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ENGELMANN SPRUCE CONE LOSSES CAUSED BY INSECTS IN NORTHERN UTAH IN A YEAR OF LOW CONE PRODUCTION

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ABSTRACT.—The impacts and timing of insect infestation were determined in developing Engelmann spruce cones throughout the summer of a year of low cone production in northern Utah. The major insects found were the western spruce budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae); fir coneworm, *Dioryctria abietivorella* Grote (Lepidoptera: Pyralidae); and the spruce seed moth, *Laseyresia youngana* Kearfott (Lepidoptera: Olethreutidae). Insects reduced the survival of cones to 11.48 cones out of 100. The high percentage of seeds and cones lost to insect predation supported previous studies of a similar nature.

Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) is a widely distributed species of the western United States and Canada. It is a major component of Rocky Mountain high-elevation forests (Fowells 1965). Engelmann spruce seed and cones are subject to various insect predators, but much of the previous research on the seed and cone insects of spruce has been done on other spruce species such as white spruce (*Picea glauca* (Moench) Voss) in Canada. Additional research information is needed on the impacts of seed and cone insects on Engelmann spruce in Intermountain subalpine spruce/fir forests.

Insects are often major biotic agents, reducing seed survival in developing cones of conifers and, at times, destroying an entire seed crop. The amount of damage an insect species causes to a seed crop depends on the relative abundance of the insect population, the timing of the damage with respect to cone phenology, and the size of the cone crop. It has been suggested that cone crop periodicity is an adaptive mechanism reducing the impact of cone predators (Mattson 1971, Miller et al. 1984). This study examined the impact and timing of several seed and cone insects observed on Engelmann spruce in northern Utah during a year of low cone production.

Materials and Methods

This study was conducted on the Utah State University Experimental Forest located on the Wasatch-Cache National Forest, approximately 15 km south of the Utah-Idaho border in Rich and Cache counties. The elevation ranged from 2,500 m to 2,700 m. The general moisture regime is semiarid, with most precipitation occurring as snow.

The predominant tree species are Engelmann spruce and subalpine fir (*Abies lasiocarpa* var. *lasiocarpa* [Hook.] Nutt.), which are late successional, climax species, and lodgepole pine (*Pinus contorta* var. *latifolia* Dougl. ex Loud.) and quaking aspen (*Populus tremuloides* Michx.), which form early successional stands. Open meadows are intermingled among the forested areas. Detailed ecological descriptions of the area are presented in Schimpf et al. (1980).

Sample trees were selected and tagged for periodic cone collections conducted throughout the growing season. Ten Engelmann spruce trees were chosen throughout the USU Experimental Forest on the basis of potential cone crop, climbing safety, and ease of access.

Ten cones per tree were collected every four weeks, beginning in late June and continuing until late September in 1986. In 1985 only one collection was made in late September. Each tree was climbed and branches were clipped until a sufficient sample size of cones was obtained. Two cones were randomly collected from each of five branches uniformly distributed in the upper third of the crown. Branches with cones, as well as any loose cones, were bagged, marked, and refrigerated until the cones were analyzed. The last

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TABLE 1. Percentage cone losses to frost and insects in 1985.

Mortality agent	Cones lost to agent %
Frost	72.18
Spruce seed moth	15.23
Western spruce budworm	3.97
Unidentified insects	6.40
Aborted	0.22
Unknown	1.99
Total	99.99

cone collection was obtained from fewer trees because some sample trees no longer had an adequate number of cones.

Half of the cones from each sample tree were dissected while the other half were placed into insect-rearing containers at room temperature. The percent of external cone damage and cone size were recorded; then the cones were cut longitudinally with a cone cutter. An ocular estimate of percentage of internal damage was made and recorded for each cone. Categories for coding percentage of damage were zero (0%), light (1–25%), low (26–50%), moderate (51–75%), and heavy (76–100%). The nature of the damage observed and the number and characteristics of any insects were recorded.

Rearing containers were constructed using three-gallon ice cream cartons with glass vials attached to the lids. Cones for each tree were placed in rearing containers, checked daily for emerging insects over the next three months, and then placed in a freezer at 0 C. The cold treatment simulated winter conditions and was designed to break diapause of any overwintering insects. After three months cones were removed from the freezer and returned to room temperature. Rearing containers were again checked for emerging insects. Adult insects obtained from rearing containers were frozen until proper identification could be made. Adult insects were keyed to species in the laboratory.

RESULTS AND DISCUSSION

In 1985 frost damage was responsible for 72% of the cone mortality (Table 1). Over half of the cones escaping the frost were infested with the spruce seed moth, *Laspeyresia youngana* (Kearfott) (Lepidoptera: Olethreutidae). Other mortality was attributed to external feeding by the western spruce budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae), unidentified insects, and cone abortion.

TABLE 2. Percentage of Engelmann spruce cones damaged by insects in 1986.

Collection date	Mortality factors	Percent dying
24 June	WSB	28.18
	Fir coneworm	12.08
	Cone abortions	2.68
	Unidentified insects	3.35
22 July	WSB	16.66
	Fir coneworm	19.56
	Spruce seed moth	15.21
	Cone axis midge	1.44
	Cone abortions	1.44
	Unidentified insects	5.07
21 August	WSB	14.85
	Fir coneworm	8.91
	Spruce seed moth	39.60
	Cone axis midge	3.96
	Unidentified insects	4.95
23 September	WSB	9.09
	Fir coneworm	6.81
	Spruce seed moth	54.54
	Cone axis midge	6.81
	Cone abortions	2.27
	Unidentified insects	9.09

In 1986 a greater diversity of mortality agents in the Engelmann spruce cones was observed (Table 2). At the time of the first collection, external feeding by western spruce budworm (WSB) was the major factor affecting cones. Other insects causing damage at other collection times included the fir coneworm, *Dioryctria abietivorella* (Grote) (Lepidoptera: Pyralidae), the spruce seed moth, and a spruce cone axis midge, *Dasineura rachiphaga* Tripp (Diptera: Cecidomyiidae) (Table 2).

WSB fed externally on the cones, impacting cone development early in the season. Rarely was WSB found to impact the developing seeds unless external feeding was extensive. In other studies extensive WSB outbreaks were found to impact foliage and many of the female buds and developing conelets (Dewey 1970, Frank and Jenkins 1987).

The spruce seed moth and fir coneworm are obligate seed and cone insects that feed internally on cones. The spruce seed moth was first described by Tripp (1954) and was previously considered to be a seedworm since larvae feed

TABLE 3. Ocular estimates of internal and external damage caused by insects to Engelmann spruce cones in 1986.

Collection	Zero (0%)	Light (1–25%)	Low (26–50%)	Moderate (51–75%)	Heavy (76–100%)
1	51.0[1]	36.2	10.7	1.3	0.6
	81.9	11.4	2.0	0.6	4.0
2	54.3	33.3	7.2	4.3	0.7
	26.1	63.7	8.7	1.4	0.0
3	64.3	21.7	12.8	0.9	0.0
	6.9	36.6	17.8	15.8	22.8
4	63.6	31.8	4.5	0.0	0.0
	4.5	15.9	36.4	34.1	9.1

[1]Top row values in each collection indicate external damage, while lower row values indicate internal damage.

almost entirely on seeds. The moth's life cycle is closely synchronized to the host phenology (Hedlin et al. 1980). Usually only one or two larvae inhabit a cone, but in this study more larvae per cone were occasionally found. When several larvae occupy the cone axis, they will separate themselves by packing frass between individuals (Hedlin 1974). Tripp and Hedlin (1956) noted that the number of larvae per cone depends on the number of cones available for attack, with more larvae persisting in a cone when fewer cones are present.

Early descriptions of fir coneworm are variable because *D. abietivorella* was often recorded as *D. abietella* (Denis & Schiffermuller), a similar coneworm species (Hedlin et al. 1980). This fir coneworm causes greater damage as its larvae tunnel indiscriminately through the cone scales and seeds. This coneworm species has been noted as a destructive insect in spruce, fir, and Douglas-fir (*Pseudotsuga*) cones (Keen 1958, Hedlin 1974, Hedlin et al. 1980).

Evidence of the spruce cone axis midge was apparent in the later cone collections. Positive identification of this species was made from adults obtained from rearing containers after the cold treatment. In a heavily infested cone, 15 to 20 larvae may converge in the cone axis, but, overall, little damage to the seeds occurs (Hedlin 1974, Hedlin et al. 1980). This study found similar results with less than 15% of the examined cones impacted by the spruce cone axis midge.

Variation in life cycles and feeding habits of a species is evident in the percentage of seed lost to the different species at each collection (Table 3). In the first collection (late June), only WSB and fir coneworm were evident. The early larval stages of fir coneworm feed on seeds at this time, while the spruce seed moth is just beginning to hatch from eggs. The spruce seed moth continues to destroy large percentages of seeds, feeding through early September until it overwinters. The fir coneworm, although found less frequently in the later collections, remains active throughout the growing season. The decline in the frequency of fir coneworm observed may be because some larvae exit cones to pupate on the ground in the late summer. The spruce cone axis midge, found in the later collections, was evident at that time because it moves into the axis to overwinter in late July. However, it impacts the cones earlier in the season as larvae feed on the ovuliferous scales.

To illustrate the impact of the species observed and relate them to cone phenology, we constructed a simple life table (Table 4). Starting with 100 cones, the life table shows the timing and relative impact of the insect species observed in this study. The life table illustrates that given 100 cones, only 11.48 escaped insect predation under the conditions observed in 1986.

Because only one collection was made in 1985, it is difficult to compare results of the two years. A frost on 23 June killed 72% of the Engelmann spruce cone crop in 1985. Of the cones surviving the frost 15% were infested with the spruce seed moth, 4% were damaged by WSB, and 6% were damaged by other insects. Nearly 100% of the cones collected were damaged by frost or insects (Table 1). These findings support other studies which report that variation in cone crop size greatly influences insect populations (Mattson 1971). Other studies have compared the percentage of cones lost to insects in years of different cone production levels (Hedlin 1964, Mattson 1971, Jenkins 1984). Typically, more cones are damaged in years of low cone production,

TABLE 4. Partial life table of mortality factors affecting cones of Engelmann spruce in 1986.

x Developmental stage	L_x x cones surviving	D_xF Mortality factors	D_x Number dying within x	100 q_x D_x as a percent of L_x	S_x Survival rate within x
Conelet I	100	WSB	19.44	19.44	
		Fir coneworm	15.44	15.44	
		Cone abortions	1.62	1.62	
		Other insects	3.35	3.35	
			39.85	39.85	.6015
Conelet II	60.15	Fir coneworm	11.76	19.56	
		Spruce seed moth	9.15	15.22	
		Cone axis midge	1.27	2.12	
		Other insects	3.05	5.07	
			25.23	41.97	.5805
Conelet III	34.92	Fir coneworm	3.11	8.91	
		Spruce seed moth	15.65	44.83	
		Other insects	1.73	4.95	
			20.49	58.69	.4132
Conelet IV	14.43	Fir coneworm	0.98	6.82	
		Other insects	1.97	13.64	
			2.95	20.46	.7955
Normal cones	11.48				

while in years of high cone production insects are satiated and excess cones escape predation. The periodic nature of cone crops has been suggested as an adaptive strategy evolved by trees to avoid seed and cone predation (Janzen 1969).

Other studies have reported such interactions between cone crop sizes and insect populations (Mattson 1971, Jenkins 1984, Miller et al. 1984). The fact that studies found more seeds escaping predation in years of high seed production has been offered as strong support for the adaptive mechanism of periodic mast crops in trees to avoid seed and cone predation.

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