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Insects and Other Factors Affecting Noble Fir Seed Production at Two Sites in Oregon[1]

Abstract

Twenty cones from eight noble fir (*Abies procera*) were dissected in 1977 (a low cone year) at two sites in Oregon and found to average 773 seeds per cone (range 559 to 964); 63 percent of the seeds were unfilled, 36 percent infested by insects, and 1 percent were sound. Nine species of insects were associated with seed damage. Two species of lonchaeid flies and a seed chalcid were associated with 94 percent of the damage. Slight damage was noted from four species of Lepidoptera. Two midge species were common in cones, but their contribution to damage could not be established. Some of the insects could survive on unfilled seed, suggesting that the number of empty seeds could have been underestimated.

Introduction

Noble fir (*Abies procera* Rehd.) grows extensively at high elevations along the Oregon and Washington Cascade Range and in fragmented populations in the middle portions of the Coast Ranges. In the Cascades, it extends south from Stevens Pass in Washington to the McKenzie River in Oregon. Farther south, it merges with the ecologically and taxonomically similar California red fir (*A. magnifica* A. Murr.) (Franklin,1964). The tree is prized in commerce because of good form and growth rate (Herman *et al.*, 1978) and its preferred status in the Christmas tree market. It is also resistant to the balsam woolly adelgid (*Adelges piceae* (Ratzeburg)), a serious, introduced pest of subalpine fir (*A. lasiocarpa* (Hook.) Nutt.) and Pacific silver fir (*A. amabilis* (Dougl.) Forbes) in the same elevation zone (Mitchell, 1966). These desirable characteristics, coupled with recent, accelerated cutting at high elevations, have dramatically increased the demand for noble fir seed. This demand has focused attention

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on how little is known about the reproductive biology of noble fir and factors affecting it.

This paper documents a study of noble fir seed production in 1977 at two places in Oregon. Objectives were to estimate seed potential and to identify the factors preventing achievement of full potential. Insect damage, its distribution and appearance, was emphasized because this is one factor affecting seed survival that can be regulated.

Methods and Procedures

Most of the investigation was conducted in the Cascade Range, at a site about 30 km east of Molalla, Oregon. Elevation of the study site was 1100 m, and the stand in the area was dominated by 40-year-old noble fir, 6-20 m tall. Another site for corroborative biological observations was established in the Coast Range at 1100 m, near the top of Mary's Peak. This site was about 15 km west of Corvallis, and the stand there was essentially pure, old-growth noble fir, 10-30 m tall.

For regular study, 18 trees with two or more cones per tree were selected at the Cascade site, five trees with five or more cones per tree at Mary's Peak. The study trees were widely dispersed at both localities because 1977 was a poor cone year throughout the region, and candidate trees were hard to find. Beginning 9 June, trees at both sites were climbed every five to seven days. Cone and insect development were observed, and cones were collected for dissection and rearing in the laboratory. Additionally, four to seven cones were bagged weekly (nylon laundry bags with 90 holes/cm^2) at the Cascade site to determine attack periods for insects pests. Insects reared from the collections were identified by specialists at the Systematic Entomology Laboratory, ARS, Beltsville, Maryland.

Another sample of 20 cones from eight randomly selected trees (collected 29 August) at the Cascade site was used to determine (1) seed potential, (2) number of seeds per cone site, (3) variance in cone size, (4) distribution of insects within cones, and (5) effects of insects and unfilled seed on seed production. Six of the sample trees had three cones per tree; two trees had one cone each. All cones came from the top whorl of the trees.

Collected cones were weighed (fresh weight), measured for length, and cut into thirds. Every seed was examined and classified as apparently undamaged or damaged by cone moths or cone maggots. Seeds that appeared undamaged were X-rayed according to standard procedures (Simak, 1970) to determine the number filled, unfilled, or infested with chalcid wasps. Seeds infested with chalcids were subsequently placed in rearing to determine the wasp's emergence pattern and the number that would remain in the seed for extended diapause.

A nested analysis of variance was used to compare the relative contributions of within- and among- tree variation—the response variables per cone being number of seeds, length, and weight. Numbers of insects in cone thirds were compared by one-way analysis of variance. Relationships between the dependent variables (length and weight of cones) were investigated by a linear regression analysis. The established level of statistical significance for all tests was $P < 0.01$.

Results

The number of seeds per cone averaged 733 ($SD = 103$) and ranged from 559 to 964.

The mean weight for green, mature cones was 314 g (SD = 79 g); mean length was 15.8 cm (SD = 1.7 cm). The between-tree variation of weight and length was significantly greater than within-tree variation. A weighted (number of cones per tree) regression ($Y = 454.7 + .90X$) to predict mean seed production per cone per tree from the mean weight of the collected cones proved significant and accounted for 62 percent of the variation in number of seeds per cone. The additional contribution of cone length to this relationship was not significant.

Only 0.7 percent of the 14,650 seeds examined proved sound, 63.3 percent were unfilled and presumably unpollinated, and 36 percent were damaged by insects. The nine species of insects found to be related to seed damage were:

1. *Megastigmus pinus* Parfitt (Hymenoptera:Torymidae)
2. *Earomyia barbara* McAlpine (Diptera:Lonchaeidae)
3. *E. longistylata* McAlpine (Diptera:Lonchaeidae)
4. *Eucosma* sp. (prob. *siskiyouana* (Kearfott)) (Lepidoptera:Olethreutidae)
5. *Laspeyresia* sp. (prob. *bracteatana* (Fernald)) (Lepidoptera:Olethreutidae)
6. *Dioryctria* sp. (prob. *abietivorella* (Grote)) (Lepidoptera:Pyralidae)
7. Unknown looper (prob. in genus *Eupithecia*) (Lepidoptera:Geometridae)
8. *Dasineura* sp. (Diptera:Cecidomyiidae)
9. Unknown resin midge (prob. genus *Resseliella*) (Diptera:Cecidomyiidae)

The first three species were associated with about 94 percent of the insect damage. The impact of gall midges (family Cecidomyiidae) was confounded by associated insects and not evaluated, although 100 percent of the cones and 7 percent of the seed were associated with this species. Cone moths (Lepidoptera) did not prove important in the total impact, but some samples showed damage approaching 100 percent. Accordingly, in another year or other places, cone moths could prove to be significant pests of noble fir seed. The western conifer seed bug (*Leptoglossus occidentalis* Heidemann) was not observed associated with noble fir cones, though it was a common associate with other tree species at lower elevations.

Counts of insect populations in cone thirds showed that the damaging insects were equally distributed throughout the cones (Table 1). Chalcid populations per cone were positively correlated with both cone length and weight. Lepidoptera and Diptera populations per cone were not correlated with cone length and weight.

TABLE 1. Percent of insect infested seed in noble fir by cone thirds.

Insect species	Cone third infested: Top	Middle	Bottom
Megastigmus pinus	17.7	25.7	20.4
Earomyia spp.	11.9	10.4	14.2
Cone moths	7.3	5.0	7.4
Total	32.6	37.0	36.6

Observations showed that insect species are usually identifiable by characteristics of damage, life history features, and appearance and location of immature forms—information useful in developing sampling schemes and control strategies.

Megastigmus pinus (Seed Chalcid)

Females began ovipositing into seeds near the end of pollen flight, just after the cone bracts completely turned down. The peak period of activity was 24 June to 14 July, with some eggs laid as late as 4 August. Eggs were inserted directly into the seeds through the insect's long ovipositer, which always pierced the cone surface at the lower margin of the bract. Only one larva was observed to develop per seed, but histological evidence suggested that more than one egg was occasionally deposited into a single seed.

The wasp has one generation per year, and the larvae overwinter in the seeds on the forest floor (Hedlin, 1974). Laboratory rearing of infested seeds (cold-treated at 1.5° C for 90 days to break hibernation) suggested that males precede females by about one week during spring emergence. The total emergence period in the laboratory was 25 days, and the sex ratio was 1.2 males per female. Some 40 percent of the infested seeds contained living larvae but did not produce adults. Presumably these insects were in the state of extended diapause and adults would emerge in subsequent years. This is a normal pattern for this species (Hedlin *et al.*, 1980).

Seeds infested by the seed chalcid could not be distinguished from sound seed without dissection or X-ray analysis.

Earomyia barbara and E. longistylata (Cone Maggots)

The two species of fir cone maggots could not be distinguished in terms of larval taxonomy or damage. The larval stages are white, legless maggots, and 8-10 mm long when full-grown; they mine throughout the cone. Feeding by both species leaves darkened empty seed coats with round, frass-free holes, a type of damage unlike that caused by any other associated species.

Both species apparently had one year life cycles, although Keen (1958) reported that extended diapause exists within this genus. The adults began ovipositing in early June, just as the start of pollen flight, and continued until the cone bracts turned down near the end of June. Eggs were deposited between cone bracts, deep within the developing cones. The larvae mined in the cones throughout the summer, burrowing from scale to scale, feeding on seeds. Cone maggots were also observed to be predaceous on other insects encountered in the cones, especially on seed chalcids and gall midge larvae. In early September, before the cones shattered, the larvae left the cones and fell to the forest floor, where they overwinter as pupae (Hedin *et al.*, 1980).

Eucosma sp. (Cone Moth)

Damage caused by the fir cone moth occurred at both study sites but was most frequent at Mary's Peak. The larva is whitish, hairless, 10-15 mm long, and has a dark brown head capsule. The pupa, which is also found in cones, is dark brown and 6-9 mm long. The larval mines are lined with pitch and silk. It was the only cone moth that pushed frass outside the cone.

The moth had one generation per year. Oviposition was not observed but occurred before the first cones were bagged on 9 June, well before pollination. Larval mining and pupation occurred throughout the cone, and the pupae fell to the ground when the cones shattered in October. Because cold treatment of pupae was needed to obtain adults, it appears likely that the insect overwinters in the pupal stage.

Laspeyresia sp. (Seed Moth)

Damage levels by this species were quite variable at the two study sites. Cones could have up to five larvae without significant damage, while all seeds were destroyed in a cone with 35 larvae. Between those extremes, damage was proportional to the number of larvae in a cone. Mature larvae are white to pink, hairless, 8-12 mm long, and have dark brown head capsules. The larvae consumed all the contents of attacked seed, entering and leaving through small holes bored in the seed near the micropylar end. This left a seed coat filled with fine frass, a characteristic unique to *Laspeyresia* and identifiable on X-ray photographs.

Bagging studies showed that eggs were laid before 9 June, and larvae were found in the cones until seed dispersal in the fall. Specific overwintering habits are unknown; but when reared, the insects passed a three month cold storage period as larvae in cocoons.

Dioryctria sp. (Cone Worm)

This insect was found at both study sites and caused general damage to seeds, scales, and bracts. It was uncommon to find more than two larvae in a cone, although one cone had six larvae which completely destroyed all seeds in the cone. Mature larvae were about 20 mm long, hairless, dark pink to green, with dark brown head capsules. Infested cones were filled with coarse reddish to brownish frass.

Oviposition was not observed in the field, but bagging studies and the literature (Keen, 1958) suggest that eggs are laid on conelet bracts in early spring, during the initial stages of cone elongation. Mature larvae left the cones before the cones shattered and apparently pupated on the forest floor. Some adults emerged from rearing without cold treatment, which supports Keen's (1958) suggestion of a partial second generation.

Eupithecia sp. (Cone Looper)

Only two specimens of this looper were found, both at Mary's Peak. The larvae were typically geometrid in shape, light green, and about 20 mm long when full-grown. Damage was similar to that caused by *Dioryctria*; that is, seeds, scales, and bracts were consumed and much coarse frass was produced.

Details of the life cycle are unknown. The larvae pupated inside the cone and apparently dropped to the forest floor when the cones shattered.

Dasineura sp. (Seed Midge)

Feeding by these midge larvae produced a gall on the scale adjacent to the seed, each gall containing one to seven tiny (1- to 3-mm) pink to orange larvae. About 7 percent of the seeds in the study were infested with this midge. Since the insect was rarely associated directly with seed, the damage caused is unknown. Franklin (1974) reports that germinability of galled *Abies* seed is not reduced, but there could be other effects. For example, it was noted in his study that galls in the upper third of noble fir cones (where the seeds are small) often replaced the seeds altogether. Galls also fused the seed to the scale, thus reducing both a seed's capacity to disperse and the efficiency of extraction machinery at seed processing centers.

Gall midge adults oviposit in early June, when the cone bracts are open to receive pollen. Larvae colonize a scale and remain there until the cone shatters in the fall. Winter is spent on the forest floor, probably in the larval stage (Hedlin, 1967).

Cone Resin Midge

This insect was encountered frequently during the study. In the feeding stage it was similar to *Dasineura*, but appeared in clusters of 3 to 20 larvae in a resinous patch between the scale and seed wing. A necrotic spot of tissue developed at the feeding location, but it appeared that damage to seed (if any) was insignificant. The life cycle is unknown but is probably similar to *Dasineura*.

Discussion and Conclusions

The mean seed potential of 733 seeds per noble fir cone found in this study is significantly larger than the 500 seeds per cone reported by Franklin (1974). It must be noted, though, that the data from this study came from 40-year-old trees, which usually have larger cones than old-growth trees.

This study, like other investigations with *Abies* (Franklin, 1974; Keen, 1958) showed that filled seed was rare (0.7 percent) and that the number of unfilled seed was large (63.3 percent). We suspect this partly reflects the poor cone year throughout the region in 1977. Franklin and Ritchie (1970) noted that male strobli are often scarce in poor cone years and suggested that a shortage of pollen in those years could result in a significant number of empty seeds.

An even greater number of unfilled seeds could have been obscured by the 36 percent seed loss we attributed to insect damage. The seed chalcid (*M. pinus*) has been observed to develop in empty seeds as well as in filled seeds.[2] We think that some of the other insects found in noble fir cones, notably *Eucosma* and *Dioryctria*, may feed on empty seeds. Thus, an insect control program might not result in a significant increase in sound seeds, even when insects are abundant, especially in years with poor to medium cone crops.

This study is important because data on and factors affecting noble fir seed potential are scarce. Additional information is needed on temporal and geographic variation. To aid in forecasting seed production, foresters need to know whether lack of pollen is a regular problem or if it occurs only in poor cone years; forecasters also need to know whether insects are feeding on comparable proportions of filled and empty seeds. Some biological measure is needed to establish when insect control will yield practical results and when it will not.

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