

RESPONSE OF DOUGLAS-FIR CONE GALL MIDGE AND  
DOUGLAS-FIR SEED CHALCID TO HOST PLANT GENOTYPE

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ABSTRACT

Seed losses to insects were measured from cones of 51 parental crosses (or families, distinct combinations of 6 x 11 parents) in a 12-year-old progeny plantation of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) in western Oregon. During 1983 and 1984 seed losses to the Douglas-fir cone gall midge (Contarinia oregonensis Foote) were significantly different ( $P < 0.05$ ) among host families. During 1984, 4 of the 5 families with the highest midge damage ( $\bar{x}=79\%$ ) shared a common parent, and 4 of 5 families with the lowest midge damage ( $\bar{x}=43\%$ ) shared a different common parent. This indicates that resistance or susceptibility to C. oregonensis is probably heritable. Losses to the Douglas-fir seed chalcid (Megastigmus spermatrophus Wachtl) were measured only in 1984 and were also significantly different ( $P < 0.05$ ) among host families. Insect responses to host genotype appear to be influenced by the position of the tree within the plantation, by the size of cone crop and, in the case of the seed chalcid, by prior activity of the cone gall midge.

Keywords: cone and seed insects, Contarinia oregonensis, Megastigmus spermatrophus, tree improvement, genetic selection, pest management

## INTRODUCTION

Despite the growing importance of tree improvement programs for reforestation purposes, few studies have addressed the effects of genetic selection on impact of insects on production of genetically "superior" seed. Cone and seed insects have been shown to concentrate on particular clones of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Hedlin and Ruth 1978), of slash pine (*Pinus elliottii* Englm.) (DeBarr et al. 1972, Merkel et al. 1965, Williams and Goyer 1980), of loblolly pine (*Pinus taeda* L.) (Goyer and Nachod 1976, Askew et al. 1985), and of western white pine (*Pinus monticola* Douglas) (Jenkins 1982). However, to our knowledge, no studies have dealt with insect responses to tree families, i.e., siblings of known parental crosses. Such studies could indicate the degree of heritability of resistance or susceptibility of cones and seeds to insect damage and the impact of insects on production of selected genotypes in progeny seed orchards.

Tree improvement programs have two primary goals: to provide for genetic gain and to maintain genetic diversity (Askew et al. 1985, Krugman 1986, Libby 1986). If host genotype influences cone and seed insect activity, then insects could influence overall genetic gain by reducing the seed output of the orchard and genetic diversity by disproportionately eliminating half sibs of a given family or sets of families. Our purpose in this study was to evaluate the susceptibility of Douglas-fir families to destruction of seeds by the Douglas-fir cone gall midge (*Contarinia oregonensis* Foote) and by the Douglas-fir seed chalcid (*Megastigmus spermatrophus* Wachtl.).

## METHODS

Cones used in this study were collected from a Douglas-fir plantation 6.5 km SW of Monmouth, Polk Co., Oregon, U.S.A. This 1.7 ha plantation was established in 1972-1973 to assess the role of controlled genetic crosses on seedling growth. It consisted of Douglas-fir progeny representing 51 distinct families (11 male parents x 6 female parents from the same parental pool). Parents 1 and 3 were from the west side of the Willamette Valley in Oregon, and the remainder from the east side. Each cross was represented in each of 7 blocks by 4 seedlings planted in a row, such that each block was a 33 x 8 matrix (the plantation was a 33 x 56 matrix) of trees at 3 x 3-m spacing. At the time of sampling, the trees were 5 to 6 m in height. The plantation occupied the northwest and southwest slopes of a low hill (5 m maximum relief) and was surrounded to the N, W and S by a 50-m buffer of commercial grass cover and to the E by a ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) plantation of similar age and tree height. The plantation was at least 500 m from any other Douglas-fir.

Five cones (all, if less than 5) produced during 1983 (the first good cone crop year for this plantation) and/or 1984 (a poor crop year) were collected in 5 blocks from all cone-producing trees at cone maturity in August 1984. Cones produced during 1983 or 1984 were identified by their position on each branch. Because Douglas-fir retains cones for at least one year, 1983 cones were adequately represented in our sample.

All cones were labelled by block, family and tree and air-dried in a greenhouse at Oregon State University. Dried cones were dissected scale by scale, and total seeds (number of scales x 2) and seeds fused to cone gall

midge galls were recorded for 1983 and 1984 cones. Because ungalled seeds (including chalcid-infested seed) from 1983 cones had dispersed, only seeds (both fused and free) of 1984 cones were sliced to record total incidence of seed chalcid. The numbers of chalcid-infested free and fused seed also were recorded in order to evaluate potential response of seed chalcid to prior seed damage by the midge.

Trees producing cones in 1983 and 1984 did not overlap completely. Therefore, the data for the two years were analyzed separately. Mean proportions of midge-damaged or chalcid-infested seed for each tree were pooled by block and family. A pooled average for each block x family combination was then transformed to the arcsine of the square-root of the proportion for analysis of variance. Transformed data were analyzed using SAS procedures for a randomized complete-block design (blocks = replicates). For significant ( $P < 0.05$ ) main effects, means were compared by the Tukey-Kramer procedure for unequal cell sizes with an experiment-wise error rate of  $\alpha = 0.05$  and  $\alpha = 0.1$  (SAS Institute, Inc. 1982). Our use of the  $\alpha = 0.1$  level was intended to reveal additional indications of genetic influences on insect activity which might be of use to tree improvement specialists. T-test and linear regression techniques were used to evaluate the relationship between midge and chalcid damage.

## RESULTS

The average cone gall midge-infestation rates were quite different for 1983 and 1984. In 1983, a year of abundant cone production, the cone gall midge damaged an average of 27.1 (13 S.D.) percent of the seed (range 16 to 39 percent). Cone gall midge damage differed significantly among families ( $F_{50,128} = 1.45$ ), but not among blocks ( $F_{3,128} = 1.22$ ). However, no family means were declared significantly different by the Tukey-Kramer method, even at the  $\alpha = 0.1$  level.

In 1984, a year of sparse cone production, damage by the cone gall midge and seed chalcid was higher than 1983 and averaged 59.7 (18.2 S.D.) and 7.6 (6.8 S.D.) percent of the seed, respectively (range 39 to 85 percent for the cone gall midge and 1.2 to 13.0 percent for the seed chalcid). Damage by the cone gall midge and seed chalcid differed significantly by family and block ( $F_{44,115} = 2.5$  and  $1.6$ , for midge and chalcid, respectively, by family;  $F_{4,115} = 26$  and  $4.4$ , for midge and chalcid, respectively, by block). Seven families with the lowest midge damage (range 39 to 52 percent) were significantly different from five families which had the highest midge damage (range 75 to 85 percent) (Table 1). Blocks 1, 2 and 3 on the southwest slope had significantly higher midge damage ( $\bar{x} = 69$  percent) than blocks 6 and 7 on the northwest slope ( $\bar{x} = 47$  percent). Family means were not declared significantly different on the basis of chalcid damage by the Tukey-Kramer procedure, even at the  $\alpha = 0.1$  level. Incomplete replication of families among blocks in 1984, due to poor cone production, prevented evaluation of the family x block interaction.

Similarly, incomplete replication of families and blocks between years prevented direct analysis of annual variation in midge damage. However, analysis of variance of the difference in midge damage between years indicated a significant effect of host block ( $F_{3,80} = 19.7$ ) but not of family ( $F_{44,80} = 1.3$ ). Blocks 1 and 2 showed a 3-fold increase in damage by *C. oregonensis*

Table 1. Percent (+ 1 S. D.) of seed, of 45 genotypes or families, destroyed or infested by *Contarinia oregonensis* in a Douglas-fir plantation in western Oregon in 1984<sup>1/</sup>.

Family	N Blocks	% Damaged Seed
1 x 2, 2 x 1	5	51(21) a
1 x 3	3	68(19) ab
1 x 4	2	39(35) a
1 x 5	3	43(19) a
1 x 6	4	67(13) ab
1 x 8, 8 x 1	5	43(20) a
1 x 9, 9 x 1	4	55(22) ab
1 x 10, 10 x 1	5	56(25) ab
1 x 11	3	54(30) ab
2 x 4	4	75(19) b
2 x 5	3	51(27) ab
2 x 6	2	59(21) ab
2 x 7, 7 x 2	3	57(31) ab
2 x 8, 8 x 2	4	55(16) ab
2 x 9, 9 x 2	4	83(15) b
2 x 10, 10 x 2	5	75(22) b
2 x 11	2	62(31) ab
2 x 12	2	85( 8) b
3 x 7	2	65( 8) ab
3 x 8	2	75( 7) ab
3 x 9	4	63(15) ab
3 x 10	3	60(14) ab
4 x 7	4	60(18) ab
4 x 8	4	55(12) ab
4 x 9	4	68(26) ab
4 x 10	5	58(24) ab
5 x 7	4	59(11) ab
5 x 8	5	52(10) ab <sup>2/</sup>
5 x 9	5	40(16) a
5 x 10	3	61(23) ab
6 x 7	2	58(23) ab
6 x 8	3	62(17) ab
6 x 10	4	67(15) ab
7 x 8, 8 x 7	4	54( 9) ab
7 x 11	4	61(13) ab
7 x 12	2	79(14) b
8 x 9, 9 x 8	5	64(12) ab
8 x 10, 10 x 8	4	63( 9) ab
8 x 11	2	57(21) ab
8 x 12	5	51(18) ab <sup>2/</sup>
9 x 10, 10 x 9	5	70( 8) ab
9 x 11	2	62( 2) ab
9 x 12	5	55(15) ab
10 x 11	5	59(18) ab
10 x 12	4	56(10) ab

<sup>1/</sup> Means in the same column followed by the same letter do not differ at the experiment-wise 0.05 level using the Tukey-Kramer procedure.

<sup>2/</sup> Significantly different at  $\alpha = 0.1$  using the Tukey-Kramer procedure.

from 1983 to 1984, differing significantly from blocks 6 and 7 which showed only a 2-fold increase in damage from 1983 to 1984.

Frequency of *M. spermatrophus*-infested seed was found to differ significantly (t-test at  $\alpha = 0.05$ ) between *C. oregonensis*-galled and ungalled seeds at 6.2 (6.3 S.D.) percent and 10.5 (10.3 S.D.) percent, respectively. The relationship between the number of *M. spermatrophus*-infested and *C. oregonensis*-galled seed was significant ( $r = .26$ ,  $\beta = -0.16$ ). Because these analyses indicated that chalcid abundance might not be independent of midge abundance, we tested the effect of midge damage as a covariate in the analysis of variance. However, the midge effect was not significant ( $F_{1,114} = 0.22$ ).

## DISCUSSION

This study indicates a potentially important effect of Douglas-fir genotype on damage by the Douglas-fir cone gall midge and the Douglas-fir seed chalcid. Similar conclusions have been reached by Hedlin and Ruth (1978) for clones of Douglas-fir, by Askew et al. (1985), DeBarr et al. (1972), Merkel et al. (1965), and Williams and Goyer (1980) for clones of southern pines, and by Jenkins (1982) for clones of western white pine. Our results suggest a genetic effect at the progeny level and indicate that site factors further modify insect response to host genotype.

Cone susceptibility or resistance to insects appears to be heritable: the highest *C. oregonensis* infestations in 1984 were primarily in progeny of parent 2; the lowest infestations were primarily in progeny of parent 1, even when crossed with parent 2 (Table 1). Furthermore, we consider the difference in infestation between the high-midge and low-midge Douglas-fir families to be substantial. Whereas Hedlin and Ruth (1978) reported that the differences in insect damage among Douglas-fir clones were minor and generally of no practical importance, our study showed that 10 of 51 families (offspring of 2 of 11 parents) differed significantly, with nearly a 2-fold difference in midge damage between the 7 significantly lowest families ( $\bar{x} = 46$  percent) and the 5 significantly highest families ( $\bar{x} = 79$  percent).

Several factors appeared to influence insect response to host genotype. One factor was annual variation in cone crop size. G. L. DeBarr (personal communication) found that differential damage among pine clones by southern pine seedbugs was more pronounced during good cone years when resources were more abundant. In our study, however, differential damage among families by the Douglas-fir cone gall midge was more pronounced during a poor cone year (1984) during which midge damage was twice that of the preceding good cone year (1983). This difference in insect responses in the two systems may reflect different responses to host conditions or to other environmental conditions varying annually and reflected in cone crop size. It is also possible that detection of statistical differences is more difficult in years of low infestation rates, such as for *C. oregonensis* in 1983 and *M. spermatrophus* in 1984. Askew et al. (1985) could not detect differences between clones in 12 of the 25 seed orchards which generally had *Dioryctria* spp. infestations of less than 5 percent.

Insect response was significantly affected by tree position within the plantation. Trees in blocks 1, 2 and 3 suffered significantly greater midge damage than did their siblings in blocks 6 and 7 in 1984. These results indicate that factors differing in effect between the north and south aspects

of the plantation (for example, differences in light intensity or degree-day accumulation which might alter insect, flower and cone phenology) affected midge activity in 1984. These results support the significant pine clone x replicate interaction reported in a study by Goyer and Nachod (1976).

Finally, we identified a potentially important effect of midge abundance on subsequent chalcid abundance. Volney (1984) reported no association between the Douglas-fir cone gall midge and the Douglas-fir seed chalcid in his study in northern California. Our results indicated a tendency for chalcid adults to avoid ovipositing in seeds from galled scales or for chalcid larvae to survive better in ungalled seeds.

The results of this study indicate important factors to consider in projecting seed production or implementing tree improvement programs. A 2-fold difference in seed production between resistant and susceptible seed-producing trees has considerable economic importance at \$1,100/kg (\$500/lb.) for Douglas-fir seed. More importantly, such a difference has important consequences for the contribution of selected genotypes in the final seed harvest. Production of different genotypes could be affected by other factors including variation in phenology of cone and pollen production, and the number of trees, the number of cones per tree, and the number of seeds/cone among genotypes. This variation could be balanced or exacerbated by selective insect activity. Local site factors also may affect seed production and insect activity (Schowalter et al. 1985).

These sources of variation should be considered in the design and management of seed orchards. The effect of host genotype on insect activity might be mitigated through manipulation of factors associated with host location within the stand or landscape mosaic, or by insect control or roguing of individual trees or entire selected genotypes. Most Douglas-fir seed orchards will soon begin to overproduce seed. When this situation occurs, differential production rates or insect damage frequencies will become a less serious concern. The seed orchard managers can simply balance the seed lots with equal or proportional amounts of seed from each family, parent or clone.

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