphora erichsonii*) and the green larch looper (*Semiothisa sexmaculata*) was identified at only one site and damage was insignificant. Larch sawfly has the potential to cause severe injury following repeated defoliations and has a wide distribution in Alberta (Muldrew *et al.* 1975).

At Site 8 (Judy Creek) where trees were planted in 1978, a high incidence of tree mortality (minimum estimate of 22.5%) was reported in 1992. Because the trees had died over several years, the cause of death could be confirmed only on most recently killed trees. Armillaria root disease (*A. ostoyae*) was the only causal agent associated with the dead and declining trees, and it is therefore reasonable to assume that the accumulated mortality also resulted from this disease. Within the plantation, there were an estimated 35.6% of empty tree spaces, assumed to represent previous mortality. Much of this mortality probably resulted from Armillaria infections. Some native tree species (lodgepole pine, white spruce, and subalpine fir), ingressed in the plantation, had also died from Armillaria root disease. This indicated that there are many infection centres within the plantation area and that the exotic Siberian larch is at least as susceptible to Armillaria as the native species (Cerezke 1993b).

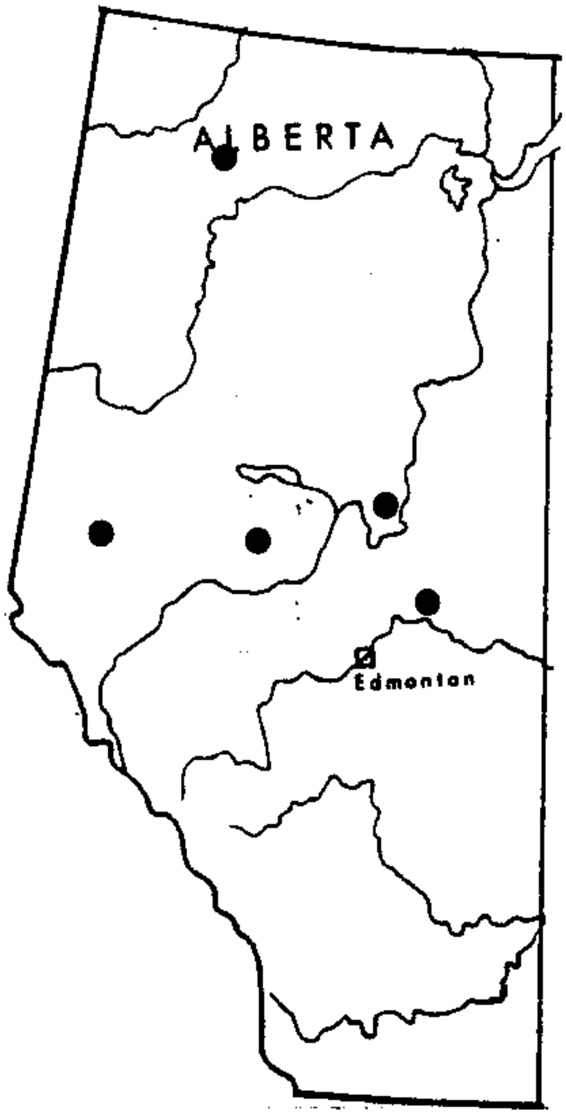

Fig. 4 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting Siberian larch.

The cause of browse injury at Sites 8 and 29 is unknown but likely resulted from snowshoe hare (*Lepus americanus*) or porcupine (*Erethizon dorsatum*). A <1% incidence of girdling injury on 0.5-2.0 m tall trees resulted from mice or voles (likely *Clethrionomys* sp.), and partial girdling of a 4 m tall tree resulted from yellow-bellied sapsucker (*Sphyrapicus varius varius*). Injury by these biotic agents is likely to be localized and sporadic.

Table 6. Genetics experimental sites surveyed for damage agents affecting Siberian larch (*Larix siberica* Led.) from 1986 to 1994 (see Fig. 1 for site location designations).

Year	Sites surveyed
1986	32
1987	No surveys
1988	No surveys
1989	11,26,29,32
1990	11,22,32
1991	22,29,32
1992	8,22,29,32
1993	32
1994	32

The incidence of late spring frost injury was common at all sites, and resulted in mostly bud and shoot tip mortality. A high incidence of double and multiple stems and leaders (range from 18.2% to 25.6% of trees) at Site 29 may have resulted from frost type injury.

Table 7. Summary of incidence of tree damage agents recorded on Siberian larch (*Larix siberica* Led.) planted in experimental sites surveyed.

Damage agent	8	11	22	26	29	32
Green larch looper						+
Larch sawfly						+
Armillaria root rot	+				+[b]	
Conifer-aspen rust						+
Rodents (browse & girdling)	+				+	
Yellow-bellied sapsucker					+	
Competition					+	
Excess moisture					+	
Hail						+
Late spring frost	+	+	+	+	+	+

[a] Sites surveyed were as follows: 8-Judy Creek; 11-Virginia Hills; 22-Huallen; 26-Calling Lake; 29-Hay River; 32-Pine Ridge Forest Nursery.
[b] Armillaria root rot was suspected as the causal agent, but the disease organism was not confirmed.

3.1.4 Scots pine:

Scots pine was surveyed for damage agents at only two Experimental Sites (Fig. 5; Tables 8, 9) Cerezke 1987, 1991a, 1993b; Cerezke and Mallett 1990, 1991). The data are limited and therefore do not provide sufficient information for pest and damage predictions. Important insect species included the two terminal weevil species (*P. terminalis* and *P. strobi*). Scots pine may be more susceptible to white pine weevil attack than either lodgepole or jack pine, as suggested from surveys of plantations in Saskatchewan (Cerezke and Brandt 1993).

Fig. 5 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting Scots pine.

Armillaria root disease (probably *A. ostoyae*) was the only disease organism reported and contributed <1% mortality of plantation grown trees at Site 32 (Pine Ridge Forest Nursery). Three trees were infected, each at a different location in the plantation, suggesting different infection sources. Scots pine was also susceptible to porcupine (*E. dorsatum*) and yellow-bellied sapsucker (*S. varius varius*) injury, but both caused <1% incidence. There were no abiotic injuries reported except J-root defect at Site 29, resulting from container-grown conditions and improper planting technique.

Table 8. Genetics experimental sites surveyed for damage agents affecting Scots pine (*Pinus sylvestris* L.) from 1986 – 1994 (see Fig. 1 for site location designations).

Year	Sites surveyed
1986	32
1987	Not surveyed
1988	Not surveyed
1989	29,32
1990	32
1991	29,32
1992	29,32
1993	32
1994	32

Table 9. Summary of incidence of tree damage agents recorded on Scots pine (*Pinus sylvestris* L.) planted in experimental sites surveyed.

Damage agent	29	32
Fir coneworm		+
Lodgepole terminal weevil		+
Northern pitch twig moth	+	+
White pine weevil		+
Armillaria root rot		+
Rodent (girdling); porcupine		+
Yellow-bellied sapsucker	+	
J-root	+	

[a] Sites surveyed were as follows: 29-Hay River; 32-Pine Ridge Forest Nursery.

3.1.5 Tamarack:

Three Experimental Sites (15, 29, 32) were monitored for damage agents affecting tamarack (Fig. 6; Tables 10, 11) (Cerezke 1987, 1993b; Cerezke and Mallett 1991). Aphid species (*Adelges* and *Cinara* spp.) were common at two sites (100% incidence of tree attack at Site 15), but injury appeared to be insignificant (Brandt 1994). The fir coneworm (*Dioryctria abietivorella*) caused <1% mortality of shoots at Site 32 in 1986, but this may be a rare occurrence for this host. Less than 5% of the trees were dead or dying from Armillaria root disease (probably *A ostoyae*) at one site (Site 15) where this disease is likely to continue causing mortality in future years.

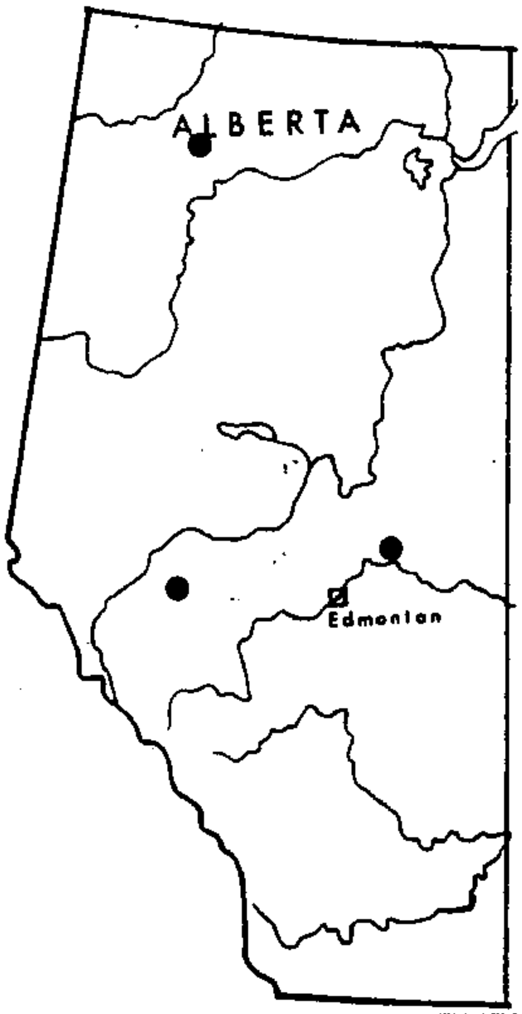

Fig. 6 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting tamarack

Table 10. Genetics experimental sites surveyed for damage agents affecting tamarack (*Larix laricina* [Du Roi] K. Koch) from 1986 to 1994
(see Fig 1. for site location designations).

Year	Sites surveyed
1986	32
1987	No survey
1988	No survey
1989	15,29,32
1990	32
1991	29,32
1992	29,32
1993	32
1994	32

Table 11. Summary of incidence of tree damage agents recorded on tamarack (*Larix laricina* [Du Roi] K. Koch) planted in experimental sites surveyed.

Damage agent	15	29	32
An aphid sp.	+		+
Fir coneworm			+
Spruce gall adelgid	+[b]		+
Armillaria root rot	+		
Rodents (girdling); mice or voles	+		
Browse		+	
Competition		+	
Hail			+
Late spring frost		+	
Weak root system		+	

[a] Sites surveyed were as follows: 15-Swartz Creek; 29-Hay River; 32-Pine Ridge Forest Nursery.
[b] Positive identification of spruce gall adelgid was not made.

Browse and girdling injury occurred on <3% of trees and were contributed by small rodents, probably mice or voles (*Clethrionomys* sp.), and possibly snowshoe hare and porcupine. A high incidence of double and multiple stems and leaders (23.1% of trees) at Site 29 were likely the result of browse, vegetative competition, and late spring frosts (Cerezke 1993b).

3.1.6 Jack pine:

Planted jack pine was monitored for damage agents at five Experimental Sites (Fig. 7; Tables 12, 13). Among the insect species causing most injury were terminal weevils (*P. terminalis* and *P. strobi*) and the northern pitch twig moth (*P. albicapitana*) (Cerezke 1987, 1993b, 1996a, 1996b; Cerezke and Mallett 1991). Incidence of leader kill by the two weevil species may occasionally exceed 5% in any one year. Their impact, however, is enhanced by the fact that dominant leaders are selected for attack, and re-attacks may continue for several consecutive years. Injury caused by the northern pitch twig moth has thus far been negligible.

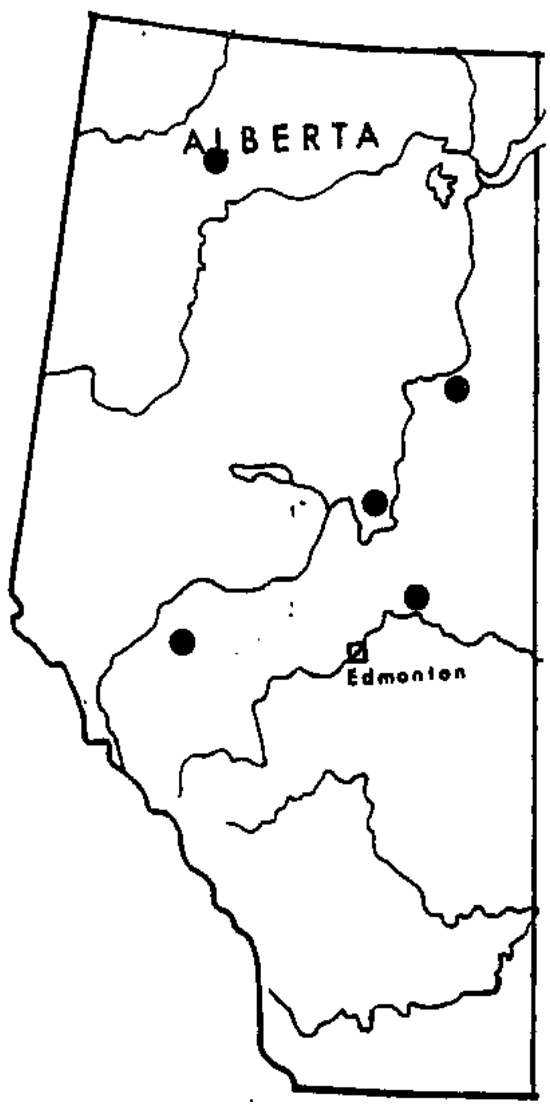

Fig. 7 Map of Alberta showing the distribution of genetic experimental site locations surveyed during 1986 to 1994 for damage agents affecting jack pine.

Jack pine is a host for Armillaria root disease (*A. ostoyae*) and western gall rust (*E. harknessii*); each disease was found in only one of the plantations surveyed and at <1% incidence. Of the abiotic injuries, J-root defect was probably the most significant, occurring in three plantation sites (Sites 15, 29, 30), and accounted for <5% incidence. Site-related factors of competition and excess moisture tend to be seasonal and affect mostly newly planted seedlings.

Table 12. Genetics experimental sites surveyed for damage agents affecting jack pine (*Pinus banksiana* Lambert) from 1986 to 1994 (see Fig. 1 for site location designations).

Year	Sites surveyed
1986	32
1987	Not surveyed
1988	Not surveyed
1989	15,26,29,30,32
1990	32
1991	29,32
1992	29,32
1993	32
1994	32

Table 13. Summary of incidence of tree damage agents recorded on jack pine (*Pinus banksiana* Lambert) planted in experimental sites surveyed.

Damage agent	15	26	29	30	32
A pyralid moth sp.				+	
Fir coneworm					+
Lodgepole terminal weevil	+	+			
Northern pitch twig moth					+
White pine weevil					+
Armillaria root rot	+				
Western gall rust					+
Rodent (girdling): mice or voles	+				
Competition	+				
Excess moisture	+	+			
J-root	+		+	+	
Frost (winter injury)					+

[a] Sites surveyed were as follows: 15-Swartz Creek; 26-Calling Lake; 29-Hay River; 30-Hangingstone; 32-Pine Ridge Forest Nursery.

3.1.7 Deciduous species: Birch, Green Ash, Trembling Aspen, and Poplar:

Observations of damage agents on hardwood species were limited to three sites (Sites 22, 29, 32), and especially at Site 32 (Pine Ridge Forest Nursery) (Table 14) (Cerezke 1993b; Cerezke and Mallett 1990, 1991). Tree species at all three Experimental Sites are small, less than 1.5 m tall, and likely have not as yet been exposed to some potential damage agents. Levels of injury may be highly variable from year to year (Cerezke and Mallett 1990, 1991).

Table 14. Summary of the incidence of tree damage agents recorded on birch (*Betula papyrifera* Marsh.), green ash (*Fraxinus pennsylvanica* Marsh.), and trembling aspen/poplar (*Populus* spp.) planted in genetic experimental sites surveyed.

Tree host and damage agent	22	29[b]	32
BIRCH			
A leaf miner sp.			+
A leaf roller sp.			+
A leaf spot fungus			+
Ambermarked birch leafminer			+
An aphid sp.			+
Birch leafminer			+
GREEN ASH			
Leaf curl (attributed to frost or mites)			+
Late spring frost	+		+
TREMBLING ASPEN/POPLAR			
Aspen leaf beetle			+
Aspen serpentine leafminer			+
A gall midge on aspen			+
A leaf roller sp.			+
Cottonwood leafmining beetle			+
An aphid sp.			+
A leaf-mining moth			+
An aspen sawfly sp.			+
Bruce spanworm			+
Large aspen tortrix			+
Aspen and poplar leaf and twig blights			+
Cytospora canker			+
Hypoxylon canker on aspen			+
Conifer-aspen leaf rust			+
Leaf spot disease			+

[a] Sites surveyed were as follows: 22-Huallen; 29-Hay River; 32-Pine Ridge Forest Nursery.
[b] No damage agents were identified on birch at Site 29.

Leaf-mining insect species (*Fenusa pusilla, Profenusa thomsoni* and an unidentified species) were the most common of biotic agents on birch, but caused only minor leaf injury. On green ash, late spring frost injury to leaves and shoots was common at two sites (Sites 22, 32). On trembling aspen and poplar hosts, leaf-mining and leaf defoliator species were the most prominent of the insect species at Site 32. All species observed are common and occur widely in the province. Overall injury was relatively minor. Similarly, all of the fungal diseases observed on trembling aspen and poplar at Site 32 are common in Alberta and caused only minor injury except Hypoxylon canker (*Hypoxylon mammatum*). This fungal pathogen usually kills its host.

About 10% incidence of shoot kill resulted from leaf and twig blights (*Venturia* spp.), and about 30% of trees were infected with conifer-aspen leaf rust (*Melampsora medusae*). This high incidence of the rust probably reflects the presence nearby of its alternate host plant, *Larix* species.

3.2 Insect and Disease Control Trial Results

Control trials were carried out in selected genetics and tree improvement plantations during the duration of the surveys (1986 to 1994) and in preceding and following years. In this section a brief description is given of the target organism, the treatment applied, and an indication where possible of the effectiveness of the control treatment. A summary table of the effectiveness of experimental and semi-operational control trials undertaken to reduce the impact of biotic damage agents affecting genetically grown seedlings is provided in Table 15 at the end of Section 3.2.

3.2.1 Insect Species

Spruce gall adelgid (*Adelges lariciatus*): Galls of this species were particularly abundant at the Pine Ridge Forest Nursery site in 1986 on planted white spruce grown for genetic tree improvement and on shelterbelt trees within the nursery. Reduction of aphid populations was accomplished on high-value trees by hand removal of the galls and destruction of the young galls before they matured and released winged adult aphids. The effectiveness of the treatment was not assessed.

Hard pine adelgid (*Pineus coloradensis*): High populations of this woolly aphid have commonly occurred on the current shoots of field-grown lodgepole pine and jack pine seedlings at the Pine Ridge Forest Nursery site (Ives and Wong 1988). The feeding injury has not killed shoots or seedlings but may have resulted in stunting and chlorosis. Control treatment consisting of applications of Diazinon at the rate of 50g per 100 l of water, has been made annually where high populations have occurred. Treatment results, though not assessed quantitatively, have given satisfactory control.

White pine weevil (*Pissodes strobi*): Infestations of this weevil have caused serious injury to mainly white spruce and black spruce leaders in several genetic plantations (e.g., Sites 15, 16, 22, 26, 28, 29, 30, 32, and 33). For example, in the Region D Seed orchard and G103P white spruce provenance trial (Site 32), an overall estimate of 5% of the trees were attacked in 1993, with the heaviest concentration (about 20% incidence) of attacked leaders along the north edge of the plantation. Control treatments have mostly been cultural, involving hand-pruning of newly infested leaders prior to maturation of adults. Infested leaders have been pruned off immediately below the last visible signs of larval feeding and were burned to destroy the weevil broods they contained. Satisfactory control has been achieved when all infested leaders are removed and the control procedures are repeated in consecutive years. Some manual control of adult populations was also carried out in early May by hand removal and destruction of adults as they occurred openly on leaders and terminal buds.

Yellowheaded spruce sawfly (*Pikonema alaskensis*): Damaging population levels of this sawfly have occurred on white spruce plantation trees at Pine Ridge Forest Nursery (Sites 32 and 33) and at Sexsmith and Huallen (Sites 16 and 22). At Sites 32 and 33, severe defoliation on 10-15% of trees was recorded in some plantations. A backpack sprayer with Malathion was required to treat trees in the white spruce provenance trials at Sites 16 and 32. Insecticidal treatments consisting of Malathion, "Raid", and Pyrethrum sprays have all been applied to foliage since 1987 to kill young larvae during their early feeding stages on both white and black spruces. Trees have been sprayed with ground-base equipment for individual infested trees and branches. Control results have generally been considered satisfactory at killing larvae and reducing needle loss impact as long as treatment was applied early enough while larvae are still small.

Warren root collar weevil (*Hylobius warreni*): A relatively high incidence of attack by this weevil was reported at Site 19 (Snuff Mountain) genetics plantation of lodgepole pine when the trees were in the seventh growing season (Cerezke 1990). Cultural treatment to reduce weevil populations and damage was undertaken in June 1988. Treatment consisted of removal of soil-duff materials around tree bases to expose the root collar and mineral soil. All live larvae and pupae that were found were removed and destroyed. Lower branches were pruned off to a height of about 60 cm. Mineral soil from an outside location was brought in and placed around the base of each treated tree. The purpose of the treatment procedure was to reduce the larval population and alter the weevil habitat by eliminating duff material and by increasing the rate of drying and air circulation around the tree base (Cerezke 1994). This method of cultural treatment had been applied successfully to control the pine rootcollar weevil (*Hylobius radicis*) (Cerezke and Pendrel 1995; Wilson 1967, 1973).

About 12.4% (713 trees) of the trees at Site 19 were treated in 1988. In a re-survey conducted in September 1988, 60 or 8.4% of the treated trees had died, presumably from weevil girdling. In a survey of the plantation in July, 1989, larvae were found on only 1.49% of the trees, indicating a reduction from the 12.4% reported in 1988. This reduction can be attributed to the intensive cultural treatment. A complete survey of all trees at Site 19 was conducted in 1994 (14^{th} growing season of planted trees) and indicated that 29.4% of the trees now had current weevil attacks (larvae and pupae present), 43.1% of trees sustained old weevil attacks, and only 0.33% of trees were dead or dying from weevil girdling injury during 1993 and 1994. This suggested that the trees were reaching a somewhat more resistant age.

The cultural treatment applied at Site 19 in 1988, when assessed two years later, showed continuous success for maintaining low weevil populations and tree injury. The treatment appeared to be effective for about 3 years post-treatment, after which there was a gradual re-invasion into the plantation by this weevil (Cerezke 1994).

Northern pitch twig moth (*Petrova albicapitana*): Attacks by this moth occurred on lodgepole, jack, and Scots pines and at several genetic plantation sites (Sites 10, 12, 17, 18, 22, 29, and 32). Control treatment has been applied only at Site 22 (Huallen). This Site contains lodgepole pine planted in 1986. The plantation was surveyed in 1989 when the trees were in the fourth growing season and measured about 0.5 m tall. The survey results indicated a 5.8% incidence of current attacked trees. Because of the small size of trees, stems and leaders were often girdled about 50% around the circumference at the internode where pitch blisters were most often formed.

Population reduction of larvae by hand-removal (each pitch blister contains only one larva) was recommended while the trees were small, to reduce the risk of stem/leader breakage. Thus, up to 100% control of second-year larvae (life cycle requires two years to complete) was carried out in 1989 by locating all main-stem blisters, popping them open, and destroying the single larva. In a similar survey of the plantation in 1990, the incidence of attacked trees was reduced to 4.1%, and similar hand-removal treatment was undertaken. Re-surveys of the plantation in 1991 and 1992 indicated that the incidence of attacked trees had increased to 16.3% and 60.8%, respectively for the two years. It was therefore apparent in 1991 that populations of this moth were not synchronized, and that there were larvae and adults produced each year. This suggested that long-range dispersal (i.e., possibly up to several km distance) by moths was occurring each year, accounting for the rapid rate of increase. No control recommendations were made for 1991 or 1992. The treatment applied in 1989 and 1990 was therefore considered only partly successful (Cerezke 1989, 1993a).

Spruce cone maggot (*Strobilomyia neanthracina*): An experimental field trial was carried out in a young white spruce seed orchard (G259A) at the Pine Ridge Forest Nursery (Site 32) in 1999 (Cerezke 2000). The efficacy of Dimethoate 480® was tested for control of the spruce cone maggot when applied with a hydraulic sprayer at a rate of 1.0% active ingredient in water to the cone-bearing portion of tree crowns. Samples of 300 cones collected from each of treated trees and from control, non-treated trees, were assessed for cone maggot attack and injury at the end of the season in August. In addition, bulk cone collections from all insecticide-treated trees and from other non-treated control trees were processed separately for seed yield, seed weight and seed germination. The results indicated that Dimethoate provided an estimated 88.9% control of the spruce cone maggot. The Dimethoate-treated cones had 14% more seeds per cone, were 3.4% heavier in weight, and seed germination rate was 4.0% higher than that of seeds from non-treated cones. Some phytotoxic effects of the Dimethoate spray occurred on current year shoots but had no apparent effect on the cones or seeds (Cerezke 2000).

Birch leafminer (*Fenusa pusilla*): A low population of this leaf miner species occurred on small birch trees at Pine Ridge Forest Nursery (Site 32) in 1990 and in subsequent years. Control treatments with a systemic insecticide (Dimethoate was applied as a soil drench treatment and as a foliar spray) were probably made annually from 1991 to 1994. Control results were not assessed, but the treatments were likely highly successful at killing the larvae mining the leaves because of the small size of trees.

3.2.2 Disease Species

Comandra blister rust (*Cronartium comandrae*): During a general survey of the Pine Ridge Forest Nursery for insect and disease pests in 1976, this stem rust was identified as a potential risk to young pine seedlings (Petty *et al.* 1977). A follow-up survey of 2-0 lodgepole pine seedlings in 1979 revealed that 1.13% of seedlings had been infected with comandra blister rust (Hiratsuka et al. 1980). This indicated a risk of transporting the disease to field-planted sites (Hiratsuka and Evans 1979). Recommendations were made to reduce the risk of this rust pathogen infection on seedlings by fall screening-out of the bare-root grown seedlings that had been infected, and by applying herbicide treatment to eliminate the rust's alternate host plants that included northern bastard toadflax, *Geocaulon lividum* and *Comandra umbellata pallida,* at the nursery site. Follow-up surveys of the nursery and surrounding area were made to identify the distribution and abundance of the two alternate host plant species (Hiratsuka and Allen 1980). Eradication trials to eliminate these plants were conducted in 1980 and 1981 using the herbicide Roundup® and by mechanical removal of plants (Hiratsuka and Allen 1981a, 1981b). These treatments have probably reduced the incidence of infections on bare-root grown seedlings. Additionally, further risk of infection by this pathogen has been reduced by the increased proportion of container-grown lodgepole pine seedlings in recent years.

During surveys of Site 22 (Huallen) in 1991 and 1992, there was about a 1% incidence of comandra blister rust-infected lodgepole pine killed by this rust (Cerezke 1992, 1993a; Cerezke and Hoberg 1996). The origin of these infections is believed to be from the Pine Ridge Forest Nursery site where the planting stock was grown since all infections occurred on the lower stem near ground level. All infected dead and dying trees were removed, and no further infections are expected at Site 22 because of the likelihood of no alternate host plants in the nearby vicinity.

Armillaria root disease (*Armillaria ostoyae)*: Infection by this disease has occurred in Sites 5, 8, 10, 12, 15, 26, and 32, and has affected several tree species. Control procedures, however, have been conducted at only one site (Site 32, Pine Ridge Forest Nursery). Control treatment consisted of the removal of infected planted trees including the root system. This treatment destroys most of the source of pathogen inoculum. Success of the treatment may be judged in subsequent years by the absence of the disease, reappearing in the same infection centers.

Western gall rust (*Endochronartium harknessii*): This stem rust has been given greater attention than other stem rust diseases because it requires no alternate plant hosts to complete its life cycle, and thus can cause pine-to-pine infections. Western gall rust infections have occurred on lodgepole and jack pines, and at several sites (Sites 5, 13, 22, 32). Control treatments to reduce inoculum sources and risk of infection have been conducted at Site 32 on a regular basis by pruning out trees with galled stem and branch infections. Other infected trees, especially those with active galls on the lower stem and on trees less than two metres tall (most of these infections likely originated at the nursery site where the seedlings were grown) have been pruned out and discarded on an on-going basis when they have been discovered at Sites 10, 11, 12, 17, 19, 22, and 32. The roguing out of such infected trees has helped to reduce the quantity of within plantation sources of inoculum, but may have little effect on reducing risk of new infections from more distant sources of inoculum.

Dwarf mistletoe (*Arceuthobium americanum*): This parasitic plant occurs abundantly on the native jack pine within and around Site 32 (Petty *et al.* 1977; Brandt 2006). Recommendations were made to undertake a sanitation control program for this disease at the Pine Ridge Forest Nursery site at an early stage (1977) in the development of the nursery, and control treatments have been applied annually since that time. Sanitation treatments consisted of the removal of heavily infected trees (i.e., especially those with multiple brooms), and the pruning of individual infected branches and stems that had brooms or well developed branch infections. Most of the treated trees occur as shelterbelt trees between bare-root fields within the nursery site, since risk is highest here for infection of adjacent bare-root grown trees or genetic plantation trees. Risk of infection in shelterbelts has been further reduced by the replacement planting of non-host species such as white spruce, poplars or Siberian larch.

Pinewood nematode (*Bursaphelenchus xylophilus*)**:** During a survey for insect and disease pests at Site 32 in 1986 , several mature jack pine trees classed as newly dead or dying, had been attacked around the stem base by the lodgepole pine beetle (*Dendroctonus murrayanae*). This insect was contributing to the death of drought-stressed or weakened trees. The pinewood nematode was identified in high numbers in two of the trees; both trees had also been attacked by the white spotted sawyer beetle (*Monochamus scutellatus*), a known vector carrier of the nematode (Bowers, Hudak and Raske 1992). Control treatment of the nematode was subsequently recommended since there was insufficient information at the time to determine whether the nematode was the prime cause of tree death, and whether there was a risk of the nematode spreading to adjacent conifer seedlings. Control treatment, carried out over the next two years, consisted of cutting, removal, and burning of the newly discovered dead and dying jack pine trees.

Spruce cone rust (*Chrysomyxa pirolata*): Spruce cone rust periodically infects cones of white and black spruce seed orchard trees grown at ATISC and at other Alberta locations. This rust causes localized epidemics of diseased cones that result in reduced or nil seed crops, cause premature opening of cones, and cause abnormal germination or failure of seeds to germinate (Sutherland et al. 1987). Losses of seed yield due to spruce cone rust in established genetic seed orchards prompted a study to gain a better understanding of the complex life cycle of this rust disease on its alternate host plant (*Pyrola asarifolia*), the environmental conditions critical for disease cycle development, and to observe the infection process in spruce cones. This study was undertaken in 1997-98 at ATISC, and the results are summarized in a report prepared by Crane (1998). Key findings in the study confirmed the importance of moisture, particularly high humidity, and temperature in the production of critical spore stages (e.g., telia and uredinia) on the alternate host plant, and of the influence of microsite conditions such as low-lying wet sites *versus* dry sites. The data suggested that the incidence of cone rust infection in a given year was dependent upon the co-occurrence of spruce female strobili, overwintered sori (spore-producing structures) on alternate host plant leaves, and rainfall or high humidity (Crane 1998).

Table 15. Summary of experimental and semi-operational control trials undertaken to reduce the impact of biotic damage agents affecting genetically grown seedlings, cones and trees.

Target organism	Host trees	Genetic sites	Year	Control assessment
Spruce gall adelgid *Adelges lariciatus*	Sw	32	1986	Not assessed
Hard pine adelgid *Pineus coloradensis*	Pl, Pj	32	---	Satisfactory
White pine weevil *Pissodes strobi*	Sw	29, 30, 32, 33	Several yrs	Variable
Yellowheaded spruce sawfly *Pikonema alaskensis*	Sw	16, 32	Annually	Successful
An aphid species *Mindaris obliquus*	Sw	32	---	Successful
Warren rootcollar weevil *Hylobius warreni*	Pl	17, 18, 19	1988	Successful for 2-3 years
Northern pitch twig moth *Petrova albicapitana*	Pl	22	1989-90	Partly successful
Spruce cone maggot *Strobilomyia neanthracina*	Sw	32	1999	88.9% control
Birch leafminer *Fenusa pusilla*	Bw	32	1991-94	Satisfactory
Comandra blister rust *Cronartium comandrae*	Pl	22, 32	1979, 1991-92	Successful
Armillaria root disease *Armillaria ostoyae*	Ps, Sw	32	---	Not assessed
Western gall rust *Endochronartium harknessii*	Pl, Pj	10, 11, 12, 17, 19, 22, 32	Annually	Successful
Dwarf mistletoe *Arceuthobium americanum*	Pj	32	Annually	Satisfactory
Pinewood nematode *Bursaphelenchus xylophilus*	Pj	32	1987-88	Not assessed

4.0 CONCLUSION

A comprehensive assessment of insect, disease and other agents causing damage and mortality to genetics and tree improvement plantings established at 33 locations throughout Alberta was carried out during 1986 to 1994 as a cooperative project between the Alberta Forest Service and Canadian Forestry Service. The plantings included species trials, provenance trials, family tests, demonstration plantings, arboreta, seed orchards, clone banks and related genetic conservation plantings covering all aspects of the newly started provincial genetics program. The plantings varied in species (native as well as promising non-native species), genetic materials (bulk seedlots representing populations, families and clonal materials), planting size (approximately 100 - 16000 trees) and age (3-year old to 19-year old trees). This report documents the work carried out, pests and damage agents found in different species over the survey period, and describes the magnitude of damage and damage characteristics of the damage agents to relatively young trees. The work provides an understanding of insect, disease and abiotic damage occurring in a wide variety of young plantations in Alberta and provides a database for planning control measures for protection in high value research plantings. The information would also be valuable for future reference as baseline information for comparative purposes as the environment is impacted by climate change and new forest health issues arise in management of genetic resources and tree breeding for forest improvement.

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Appendix A: List of Organisms by Common and Scientific Names, and Tree Hosts Identified in all Experimental Sites.

Common name	Scientific name	Tree hosts[a]
INSECTS AND MITES		
A gall midge	*Cecidomyia* sp.	At
A leaf miner sp.	Species not identified	B
A leaf-mining moth	*Phyllonorycter* sp.	At
A leaf roller sp.	Species not identified	B
A leafroller sp.	Species not identified	At
Ambermarked birch leafminer	*Profenusa thomsoni* (Konow)	B
An aphid sp.	*Cinara* sp.	Sw
An aphid sp.	*Cinara laricifex* (Fitch)	Le
An aphid sp.	Species not identified	B
An aphid species	Species not identified	At
A needle-feeding sawfly	Prob. *Neodiprion nanulus contortae* Ross	Pl
A pitch moth	Prob. *Synanthedon* sp.	Pl
A pyralid moth	*Dioryctria* sp.	Pj,Pl
A pyralid moth	*Dioryctria* (prob. b*anksiella* Mutuura, Monroe & Ross)	Pl
A sawfly sp.	Prob. *Fallocampus* sp.	At
Aspen leaf beetle	*Chrysomela crotchi* Brown	At
Aspen serpentine leafminer	*Phyllocnistis populiella* Chambers	At
A web-spinning sawfly	*Cephalcia* (prob. p*rovancheri*) [Huard]	Sw
A web-spinning sawfly	*Cephalcia* sp.	Pl
Birch leafminer	*Fenusa pusilla* (Lep.)	B
Bruce spanworm	*Operophtera bruceata* (Hulst)	At
Cooley spruce gall adelgid	*Adelges cooleyi* (Gillette)	Sw
Cottonwood leafmining beetle	*Zeugophora scutellaris* Suffrian	P
Fir coneworm	*Diorycria abietivorella* (Grote)	Le,Pj,Pl,PS,Sw
Green larch looper	*Semiothisa sexmaculata* (Packard)	LS
Hard pine adelgid	*Pineus coloradensis* (Gillette)	Pl
Larch sawfly	*Pristiphora erichsonii* (Hartig)	LS
Large aspen tortrix	*Choristoneura conflictana* (Walker)	At
Lodgepole terminal weevil	*Pissodes terminalis* Hopping	Pj,Pl,PS
Northern pitch twig moth	*Petrova albicapitana* (Busck)	Pj,Pl,PS
Ragged spruce gall adelgid	*Pineus similis* (Gillette)	Sw
Spruce bud midge	*Rhabdophaga swainei* Felt	Sw
Spruce bud moth	*Zeiraphera canadensis* Mutuura & Freeman	Sw
Spruce budworm	*Choristoneura fumiferana* (Clem.)	Sw
Spruce coneworm	*Dioryctria reniculelloides* Mutuura & Monroe	Sw
Spruce gall adelgid	*Adelges lariciarus* (Patch)	Le,Sw
Spruce spider mite	*Oligonychus ununguis* (Jacobi)	Sw
Warren rootcollar weevil	*Hylobius warreni* Wood	Pl
White pine weevil	*Pissodes strobi* (peck)	Pj,Pl,PS,Sw
Yellowheaded spruce sawfly	*Pikonema alaskensis* (Rohwer)	Sw

Common name	Scientific name	Tree hosts[a]
DISEASES		
A leaf spot fungus	Species not identified	B
Aspen leaf and twig blight	*Venturia macularis* (Fr.) E. Muller	At
Armillaria root rot	*Armillaria ostoyae* (Romag.) Herink	Le,LS,Pj,Pl,PS,Sw
Comandra blister rust	*Cronartium comandrae* Pk.	Pl
Conifer-aspen leaf rust	*Melampsora medusae* Thuem.	At,Le,LS
Cytospora canker	*Cytospora chrysosperma* (Pers.) Fr.	At,P
Hypoxylon canker	*Hypoxylon mammatum* (Wahl.) J.H. Miller	At
Leaf spot disease	*Mycosphaerella* sp.	P
Pine needle cast	*Lophodermella concolor* (Dearn.)	Pl
Poplar leaf and twig blight	*Venturia populina* (Vuill.) Fabric.	P
Spruce cone rust	*Chrysomyxa pirolata* (Korn.) Winter	Sw
Spruce needle rust	*Chrysomyxa ledicola* (Peck) Lagerh.	Sw
Western gall rust	*Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka	Pj,Pl
RODENTS		
Mice or voles	Prob. *Clethrionyomys* sp.	Le,LS,Pj,Pl
Porcupine	*Erethizon dorsatum* Cuvier	PS
Snowshoe hare	*Lepus americanus* Erxleben	LS,Pj
BIRDS		
Yellow-bellied sapsucker	*Sphyrapicus varius varius* L.	LS,Pl,PS

[a] Tree species are identified as follows: At=trembling aspen; B=birch; Le=eastern larch; Ls=Siberian Larch; P=poplar; Pj=jack pine; Pl=lodgepole pine; PS=Scots pine; Sw=white spruce.