SEASONAL DAMAGE BY INSECTS AND SQUIRRELS TO FEMALE REPRODUCTIVE STRUCTURES OF BLACK SPRUCE, *PICEA MARIANA* (MILL.) B.S.P.

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Abstract

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The seasonal damage to female reproductive structures (buds, flowers, and cones) of black spruce, *Picea mariana* (Mill.) B.S.P., was assessed during 1983 and 1984. Nineteen insects (five Orders) and the red squirrel, *Tamiasciurus hudsonicus* (Erxleben), were found feeding on these reproductive structures. Collectively, these organisms damaged 88.9 and 53.5% of the cones in 1983 and 1984, respectively. In the 2 years, Lepidoptera damaged 61.8% of the cones in 1983 and 44.4% of the cones in 1984. The spruce budworm, *Choristoneura fumiferana* (Clem.), and the spruce coneworm, *Dioryctria reniculelloides* Mut. and Mun., were the most important pests. Cones damaged by Lepidoptera could be classed into three categories: (*a*) severe, yielding no seeds; (*b*) moderate, yielding 22.3 seeds per cone; and (*c*) light, yielding 37.5 seeds per cone. Undamaged cones yielded on average 39.9 seeds per cone. Red squirrels removed 18.8% of the cones in 1983 and none in 1984. The spruce cone axis midge, *Dasineura rachiphaga* Tripp, and the spruce cone maggot, *Lasiomma anthracinum* (Czerny), caused minor damage in both years. Feeding by spruce cone axis midge did not reduce cone growth significantly or the number of viable seeds per cone, but feeding by the spruce cone maggot did. During both years new damage by insects to the female reproductive structures of the experimental trees was not observed after mid-July. In 1983 damage by red squirrels occurred from early to late September. In 1984 damage to cones on trees treated with dimethoate was 15.6% compared with 53.5% for untreated trees, without an increase in the number of aborted cones.

Résumé

Les dommages saisonniers des structures réproductives femelles (bourgeons, fleurs, et cônes) de l'épinette noire, *Picea mariana* (Mill.) B.S.P., ont été evalués en 1983 et 1984. Dix-neuf insectes (cinq ordres) et l'écureuil roux, *Tamiasciurus hudsonicus* (Erxleben), se sont nourri de ces structures réproductives. Ces herbivores ont endommagé 88,9 et 53,5% des cônes en 1983 et 1984 respectivement, les lépidoptères ont endommagé 61,8 et 44,4%. La tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clem.), et la pyrale du cône de l'épinette, *Dioryctria reniculelloides* Mut. and Mun., étaient les plus importants. Les cônes endommagés par les lépidoptères ont été classés dans trois catégories: (*a*) sévère, ne produisant aucune graine; (*b*) modéré, contenant en moyenne 22,3 graines par cône; et (*c*) léger, contenant 37,5 graines par cône. Les écureuils roux ont endommagé 18,8% des cônes en 1983 et n'ont causé aucun dégât en 1984. La cécidomyie du cône de l'épinette, *Dasineura rachiphaga* Tripp, et la mouche du cône de l'épinette, *Lasiomma anthracinum* (Czerny), ont causé peu de dommage pendant les deux années. Le dommage par la cécidomyie du cône n'a eu aucun effet sur la croissance du cône ni sur le nombre de graines viables par cône, tandis que le dommage par la mouche du cône les a diminué significativement. En 1983 et 1984 aucun nouveau dégât par les insectes aux structures reproductive femelles des arbres experimentaux on a été observé après la mi-juillet. En 1983 les dégâts par les écureuils ont eu lieu pendant septembre. En 1984, les ravages aux cônes provenant d'arbres traités avec du diméthoate one été limités à 15,6, comparé à 53,5% pour les arbres non-traités, sans augmenté le nombre de cônes avortés.

Introduction

Black spruce, *Picea mariana* (Mill.) B.S.P., is widely planted in Ontario, but there is little information on the impact of organisms on its cone and seed production. Previous

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studies of the insect damage to cones has revealed that the composition of insect species can remain constant or vary from one location to another and from year to year. Lepidoptera and Cecidomyiidae attacked less than 10% of black spruce cones at Black Sturgeon Lake in north-central Ontario during 1963 and 1964 (Fye and Wylie 1968). During 1965–1968, 22–57% of black spruce cones were damaged by the spruce cone axis midge, *Dasineura rachiphaga* Tripp, in a seed orchard at Longlac (Haig and McPhee 1969). Across northern Ontario during 1980, Lepidoptera, i.e. spruce budworm, *Choristoneura fumiferana* (Clem.), and spruce coneworm, *Dioryctria reniculelloides* Mut. and Mun., caused 40–92% damage to black spruce cones (Syme 1981). In the same study, the spruce cone maggot, *Lasiomma anthracinum* (Czerny), damaged 18% of the cones, and the spruce cone axis midge damaged 5–25%. During 1977, Schooley (1980) found that spruce budworm had damaged 94% of the black spruce cone crop in Newfoundland. With cone damage as summarized above, seed losses are undoubtedly significant.

The use of life tables to assess insect damage to plants has been discussed by Harcourt (1970). Damage to cones has been assessed using cone life tables for several species of pine (Ebel and Yates 1974; DeBarr and Barber 1975; Roques 1977; Yates and Ebel 1978; Mattson 1978; Rauf *et al*. 1985). The objectives of the present study were (*a*) to catalogue the insects feeding on female reproductive structures, i.e. buds, flowers, and cones; (*b*) to record the stage in the female reproductive process where organisms cause the greatest damage; and (*c*) to define the relative significance of the various organisms to black spruce cone and seed production.

Cone production drains energy reserves of conifers (Eis *et al*. 1965) and by allowing the full cone complement to mature by preventing insect damage there may be an increase in the number of aborted cones. Accordingly, a fourth objective was (*d*) to control insect damage to the cones and determine if this caused increased cone abortions.

Materials and Methods

During the summer and fall of 1982, a general survey was made to catalogue the insects associated with cone development in black spruce stands across northern Ontario. In the early spring of 1983, 10 upland black spruce trees were chosen randomly near Sault Ste. Marie, Ont. Trees in the stand were 12–15 m high and 30–35 years old. The stand, situated on a well-drained sandy-loam site, was 30 km from other black spruce stands. In the spring of 1984, three other trees bearing female reproductive buds that were swelling were selected in the same stand to determine what proportion of the female buds could become mature cones in the absence of insects. In these three trees, the top half of the crowns were sprayed on 10 May 1984 with a 0.044 g AI/L solution of dimethoate (Cygon®-2E) to the point of run-off (*ca*. 7 L per tree), using a Solo® back-pack mist sprayer.

Access to the tree tops was gained using a bucked-equipped lift truck. In early May 1983 and 1984, when the buds had started to swell, all branches bearing female reproductive buds were identified with aluminum tags and the female buds were counted. External damage to the female reproductive structures was assessed weekly from mid-May to mid-July, and then at the end of August and September. At each observation, damaged buds, flowers, or cones were marked with thin, color-coded, plastic-coated wires. A different color identified the damage that occurred during each observation period.

After the final damage assessment in late September, all mature female cones were collected, placed in numbered polyethylene bags, and stored at 0.5°C until examined. All cones were dissected to determine internal damage and/or the presence of insects.

Tables were constructed to show the observation interval, the number of sound female cones at the beginning of each interval, percentage of the sound female cones damaged during the interval, and the cause of damage.

Insects observed feeding on cones in the field were left *in situ*. Samples of all unidentified insects, collected in the field and dissected from cones, were preserved in 70%

alcohol. These were identified by the Forest Insect and Disease Survey, Great Lakes Forestry Centre (Sault Ste. Marie, Ont.) and the Biosystematics Research Centre (Ottawa, Ont.). Voucher specimens were deposited at the Department of Environmental Biology, University of Guelph, Guelph, Ont.

All cones were classified according to the following degrees of external damage and counted: (*a*) undamaged, (*b*) severe, truncated or hollowed-out, (*c*) moderate, lacerated over more than 50% of their surface area; and (*d*) light, superficial lacerations to less than 50% of their surface. The volume of 400 undamaged cones was measured by water displacement. One hundred cones from each damage class and all undamaged cones were placed separately in bags made from fiberglass screening. The bags were placed into an oven at 50°C for 12 h to open the scales of the cones. Cones were shaken in 135-mL cardboard containers for about 30 s to separate the seeds from the cones; the seeds were put aside. The cones were returned to their screen bags, placed in water at room temperature for 3 h to close the scales, and then returned to the oven. The procedures were repeated three times. The cones were cut in half using secateurs, and the presence of the spruce cone axis midge and spruce cone maggot was noted. Seeds remaining in cones were extracted with forceps. When the total number of seeds per cone was determined, the seeds were placed into Petri dishes with Kimpak® germination paper.

Seed germination was determined under the International Seed Testing Association (1976) standards. Germination was evaluated weekly during the 28-day germination testing period. After the 4 weeks, all ungerminated seeds were dissected to determine if they were filled (containing both embryo and endosperm) or empty. The germination capacity (proportion of the filled seed which had germinated) was calculated for each cone.

If the cone was destroyed entirely the number of viable seeds lost was calculated based on 18.9 filled seeds per cone. If moderate damage due to Lepidoptera occurred, the calculation was based on 8.6 filled seeds lost per cone, the difference between the filled seeds per sound cone and the filled seeds per moderately damaged cone. If the spruce cone maggot damaged the cone, then the calculation was based on 9.2 filled seeds per sound cone and the filled seeds per maggot-damaged cone.

Results

Nineteen species of insects were identified, representing Lepidoptera, Diptera, Coleoptera, Homoptera, and Hymenoptera (Table 1). Lepidoptera were the most prevalent (12 species). The sole non-insect species was the red squirrel, *Tamiasciurus hudsonicus* (Erxleben).

Most of the damage to female reproductive structures by insects occurred between mid-May and mid-July in both 1983 and 1984 (Table 2). Some flowers, which were open for pollination, desiccated, and accounted for 2.5 and 0.5% losses in potential cone production during 1983 and 1984, respectively. Several of these flowers were dissected and no insects or insect damage were seen. The specific cause for abortion is unknown.

Damage caused by Diptera was internal. Even though damage was assessed at the end of the growing season, initial damage began at pollination, just after the larvae hatched, about 4 June 1983, and 25 May 1984. Cones damaged by the spruce cone maggot were destroyed entirely. The spruce cone maggot damaged 2.1 and 3.8% of the cones during 1983 and 1984, respectively (Table 2), and damage occurred in all experimental trees. Damage by the spruce cone axis midge consisted of small cavities in the cone axis but the seeds were untouched. The spruce cone axis midge damaged 0.9 and 2.5% of the cones during 1983 and 1984, respectively. Damage occurred in only two of the 10 experimental trees during 1983, but in all trees during 1984 when the cone crop was heavy. The impact of the spruce seed midge, *Mayetiola carpophaga* Tripp, and the spruce seed chalcid, *Megastigmus atedius* Walker, was not measured, but these species were encountered very rarely.

Table 1. Organisms damaging black spruce cones and seeds from 1982 to 1984 at Sault Ste. Marie, Ont.

ORDER	FAMILY	
		Class Insecta
Lepidoptera	Tortricidae:	Black-headed budworm, *Acleris variana* (Fernald)
		Oblique-banded leafroller, *Choristoneura rosaceana* (Harris)
		Spruce budworm, *Choristoneura fumiferana* (Clemens)
		Spruce needleworm, *Archips packardianus* (Fernald)
		Archips alberta (McDunnough)
	Gelechiidae:	Orange spruce needleminer, *Coleotechnites piceaella* (Kearfott)
		A needleminer, *Coleotechnites atrupictella* Dietz
		A needleminer, *Coleotechnites blastovora* McLeod
	Pyralidae:	Fir coneworm, *Dioryctria abietivorella* (Grote)
		Spruce coneworm, *Dioryctria reniculelloides* Mutuura and Munroe
		Herculia thymetusalis (Walker)
	Blastobasidae:	*Holcocerina immaculella* (McDunnough)
Diptera	Anthomyiidae:	Spruce cone maggot, *Lasiomma anthracinum* (Czerny)
	Cecidomyiidae:	Spruce cone axis midge, *Dasineura rachiphaga* Tripp
		Spruce seed midge, *Mayetiola carpophaga* Tripp
Coleoptera	Anobiidae:	Deathwatch cone beetle, *Ernobius* sp.
	Trogositidae:	A cadelle, *Tenebroides* sp.
Homoptera	Aphididae:	Balsam twig aphid, *Mindarus abietinus* Koch
Hymenoptera	Torymidae:	Spruce seed chalcid, *Megastigmus atedius* Walker
		Class Mammalia
Rodentia	Sciuridae:	Red squirrel, *Tamiasciurus hudsonicus* (Erxleben)

The type of damage to the female reproductive structures by Lepidoptera appeared to be related to the reproductive structure's stage of development: buds and flowers usually were destroyed entirely; the young expanding cones were truncated, lacerated, or hollowed out; hardened scales of maturing cones were rasped. Lepidoptera damaged 61.8 and 44.4% of female reproductive structures from the time of bud formation in May to cone maturity

Table 2. Seasonal progression of damage by insects and squirrels to female reproductive structures (frs) from 10 black spruce trees during 1983 and 1984 at Sault Ste. Marie, Ont.

1983				1984			
Date	Number of sound frs	% frs damaged of potential 7870 cones	Cause of damage*	Date	Number of sound frs	% frs damaged of potential 11 402 cones	Cause of damage*
26 May	7870	2.5	A	16 May	11 402	1.4	L
4 June	7673	2.1	La	19	11 242	0.5	A
		0.9	Dr			3.4	L
		0.4	B	25	10 798	3.8	La
		5.2	L			2.5	Dr
14	6996	15.0	L			0.1	B
21	5816	21.0	L			11.7	L
29	4163	13.3	L	5 June	8733	10.3	L
7 July	3116	6.4	L	12	7560	9.1	L
		2.4	U	20	6522	6.0	L
17	2422	0.9	L	28	5838	2.5	L
2 Sept.	2351	18.8	S			2.2	U
27	875			15 July	5302	0	
				31 Aug.	5302	0	
				28 Sept.	5302		

*L = Lepidoptera; A = abortion; La = *L. anthracinum*; Dr = *D. rachiphaga*; B = broken; U = unknown; S = squirrel.

Table 3. Seasonal progression of damage by insects to female reproductive structures (frs) during 1984 from three black spruce trees sprayed with dimethoate on 10 May 1984 at Sault Ste. Marie, Ont.

Date	Sound frs	Number of frs damaged	% frs damaged of potential	Cause of damage,* 2970 cones
16 May	2970	0	0	
19	2970	15	0.5	A
25	2955	15	0.5	L
		142	4.8	La
		25	0.8	Dr
5 June	2773	38	1.3	L
12	2735	62	2.1	L
20	2673	74	2.5	L
27	2599	57	1.9	L
		18	0.6	U
15 July	2524	20	0.7	L
31 Aug.	2504	0		
28 Sept.	2504			

*L = Lepidoptera; A = abortion; La = *L. anthracinum*; Dr = *D. rachiphaga*; B = broken; U = unknown.

in mid-July during 1983 and 1984, respectively (Table 2). Larvae of Tortricidae, Pyralidae, and Blastobasidae fed on buds, flowers, and expanding cones, whereas the larvae of the Gelechiidae fed on previously damaged cones. Even though the damage could not be specifically differentiated for the species of Lepidoptera, the spruce budworm was assumed to cause the most damage, based on its numbers, and the spruce coneworm was assumed to be second in importance. The black-headed budworm, *Acleris variana* (Fernald), the oblique-banded leafroller, *Choristoneura rosaceana* (Harris), and the spruce needleworm, *Archips packardianus* (Fernald), were of minor importance individually but collectively may cause significant damage to black spruce flowers and cones.

Examination of trees other than the experimental trees revealed that larvae of *Archips alberta* (McDunnough), *Dioryctria abietivorella* (Grote), *Herculia thymetusalis* (Walker), and *Holcocerina immaculella* (McDunnough) can live in association with one another and feed on reproductive structures in black spruce trees having compact crowns. This cohabitation occurs in dense silken nests ranging in length from 10 to 70 cm within the crowns; the inner branches formed the infrastructure of the nest that contained the damaged cones and frass. One nest contained 384 damaged cones, which represented all of the current year's cone production.

The red squirrel significantly reduced cone availability in black spruce by clipping off individual cones and cone-bearing twigs. During 1983, squirrels harvested mature

Table 4. Damage by insects to female reproductive structures from non-sprayed and dimethoate-sprayed black spruce trees during 1984 at Sault Ste. Marie, Ont.

	Non-sprayed		Dimethoate-sprayed	
Number of trees	10		3	
Number of cones	1140*	(385)	990*	(419)
% of aborted flowers	0.5	(0.1)	0.5	(0.3)
% damaged by:				
L. anthracinum	3.8	(1.2)	4.7	(3.4)
D. rachiphaga	2.5	(0.9)	0.8	(0.8)
Lepidoptera	44.4	(4.7)	9.0	(4.3)†
% misc. losses	2.2	(0.6)	0.6	(0.2)†
% sound cones	46.5	(5.9)	84.3	(8.9)†

*Values given are means per tree (SE).
†Significantly different from control at $P=0.05$ as determined by the sample t-tests.

Table 5. Seed yield and quality from black spruce cones sustaining damage by Lepidoptera and Diptera during 1983 at Sault Ste. Marie, Ont.

Damage class	Number of cones*	Cone volume, mL (SE)	Seeds per cone (SE)	Filled seeds per cone (SE)	Seeds germinated (SE)	Germination capacity (SE)
Undamaged	335	1.57(0.06)[a]†	39.9(0.52)[a]	18.9(0.28)[a]	13.5(0.31)[a]	0.71(0.01)[a]
Lepidoptera						
Severe	100	—	0.0	0.0	0.0	0.0
Moderate	100	—	22.3(2.59)[c]	10.3(0.17)[b]	7.6(0.34)[b]	0.74(0.03)[a]
Light	100	—	37.5(0.63)[b]	19.7(0.41)[a]	14.8(1.28)[a]	0.75(0.03)[a]
Diptera						
L. anthracinum	30	1.01(0.04)[b]	6.5(2.43)[d]	9.7(1.32)[b]	2.4(0.97)[c]	0.25(0.07)[b]
D. rachiphaga	35	1.56(0.07)[a]	38.6(0.82)[ab]	18.7(0.41)[a]	13.2(0.57)[a]	0.72(0.03)[a]

*Cones collected 25 September 1983.
†Means within a column followed by the same letter are not significantly different at $P=0.05$ as determined by Tukey's test.

cones amounting to 18.8% of the total potential for cone production as represented by female flowers. During 1984, no squirrel depredation was observed.

Trees sprayed with dimethoate had approximately 115% of their cones damaged by insects (Tables 3 and 4). Damage by Lepidoptera to cones in sprayed trees was significantly less than in nonsprayed trees (9.0 versus 44.4%: $P=0.05$) (Table 4). The two dipterans damaged 5.5 and 6.3% of the cones (not significantly different: $P=0.05$) on the sprayed and unsprayed trees, respectively (Table 4).

The number of seeds extracted from damaged cones, the number of filled seeds, and consequently the number of seeds germinating per cone were influenced by the severity of the damage by Lepidoptera. On average, 40 seeds per cone were extracted from undamaged cones, of which 19 were filled and of these, 71% germinated (Table 5). Severely damaged cones yielded no seeds, whereas moderately damaged cones yielded an average of 22 seeds per cone of which 10 were filled and 74% germinated. Moderately damaged cones yielded significantly fewer viable seeds per cone than did the undamaged cones. The total number of seeds per lightly damaged cone differed significantly from that per undamaged cones. Lightly damaged and undamaged cones did not differ significantly in the number of filled seeds per cone and the number of seeds germinated per cone. Germination capacity of seeds from moderately damaged, lightly damaged, or undamaged cones did not differ significantly from one another. As well, moderately damaged cones yielded much more debris when shaken, and their cone scales did not open as early as undamaged cones.

The feeding of one spruce cone axis midge larva in a cone had no significant effect on cone growth, the number of seeds per cone, the number of viable seeds per cone, or their germination capacity (Table 5). In contrast, the feeding of the spruce cone maggot significantly decreased all of these characters (Table 5). Damage by the spruce cone maggot did not allow normal spreading of the cone scales and most of the seeds had to be extracted using forceps. As well, the maggot-damaged cones were brittle and much debris was obtained when they were shaken.

Reduced seed production is closely related to the destruction of the female reproductive structures (Table 6). The destruction of buds, the flower abortion, resulted in the complete loss of potential viable seeds. Cones damaged by the spruce cone maggot resulted in a loss of about half the seeds, but no seeds were lost from cones damaged by the spruce cone axis midge. Severe damage to cones by Lepidoptera resulted in complete loss of seeds, whereas about half the seeds and no seeds were lost from cones moderately and lightly damaged, respectively. The type of damage observed on cones from trees sprayed with dimethoate was the same as those from unsprayed trees; however the severity of the damage was less (Table 6).

Table 6. Seed production related to types and causes of damage to female reproductive structures (frs) from 10 unsprayed (us) black spruce trees during 1983 and 1984 and from three trees sprayed with dimethoate (d) during 1984 at Sault Ste. Marie, Ont.

	1983			1984				
Potential cones (seeds)*	7 870 (148 743) 1983			11 402 (215 498) 1984 (us)			2 970 (56 133) 1984 (d)	
	No. of frs damaged	Cause of damage†	No. of seeds lost*	No. of frs damaged us	No. of frs damaged d	Cause of damage†	No. of seeds lost* us	No. of seeds lost* d
Mining of cone buds	0	—	—	547	0	L	10 338	0
Flower desiccation	197	A	3 723	57	15	A	1 077	284
Mining of scales and seeds	165	La	1 568‡	432	142	La	3 974‡	1 306‡
Mining of cone axis	71	Dr	0	289	25	Dr	0	0
Laceration and mining of cones								
Severe	3 274	L	61 879	2 727	198	L	51 540	3 742
Moderate	1 208	L	22 831§	1 383	53	L	11 894§	456§
Light	383	L	0	402	15	L	0	0
Cone disappearance	221	U,B	4 177	263	18	U,B	4 971	340
Clipped clones	1 476	S	27 896	—	—	—	—	—
Sound cones (seeds)*	875 (16 538) 1983			5 302 (100 208) 1984 (us)			2 504 (47 326) 1984 (d)	

*Based on 18.9 filled seeds per cone.
†L = Lepidoptera; A = abortion; La = *L. anthracinum*; Dr = *D. rachiphaga*; B = broken; U = unknown; S = squirrel.
‡Based on 9.2 filled seeds per cone.
§Based on 8.6 filled seeds per cone.

Discussion

Lepidoptera, especially the spruce budworm and the spruce coneworm, caused the greatest amount of damage to flowers and cones of black spruce in this study, as similarly reported by Schooley (1980) and Syme (1981). The spruce budworm was usually the most numerous insect and it caused the most damage to the cones. In Maine, populations of the spruce coneworm sometimes exceeded those of the spruce budworm and caused more damage to foliage (Spies and Dimond 1985), which suggests that in certain years the spruce coneworm may cause the most damage to black spruce cones. Moreover, McLeod and Daviault (1963) reported that populations of spruce coneworm wax and wane with good and poor cone years. In seed orchards, where cone production is encouraged, the potential damage to cones by the spruce coneworm appears to be great.

Even though cones damaged by Lepidoptera still contain viable seeds, extraction of seeds from moderately damaged cones is difficult because the cone scales do not open normally. Because of this and the excess debris produced by the damaged cones during normal seed extraction procedures, commercial collection of these cones is avoided. In general, the same can be said for lightly damaged cones, although the problems of scale opening and debris are not as severe.

The spruce cone maggot attacked the cones in all experimental trees during both years, but the number of cones attacked was small. The maggots had tunneled spirally around the rachi of the cones eating through the bases of the scales and destroying the seeds as observed by Tripp (1954). Even though only half of the seed complement in a cone is destroyed by the maggot, the entire cone can be considered destroyed because the remaining viable seeds cannot be extracted by normal procedures. The potential for damage in seed orchards by this species is considerable as it overwinters as a pupa in the duff (Tripp 1954) and is not removed from the site with the collected cones.

The variable distribution of the spruce cone axis midge among the experimental trees in 1983 and 1984 suggests that the abundance of the insect is directly related to the abundance of cones. In seed orchards, where cone crops are encouraged, populations of the spruce cone axis midge may build up if cone crops are not harvested yearly. When more than one larva feeds in the cone axis, damage may be severe enough to interfere with nutrient flow to the developing seeds, and thus affect seed viability as suggested by Tripp (1955). However, 80% of the 4000 infested cones dissected from 1982 to 1984 had only one larva per cone (unpublished data) which suggests that the impact of the spruce cone axis midge on seed production in black spruce is not important. This is probably why Haig and McPhee (1969) did not observe a significant difference in yield of viable seeds per cone when cones infested with spruce cone axis midge were sprayed with insecticide.

Abortion of flowers from unknown causes slightly decreased the production of cones. Feeding on the flowers by the balsam twig aphid or some other species of insect might have caused some of the cones to abort. DeBarr and Ebel (1974) and DeBarr and Kormanik (1975) reported that the seedbug, *Leptoglossus corculus* (Say), caused conelets of shortleaf pine, *Pinus echinata* Mill., and loblolly pine, *P. taeda* L., to abort. Abortions of black spruce flowers also may be attributed to frost (unpublished data).

The complex of *A. alberta, D. abietivorella, H. thymetusalis*, and *H. immaculella* should be considered as a threat to cone production in seed orchards, because complete destruction of cone crops occurs in trees attacked by these insects. Wong *et al.* (1959) reported that the first three insects fed on some black spruce cones. This insect complex appeared to be present only in dense tree crowns, as reported also by Wong *et al.* (1959). In seed orchards the apical leaders are pruned to facilitate cone collecting. This pruning results in denser tree crowns that offer a preferred site for development of these Lepidoptera.

Similar to Schooley (1983), we found that the deathwatch cone beetle bored into the cone tissue destroying it and the seeds; the cadelle fed only on the seeds. Therefore a recommendation to avoid cone damage by these Coleoptera would be that cones collected for seed extraction should be processed as soon as possible or placed in cold storage.

Treatment with dimethoate prevented damage to black spruce cones caused by Lepidoptera without increasing abortions, but had no effect on damage by the spruce cone maggot or the spruce cone axis midge. This contrasts with the findings of Haig and McPhee (1969), Hedlin (1973), and Miller and Hutcheson (1981) who applied dimethoate to trees during or after pollination. The ineffectiveness of dimethoate in our study can be explained by the relatively short persistence period [1–3 weeks (Cyanamid 1979)] of dimethoate. As well, dimethoate is a systemic pesticide and was probably translocated throughout the tree. Because spraying took place about 2 weeks before pollination (the time of oviposition by the flies), the amount of dimethoate remaining was probably insufficient to kill the maggots but was sufficient to kill the Lepidoptera.

During 1983, a poor year for cone production for most species of conifers in northeastern North America, black spruce cones were taken readily by red squirrels but cones were not taken in 1984, a good year for cone production. In 1984, squirrels were observed harvesting white spruce, *Picea glauca* (Moench) Voss, and white pine, *Pinus strobus* L., cones, suggesting that black spruce cones were less preferred. A preference for white spruce cones over those of black spruce by squirrels was suggested by Brink and Dean (1966). Squirrels also affect crown architecture after several years of damage with the crown becoming denser in some cases, or with branch-free openings in other cases. This could influence air turbulence near the flowers and hence affect pollination and fertilization of the ovules (Niklas 1984).

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