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Effects of Six Insecticides on Emergence of Some Parasites and Predators from Southern Pine Beetle[1] Infested Trees[2]

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ABSTRACT

Six insecticides (lindane, phosmet, diazinon, acephate, propoxur, and carbaryl) were tested to determine effects on predators and parasites associated with southern pine beetle, *Dendroctonus frontalis* Zimmerman, in eastern Texas. Eleven species of parasites and predators emerged from insecticide-treated pine bolts. The most prevalent species was *Coeloides pissodis* followed by *Medetera bistriata*, *Roptrocerus xylophagorum*, *Corticeus glaber*, and *Thanasimus dubius*. In terms of emergence from treated pines, only diazinon significantly reduced the total number of associated insects. They were 65% fewer in number following diazinon treatment. The insecticides differed in their effects on the 11 associates. *C. glaber*, *C. pissodis*, *M. bistriata*, *R. xylophagorum*, and *Dinotiscus dendroctoni* were the only species showing significant effects due to chemical treatment. *R. xylophagorum* emergence was significantly greater from all insecticide treatments than from the untreated pines.

Chemical control of the southern pine beetle *Dendroctonus frontalis* Zimmerman, presently relies solely on BHC and its gamma isomer lindane. Although these chemicals have effectively killed southern pine beetles in individual trees (Bennett and Pickard 1966), they have not been demonstrated to control beetle populations over wider areas. Objections to their use have arisen due to possible environmental contamination and adverse impact on beneficial insects (Williamson and Vité 1971). We report here studies designed to determine the effects of lindane and 5 other insecticides on the emergence from treated pines of predators and parasites of the southern pine beetle.

Methods and Materials

Insecticides

The chemicals chosen for study were phosmet 50% WP, diazinon 24% EC, acephate 75% SP, propoxur 70% WP, carbaryl 31% FP, and lindane 17% EC. Insecticides were applied in water solutions at the following concentrations: phosmet 0.8%, diazinon 1.0%, acephate 0.12%, propoxur 1.1%, carbaryl 2.2%, and lindane 0.25%. Insecticide concentrations were based on manufacturer's suggestions since only lindane has been used for bark beetle control. A control treatment received water only. Fuel oil solutions were not tested since fuel oil alone causes significant mortality of bark beetles (Cibulsky and Hyche 1974) and it was desired to evaluate only the insecticide formulation.

Preparation of Infested Pines

Six loblolly pines, *Pinus taeda* L., averaging 7 in. (17.8 cm) DBH and containing predominantly larvae and pupae of the southern pine beetle, were felled and each was cut into consecutive bolts, beginning at ca. 4 ft (1.2 m) above ground level in the manner shown in Fig. 1. To provide data on brood density and stage of development of southern pine beetle at the time of treatment, circular bark samples 4.5 in. (11.4 cm) diam were taken at the lower and upper ends of each bolt. The length of each bolt was then trimmed to 18 in. (45.7 cm) by removing the sampled ends. The circular bark samples were examined using a Faxitron® 805 x-ray unit. Radiographs were examined on an illuminator where the adults, larvae and pupae were counted.

The water solutions were applied with a hand-pressure back sprayer until the bark was wet and the insecticide ran in rivulets. The sprayed bolts were placed upright in cylindrical rearing cages with collecting jars (Germain and Wygant 1967). Emerging insects were collected daily.

Statistical Treatment of Results

The experimental design used was a randomized complete-block. Each tree (block) contained all treatments which were assigned randomly to the experimental units (bolts) from the tree.

Analyses of variance were used to examine the variation in numbers of southern pine beetles in the various trees prior to treatment, and the numbers of each of the predators and parasites that emerged from the bolts following treatment.

Prior to the analyses of variance of predator and parasite numbers, the sample means were plotted

[1]Coleoptera: Scolytidae.

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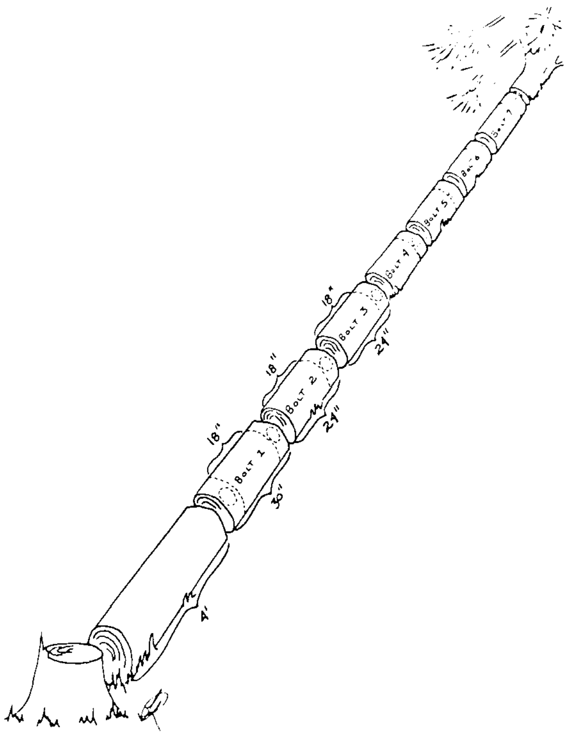

FIG. 1. — Sampling scheme for obtaining treatment bolts and bark samples.

over the sample variances for all of the treatments. These plots indicated a weak linear relationship between the means and variances. The following square root transformation was, therefore, applied to the data (Dunn and Clark 1974):

$$Y'_i = \sqrt{Y_i} + \sqrt{Y_i + 1}$$

Y'_i is the transformed value of an original emergence measurement (Y_i) for one predator or parasite species from one test bolt. The transformation rectified the linear relationship. Duncan's new multiple-range test was used to determine significant differences among means. Unless stated otherwise, the 5% level of probability was used to judge significance in all analyses.

A randomized complete-block analysis of covariance, with height above ground level of each bolt as the covariate, was used to examine the emergence data of the total predators and parasites by treatment. The model used in this analysis was:

$$Y_{ij} = \mu + \gamma_i + \rho_j + \beta(X_{ij} - \bar{X}) + \epsilon_{ij}; \quad i = 1,\ldots,7. \quad j = 1,\ldots,6.$$

An observation, Y_{ij}, consisted of a contribution from the population mean, μ; a contribution due to the effect of the $_i$th treatment, γ_{ij}; a contribution due to the $_j$th tree, ρ; a contribution due to deviation of the observed height, X, for the $_i$th treatment and the $_j$th tree from overall mean height for the experiment, $\bar{X}$; and a random error contribution peculiar to treatment $_i$ and tree $_j$. Height was included as a covariate since the nature of any vertical variation in predators and parasites within single trees was not known.

Results and Discussion

There were no significant differences in the numbers of larvae, pupae, or adults of the southern pine beetle in the pre-treatment bolts. There were, however, highly significant variations for trees. This was as expected and confirms the rationale for blocking the design by trees. The average number of all life stages of the southern pine beetle at the time of treatment for all bolts was 328.7 ± 75.8 (SE). The mean percent total of larvae, pupae, and adults was 58.3%, 23.0%, and 18.7%, respectively.

Eleven species of predators and parasites of the southern pine beetle (Bushing 1965, Overgaard 1968, Moser et al. 1971) were identified from the pine bolts. The species were:

HYMENOPTERA

Braconidae (det. P.M. Marsh); *Dendrosoter sulcatus* Muesebeck, *Coeloides pissodis* (Ashmead), *Spathius pallidus* Ashmead

Eurytomidae (det. B. D. Burks); *Eurytoma cleri* Ashmead

Pteromalidae (det. B. D. Burks); *Dinotiscus (Cecidostiba) burkei* (Crawford), *Dinotiscus (Cecidostiba) dendroctoni* (Ashmead), *Heydenia unica* Cook and Davis

Torymidae (det. B. D. Burks); *Roptrocerus xylophagorum* (Ratzeburg)

DIPTERA

Dolichopodidae (det. G. Steyskal); *Medetera bistriata* Parent

COLEOPTERA

Cleridae; *Thanasimus dubius* (Fronk).

Tenebrionidae (det. T.J. Spillman); *Corticeus glaber* (LeConte)

The specimens of *T. dubius* were all larvae while those of all other species were adults. *T. dubius* larvae are known to leave the southern pine beetle egg galleries and move about on the surface of trees (Thatcher and Pickard 1966). Mortality of *T. dubius* larvae on BHC-treated logs has been reported by Williamson (1970).[4] A parasitic role for *E. cleri* and *D. burkei* on southern pine beetle has not been established, but is assumed because other *Eurytoma* spp. are parasitic on scolytids and *D. burkei* has been reported from *Dendroctonus* spp. in the western U.S. (Bushing 1965, Dahlsten and Bushing 1970). *D. burkei* has not been previously reported as an associate of southern pine beetle. Moser et al. (1971) observed *C. glaber* as a probable facultative predator, although this role has not been verified. An undetermined species of *Corticeus* was reared from southern pine

[4]D. L. Williamson. 1970. A pest management system for the southern pine beetle, *Dendroctonus frontalis* Zimmerman, in East Texas. Ph.D. thesis, Texas A & M Univ.

Table 1. — Percent frequency distribution of associated insects from insecticide-treated pine bolts infested with southern pine beetle, Nacogdoches, TX, 1973.

	Treatment							
Species[a]	Control	Lindane	Acephate	Carbaryl	Propoxur	Diazinon	Phosmet	Species % Total
	— % distribution per treatment —							
T. dubius (294)	8.8	25.0	7.7	14.0	16.4	9.8	13.4	13.0
E. cleri (11)	0.7	0.0	0.0	1.8	0.3	0.7	0.3	0.5
S. pallidus (81)	4.5	0.7	2.6	3.3	4.8	3.5	5.1	3.6
C. glaber (389)	31.4	11.7	14.9	17.3	11.3	18.9	12.1	17.1
M. bistriata (391)	17.0	21.6	13.0	16.9	21.5	16.1	16.6	17.2
C. pissodis (489)	22.5	6.1	43.9	11.7	12.7	10.5	21.1	21.6
R. xylophagorum (388)	3.1	31.1	8.7	26.8	25.7	25.2	15.7	17.1
H. unica (111)	4.3	1.1	4.6	3.7	4.8	9.8	8.3	4.9
D. dendroctoni (32)	2.9	0.0	1.8	1.5	0.3	2.0	1.0	0.4
D. sulcatus (69)	2.9	2.7	2.8	1.8	2.2	2.8	6.1	3.0
D. burkei (13)	1.9	0.0	0.0	1.1	0.0	0.7	0.3	0.6
TREATMENT TOTALS	418	264	504	272	354	143	313	2268

[a]Number in parentheses indicate total number of each species which emerged from all treatments.

beetle infestations in Texas by Overgaard (1968) but it was described as a plant feeder.

The most prevalent associate was *C. pissodis* (21.6% of total) followed by *M. bistriata, R. xylophagorum, C. glaber*, and *T. dubius* (Table 1). Together, these 5 spp. accounted for 86% of the total emergence of identified beneficials. Stein (1975)[5] studied the insect associates of southern pine beetle in the same area of East Texas as the present studies and found that the most common of the known parasites and predators was *C. glaber* followed by *Aulonium tuberculatum* Leconte (Coleoptera: Colydiidae), *Scolopscelis* sp. (Hemiptera:Anthocoridae), *Roptrocerus eccoptogastri* (Ratzeburg), *D. sulcatus, Lasconotus referendarious* Zimmerman (Coleoptera:Colydiidae), *T. dubius, H. unica, C. pissodis*, and *M. bistriata*. Camors and Payne (1973) found *M. bistriata* to be the most abundant associate attracted to infested pines, while Moser et al. (1971) found that, based on numbers emerging per sq ft of bark, *R. xylophagorum* was most common of the known beneficials.

The analysis of covariance for emergence of 11 associated species, using height above ground for each bolt as the covariate, was used to test the following hypotheses: (1) there were no differences among the unadjusted (for height) treatment means for emergence (i.e., a randomized complete-block analysis of variance), (2) there were no differences among treatment means for height, (3) that the true regression coefficient, β, is 0 and (4) that there were no differences among treatment means for emergence adjusted for the regression of emergence on height.

The F-test for hypothesis 1 was highly significant (F 6, 30 = 3.56) showing that real differences exist for the effects of the insecticides on emergence of total predators and parasites when the means are uncorrected for height. The 2nd hypothesis was rejected (F 6, 30 = 1.48) indicating that the mean heights among the treatments did not differ significantly. The test of the regression coefficient is, in reality, a test whether the use of height as a covariate is justified in reducing the random error of the experiment. If $\beta = 0$ there is no significant regression of height on emergence and no justification for including the covariate. The F-test for the regression coefficient was not significant (F 6, 30 = 0.03). The remaining testable hypothesis, that the adjusted means differed, was, of course, significant (F 6, 29 = 3.43). Subsequent analysis of emergence employed a randomized complete-block analysis of variance.

The nonsignificance of the regression coefficient test should not be interpreted to mean that predators and parasites show no vertical gradients in density within southern pine beetle attacked trees. The results simply signify that the random allocation of treatments to bolts for each tree was sufficient to remove any height bias in the experiment.

The transformed emergence data for all 11 species of associates indicated significance (P<0.01) due to treatment. When the transformed means for the insecticides were compared to the control treatment, only diazinon significantly reduced total emergence of the associated insects (Table 2). The means shown in Table 2 are the back-transformations of the analyses of variance and were obtained by the formula

$$y = \left[\frac{x^2 + \frac{1}{x^2}}{4}\right] - 0.5$$

where y is the back-transformed mean and x is the transformed mean. Associated insects were 65% fewer in number following diazinon treatment. When compared to other insecticides, emergence of associates from diazinon did not differ significantly from lindane, carbaryl, and phosmet.

[5]C. R. Stein. 1975. Seasonal and height distribution of predators and parasites of the southern pine beetle (Coleoptera: Scolytidae) in two species of pine in East Texas. M.S.F. Thesis. Stephen F. Austin State Univ.

Table 2. — Emergence[a] of total insect associate (11 species) and 4 selected predators and parasites of the southern pine beetle from insecticide-treated pine bolts, Nacogdoches, TX, 1973.

Insecticide	Total	*C. glaber*	*M. bistriata*	*C. pissodis*	*R. xylophagorum*
Acephate	70.63a	8.24 b	9.75abc	16.89a	4.94a c
Control	60.18ab	16.23a	11.44ab	7.74ab	1.65 c
Propoxur	53.40ab	3.38 cde	11.72a	4.18 b	10.96a
Lindane	40.07abd	2.70 cde	8.56 cd	1.56 b	10.93a
Carbaryl	36.82 bd	3.46 cd	6.91 de	2.83 b	6.91a
Phosmet	33.68 bd	3.81 c	7.89 cde	5.46ab	5.54a c
Diazinon	20.93 d	2.33 de	2.21 f	1.56 b	3.94a c

[a]Emergence is mean number from 6 pine bolts (7 × 18 in [17.8 × 45.7 cm]) for each insecticide. Means in a column followed by a common letter are not significantly different ($p < 0.05$) as determine by Duncan's multiple-range test. Means are the back-transforms of those used in the analysis of variance (see text).

The transformed emergence data for each of the 11 species were examined by analysis of variance and it was found that only the following 5 species showed significant variation due to treatment: *C. glaber* ($P<0.005$), *M. bistriata* ($P<0.025$), *C. pissodis* ($P<0.05$), *R. xylophagorum* ($P<0.05$), and *D. dendroctoni* ($P<0.05$). The mean emergences for 4 of these species from each treatment are shown in Table 2. *D. dendroctoni* was not included in Table 2 because of the small total emergence (32) of this species.

When compared to the control treatment, the most common beneficial, *C. pissodis* was adversely affected by all insecticides except acephate and phosmet. Using an average emergence for the 4 significant treatments (2.53 insects/bolt) the number of *C. pissodis* was reduced to 33% of the number in the control.

M. bistriata emergence from diazinon-treated logs was 19% of that in the control. Significant reductions from the control emergence were also noted for carbaryl (60%), phosmet (69%), and lindane (75%).

All insecticides significantly reduced *C. glaber* numbers. Diazinon had the greatest impact (14% of the control) but this was not significantly different from the emergence from the lindane, propoxur, and carbaryl treatments.

The situation with *R. xylophagorum* is unclear since the control had the lowest mean emergence and this was significantly lower than all insecticide treatments. The experiments suggest no explanation for the increase in *R. xylophagorum* from insecticide-treated trees.

The relative importance of beneficial species in natural regulation of southern pine beetle populations is unknown and therefore the net effect of a given chemical on natural control of southern pine beetle cannot yet be determined. Many emerging southern pine beetle adults die from poisoning within 24–48 h as a result of boring through insecticide-treated bark (Ragenovich and Coster 1974). Survival of predators and parasites after emergence from insecticide-treated pines was not tested in the present study. Furthermore, beneficial insects are attracted to infested pines in the forest (Camors and Payne 1973). Insecticide treatment of such trees results in mortality of beneficials and this effect on the insects as they search for southern pine beetles must also be evaluated in order to accurately assess the importance of chemical control on beneficial insect populations.

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