PEST DAMAGE TO ONTARIO SEED ORCHARDS RESULTS OF FIDS SEED ORCHARD SURVEYS 1990–1992

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ABSTRACT

From 1990 to 1992 a total of 28 seed orchards, including 16 black spruce (*Picea mariana*), 8 white spruce (*Picea glauca*), and 4 jack pine (*Pinus banksianae*) orchards, were assessed twice each season for pest damage. Damage due to a variety of insect and disease problems was recorded in most orchards. *Armillaria* spp. caused up to 6% annual mortality in black spruce orchards and up to 5% in white spruce orchards; jack pine was least affected. Diplodia tip blight (*Sphaeropsis sapinea*) caused top kill to an average of 12 and 7% of the black spruce trees in two consecutive years. Cone rust (*Chrysomyxa pirolata*) was found one year only in two white spruce orchards, but affected less than 2% of the cones. Frost damage was evident on all species, but particularly on white spruce where damage was detected in 67% of the evaluations. Damage was generally at trace to low levels athough moderate damage was also reported on both white spruce and black spruce. Damage was not recorded on jack pine.

Other diseases, such as needle rusts on spruce (*Chrysomyxa ledicola*, *C. ledi*) and pines (*Coleosporium asterum*) were common but caused only trace damage. Needle casts (*Davisomycella* spp.; *Lophodermium* spp.) and western gall rust (*Endocronartium harknessii*) caused only trace levels of damage in jack pine orchards. Spruce budworm (*Choristoneura fumiferana*) was reported in 90% of the spruce orchards. Damage to foliage was widespread but generally at trace to low levels. In jack pine orchards, budworm (*Choristoneura pinus*)was present in only 17% of the evaluations. This insect caused only trace levels of damage; however, it was widespread in affected orchards. Spruce coneworm (*Dioryctria reniculelloides*) affected 25% of the white spruce and 10% of the black spruce orchards, but damaged up to 100% of the trees on these sites. The yellowheaded spruce sawfly (*Pikonema alaskensis*) affected 35% of the black spruce orchards and caused localized moderate to severe defoliation. The spruce budmoth (*Zeiraphera canadensis*) was also reported in several orchards of both spruce species but occurred at higher levels on some black spruce sites. Significant damage due to this pest was not reported.

The white pine weevil (*Pissodes strobi*) was observed on all species, but was most widespread in jack pine. Lesser numbers of this pest were reported on black spruce and white spruce. Other insect pests of jack pine included the eastern pine shootborer (*Eucosma gloriola*), which occurred in 100% of the evaluations. This pest affected up to 35% of the trees in some years and attacked both laterals and leaders. The red pine cone beetle (*Conophthorus resinosae*) was found in 50% of the evaluations on jack pine but attacked an average of only 2–4% of the trees.

RÉSUMÉ

De 1990 à 1992, on a évalué deux fois par saison les dommages causés par des organismes nuisibles à 28vergers à graines, dont 16 étaient constitués d'épinettes noires (*Picea mariana*), 8d'épinettes blanches (*Picea glauca*) et 4de pins gris (*Pinus banksiana*). On a noté des dommages causés par différents insectes et maladies dans la plupart des vergers. *Armillaria* spp. était responsable d'une mortalité annuelle pouvant atteindre 6% dans les vergers d'épinettes noires et 5% dans les vergers d'épinettes blanches; le pin gris a été le moins touché. La brûlure des pousses (*Sphaeropsis sapinea*) a détruit en moyenne 12 et 7% des cimes d'épinettes noires durant deux années consécutives. La rouille des cônes (*Chrysomyxa pirolata*) a été observée une seule année dans seulement deux vergers d'épinettes blanches, et elle a touché moins de 2 % des cônes. On a observé des dégâts causés par la gelée chez toutes les espèces, mais particulièrement chez l'épinette blanche dans 67% des évaluations. Ces dégâts étaient généralement décelés à l'état de traces ou à faible intensité, bien qu'on en ait aussi relevé d'intensité modérée chezl'épinette blanche comme chez l'épinette noire. On n'en a pas vu chez le pin gris.

D'autres maladies telles que la rouille des aiguilles sur les épinettes (*Chrysomyxa ledicola, C. ledi*) et les pins (*Coleosporium astarum*) étaient communes, mais elles ne causaient des dégâts mesurables qu'à l'état de traces. Le rouge (*Davisomycella* spp., *Lophodermium* spp.) et la rouille-tumeur (*Endocronartium harknessii*) n'ont causé des dégâts observables qu'à l'état de traces dans les vergers de pins gris. La présence de la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana*) a été rapportée dans 90% des vergers d'épinettes. Les dommages causés au feuillage étaient répandus, mais généralement à l'état de traces ou à faible intensité. Dans les vergers de pins gris, la tordeuse du pin gris (*Choristoneura pinus*) n'était rapportée que dans 17% des évaluations. Cet insecte n'a causé que des dégâts à l'état de traces; cependant, il était répandu dans les vergers qui étaient atteints. La pyrale des cônes de l'épinette (*Dioryctria reniculelloides*) avait attaqué 25 % des vergers d'épinettes blanches et 10% des vergers d'épinettes noires, mais elle causait des dégâts pouvant atteindre 100% des arbres là où elle était présente. La tenthrède à tête jaune del'épinette (*Pikonema alaskensis*) était observée dans 35% des vergers d'épinettes noires et elle provoquait des défoliations locales d'intensité modérée à grave. La présence de la tordeuse de l'épinette (*Zeiraphera canadensis*) a aussi été rapportée dans plusieurs vergers des deux espèces d'épinettes, mais en plus grande abondance dans certains sites d'épinettes noires. On n'a pas rapporté de dégâs importants causés par cette espèce.

Le charançon du pin blanc (*Pissodes strobi*) a été observé chez toutes les espèces, mais il était le plus répandu chez le pin gris. On a rapporté sa présence, mais en moindre abondance, chez les épinettes noires et les épinettes blanches. Parmi les autres insectes nuisibles du pin gris, mentionnons le perce-pousse du pin (*Eucosma gloriola*), qui a été décelé dans 100% des évaluations. Cet organisme nuisait à un maximum de 35% des arbres au cours de certaines années et s'attaquait tant aux branches latérales qu'à la tige principale. Le scolyte du cône du pin (*Conophthorus resinosae*) a été décelé dans 50 % des évaluations de pins gris, mais il n'attaquait en moyenne que de 2 à 4% des arbres.

TABLE of CONTENTS

cover photo:
Black spruce seed orchard
near Sioux Lookout, Ontario.

INTRODUCTION

Seed orchards can be considered as one management option for tree improvement. However, due to the initial investment and intensive management required, they are arguably the most expensive tree plantations in Canadian forestry. After orchard establishment, pests can and do impact on the health and existance of the trees. To date, most efforts have concentrated on cone and seed pests due to their obvious impact on seed production. Excellent summaries of these pests have been produced (Hedlin et al. 1981, Churcher et. al. 1985, Sutherland et al. 1987, Turgeon and De Groot 1992). The impact of insects and diseases affecting foliage and woody tissue, however, has been studied to a much lesser degree. These pests can have a significant impact on all plantations, including seed orchards, if left unchecked. Insects and diseases can cause whole-tree mortality or affect potential cone and seed production by decreasing tree vigor and causing branch and shoot mortality.

In Ontario, seed orchard establishment on a large scale is a relatively recent phenomenom as most orchards were established in the 1980's. Presently there is a total of 68 seed orchards in the province, representing approximately 600 hectares of intensely managed planatation. The issue of the general effect of pests on seed orchard trees in Ontario has not been previously investigated. In order to address this shortage of information, the Forest Insect and Disease Survey (FIDS) Unit in Ontario undertook a 3-year survey of seed orchards. The goal of this study was to develop an inventory of pest problems and determine their relative abundance and ability to cause damage in seed orchards.

METHODS

Twenty-eight orchards (Fig. 1, Table 1) comprised of 16 black spruce, 8 white spruce, and 4 jack pine orchards were chosen for evaluation in 1990. Orchards were generally selected at random although several of particular

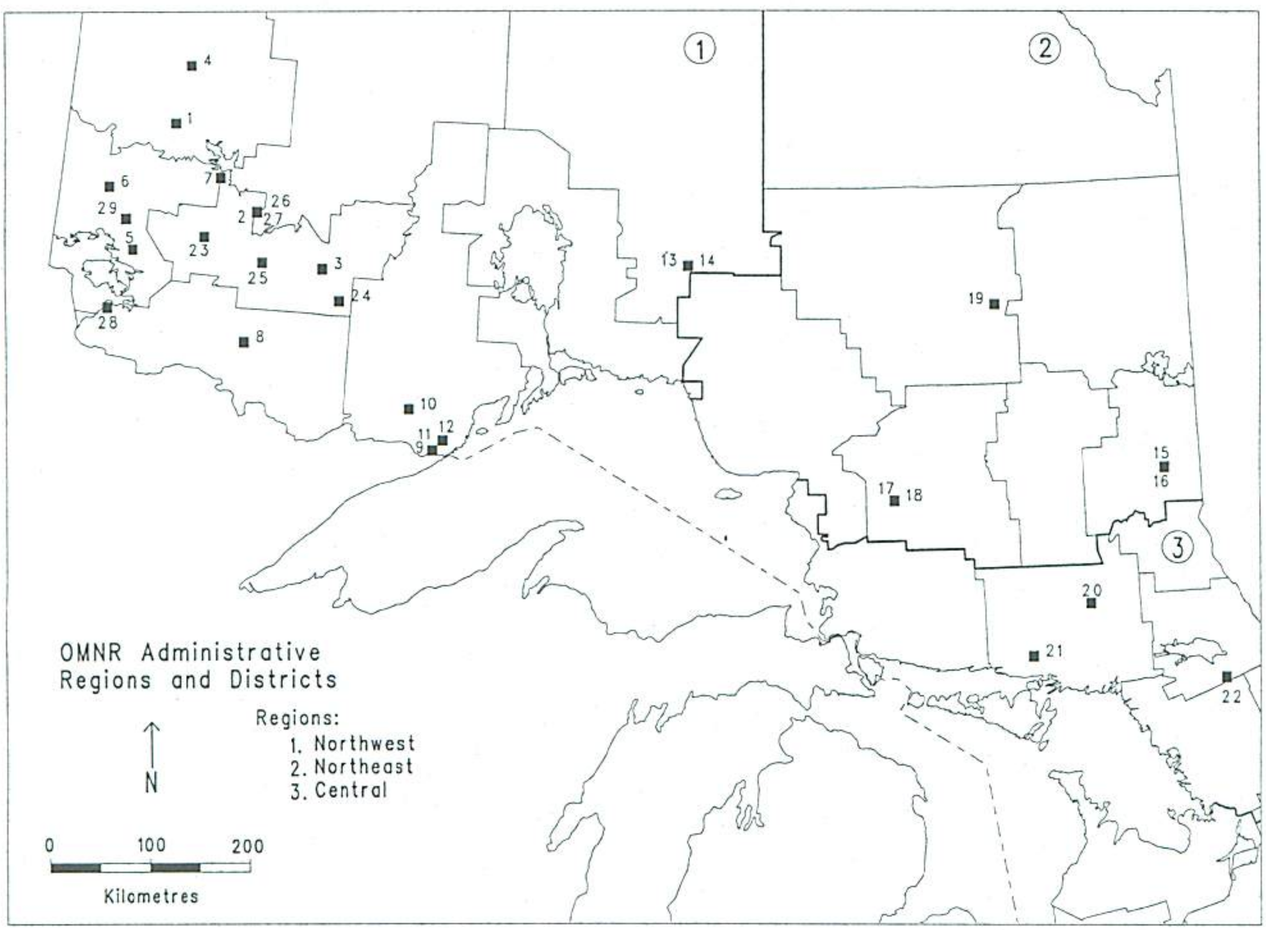

Figure 1. Locations of seed orchards in Ontario evaluated by FIDS 1990–1992. Plot numbers refer to those listed in Table 1.

Table 1. Seed orchards evaluated in FIDS survey, 1990 to 1992.

Orchard name	Tree species[a]	Region	District	Size	Year established	Plot number
Beauregard	bS	Northwest	Red Lake	5	1982	1
Skurban Lake	bS	Northwest	Sioux Lookout	5	1982	2
Dawe	wS	Northwest	Dryden	11	1983	3
Bawlb	wS	Northwest	Red Lake	8	1986	4
Ulster Lake	bS	Northwest	Kenora	5	1982	5
Minnesabic	bS	Northwest	Kenora	5	1982	6
Glatz	wS	Northwest	Dryden	4	1982	7
Manion Lake	wS	Northwest	Fort Frances	8	1984	8
Partridge Falls	bS	Northwest	Thunder Bay	16	1989	9
Mattawin	bS	Northwest	Thunder Bay	5	1970	10
Pearson	bS	Northwest	Thunder Bay	1	1971	11
Pearson	wS	Northwest	Thunder Bay	1	1971	12
Longlac	bS	Northwest	Geraldton	1	1959	13
Longlac	wS	Northwest	Geraldton	1	1959	14
Aidie Creek	bS	Northeast	Kirkland Lake	13	1986	15
Aidie Creek	jP	Northeast	Kirkland Lake	10	1983	16
Island Lake	bS	Northeast	Chapleau	12	1986	17
Island Lake	jP	Northeast	Chapleau	12	1984	18
Bonner Centre	bS	Northeast	Hearst	9	1986	19
Lumsden	jP	Central	Sudbury	10	1985	20
Hallam	jP	Central	Sudbury	25	1984	21
Gurd	wP	Central	North Bay	25	1965	22
Aubrey	bS	Northwest	Dryden	3	1975	23
Ferguson	bS	Northwest	Dryden	10	1982	24
Melgund	bS	Northwest	Dryden	5	1982	25
Goodie Lake N	bS	Northwest	Sioux Lookout	5	1982	26
Goodie Lake S	bS	Northwest	Sioux Lookout	5	1982	27
Morson	wS	Northwest	Fort Francis	8	1984	28
High Lake	wS	Northwest	Kenora	10	1983	29

[a] bS = black spruce, jP = jack pine, wP = white pine, wS = white spruce.

interest were included. The survey consisted of two annual evaluations and was conducted by FIDS field staff over three field seasons from 1990 to 1992. The first visit occurred in mid-June followed by a second in late July to early August. Each orchard was assessed on the basis of a 150-tree evaluation. Ten transects, each containing 15 trees, were randomly evaluated in every orchard. Each tree within the transect was assessed for the incidence of insects and diseases and for levels of defoliation or woody tissue damage caused by the pest. Damage levels (Figs. 2a, 3a, 4a; Tables 2–4) were assessed on the basis of incidence (percentage of trees infested) for nonfoliar pests (Armillaria, diplodia, weevil, pine shootborer, red pine cone beetle) or stem infections (gall rust) and recorded as: trace–light damage = 1–5% trees affected or moderate–severe damage = >5% trees affected. For defoliating pests (spruce budworm, spruce coneworm, spruce sawfly, needle rusts, needle casts, frost), damage was based on average defoliation levels: trace–light damage = 1–25% and moderate–severe damage = > 25%.

The following is a summary of incidence and damage caused by pests recorded during the survey.

BLACK SPRUCE SEED ORCHARDS

Armillaria Root Rot (*Armillaria* spp.)

Armillaria-induced mortality was evident in 39% of the black spruce orchards evaluated during the course of the survey (Fig. 2a). Generally, less than 1% of the trees in these orchards were affected; however, levels of 6% annual mortality due to the disease were encountered in some orchards (Fig. 2b, Table 2) in 1990 and 1992. In his study of young black spruce plantations, Whitney (1988) found an average rate of Armillaria-induced mortality of

1.5% in affected stands. The maximum annual mortality rate was 4.8%, similar to that found in the seed orchards.

Stress is considered an important factor in predisposing trees to Armillaria (Wargo and Harrington 1991). However, some Armillaria species are considered able to attack healthy trees. Due to the frequent periods of stress that orchard trees experience, Armillaria can cause whole-tree mortality when established in the root system. Because of the close proximity of trees and the frequent root grafting that occurs, this disease can rapidly spread throughout sections of the orchard. Armillaria generally spreads from its initial location (e.g., previously infected stumps or trees) through root contact or by rhizomorph production (Redfern and Filip 1991). In the case of a highly virulent species such as *A. ostoyae*, considered to be the most common Armillaria species in northern Ontario (Dumas 1988), spread occurs predominantly through root contact because of limited rhizomorph production. Armillaria root rot is seldom widespread in a stand and is usually evident by the pockets of tree mortality it causes. The disease is best controlled through avoidance of high hazard areas. Establishment of orchards on previously untreed sites, such as agricultural fields, is a recommended strategy as these areas seldom contain significant amounts of inoculum (Sutherland 1991). If limited site selection is available, inoculum reduction or disease control is possible through stump removal and site preparation (Morrison 1981) in addition to other silvicultural procedures (Hagle and Shaw 1991) such as matching tree species to the site and the use of trenching to isolate uninfected trees from infected regions. Once the disease is established in an orchard, some workers recommend the complete removal of the diseased tree and the associated root system (Sutherland 1991). However, prior to commencing control measures a pest specialist should be contacted to evaluate the situation.

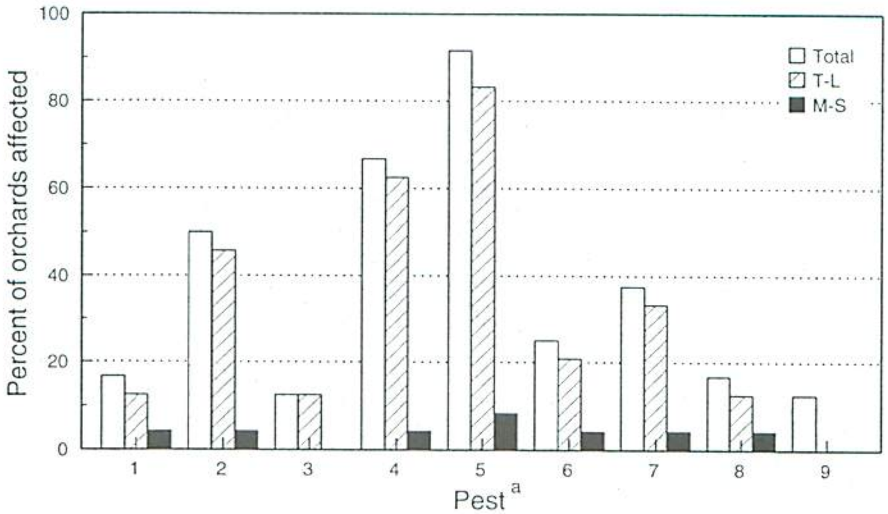

Figure 2a. Frequency of pest occurrence and damage levels in black spruce seed orchard evaluations (1990–1992).

[a] 1. Armillaria, 2. Spruce needle rust, 3. Diplodia, 4. Frost damage, 5. Spruce budworm, 6. Spruce coneworm, 7. White pine weevil, 8. Yellowheaded spruce sawfly, 9. Spruce budmoth.

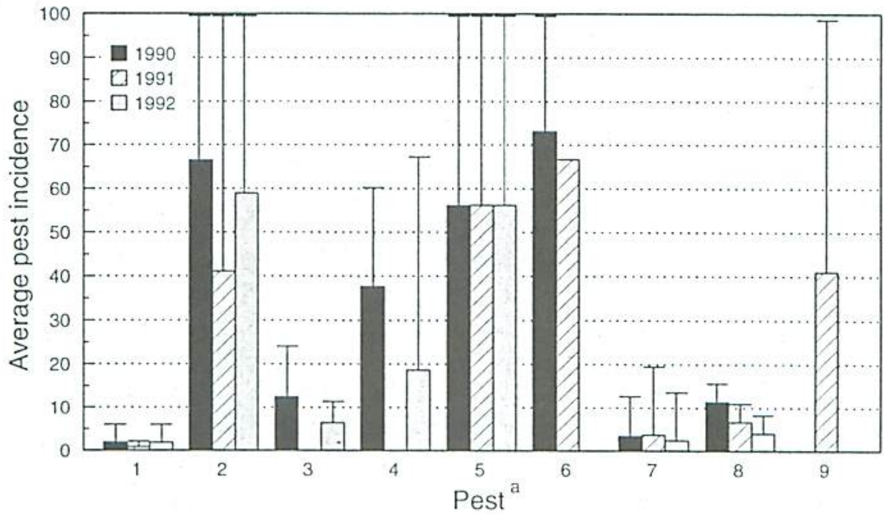

Figure 2b. Average annual incidence of pests in affected black spruce seed orchards. Note: Bars mark the maximum pest incidence.

[a] 1. Armillaria, 2. Spruce needle rust, 3. Diplodia, 4. Frost damage, 5. Spruce budworm, 6. Spruce coneworm, 7. White pine weevil, 8. Yellowheaded spruce sawfly, 9. Spruce budmoth

Spruce Needle Rust (*Chrysomyxa ledicola* Lagh., *C. ledi* d By.)

This disease was observed in 41% of the evaluations (Fig. 2a). In affected orchards incidence of needle rust was high in all years, with up to 100% of the trees affected

Table 2. Summary of average annual pest incidence in affected black spruce seed orchards in northern Ontario from 1990 to 1992.

	1990 Pest incidence		1991 Pest incidence		1992 Pest incidence	
Pest type	Average	Range	Average	Range	Average	Range
Armillaria root rot	11.3	0.2 – 6.0	0.8	0.7 – 1.3	1.8	0.7 – 6.0
Spruce needle rust	66.5	3.3 – 100.0	41.1	3.3 – 100.0	59.0	2.7 – 100.0
Diplodia	12.4	1.6 – 23.8	0.0	0.0	6.4	0.7 – 11.3
Frost	37.7	5.0 – 60.0	0.0	0.0	18.6	1.0 – 67.0
Spruce budworm	56.1	7.2 – 100.0	56.2	0.7 – 100.0	56.2	2.7 – 100.0
Spruce coneworm	73.1	19.3 – 100.0	66.7	66.7 – 66.7	0.0	0.0
White pine weevil	3.4	0.6 – 12.0	3.7	0.7 – 19.7	2.4	0.7 – 13.3
Yellowheaded spruce sawfly	11.3	3.3 – 15.3	6.7	3.0 – 10.7	4.0	0.7 – 8.0
Spruce budmoth[1]	na	na	41.0	9.3 – 99.0	0.0	0.0

[1] Data not collected in 1990.

(Fig. 2b, Table 2). Damage due to defoliation, however, was rated at only trace to light levels (Fig. 2a).

This rust has been previously documented as causing severe defoliation during moist years; however, impact is generally considered minimal and control is only justified under epidemic conditions (Ziller 1974). Recently, high levels of infection have been reported in the Ontario Ministry of Natural Resources (OMNR) Northeast Region of the province where 100% of the trees were affected in several townships. Foliar damage levels of 5–70% were observed on current year shoots (Ingram et al. 1991). Infection can be prevented by establishing orchards away from swampy areas where the alternate host *Ledum* spp. occurs. Alternation between hosts (*Ledum*–spruce) is essential for this disease to infect conifers. While it is not necessary for the alternate host to exist within the orchard, it is generally accepted that it must exist in sufficient numbers within 1,000 metres of the stand.

Diplodia Tip Blight
(*Sphaeropsis sapinea* [Fr] Dyko & B. Sutton)

This disease was recently reported for the first time on black spruce in Ontario (Myren 1991). In the current survey, diplodia was evident in 15% of the evaluated orchards and damage was assessed at moderate to severe levels in 11 % of these (Fig 2a). In affected orchards, diplodia infected an average of 12.4 and 7% of the trees in 1990 and 1992, respectively, with infection levels as high as 24% (Fig. 2b, Table 2). Sanitation, involving the removal of diseased branches and severely infected trees, apparently controlled the disease in 1990 in affected orchards as it was not detected on these sites in 1991. However, the disease appeared in three additional orchards in 1992. In 1989 this disease caused significant damage at three seed orchards in northwestern Ontario (Sajan and Brodersen 1989). This pathogen, which typically causes a tip blight, can kill significant portions of the upper tree stem (Fig. 2c) and can cause whole-tree mortality in black spruce orchards. The disease is known to be particularly damaging to host trees that have been exposed to stress

Figure 2c. Damage to black spruce orchard tree infected with Sphaeropsis sapinea. *Note damaged shoots, which appear prior to shoot and branch mortality.*

from wounding, drought, or poor site conditions (Nicholls and Ostry 1990). As previously described, sanitation is a suitable control in most instances. In pine species, cones are known to harbour the disease and serve as an important source of inoculum (Palmer et al. 1988). To date, *S. sapinea* has not been associated with black spruce cones. As such, this makes their removal in diseased orchards unneccessary.

Frost Damage

Frost damage to new foliage was evident in 15% of the orchards evaluated (Fig 2a). Damage was assessed at trace to light levels in 10.5% of the evaluations and had little effect on the tree; however, the damage to potential cone production is less certain. Moderate to severe damage was evident in 4% of the evaluations (Fig.2a). Incidence of frost in affected orchards is potentially high. In 1990 and 1992 respectively, 60% and 67% of the trees in a given orchard sustained frost damage, albeit at trace levels (Fig. 2b, Table 2).

Frost damage generally occurs on new foliage (Fig. 2d) although direct damage to black spruce cones has been reported (West 1986). The occurrence of frost and the extent of damage are often related to exposure and topography. Site selection and the avoidance of depressions and north facing slopes and flat plateaus, where reduced air flow is more likely, are simple control measures (Stathers 1989). In addition, site preparation techniques that increase air movement on the site, or plowing of the soil to incorporate the organic horizon and increase soil heat storage (Bjor and Sandvik 1984), have proven effective.

Figure 2d. Frost damage to a black spruce seed orchard tree.

Eastern Spruce Budworm (*Choristoneura fumiferana* Clem.)

Eastern spruce budworm, found in 89% of the evaluations (Fig 2a), was the most commonly observed pest in black spruce seed orchards. The average incidence of the pest in affected orchards was consistently between 50 and 60% over the 3-year survey and up to 100% of the trees were infested in a given orchard (Fig. 2b, Table 2). Although damage to orchard trees is potentially high when the insect is at epidemic levels, only 4.3% of the orchards recieved moderate to severe levels of defoliation during the study (Fig. 2a).

Low levels of defoliation, while not affecting tree vigor, can reduce future cone crops due to destruction of flower buds (Schooley 1980). In addition, heavy defoliation can inhibit cone production for up to several years (Powell 1973). Spruce budworm is also known to be a serious pest of cone crops on spruce. In previous studies on black spruce in Ontario (Syme 1981, Prevost et al. 1988), spruce budworm was found to be the most damaging insect to cones and reproductive structures. This insect is an early season defoliator, feeding initially on unopened buds and male flowers when available, then on the expanding buds as the season progresses (Rose and Linquist 1977). The effect of spruce budworm on black spruce seed orchards is uncertain given present knowledge. Previous observations suggest that pure stands of black spruce (lowland or plantation) generally sustain less damage during budworm outbreaks as compared to mixedwood stands (Howse 1981). However, given the potential effect on cone crop, control measures should be considered when either heavy defoliation or flower loss is noted or when a severe outbreak is observed in the surrounding area.

Spruce Coneworm (*Dioryctria reniculelloides* Mutuura & Munroe)

This insect was found in only 9% of the evaluations and defoliation was rated at trace to light levels (Fig. 2a). However, the incidence of coneworm was considered high in those orchards that were affected in 1990 and 1991. In 1990, up to 100% of the trees in affected orchards were infested (Fig. 2b, Table 2). In 1992, spruce coneworm was not detected in FIDS seed orchard surveys; earlier work has suggested that populations are related to the availability of cones (McLeod and Daviault 1963). Most orchards surveyed were not yet producing cones or had only light cone crops due to the age of the trees. This may have accounted for the low insect populations in most orchards. In all cases the pest was found in association with spruce budworm, thereby making it difficult to determine its impact on the host tree. However, unlike spruce budworm, spruce coneworm is not considered a serious defoliator but has been found to cause significant damage to cone crops in other studies on black spruce (Syme 1981, Prevost et al 1988).

White Pine Weevil (*Pissodes strobi* Peck)

This insect was evident in 65% of the black spruce seed orchard evaluations (Fig 2a). The incidence of the pest (Fig 2b, Table 2) in affected orchards, and associated damage levels, were generally low. However, moderate to severe damage was evident in 9% of the evaluations (Fig. 2a). Within affected orchards an average of 3% of the trees were infected each year, however, up to 20% of the trees were attacked in one orchard (Fig. 2b, Table 2).

This insect can cause losses in black spruce cone crops on young, cone-bearing trees (2–3 m) when the terminal leader is attacked (Fig. 2e). Damaged terminals can also allow fungal pathogens to enter the tree and cause further injury (Martineau 1984). The impact of white pine weevil on black spruce, particularly in orchards, is unclear as most published accounts of this insect concern its association with white pine. Plantation surveys previously conducted by FIDS suggest that weevil on black spruce is less prevalent on trees over 6 m in height. This is consistent with the general literature dealing with weevil on white pine. Conversely, this reinforces the common belief that smaller, open-grown trees such as those in seed orchards are at the greatest risk. Control of the weevil through mechanical or chemical means is recommended in young black spruce orchards.

*Figure 2e. A black spruce seed orchard tree damaged by white pine weevil (*Pissodes strobi*). Note the cones on the dead terminal leader.*

Yellowheaded Spruce Sawfly (*Pikonema alaskensis* Rohwer)

Spruce sawfly was detected in all years in 34% of the evaluations. Damage was generally at trace to light levels although moderate to severe defoliation was evident in 4% of the evaluations (Fig. 2a). Incidence of this insect in affected orchards was relatively light with a maximum of 15% of the trees affected (Fig. 2b, Table 2).

Severe and repeated defoliation can result in loss of tree vigor and mortality. Yellowheaded spruce sawfly feed first on current year needles and later on previous years foliage, sometimes causing complete defoliation. Episodes of severe defoliation are commonly observed on young spruce (0.5–2m) during general FIDS surveys in Ontario (Evans et al. 1992). Generally though, infestations are short in duration and are confined to a very small area (Martineau 1984). The insect is known to prefer open-grown trees and to concentrate its attack on previously defoliated trees (Ives and Wong 1988). These preferences increase the likelihood of damage to orchard trees. Earlier work (Bartelt et al. 1982) has shown that *P. alaskensis* gravitates to sunny locations and suggests that orchards might be at some risk.

Spruce Budmoth (*Zeiraphera canadensis* Mutuura & Freeman)

This insect was detected in black spruce seed orchards only during the 1991 survey. In that year, spruce budmoth was noted in only 9.4% of the evaluations (Fig. 2a). However, in the affected orchards the pest was found on up to 99% of the trees (Fig. 2b, Table 2). Resulting damage was not determined by this survey as budmoth was always found in association with spruce budworm, and damage caused by the two insects is similar.

Larvae of spruce budmoth typically feed on young needles under the budcap and on the bark of young shoots. This latter activity results in the weakening, bending, and sometimes breakage of the shoot. Feeding activity is concentrated in the upper crown and is most visible on the leader (Turgeon 1992). The insect is also known to feed on male and female flowers in black spruce (Schooley 1983) and white spruce (Pilon 1965). The economic impact of spruce budmoth on black spruce orchards is uncertain, but probably minimal, as the insect is most often associated with white spruce and only occasionally with other conifers (Rose and Linquist 1977, Carrow 1985).

WHITE SPRUCE SEED ORCHARDS

Armillaria Root Rot (*Armillaria* spp.)

Root rot was detected in 17% of the evaluations (Fig. 3a) over the 3-year period. On average, between 0.7 and 2.9% of the trees in affected orchards were killed annually by Armillaria from 1990 to 1992 (Fig. 3b, Table 3), with up to 5.0% mortality occurring in one orchard. Whitney (1988) noted an annual average mortality rate of 1.4% in young white spruce plantations affected by armillaria root rot. He also noted that black spruce and white spruce were more susceptible to Armillaria than was jack pine. In the current survey, higher damage levels occurred in spruce orchards than in jack pine orchards. As is the case in black spruce orchards, this disease is one of the main causes of annual tree mortality and has good potential for spread after it is established (*see also* the black spruce section).

Spruce Needle Rust (*Chrysomyxa ledicola, C. ledi*)

This organism was observed in 50% of the white spruce orchards (Fig. 3a). In affected orchards up to 100% of the trees were infected although average values ranged from 21 to 40% (Fig. 3b, Table 3). The defoliation caused by the disease was generally rated at trace to light levels (Fig. 3a) during this survey. Impact due to this disease is usually not significant although epidemic levels should be controlled (*see also* the black spruce section).

Spruce Cone Rust (*Chrysomyxa pirolata* Wint.)

Spruce cone rust was found in 12.5% of the evaluations but caused only trace to light levels of damage (Fig. 3a). The pest was recorded only during the 1992 survey when it infected a maximum of 1.5% of the trees in affected orchards (Fig. 3b, Table 3).

In some areas spruce cone rust is considered one of the major cone diseases by many pathologists and is capable of causing significant losses to cone crops (Sutherland et

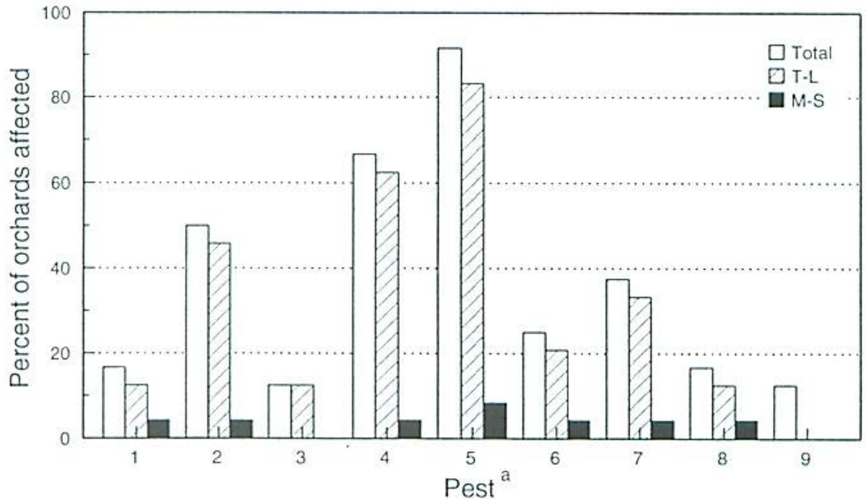

Figure 3a. Frequency of pest occurrence and damage levels in white spruce seed orchard evaluations (1990–1992).

[a] *1. Armillaria* | *2. Spruce needle rust* | *3. Spruce cone rust* | *4. Frost damage* | *5. Spruce budworm* | *6. Spruce coneworm* | *7. White pine weevil* | *8. Yellowheaded spruce sawfly* | *9. Spruce budmoth*

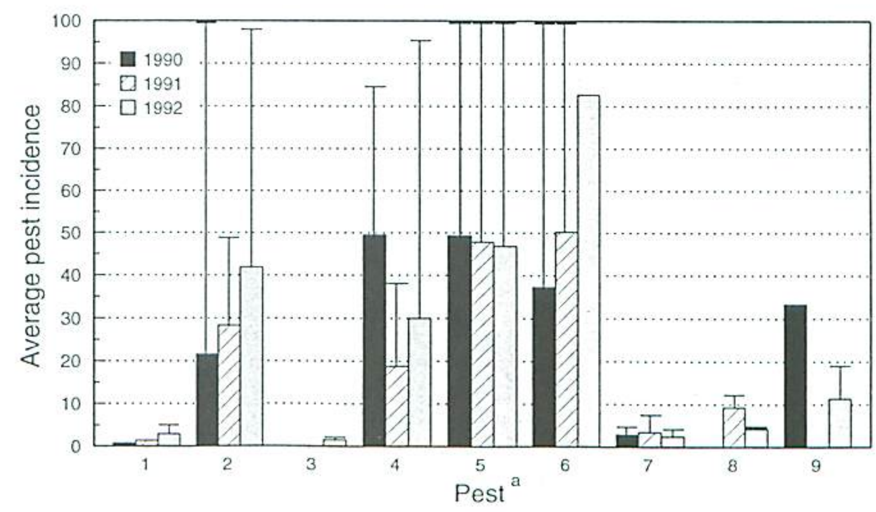

Figure 3b. Average annual incidence of pests in affected white spruce seed orchards. Note: Bars mark the maximum pest incidence.

[a] *1. Armillaria* | *2. Spruce needle rust* | *3. Spruce cone rust* | *4. Frost damage* | *5. Spruce budworm* | *6. Spruce coneworm* | *7. White pine weevil* | *8. Yellowheaded spruce sawfly* | *9. Spruce budmoth.*

Table 3. Summary of average annual pest incidence in affected white spruce seed orchards in northern Ontario from 1990 to 1992.

	1990 Pest incidence		1991 Pest incidence		1992 Pest incidence	
Pest type	Average	Range	Average	Range	Average	Range
Armillaria root rot	0.7[1]	na	1.3[1]	na	2.9	0.7 – 5.0
Spruce needle rust	21.5	1.0 – 100.0	28.3	8.0 – 48.7	41.9	8.4 – 98.0
Spruce cone rust[2]	na	na	0.0	0.0	1.5	1.0 – 2.0
Frost damage	49.5	16.0 – 84.7	18 .8	7.3 – 38.0	30.0	2.7 – 95.3
Spruce budworm	49.3	7.3 – 100.0	47.8	4.0 – 100.0	46.9	0.6 – 100.0
Spruce coneworm	37.3	0.7 – 100.0	50.3	0.7 – 100.0	82.7	82.7 – 82.7
White pine weevil	2.9	1.2 – 4.6	3.5	0.7 – 3.5	2.5	0.7 – 4.0
Yellowheaded spruce sawfly	0.0	0.0	9.3	6.7 – 12.0	4.3	4.0 – 4.6
Spruce budmoth	33.3[1]	na	0.0	0.0	11.3	4.0 – 18.7

[1] Only one orchard affected.

[2] Data not collected in 1990.

al. 1987). Singh and Carew (1990) observed sporadic and localized epidemics of cone rust on black spruce and white spruce in Newfoundland. These infections resulted in a reduction of available seed from those areas. Spruce cone rust is known to infect both white spruce and black spruce but was not evident on the latter species during this survey. The disease has been sampled throughout much of northern Ontario, particularly in the Great Lakes region during annual FIDS surveys. High levels of infection have not been commonly recorded in this province but do occur occasionally (McPherson et al. 1982). However, routine monitoring of cone crops in areas where the disease is present is recommended. Like spruce needle rust, cone rust alternates from another host (*Pyrola* spp.) to the conifer and can be dispersed several kilometers (Ziller 1974). Avoidance of areas containing *Pyrola* is the best control measure against this pest. Controlling the alternate host by various means (Sutherland 1991) is a possible option in areas of concern, but is usually not practical. In spruce seed orchards where the disease is evident, or in high risk areas near the Great Lakes, a pest specialist should be consulted to discuss control options.

Frost Damage

Frost damage to new foliage was observed in 67% of the orchards evaluated although damage was generally rated at trace to light levels (Fig. 3a). Within affected orchards, an average of 19–49% of the trees were damaged between 1990 and 1992. However, within a single orchard up to 95% of the trees could be affected (Fig. 3b, Table 3). The incidence of frost damage was observably greater on white spruce than on black spruce, although damage to current foliage was often at trace to light levels in both species. White spruce is generally considered to be more susceptible to frost damage than either black spruce or jack pine (Lavallee 1992b) and greater care should be given to reducing frost incidence. Zasada (1971) observed high mortality rates in young cones of white spruce, as well as a reduction in seed production, after a mild spring frost in Alaska. Strategies to avoid frost damage include the identification and avoidance of frost susceptible areas where cold air drainage occurs. As well, maximizing air circulation on a site by pruning the lower tree branches is recommended (*see also* the black spruce section).

Eastern Spruce Budworm (*Choristoneura fumiferana*)

This insect was the most commonly found pest in white spruce orchards and infested 92% of the evaluated sites (Fig. 3a). The incidence of budworm within affected orchards was generally high (Fig. 3b, Table 3) in all years with up to 100% of the trees infested in some orchards. As with black spruce, although the potential for significant damage exists, only a minority of white spruce orchards surveyed (8.3%) showed moderate to severe levels of defoliation (Fig. 3a) (*see also* the black spruce section).

Spruce Coneworm (*Dioryctria reniculelloides*)

Spruce coneworm was observed in 25% of the evaluations and was associated with moderate to severe defoliation in 4.2% of the surveys (Fig. 3a). Within affected orchards, a high incidence of coneworm was observed at some locations in all years (Fig. 3b, Table 3), with up to 100% of the trees infested in a given orchard in both 1990 and 1991. Although coneworm was found associated with moderate to severe defoliation in some orchards, spruce budworm was likely responsible for most of this damage. Defoliation resulting from coneworm feeding is not distiguishable from that caused by eastern spruce budworm when the two occur on the same tree. Generally however, spruce coneworm consumes less foliage and has less effect on host vigor than does spruce budworm (Ives and Wong 1988). Also, it is reported to favor cones as a food source (Hedlin et al. 1981). However, this insect is often associated with other defoliators such as spruce budworm and does contribute to crown deterioration. The major impact of this pest is on cone crops where it is known to cause significant damage (*see also* the black spruce section).

White Pine Weevil (*Pissodes strobi*)

The white pine weevil was in evidence in 38% of the orchards evaluated (Fig. 3a). Pest incidence in affected orchards averaged 3%, although levels as high as 7.3% were found in individual orchards (Fig. 3b, Table 3). This insect impacts younger trees, under 2 m in height, by removing the uppermost portion of the crown. Over the 3-year survey, the weevil was found more frequently in black spruce orchards than in white spruce orchards. However, incidence levels as high as 7.3% in one seed orchard would indicate the potential for damage by this insect to white spruce. As with black spruce, it is uncertain how persistent white pine weevil is on white spruce (*see also* the black spruce section).

Yellowheaded Spruce Sawfly (*Pikonema alaskensis*)

This sawfly was found in less than 17% of the orchards evaluated and caused moderate to severe defoliation to 4.2% of the white spruce orchards surveyed (Fig. 3a). It was recorded in white spruce orchards only in 1991 and 1992 and affected an average of 9.3 and 4.3% of the trees, respectively (Fig. 3b, Table 3). However, up to 12% of the trees were affected by the sawfly in one orchard. This pest affected fewer white spruce orchards than black spruce orchards; however, it was found at damaging levels in some orchards of both species (Figs 2a, 3a).

Spruce sawfly is known to prefer open-grown trees (Ives and Wong, 1988). Other work (Morse and Kulman 1986) suggests that trees on south facing slopes are more vulnerable to this pest, likely due to increased ambient air temperatures. In this regard, growing young white spruce with a light overstorey has been recommended as a silvicultural control method (Morse and Kulman 1984) (*see also* the black spruce section).

Spruce Budmoth (*Zeiraphera canadensis*)

Spruce budmoth was found in 12.5% of the orchards evaluated (Fig. 3a). In 1990 it affected 33% of the trees in one white spruce orchard and up to 18.7% of the trees in 1992 (Fig. 3b, Table 3). The impact of this pest remains uncertain in orchard and plantation situations although pure stands of white spruce are known to be most susceptible to vegetative feeding by the budmoth (Carrow 1985). The insect has also been reported to feed on both male and female flowers in white spruce (Pilon 1965). Carrol et al. (1993) determined that radial growth in white spruce was affected only after several years of severe damage. However, these researchers also observed that crown architecture was affected by chronic hebivory and this resulted in shrublike growth. This indicates a potential impact to seed orchards, as altered crown architecture could result in the reduction or elimination of the cone-bearing ability of white spruce. It has been previously reported that feeding by *Dioryctria albovitella* Hust. on pinyon pine resulted in similar changes in crown architecture and the loss of female cones (Whitman and Mopper 1985). Spruce budmoth populations are highest in plantations under 3 m in height and typically decline with increased tree height and crown closure (Turgeon 1992). This would suggest that white spruce orchards, which are typically open grown, would be at greater risk than planatations where crown closure will occur.

JACK PINE SEED ORCHARDS

Armillaria Root Rot (*Armillaria* spp.)

Armillaria was observed in 42% of the jack pine orchards evaluated. Damage was always rated at trace to light levels (Fig. 4a) as the disease usually affected less than 1.3% of the orchard trees (Fig. 4b, Table 4). The disease, while common in jack pine seed orchards, caused less mortality than in spruce orchards during the survey period. Whitney (1988) noted that jack pine was more resistant to root rot than either white spruce or black spruce. He also observed that Armillaria caused an annual average mortality of only 0.5% in young jack pine plantations (*see also* the white spruce and black spruce sections).

Pine Needle Rust (*Coleosporium asterum* [Diet.] Syd.)

Needle rust was commonly observed in jack pine seed orchards and occurred in 67% of the evaluations. In all cases damage due to defoliation was rated at trace to light levels (Fig. 4a). While pest incidence varied over the 3-year survey, it was most abundant in 1991 and 1992 (Fig. 4b, Table 4) when an average of more than 40% of the trees were affected.

This rust, although commonly observed in Ontario, is not considered a major problem as only heavily infected or old, diseased needles are prematurely cast. However,

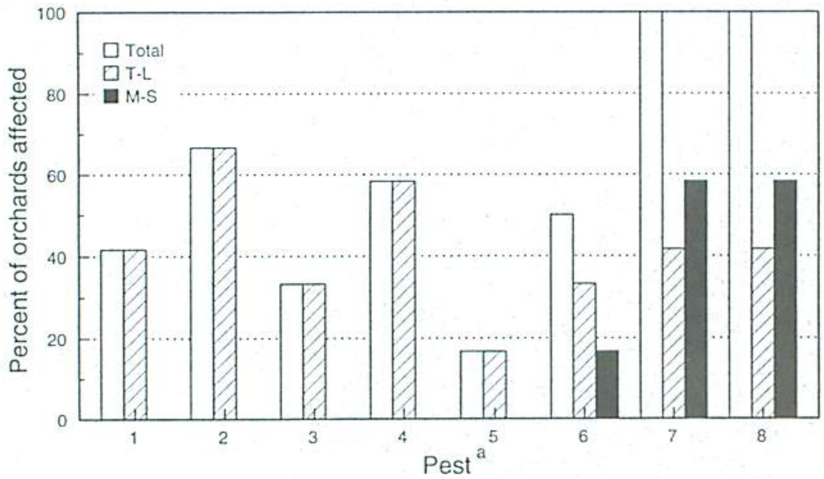

Figure 4a. Frequency of pest occurrence and damage levels in jack pine seed orchard evaluations (1990–1992).

[a] *1. Armillaria* *2. Pine needle rust* *3. Western gall rust* *4. Pine needle cast* *5. Jack pine budworm* *6. Red pine cone beetle* *7. White pine weevil* *8. Eastern pine shootborer*

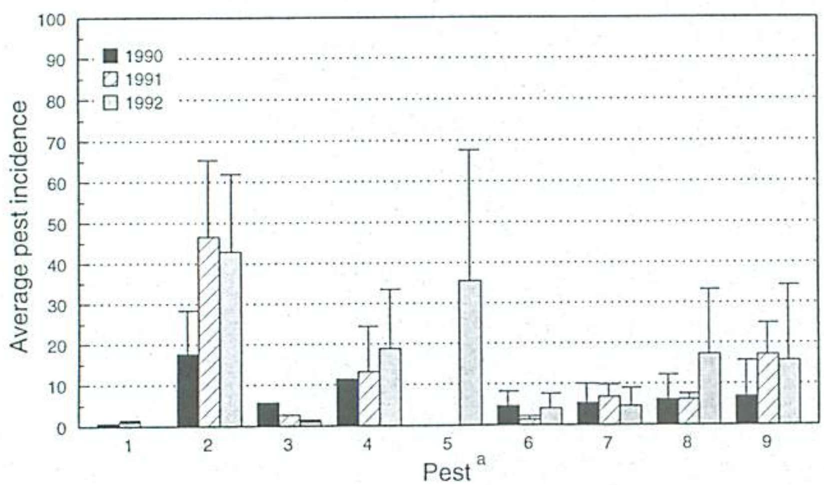

Figure 4b. Average annual incidence of pests in affected jack pine seed orchards.

[a] *1. Armillaria* *2. Pine needle rust* *3. Western gall rust* *4. Pine needle cast* *5. Jack pine budworm* *6. Red pine cone beetle* *7. White pine weevil* *8. Eastern pine shootborer*

moderate to severe levels of infection are periodically recorded (MacLeod et al. 1989, Ingram et al. 1991). Control of the disease would only be considered under epidemic situations. As with most rust fungi, pine needle rust requires alternation between hosts, in this case pine to *Aster* spp. (Ziller 1974). Infection of pines occurs in the late summer to fall, but symptoms are not apparent until the following spring.

Western Gall Rust (*Endocronartium harknessii* [J.P. Moore] Y. Hirat.)

This rust, considered by some as a major disease problem of hard pines (Hiratsuka 1987), was observed in 33% of the evaluated jack pine orchards; however, all were affected at only trace to light levels (Fig. 4a). In the affected orchards, infection (branch and stem) levels were generally low in all years. A maximum of 5.7% of the trees were affected in one orchard in 1990 (Fig. 4b, Table 4).

The disease is harmful to trees only when stem infections or numerous branch infections occur; conditions not commonly observed during our survey. Mortality is common on young jack pine affected by stem galls (Gross 1983). Juzwik and Chong (1990) found cumulative mortality in jack pine plantations to average 3.4% with most infections occurring on trees up to 10 years of age. The effect of branch galls on tree survival is more questionable although these will often result in branch mortality. The rust does not require an alternate host and travels from pine to pine (Ziller 1974) thereby making spread within an orchard more likely. Infection occurs through young shoots and results in galls on branches or the main stem. Galls produced by this disease are perennial and produce spores each year. This combination can result in effective spread within a stand when conditions for infection are suitable. Prevention, by establishing orchards in areas where gall rust is not common, is the best control. However, pruning of infected branches provides an efficient control in reducing spread.

Pine Needle Cast (*Davisomycella* spp., *Lophodermium* spp.)

Needle casts were observed in 58% of the evaluations but caused only trace to light levels of defoliation (Fig. 4a). In affected orchards, annual incidence averaged 11–19% with the highest level of infection in a given orchard affecting 33% of the trees (Fig. 4b, Table 4). Needle cast

Table 4. Summary of average annual pest incidence in affected jack pine seed orchards in northern Ontario from 1990 to 1992.

	1990 Pest incidence		1991 Pest incidence		1992 Pest incidence	
Pest type	Average	Range	Average	Range	Average	Range
Armillaria root rot	0.7[1]	na	1.0	0.7 – 1.3	0.0	0.0
Spruce needle rust	17.6	7.3 – 28.0	46.6	12.0 – 64.7	42.9	22.6 – 61.3
Western gall rust	5.7[1]	na	2.7[1]	na	1.0	0.7 – 1.3
Pine needle cast	11.3[1]	na	13.1	1.3 – 24.0	18.8	2.7 – 33.0
Jack pine budworm	0.0	0.0	0.0	0.0	35.5	4.0 – 67.0
Jack pine tip beetle	4.6	1.3 – 8.0	1.3	0.7 – 2.0	4.0	0.7 – 7.3
White pine weevil	5.3	0.7 – 10.0	6.8	2.7 – 10.0	4.6	1.3 – 8.7
Eastern pine shootborer (Leaders only)	6.1	1.3 – 12.0	6.2	5.0 – 7.3	17.2	2.0 – 32.7
Eastern pine shootborer (Laterals only)	6.8	1.3 – 15.3	17.1	6.0 – 24.7	15.6	1.2 – 34.0

[1] Only one orchard affected.

has been reported as a severe problem in Scots pine (*Pinus sylvestris* L.) plantations (Skilling and Nicholls 1975), but little information exists on damage to jack pine. This disease, while commonly found on jack pine, likely impacts tree health only after repeated severe defoliation (Hiratsuka 1987) and control is warranted only under extreme conditions.

Jack Pine Budworm (*Choristoneura pinus* Freeman)

This insect was observed in 17% of the evaluations, but caused only trace to light levels of defoliation (Fig. 4a). Jack pine budworm was observed in seed orchards only during the 1992 survey. It infested an average of 36% of the trees in affected orchards. However, in one orchard 67% of the trees were affected at low levels (Fig. 4b, Table 4).

Although budworm outbreaks are generally short lived on jack pine, the pest can cause top kill, loss of vigor, and sometimes mortality (Martineau 1984). The survey failed to detect any significant defoliation on orchard trees. Previous FIDS surveys and personal observations (Gordon M. Howse, pers. comm. 1994) suggest smaller trees under 6 m in height are not at great risk to defoliation by this insect. However, the insect is known to devour flowers and damage young pollen and seed cones during its feeding (Turgeon and de Groot 1992). There is some suggestion that populations of this pest might be related to the availability of host flowers (Mattson et al. 1991). Routine surveillence of population levels of this insect is recommended when outbreaks are anticipated.

Red Pine Cone Beetle (*Conophthorus resinosae* Hopkins = *C. banksiana* McPherson)

This pest, formerly called jack pine tip beetle, has been reduced to synonymy with the red pine cone beetle (Wood 1989). It was found to be present in 50% of the orchard evaluations and damage caused to leaders was rated at moderate to severe in 17% of the visits (Fig. 4a). Distribution of the insect in affected orchards was limited, averaging 1.3–4.6% of the trees affected between 1990–1992. A maximum of 8% of the trees were infested in one orchard (Fig. 4b, Table 4).

The beetle is not generally considered to cause tree mortality or significant loss of vigor, although some work (Mattson, 1989) suggests that damage increases with tree height. Relative damage due to this insect was measured by leader mortality. However, the true impact to cones could result from attack to both lateral and terminal shoots, when beetle populations are at high levels. The insect does not feed on cones of jack pine, as do some other members of the genus (de Groot 1991), but can indirectly result in cone loss by causing shoot mortality. Control of the organism is not commonly required as population levels are usually not high enough, nor sustained enough, to cause significant damage (de Groot 1990, 1991).

White Pine Weevil (*Pissodes strobi*)

Weevil damage was recorded in 100% of the jack pine orchard evaluations (Fig. 4a). In almost 60% of these damage was rated as moderate to severe. Average annual incidence in affected orchards was between 4.6 and 6.8%

(Fig. 4b, Table 4). The highest incidence of weevil on jack pine was 10%. Weevil damage typically affects tree form in pines and can cause some problems in family trials. However, in orchards, some cone loss can occur in the upper portion of the crown when severe weevil damage occurs on young trees. In addition to mechanical and chemical control measures, there is some evidence that site (Lavallee 1992a) and stand (Wallace and Sullivan 1985) conditions might influence the level of vulnerability to this pest.

Eastern Pine Shootborer (*Eucosma gloriola* Heinrich)

This pest was found in 100% of the visits (Fig. 4a). Annual incidence within affected orchards averaged between 6.1 and 17% of the trees infested; however, up to 34% of the trees in one orchard sustained damage to lateral branches (Fig. 4b, Table 4). For the purpose of this survey, damage levels for shootborer were based on the percentage of trees sustaining leader damage. As such, in 58% of the evaluations moderate to severe levels were recorded (Fig. 4a). In each year of this survey, damage to laterals was recorded on an equal or greater number of trees than was leader damage (Fig. 4b, Table 4). Lateral damage could indirectly affect cone crops by causing shoot mortality.

This pest is most commonly found on open grown trees (Rose and Linquist 1977) and some work has shown a host preference for jack pine of an intermediate height class (Wong et al. 1966). The insect normally causes the greatest damage to leaders, as well as to lateral branches in the upper portion of the crown, and repeated feeding causes stunted and deformed growth (DeBoo et al. 1971). Jeffers (1978) also noted a relationship between jack pine seed source and damage; seed from the coldest source was more vulnerable to the pine shootborer. Other surveys (McKeague and Simmons 1978) have found the pest at high levels and have recommended pruning as a standard control measure.

SUMMARY

Seed orchard trees are often under stress and this can predispose them to damage by what are normally considered to be minor pests. Due to the value of orchards and individual orchard trees, damaging levels of insects or diseases may or may not be acceptable. The need to control such minor pests will depend on the goal of the individual orchard. Churcher et al. (1985) suggested four basic recommendations for control of cone and seed insects that are applicable to all pests of seed orchards:

1. Determine what pests are involved.
2. Determine the importance of the pest species.
3. Conduct biological studies on damaging pests where information is lacking.
4. Determine the need for preventative or control measures on the basis of pest impact and available biological information

The first step in controlling pests in seed orchards, or elsewhere, is to determine what insects and diseases are involved at a local or regional level. FIDS surveys indicate that the majority of seed orchard trees sustained only trace to light levels of pest damage over the 3-year survey. However, some pests caused significant damage in individual orchards and/or were found at high levels, thereby indicating the potential for damage.

Armillaria root rot caused significant annual mortality in spruce orchards, most commonly in black spruce. Jack pine was least affected. Diplodia tip blight (*Sphaeropsis sapinea*) caused significant damage in several black spruce orchards and resulted in top kill during 2 years. On average, 12 and 7% of the trees were affected in 1990 and 1992, respectively. Cone rust was found in 1 year in two white spruce orchards where it affected less than 2% of the cones. Frost damage was evident on all species but was most common on white spruce. Moderate levels of frost damage were also reported on black spruce, but none was reported on jack pine.

Other diseases, such as needle rusts on spruce and pines, were common but caused only trace damage. Needle casts and western gall rust also resulted in trace levels of damage in jack pine orchards. Spruce budworm, the most common insect pest of spruce, was reported in 90% of the orchards and infested approximately 50% of the trees. However, damage to foliage was generally reported at trace to low levels. Budworm was present in only 17% of the jack pine orchard evaluations and caused trace levels of damage, but was widespread in affected orchards.

Other insects of concern included the spruce coneworm, which affected 25% of the white spruce and 10% of the black spruce orchards. Up to 100% of the trees on these sites were infected. The yellowheaded spruce sawfly was most prevelant in black spruce orchards and affected about 35% of these. This pest caused moderate to severe defoliation on some trees but was not widespread in affected orchards. The spruce budmoth was also reported in several orchards of both spruce species but occurred at higher levels in black spruce sites. Significant damage due to this pest was not reported.

The white pine weevil was observed in both pine and spruce orchards. This pest was most widespread in jack pine and affected all orchards surveyed. Fewer infestations were recorded in black spruce or white spruce orchards. Other insect pests of jack pine included the eastern pine shootborer, which occurred in 100% of the evaluations. It affected up to 35% of the trees in some years and attacked both laterals and leaders. The red pine cone beetle was found in 50% of the evaluations on jack pine but was limited in its distribution and affected only 2–4% of the trees.

Perhaps the most critical information required before pest control options are considered is the impact caused by the damaging agent. The actual impact of pests on seed orchard trees was not addressed by this survey. Pest-induced mortality is an obvious impact and easy to quantify. However, the effect that pests have on potential cone crops is beyond the scope of this study and should be the focus of future work.

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