DAMAGE BY TWO DOUGLAS-FIR CONE AND SEED INSECTS: CORRELATION WITH CONE CROP SIZE

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ABSTRACT

Damage by the Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott), in year N was significantly related to the size of the cone crop the preceding year (N-1) in the interior of British Columbia but not at the coast. Damage by the Douglas-fir cone gall midge, *Contarinia oregonensis* Foote, at the coast was also significantly related to cone crop size the preceding year. Fluctuations in cone crop size appear to limit populations of these cone insects.

RESUME

L'ampleur des dommages causés par le perce-cône du Douglas *(Barbara colfaxiana* [Kearfott]) au cours de l'année N est étroitement liée à l'importance de la récolte de cones de l'année précédente (N-1) en Colombie-Brittanique, exception faite de la région côtiere. Il en va de même pour les dommages causés par la cécidomyie des cones du Douglas *(Contarinia oregonensis* Foote) sur la côte. Il semble y avoir un rapport entre l'importance de la récolte de cônes et les populations de ces insectes.

INTRODUCTION

Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott) (Lepidoptera: Olethreutidae), and Douglas-fir cone gall midge, *Contarinia oregonensis* Foote (Diptera: Cecidomyiidae), are the two most frequent and damaging seed pests of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in British Columbia. Douglas-fir cone moth occurs most commonly in dry interior areas whereas Douglas-fir gall midge is most common in wet coastal areas (Hedlin *et al.* 1980).

Both insect species are univoltine although individuals may diapause for more than one winter (prolonged diapause) (Hedlin 1960, 1961). Adults of each species emerge and oviposit when seed cones are open to receive pollen, in April and early May. Feeding by cone moth larvae begins in May and is completed by mid July at which time pupation takes place. The cone moth overwinters as a pharate adult (Sahota *et al.* 1982) in the cones. Larval feeding by cone gall midge, which causes gall formation on cone scales, occurs from May to September. When the matured and dried cones are wetted by rain in September the fully-developed larvae leave them to overwinter in the duff. Damage by cone moth is the result of direct consumption of seeds (Hedlin 1960) while gall formation by cone gall midge inhibits ovule development and impairs seed extractability (Johnson and Heikkenen 1958).

Cone and seed production by Douglas-fir varies widely over a period of years. For example, in the Vancouver Forest Region between 1935 and 1974, three heavy crops, five medium crops, 10 lights crops, nine very light crops, and 12 crop failures occurred (Dobbs *et al.* 1976). Variations in cone and seed abundance affect both populations of and damage by cone and seed insects attacking pines, *Pinus* spp., and Norway spruce, *Picea abies* (L.) Karst. (Mattson 1971, 1980; Forcella 1978, 1980; Annila 1981), but relationships between cone crop size and damage by Douglas-fir cone moth and cone gall midge have not been reported. The objective of this study was to determine whether or not damage by these insect species was related to cone abundance.

MATERIALS AND METHODS

Cones were collected in August or September in the interior near Keremeos, B.C., between 1959 and 1982 and at the coast near Lake Cowichan, B.C., between 1957 and 1982. No cone collections were made in 1971 and 1972 at the coast or in 1972 and 1976 in the interior. The number of cones collected each year depended on the size of the cone crop and ranged from 20 to 1080. The number of sample trees ranged from 3 to 40. The cones were sliced longitudinally along their axes (Winjum and Johnson 1960) and the numbers of filled and damaged seeds per axial slice were determined.

Cone crops were rated at the time of collection as nil, very light, light, moderate or heavy; the criteria for each rating were similar to those of Dobbs *et al.* (1976). The numbers of damaged seeds per axial slice were grouped according to crop rating in the year of cone collection (N) and in the previous year (N-1), then submitted to analysis of variance and Duncan's New Multiple Range Test. Damage counts were also grouped by years since previous heavy or moderate crops and analyzed. Damage counts were transformed by log $(x + 1)$ prior to analysis to correct for heterogeneity of variance (Sokal and Rohlf 1969). Damage by cone gall midge near Keremeos was not analyzed because of the low incidence of damage.

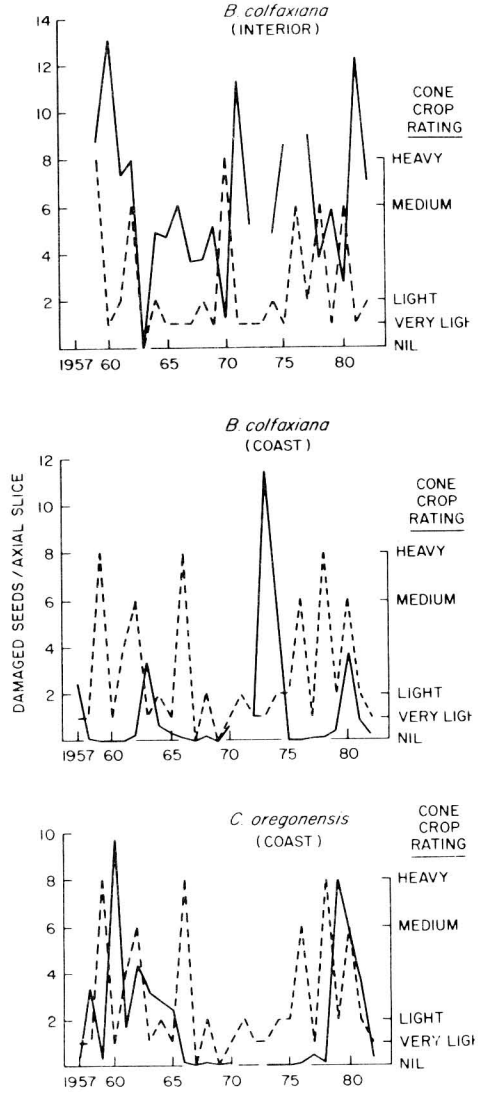

Fig. 1. Cone crop rating (dashed line) and damage (solid line) by *B. colfaxiana* and *C. oregonensis* near Keremeos (interior) and Lake Cowichan (coast) from 1958 to 1982.

RESULTS AND DISCUSSION

Damage by Douglas-fir cone moth and Douglas-fir cone gall midge fluctuated widely from year to year at both locations (Fig. 1). Average number (± S.E.) of damaged seeds per axial slice associated with heavy, medium, light and very light cone crops were 3.59 (± 2.57), 3.86 (± 2.17), 5.75 (±0.80), and 7.90 (±1.02) respectively for Douglas-fir cone moth near Keremeos; 0.13 (±0.06), 2.00 (±1.68), 1.21 (±0.84), and 2.08 (±1.23) respectively for cone moth near Lake Cowichan; and 0.21 (±0.05), 4.89 (±0.48), 2.49 (±1.04), and 2.04 (±1.17) respectively for Douglas-fir cone gall midge near Lake Cowichan. Differences in damage among categories of cone crop size in the year damage occurred (N) were not significant ($P = 0.12$) in either species. Contrary to our results with cone moth and cone gall midge, an inverse relationship between seed abundance and damage by the Douglas-fir seed chalcidoid, *Megastigmus spermotrophus spermotrophus* Wachtl (Hymenoptera: Torymidae), has been reported in Britain (Hussey 1956).

Damage by Douglas-fir cone moth near Keremeos and Duglas-fir cone gall midge near Lake Cowichan increased significantly ($P<0.01$) with

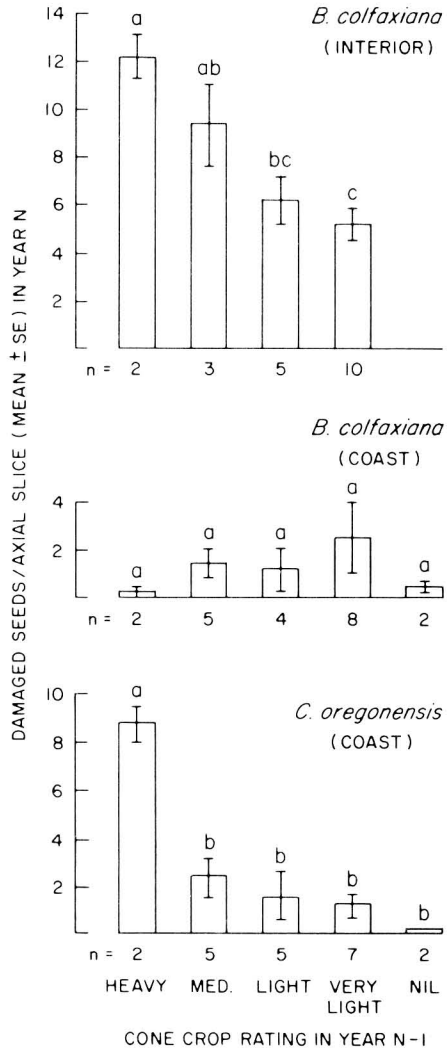

Fig. 2. Number of seeds damaged by *B. colfaxiana* and *C. oregonensis* in relation to the size of the cone crop of the preceeding year. Bars under the same letter are not significantly ($P<0.05$) different, Duncan's multiple range test.

the size of the crop the previous year (N-1) but near Lake Cowichan no relationship between cone moth damage and cone abundance the previous year could be detected ($P=0.85$) (Fig. 2). Damage by cone moth near Lake Cowichan was generally light but heavy damage occurred periodically (e.g., an average of 11.5 damaged seeds per axial slice in 1973). Reasons for the periodic occurrences of heavy damage are not known.

In all instances in this study, abundant crops (heavy or moderate ratings) were followed the next year by light crops or crop failures. Abundant cone crops allowed the insect populations to increase and the light crops which followed were usually heavily damaged due to the high ratio of insects to cones. Damage by both Douglas-fir cone moth near Keremeos and Douglas-fir cone gall midge near Lake Cowichan was significantly ($P<0.01$) higher in the year following abundant crops than in other years (Fig. 3). Others have also noted this effect (Hedlin 1964; Mattson 1980; Annila 1981). Differences in insect-caused damage among other years were not significant, although there was a tendency for damage to decrease as the period since the last abundant crop increased. These results suggest that fluctuating cone abundance limits Douglas-fir cone moth in interior areas and Douglas-fir cone gall midge in coastal areas. Similar studies on red pine,

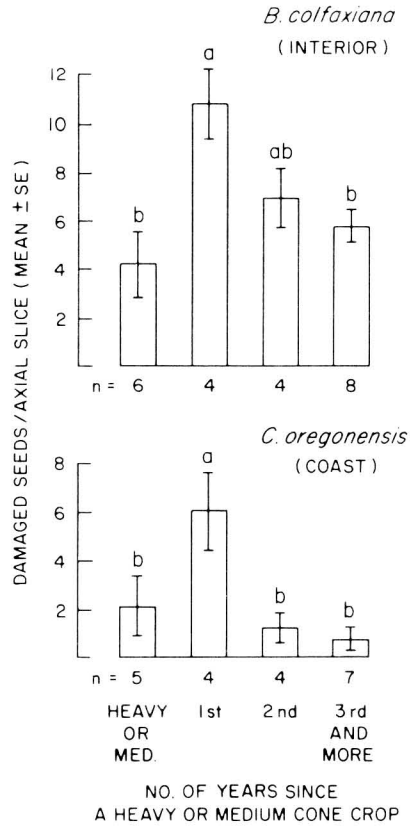

Fig. 3. Number of seeds damaged by *B. colfaxiana* and *C. oregonensis* in relation to the number of years since the last occurrence of a heavy or medium crop. Bars under the same letter are not significantly ($P<0.05$) different, Duncan's multiple range rest.

Pinus resinosa Aiton, and pinyon pines, *Pinus edulis* Engelm. and *P. monophylla* Torr. & Frem., also showed that insect-caused cone damage was limited by cone abundance the preceding year (Lester 1967; Mattson 1971; Forcella 1978, 1980).

Emergence of insects from prolonged diapause can result in heavier damage than expected in some years (Hedlin 1964; Annila 1981). Induction of prolonged diapause is inversely correlated with cone abundance the year following feeding by Douglas-fir cone moth larvae at Keremeos (Hedlin *et al.* 1982). No correlation between prolonged diapause and crop size was apparent for Douglas-fir cone gall midge at Lake Cowichan (Hedlin 1964). Emergence from prolonged diapause in relation to sizes of subsequent crops has not been examined in Douglas-fir cone moth or Douglas-fir cone gall midge but such emergence appears to be related to crop size in Douglas-fir seed chalcidoid (Annila 1982) and some insects attacking Norway spruce (Annila 1981).

Janzen (1971) hypothesized that erratic seed production in plants has evolved in response to seed predation by animals. Such may be the case in Douglas-fir. Typically, moderate and heavy cone crops are preceded by crop failures or light crops. Sharp increases in cone production can outstrip the reproductive capabilities of the insect populations and allow for production of large quantities of seed. There are fewer crop failures and more cones are usually produced in years of light production at Keremeos than at Lake Cowichan which may account for the consistntly heavier damage occurring at the former location. Damage to pine cones tends to be greatest where cone production is most consistent (Mattson 1971; Forcella 1980). Consistent cone production from year to year could result in loss of most seed every year due to build up of cone and seed insect populations.

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