A Six-Year Plot Study on Douglas-Fir Cone Insect Population Fluctuations

BY
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Abstract. From 1957 to 1962 records were obtained on cone production, insect-caused damage to cones, and cone-insect populations in four plots of *Pseudotsuga menziesii* (Mirb.) Franco on Vancouver Island, British Columbia. Cone crops and insect populations varied extremely. In order of importance *Contarinia oregonensis*, *C. washingtonensis*, *Barbara colfaxiana* and *Megastigmus spermotrophus* were the main seed-destroyers. Apart from availability of cones, the phenomenon of diapause was probably the most important single factor affecting insect population fluctuations.

DAMAGE to seed of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, by insects has been recognized for many years. Recently publications on the life histories, habits, seed-destroying capabilities, and control of the more important species have appeared (Hedlin 1960, 1961, Hussey 1955, Johnson and Heikkenen 1958, Johnson and Winjum 1960, Keen 1958, Koerber 1962). However, to date nothing has been published on the interrelationships of fluctuations in insect populations, seed losses and cone crops.

In 1957, four permanent plots were selected at different elevations about 10 miles from Cowichan Lake on Vancouver Island, B.C. (Table 1). All plots were ¼-acre in size except Plot 2 which was ½-acre since it had fewer trees of conebearing age. However, the stand density was comparable because a number of trees slightly below conebearing age were present in Plot 2. Each year as far as possible the following data were recorded for all trees in the plots: time of flowering and flushing, number of cones produced, percentage of cones infested and percentage of seed destroyed by each species of insect.

The object of the study was to observe cone production at four elevations over a period of years and to record insect damage and population fluctuations for the major species of cone insects in relation to varying cone crops. It was hoped in this way to establish a basis from which fluctuations could be predicted. All data were calculated on an acre basis.

Trees were examined at weekly inter-

TABLE 1. Characteristics of the Douglas-fir sample plots used in studying cone crop and cone insect fluctuations, Cowichan Lake, B.C.

Plot[1]	No. trees	Age (yrs.) Ave.	Range	Elev. (ft.)
1	28	19	13–23	1625
2	42	19	15–23	1300
3	41	18	13–23	860
4	59	22	13–28	400

[1]The distance between plot 1 and plot 2 was 2.4 miles; between plots 2 and 3 was 2.3 miles; and between plots 3 and 4 about 5 miles.

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vals in the spring with the aid of binoculars to determine time of flowering and cone development. Cone counts were made for each producing tree. When the crop was light all cones were counted, but when it was heavy only cones on one branch in each whorl on two sides of the tree were counted. The number was halved and multiplied by the average number of branches per whorl. A sample of cones was collected from each plot every year from as many trees as possible in each plot. The cones were sliced longitudinally and examined for damage by insects. Where a seed was damaged the loss was attributed to the insect species concerned even though the seed may have been hollow or aborted. In calculating the potential seed crop a figure of 50 seeds per cone was used.

Insect populations were calculated as follows: for the midges, *Contarinia oregonensis* Foote and *C. washingtonensis* Johnson, actual counts of larvae per infested cone were made from a sample of cones each year and the average used in conjunction with cone count data to calculate total numbers; the cone moth, *Barbara colfaxiana* (Kft.), and seed chalcid *Megastigmus spermotrophus* Wachtl, were calculated on the basis of one per infested cone or seed, respectively.

Results

There were no appreciable variations due to differences in elevation so data from all plots were grouped for each year.

Table 2 shows yield in cones per acre, and for each of the four insect species the percentages of cones infested and seed destroyed, and the number of insects per acre for the years 1957 to 1962.

Fluctuation in cone yield was extreme as the period includes the excellent crop of 1959 and the failure of 1960. In other years crops varied from light to medium.

There was considerable variation in the percentage of cones infested and seed destroyed by the different species of insects in different years.

The lowest percentage of cones infested by *C. oregonensis*, the most important species, occurred in 1959 as might be expected because of the abundance of cones, and the highest in 1960 when cones were scarce. However, when crops ranged between these extremes attacks did not always occur as might be predicted. In 1962 the percentage of cones infested was almost as high as in 1960 but the cone yield was 517 times as great, with the result that the total seed loss and total insect populations were far greater. The number of insects per acre ranged from 1,215 in 1960 to 769,000 in 1962 (Fig. 1).

Damage by *C. washingtonensis* was first recorded in 1958. In 1961 52 percent of the cones were infested. As this insect feeds within the cone scale and not always in the immediate vicinity of the seed, losses may not be as great as shown in Table 2. However, when infestations are severe as in 1961 and 1962 cone scales are killed before maturity undoubtedly reducing seed viability, if not actually killing the seeds.

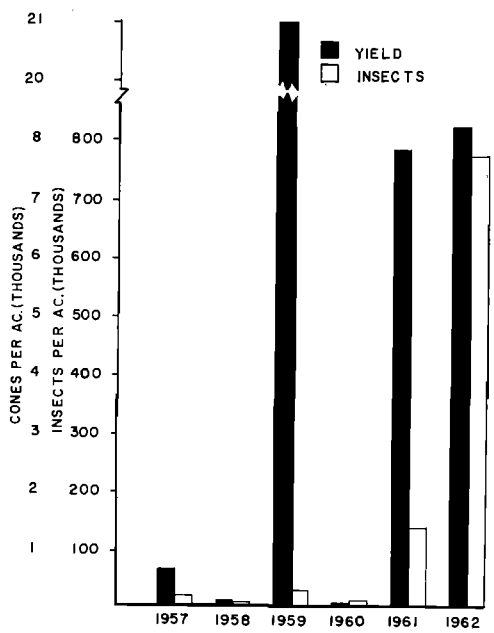

FIGURE 1. *A comparison of cone yield and* Contarinia oregonensis *populations, Cowichan Lake, B.C., 1957-1962.*

Of the true cone insects *Barbara colfaxiana* is the only cone moth generally present in this area. However *Dioryctria* sp., which is not a specific cone feeder, may cause considerable damage in some years. Damage by the two species can be separated readily. In 1957 the percentage of cones infested by *B. colfaxiana* was relatively high but decreased sharply by 1960 when all cone moth damage was due to *Dioryctria* sp. The *B. colfaxiana* population increased in 1961 and 1962.

Seed loss caused by *Megastigmus spermotrophus* was relatively light in all years although the population increased to a fairly high level in 1961 and 1962. In 1958 no record of seed loss was obtained because forest closure due to fire hazard prevented cone collection until many seeds were shed. This species is the only one of those studied here which remains inside the seed and thus is lost when seeds are shed.

Population figures in Table 2 were calculated from percentage of cones infested, size of cone crop and number of insects per infested cone. Midge populations show great variability because of the difference in numbers of insects per cone, e.g. the range in 1962 was from 0 to 331 larvae per cone. Numbers of cone moths and seed chalcids are much less variable.

Since *C. oregonensis* is the most important seed destroyer and relatively complete records were obtained in all six years, data for this species were used to illustrate population fluctuations in relation to size of cone crop (Fig. 1). The data show fluctuations to be extreme.

Discussion

Cyclical cone production of conifers has been recognized for many years (Baldwin 1942). During the period 1935 to 1954, Douglas-fir averaged one good crop every four years on the Cowichan Lake Experiment Station, B.C. (Garman 1955).

Workers studying cone insects have recognized these fluctuations and the effect which this variable supply must have on insects which are completely dependent on cones. It has been the belief that poor crops will be severely damaged by a rela-

TABLE 2. Plot yield, seed loss and cone insect populations in Douglas-fir plots, Cowichan Lake, B.C., 1957-62.

	1957	1958	1959	1960	1961	1962
Yield (cones/ac.)	669	170	21,043	16	7,809	8,280
Contarinia oregonensis						
% cones infested	33	64	17	92	45	84
% seed destroyed	7.3	17.8	2.5	70.0	11.5	36.5
No. insects/acre	10,448	6,492	23,337	1,215	134,659	768,848
C. washingtonensis						
% cones infested		3	2	0.3	52	37
% seed destroyed		0.42	0.44	0.0	9.2	7.4
No. insects/acre		356	2,643	36	183,138	128,328
Barbara colfaxiana						
% cones infested	23	4	0.5	0	3.0	10
% seed destroyed	1.8	0.35	0.1	0	0.7	2.8
No. insects/acre	145	13	93	0	339	817
Megastigmus spermotrophus						
% cones infested	0.7	no record	1	17	17	14
% seed destroyed	0.05		0.09	1.8	1.9	1.5
No insects/acre	17		984	14	5,180	5,315

tively large number of insects seeking the few available cones, and conversely, that when good crops occur there will be comparatively few insects from the preceding light crop and damage will be light. Predictions of this nature are not illogical and may be fairly accurate. However, this study shows that factors other than variable cone crops can have a marked effect on insect population fluctuations.

The percentage of cones infested by *C. oregonensis* in 1958 was almost doubled over that in 1957, but because of the reduced number of cones there was a decrease in the number of insects. This situation could be expected because even a portion of the 1957 insect population emerging in 1958 could give this result. In 1959 only a small percentage of the cones was infested and the insect population was relatively small. Several factors could have contributed to this situation but it was probably due largely to the fact that about 50 percent of the 1958 population remained in diapause in the spring of 1959. The result was that an insufficient number of insects emerged to cause serious damage. In 1960 the crop was very light, almost all cones were infested, and the total insect population was small. The portion of the population remaining in diapause (43 percent) was almost as great as in 1959. Because of this small population it was surprising that the medium crop in 1961 was severely infested. The insect population increased by 111 times over 1960 which could not have resulted from emergence of insects of the previous year only, and the attacking population must have been reinforced by emergence of diapausing insects from earlier years. However, a factor which undoubtedly aided in the increase was the almost complete emergence of the 1960 population. Only two percent remained in diapause. The increase in 1962 (5×) could easily have resulted from oviposition by a portion of the 1961 insect population. Of the 1961 population 15 percent remained in diapause in 1962.

During the years 1959 to 1961 observations were made on diapause in the cone moth *B. colfaxiana* in the Okanagan Valley (Hedlin 1960b). Ninety percent of the cones of the heavy 1959 crop were infested. In 1960 when the crop was extremely light, 63 percent of the pupae remained in diapause. In 1961, 99 percent of the 1959 living diapause insects emerged with the result that 77 percent of the cones were infested in spite of the extremely poor crop the previous year.

In his studies on *M. spermotrophus* in Britain, Hussey (1956) showed that variations in weather affected adult emergence so that it did not coincide with cone development and therefore prevented maximum oviposition. Unfavorable weather during the oviposition period also reduced egg laying. He found that diapausing insects from earlier years emerged to increase expected damage, and that parasites effectively reduced pest populations. These are factors which vary with the insect species involved and location. It was shown by Hedlin (1961) that *C. oregonensis* will oviposit under very unfavorable weather conditions.

It is apparent from these observations that it is difficult to predict cone-insect damage without some knowledge of potential insect emergence in addition to expected cone yield. Insect population figures in Table 2 would indicate that Douglas-fir cone crops in the Cowichan Lake area of Vancouver Island could be seriously infested in 1963 and also in 1964 regardless of crop size.

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