UNIVERSITY OF IDAHO
COLLEGE OF FORESTRY-WILDLIFE AND RANGE SCIENCE

EFFECTS OF TRUNK-INJECTED OXYDEMETONMETHYL ON DOUGLAS-FIR CONE AND SEED INSECTS, SEEDLING PRODUCTION, AND MICE

By

John A. Schenk, Robert H. Giles, Jr., and Frederic D. Johnson

Forest, Wildlife and Range Experiment Station
Moscow, Idaho

Station Paper No. 2

August, 1967

CONTENTS

Effects of Trunk-Injected Oxydemetonmethyl on Douglas-Fir Cone and Seed Insects, Seedling Production, and Mice[1]

by

John A. Schenk, Robert H. Giles, Jr., and Frederic D. Johnson[2]

Within the past decade there has been increased interest in research on the biology and control of cone-infesting insects, and recognition of the need for additional information concerning the influence of insecticides on the treated trees, seed germination, and seedling development. Insufficient data on the effects of insecticides on other animal life continues to create concern and controversy.

Insects attacking conifers have been successfully controlled by means of trunk application of systemic insecticides; however, many failures also have been reported. Watchtendorf (16) applied oxydemetonmethyl-impregnated bands to the trunks of spruce, but failed to control certain species of *Ips* and *Pityogenes* bark beetles. Using similar methods with demeton, Vite′ (13) also was unsuccessful in preventing either the formation of galls by two adelgid species, or in killing the nymphs within the galls. On the other hand, Kinghorn (7) obtained systemic control of the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (=*monticolae* Hopk.), in lodgepole pine using bands impregnated with demeton and schraden, but did not achieve control of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., in Douglas-fir. Vite′ (13) did obtain good control of the adelgid, *Dreyfusia musslini* C.B., on pine with the use of oxydemetonmethyl-impregnated bands. Vite′ (12) also found that both demeton and oxydemetonmethyl-impregnated bands gave acceptable systemic control of a thrips species and young larvae of the casebearer, *Colephora laricella* Hbn., on larch. Oxydemetonmethyl apparently was more rapidly translocated than demeton.

Vite′ (14) reported that efficient control of the thrips species and the casebearer also was obtained by trunk injection of oxydemetonmethyl, but that similar use of demeton resulted in some phytotoxicity. Giese, et al. (5) tested five systemic insecticides, including demeton, against a midge by trunk injection into balsam fir. This insecticide provided the most rapid and complete kill of the midge larvae at the lowest dosage (1 gm active per tree); however, phytotoxicity was serious enough to preclude usage of

[1]Published with the approval of the Director, Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. Supported in part by McIntire-Stennis funds.

[2]Associate Professor (Forest Entomology), Assistant Professor (Wildlife Management), and Associate Professor (Forest Ecology), respectively, Forest, Wildlife and Range Experiment Station, University of Idaho.

even this low dosage in balsam fir. Of special interest was the finding that tree diameter was positively correlated with the time required for complete kill of the midge larvae for any given concentration of insecticide.

Pitkin and Portman[3] tested eight systemic insecticides in pole-sized Douglas-fir during 1963. Varying dosages of each insecticide (actual toxicant per diameter inch) were injected in holes drilled near the base of each tree. Only dimethoate at 13.9 gms and oxydemetonmethyl at 3.7 gms per diameter inch showed promise. No symptoms of phytotoxicity were found.

Johnson and Rediske (6) developed and used an isotope technique in testing systemic insecticides for the control of cone and seed insects. Of the eight tested, only dimethoate, schraden, and demeton gave good control of the seed chalcid, *Megastigmus spermothrophus* Wachtl., and both dimethoate and demeton produced some symptoms of phytotoxicity, even at the lowest dosages. Published accounts of studies of phytotoxic reaction in seeds or seedlings were not found.

Translocation of inorganic salts in conifers was traced by Moreland (9), Fraser and Mawson (4), and Ferrell, et al. (2), among others. Translocation of organic compounds, such as growth hormones and some phytotoxins, in trees was reported by Ferri (3), and Beckman and Kuntz (1). Vite' and Rudinsky (15) have investigated the importance of water conducting systems in conifers to the distribution of trunk-injected chemicals. Wedding (17) has explored the plant physiological aspects of the use of systemic insecticides, including studies of deposition patterns and rates of movement.

Leedy (8) and Rudd (10) pointed out the need for a cooperative approach to pest control programs, and in the development of methods that minimize hazards to fish and game. Systemics seldom have been investigated for their effects on wildlife, although laboratory tests for toxicity have been conducted. Rudd and Genelly (11) did not report on the effects of systemics on wildlife in their intensive treatment of the subject. These omissions may be due to the relatively recent development and use of systemics, to the rapid absorption by the plants, and to the initial unavailability of the toxicant to wildlife. To date, no studies on the effects of systemic insecticides on wild vertebrate populations have been found in the literature. N. B. Kverno (pers. communication) told of a study with tetramine to produce Douglas-fir seed repellent to rodents using a bioassay with wild-trapped *Peromyscus leucopus* Fisher as his only method of analysis. The method proved unsuccessful. The need for such an evaluation will become even more manifest as the use of systemics increases, and if low toxicity insecticides show effects on populations of the smaller forest mammals.

---

[3]Pitkin, F. H. and R. W. Portman (University of Idaho), unpublished data.

Description of Test Areas

In 1964, the treatments were applied to Rocky Mountain Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, on the University of Idaho Experimental Forest near Princeton, Idaho. The site is located on a flat bench in the foothills of Moscow Mountain at 2,800 feet, and is dominated by seral Douglas-fir and lodgepole pine, *Pinus contorta* ssp. *latifolia* Engelm. Other tree species include: grand fir, *Abies grandis* (Dougl.) Lindl.; western larch, *Larix occidentalis* Nutt.; western redcedar, *Thuja plicata* Donn; ponderosa pine, *Pinus ponderosa* var. *ponderosa* Laws.; and western white pine, *Pinus monticola* Dougl. The stand is quite open due to past selective logging and intensive grazing. Some of the trees approach 100 percent living crown. The understory is dominated by *Poa pratensis* L. and *Trifolium repens* L., with scattered herbaceous weeds and small shrubs. The climax association is *Thuja plicata/Pachistima myrsenites*.[4]

The 1965 site is on the St. Joe National Forest, southern Benewah County, approximately 1 mile northwest of Baldy Mountain along the "Palouse Divide Road" at an elevation of 4,050 feet, on a steep, north-facing slope. The site is dominated by seral western white pine and Douglas-fir, with scattered western redcedar, grand fir, and western larch, in order of decreasing abundance. The understory is dominated by scattered, 10 to 15 foot Scouler willow, *Salix scouleriana* Barr., and relatively dense, 5 to 7 foot, Sitka alder, *Alnus sinuata* (Req.) Rydb., and various other members of the *Pachistima* union. Conifer reproduction is chiefly western redcedar and scattered grand fir; the climax association is *Thuja plicata/Pachistima myrsenites*.[4]

Procedures

In 1964, two replicates of six Douglas-fir were selected as test trees, with two in each replicate serving as controls. All were selected for heavy, current cone crop and suspected cone-insect populations. Additional characteristics of the test trees are given in Table 1. Oxydemetonmethyl was selected as the test systemic insecticide as it exhibited the greatest effectiveness at the lowest

Table 1. Characteristics of Douglas-fir used as test trees. Northern Idaho, 1964-1965.

	Ave. Ht. (ft.)		Ave. dbh (in.)		Ave. Crown (%)	
Treatment	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
1964						
Control	53.5	38.2	12.5	9.9	88.0	91.0
Treated	47.8	45.0	12.2	12.6	84.0	87.0
1965						
Control	51.4	42.0	11.8	10.7	89.0	80.0
Treated	49.0	48.0	10.9	11.6	90.0	87.0

[4]From Daubenmire, R. "Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetational classification." Ecol. Monog. 22(4), 1952.

dosages during preliminary screening tests by Pitkin and Portman[3].

The chemical was injected during the early afternoon of June 22 by means of "Mauget Tree-Injector Units," each of which contained 3 gms active toxicant (cover photo). The weather was sunny and warm (70° F) with a gentle breeze. Cones were pendent and approximately 1½ in. long, and shoot growth had reached 1-2 in.; thus both were in periods of great metabolic activity. The contents of 8 units (24 gms) were introduced into each tree (ca 1.7 to 2.7 gms per diameter inch) to a depth of ½ to 1 in. into the sapwood. The times required for total absorption of the chemical were recorded.

Cone and branch-tip samples were collected one week after the treatment (June 29) and at two-week intervals thereafter. Samples of 24 cones each were obtained by handpicking 6 from the outer most one-foot portion of a single branch in each cardinal direction of the cone-bearing crown of each tree[5]. Four, one-foot branch-tips were collected from four different sides in each of the upper, middle, and lower thirds of the crown. Sub-samples of both cones and branch-tips (foliage) were ground in a Waring blender, placed in plastic sacks labeled as to date and crown position, and stored at 30° F for subsequent determination of toxicant concentration[6]. Branches in all parts of both test and control trees were examined for signs of phytotoxic effects before and during the sampling period, and subsequent to the end of the 1964 tests.

Twelve cones from each tree and collection were placed in rearing containers to obtain supplemental biological data. The remaining cones from each tree and collection were examined, first by the axial-slice method, and finally, by a scale-by-scale examination. The following information was recorded for each method: number of insect damage and filled seed; species and number of insects responsible for the observed damage; and insect mortality by species. A representative sub-sample of larvae and pupae was dissected to ascertain the percent parasitism of the host insect species that were sufficiently abundant to provide an adequate sample. All insect data were processed by IBM computer.

To examine the effects of oxydemetonmethyl on seed germination and early seedling development, cones were collectd in September from all crown levels and aspects from treated and control trees; and the seed was hand-extracted. Empty seeds were eliminated by water flotation. The seeds from all control trees were combined to constitute one source, and those from all treated trees

[5]The first cone sample from each branch was placed in a plastic bag, sealed, and stored at 34° F until examined for seed loss and insect mortality. This procedure caused 100 percent insect mortality in all cones, and subsequent samples were placed in paper sacks.

[6]Initial plans called for both qualitative and quantitative analysis for oxydemetonmethyl in cone tissue, twigs, and foliage, with subsequent determination of insect mortality-concentration curves, rates of translocation, and metabolic by-products of the insecticide. Interference due to resins prevented consulted chemists from obtaining this information.

constituted the second source. Moist seeds were stratified in plastic sacks in the University of Idaho Forest Nursery cold house for three months at about 40° F, following standard nursery practice. Three flats were prepared, each with 50 treated and 50 untreated control seeds planted ¼ in. deep in a randomized block design. Each seed was located by a colored toothpick. The flats contained a 1:1 mixture of nursery sand and ground peat, with 1 in. topping of coarse sand. Flats were kept in a greenhouse in full light with temperatures averaging 40-50° F night and 65-78° F day. The number of germinated seed was recorded every other day until all germination had ceased. More extensive tests were not possible due to the low supply of seed remaining after intensive cone sampling for insect activity.

A live-trapped colony of the deer mouse, *Peromyscus leucopus* Fisher, and a colony of the laboratory white mouse, *Mus musculus* L., were established and maintained in the laboratory to ascertain the effects of a diet of seeds and cone tissue from treated trees. Two groups, each made up of 5 deer mice, were provided a diet of treated and untreated cones, respectively, supplemented occasionally with Purina Dog Chow. Both groups were stressed with inadequate food, and later, with water removal. Similar tests were conducted for 15 months with 70 deer mice and some 400 white mice. Records on mortality, weight, repellency, and behavior were maintained. Exploratory dermal toxicity tests with 50 percent technical material also were conducted.

In 1965, extensive cone-crop failure, an aerial spray for a Douglas-fir tussock moth outbreak, and inability to obtain quantitative analysis of the insecticide concentrations in the foilage and cones, resulted in a number of procedural modifications and changes in research emphasis: (1) the study area was shifted to a small group of cone-bearing Douglas-fir found in southern Benewah County; (2) sixteen cones were collected from each of 20 trees making up two replicates of 10 control and 10 treated trees. Eight cones were selected from each of the upper and lower halves of the cone-bearing crowns, with no more than two selected from any one branch; (3) four cones from each tree were placed in rearing and the remainder examined for seed loss and insect mortality, using the axial-slice method only; (4) the dosage of oxydemetonmethyl was standardized at 1 gm per diameter inch for each tree, which constituted a reduction in dosage from the previous year. Characteristics of the test trees used in 1965 are given in Table 1. High cone losses to squirrels, and low insect population complicated analysis of data. Weather at time of treatment was cloudy, humid, and calm.

Four western white pine trees, supporting very light infestations of the cone beetle, *Conophthorus monticolae* Hopk., and the cone moth, *Eucosma rescissoriana* Hein., also were treated with approximately 1 gm of oxydemetonmethyl (actual) per diameter inch. Two untreated trees served as controls. The untreated trees averaged 14.3 inches dbh, 56.5 feet in height, and were 93 percent crown. Untreated trees averaged 12.8 inches dbh, 46.5 feet in height, and were 86 percent crown.

Results

Efficiency of Procedures

A total of 1.75 hours were required by a 3-man crew to select, prune, tag, and treat eight trees. Actual treatment, including placement of feeder tubes and positioning eight injector units, required an average of 8.75 minutes per tree. Absorption of the systemic into the Douglas-fir trees was complete in 2.0 to 2.4 hours under the variable weather conditions prevailing during the 1964 treatment. A substantitally longer time of 3 days was required the following year when cloudy, cool, and humid weather prevailed. The feeder tubes were inserted deeper into the sapwood in 1965, which also would tend to increase the time of absorption. Absorption by white pine was not complete until July 1, or about one week after treatment.

In 1965, the odor of insecticide was detected in the crowns of treated Douglas-fir during the first collection (July 1) one week after treatment, but was most apparent during the third collection (July 29). No odor was detectable during the fourth collection on Aug. 12, nor on subsequent collection dates. No chemical odor emanated from the foliage of treated white pine, except for a trace on July 1, one week after treatment. Continual inspection for abnormalities such as chlorosis and changes in growth patterns, revealed no differences between test and control trees.

Relationship Between Sample and Total Seed Counts

Correlation analysis of 1964 seed counts obtained by the axial-slice method and by total dissection confirmed the validity of the sample method. Correlation coefficients by collection date ranged from 0.54 to 0.97 for estimates of damaged seed, and from 0.49 to 0.61 for estimates of total seed per cone. All r-values were highly significant.

Species Present

Four insect species were responsible for most, if not all, detectable damage to the cones and seeds of Douglas-fir. These were: Two cone moths, *Barbara colfaxiana* (Kearf.) and *Dioryctria abietella* (D. & S.); a gall midge, *Contarinia* sp.; and the seed chalcid, *Megastigmus spermotrophus* Wachtl. All determined insect specimens recovered from the Douglas-fir cones are presented in Table 2. Identification of many specimens has not yet been made. Some of the treated trees had heavier infestations of tussock moths than control trees, probably due to chance selection.

Effectiveness of Treatment

Reduction in seed loss. Trunk injection of oxydemetonmethyl at 24 gms per tree (ca 2 gms per diameter inch) significantly reduced seed losses in open-growing, pole-sized Douglas-fir in 1964

Table 2. Insect species collected from Inland Douglas-fir cones in Northern Idaho, 1964-65.

Species		Determined by:
COLEOPTERA:		
Scolytidae:	*Conophthorus* sp. (Incidental?)	D. M. Anderson
HYMENOPTERA:		
Braconidae:	*Apanteles petrovae* Walley	C. F. Muesebeck
	Apanteles sp.	C. F. Muesebeck
	Apanteles sp.	C. F. Muesebeck
	Eubadizon n. sp.	C. F. Muesebeck
Encyrtidae:	*Homalotylus terminalis* (Say)	B. D. Burks
Elasmidae:	*Elasmus atratus* How.	B. D. Burks
Eulophidae:	*Elachertus pini* Gahan	B. D. Burks
	Tetrastichus coerulescens Ashm.	B. D. Burks
	Tetrastichus sp.	B. D. Burks
Ichneumonidae:	*Exeristes comstockii* (Cress.)	L. M. Walkley
Platygasteridae:	*Piestopleura* n. sp.	C. F. Muesebeck
Pteromalidae:	*Habrocytus* sp.	B. D. Burks
Torymidae:	*Megastigmus spermotrophus* Wachtl.	B. D. Burks
DIPTERA:		
Acroceridae:	*Acrocera* sp.	C. W. Sabrosky
Cecidomyiidae.	*Rubsaamenia keeni* Foote	R. J. Gagne
	Contarinia sp.	R. J. Gagne
	Holoneurus sp.	G. Steyskal
	Lestodiplosis sp.	R. J. Gagne
Sciaridae:	*Bradysia* sp.	A. Stone
Tachinidae:	Blondeliini: genus-species near Lixophaga	C. W. Sabrosky
LEPIDOPTERA:		
Olethreutidae:	*Barbara colfaxiana* (Kearf.)	J. A. Schenk
Phycitidae:	*Dioryctria abietella* (D. & S.)	J. A. Schenk
Tortricidae:	*Choristoneura fumfiferana* (Clem.)	D. M. Weisman
PSOCOPTERA:		
Lachesillidae:	*Lachesilla* sp.	A. B. Gurney

Table 3. Significance levels of seed losses between treated and untreated Douglas-fir trees. Northern Idaho, 1964. * Significant at 5% level; ** significant at 1% level; — insufficient data.

Days after trtmt	Source	% Seed Damaged		Seed Loss by Species			
				B. colfaxiana		Contarinia	
		face count	total count	% dmgd seed	% total seed	% dmgd seed	% total seed
21	Reps	—	**	—	—	—	**
	Trt	*	**	—	**	—	**
	RxT	—	*	—	*	—	**
35	Reps	**	**	*	—	—	*
	Trt	**	**	**	**	—	*
	RxT	**	*	**	—	—	**
49	Reps	**	**	**	—	—	—
	Trt	**	**	**	**	—	—
	RxT	**	**	**	—	—	—
63	Reps	**	**	**	*	—	—
	Trt	**	**	**	**	—	—
	RxT	**	**	**	*	**	—
79	Reps	**	**	—	—	—	**
	Trt	**	**	—	**	—	**
	RxT	**	**	—	—	—	**

Table 4. Seed losses by casual agent on treated (T) and untreated (C) Douglas-fir based on total seed counts. Northern Idaho, 1964.

Days after trtmt	Rep	Trt-ment	Available Seed Lost Due to Casual Agent			
			B. colfaxiana	Contarinia	Other insects	All causes
			percent	percent	percent	percent
21	1	C	11.3	1.8	0.4	13.5
	2	C	6.6	20.6	4.3	31.5
	Average		9.5	8.9	1.9	20.3
	1	T	0.1	0.3	1.5	1.9
	2	T	1.0	1.5	2.9	5.4
	Average		0.5	0.9	2.2	3.6
35	1	C	13.8	1.3	1.9	17.0
	2	C	12.2	38.3	2.2	52.6
	Average		13.2	15.4	1.9	30.5
	1	T	0.2	9.4	1.7	11.3
	2	T	1.0	4.8	3.4	9.2
	Average		0.6	7.2	2.5	10.3
49	1	C	17.4	1.2	2.3	20.9
	2	C	10.2	32.9	0.6	43.7
	Average		14.7	12.8	1.7	29.2
	1	T	0.6	2.9	2.7	6.2
	2	T	0.4	4.3	2.6	7.3
	Average		0.5	3.6	2.7	6.8
63	1	C	15.1	0.8	2.6	18.5
	2	C	7.6	33.2	4.1	44.9
	Average		12.2	13.2	3.2	28.6
	1	T	0.3	1.7	2.3	4.3
	2	T	0.3	0.9	2.1	3.3
	Average		0.3	1.3	2.2	3.8
79	1	C	8.4	3.1	6.0	17.6
	2	C	5.0	30.0	5.0	40.0
	Average		7.2	12.8	5.6	25.6
	1	T	0.0	3.3	0.4	3.7
	2	T	1.2	2.2	1.4	4.8
	Average		0.5	2.8	0.9	4.2

(Table 3). Although significant variation appeared between trees and replicates, percent seed losses from all causes in treated trees averaged approximately one-fifth the losses in untreated trees. For example, 20.3 percent of the available seed was destroyed in the check trees, while only 3.6 percent was lost in the treated trees 21 days after treatment. The maximum reduction occurred 63 days afer treatment when 28.6 and 3.8 percent seed losses were recorded in all check and treated trees, respectively (Table 4, Figure 1). In one instance (Rep. 26, 35 days), over half the available seed from two untreated trees was destroyed in contrast to approximately 9 percent of the seed from four treated trees in that replicate. Seed losses from a single untreated tree in 1964 ranged from 9.5 to 57.2 percent, and from 0.2 to 27.8 percent in a single treated tree. The minimum in the untreated and the maximum in the treated categories were unusual occurrences, and may reflect potentials for improved treatment procedure and technology.

A comparison of 1964 average losses by major causal species (Table 4) indicated a fairly even distribution between *B. colfaxiana* and *Contarinia* sp. on the basis of total available seed destroyed; however, the between-tree variation for *Contarinia* was much

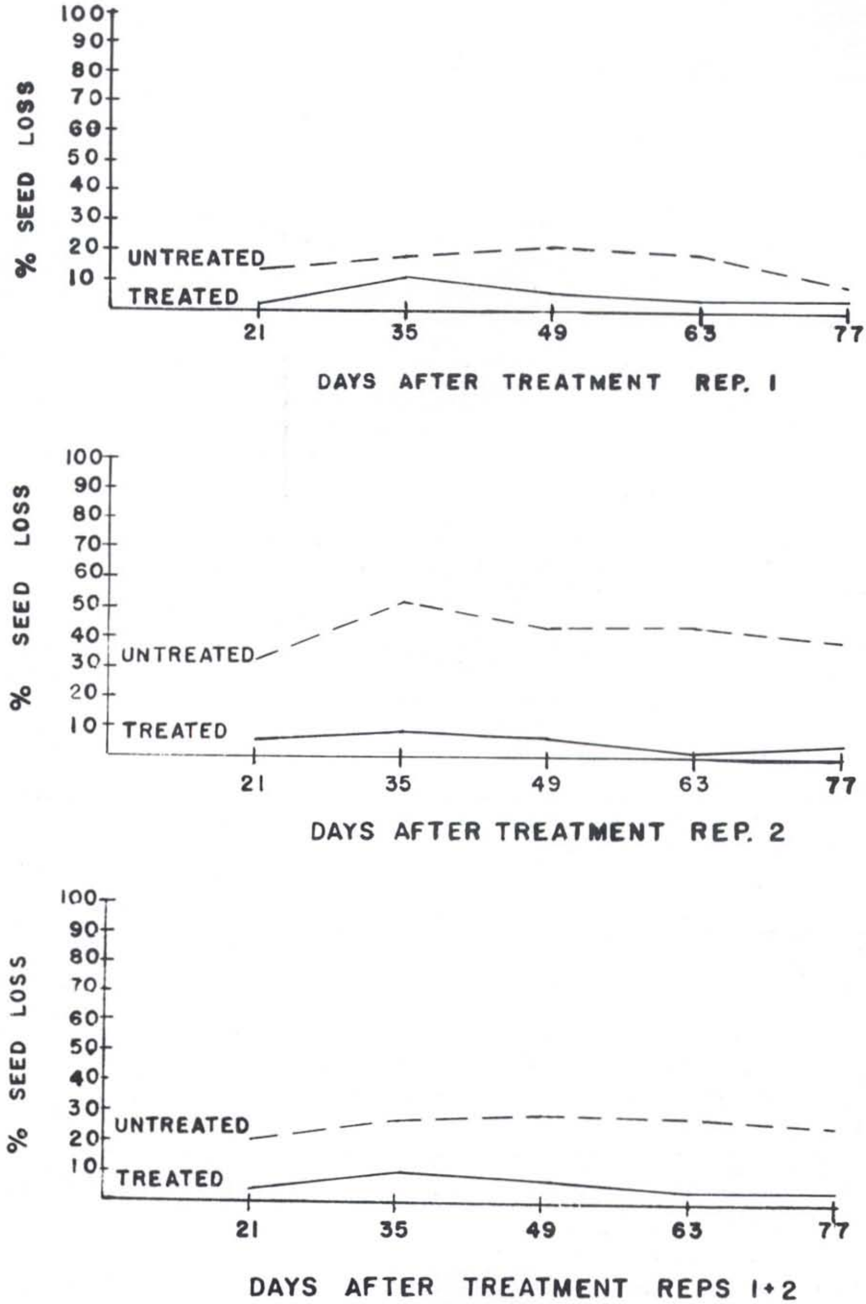

Fig. 1. Seed losses in untreated and treated Douglas-fir. Northern Idaho, 1964.

Table 5. **Proportion of damaged Douglas-fir seeds destroyed by Barbara colfaxiana (Kearf.) and Contarinia sp. in treated (T) and untreated (C) trees. Northern Idaho, 1964.**

Days After Trtmt.	Trt-ment	Total # Seed Damaged	Casual Agent		
			B. colfaxiana	Contarinia sp.	Other Insects
			percent	percent	percent
21	C	1052	46.7	44.1	9.2
	T	365	14.2	25.2	60.6
35	C	1423	43.2	50.3	6.5
	T	984	5.6	69.8	24.5
49	C	1328	50.4	43.8	5.8
	T	635	7.4	53.2	39.4
63	C	1312	42.7	46.2	11.1
	T	350	7.4	33.4	59.1
79	C	1185	28.0	50.0	22.0
	T	386	13.2	66.6	20.2

greater, particularly in the untreated trees. Losses from both the cone moth and the midge were reduced by the treatment, but *Contarinia* assumed a greater role as the cone moth population was reduced. The phenomenon is even more evident when seed loss data is presented as percent of damaged seed (Table 5), and is believed to be due to the application of the insecticide after gall formation (and seed destruction) was well advanced. Although examinations of the midge larvae were not made in all galls, "spot checks" in treated and untreated cones from each collection indicated complete mortality of the species in the treated cones, and resulted in an overall reduction in number of galls initiated and completed (Table 6). The effectiveness of the treatment in re-

Table 6. **Mortality of Barbara colfaxiana (Kearf.) and reduction in number of midge-galls in untreated (C) and treated (T) Douglas-fir trees. Northern Idaho, 1964.**

Days after trtmt.	Treat-ment	B. colfaxiana		Number of midge galls[b]
		Total # larvae[a]	Percent mortality	
21	C	40	0.0	747
	T	8**	100.0	507
35	C	29	13.8	760
	T	6**	100.0	696
49	C	38	13.2	577
	T	6**	67.7	339
63	C	32	12.5	618
	T	4**	75.0	117
79	C	23	4.3	592
	T	3**	0.0	257

[a]Significant differences between untreated and treated trees at 0.1 level.**
[b]Represents actual number of galls initiated, not number of seed destroyed by Contarinia sp.

ducing seed losses due to *B. colfaxiana* is shown graphically in Figure 2 in terms of percent available seed and in Figure 3 as percent damaged seed. Differences between replicates are apparent.

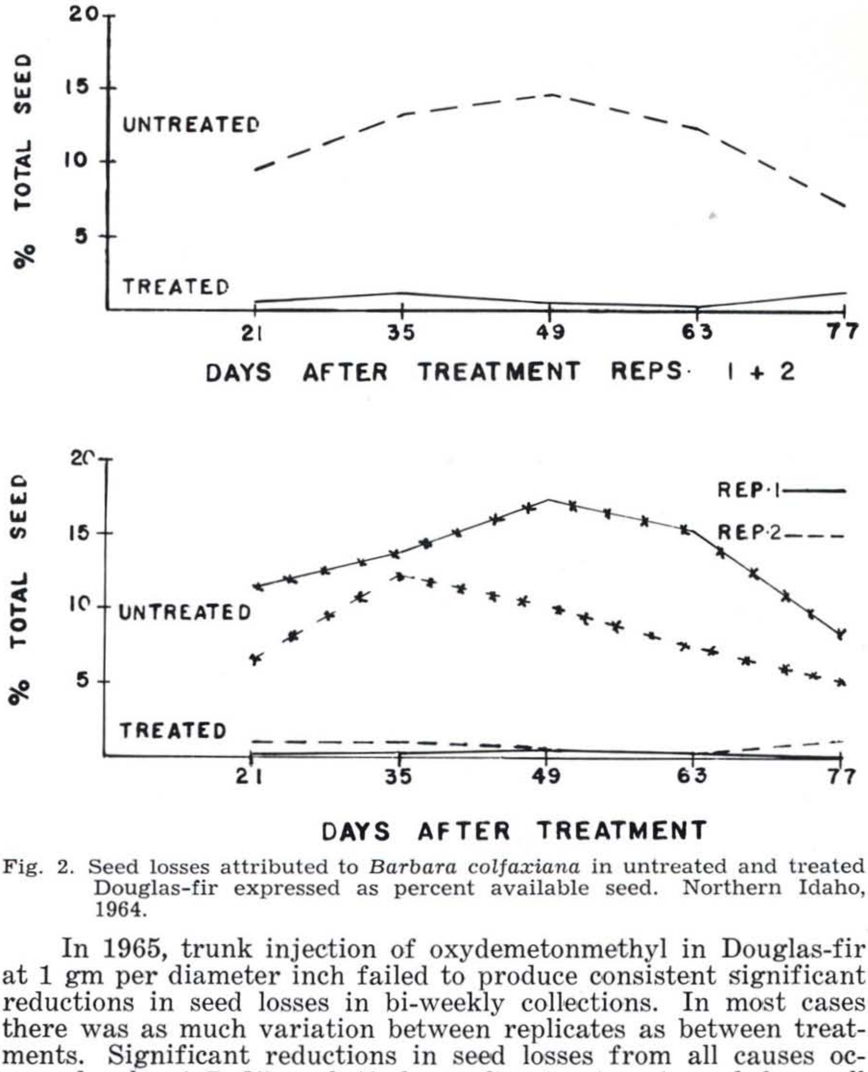

Fig. 2. Seed losses attributed to *Barbara colfaxiana* in untreated and treated Douglas-fir expressed as percent available seed. Northern Idaho, 1964.

In 1965, trunk injection of oxydemetonmethyl in Douglas-fir at 1 gm per diameter inch failed to produce consistent significant reductions in seed losses in bi-weekly collections. In most cases there was as much variation between replicates as between treatments. Significant reductions in seed losses from all causes occurred only at 7, 35, and 49 days after treatment; and from all insects only at 35 and 63 days after treatment. However, losses in the treated trees were slightly below those in the untreated trees at each examination date (Table 7, Figure 4).

Seed losses in 1965 were assigned to all causes, to each causal insect species, to all insect species, and to unknown causes (Table 7). Losses to *B. colfaxiana* (the major causal species) within single replicates ranged from 2.6 to 38.8 percent in the untreated and from 0.0 to 24.7 percent in the treated trees. Intensity of loss due to this insect species tended to increase from a minimum at 7 days after treatment (July 1) to a maximum at 35 days after treatment (July 29) in both untreated and treated trees. In contrast,

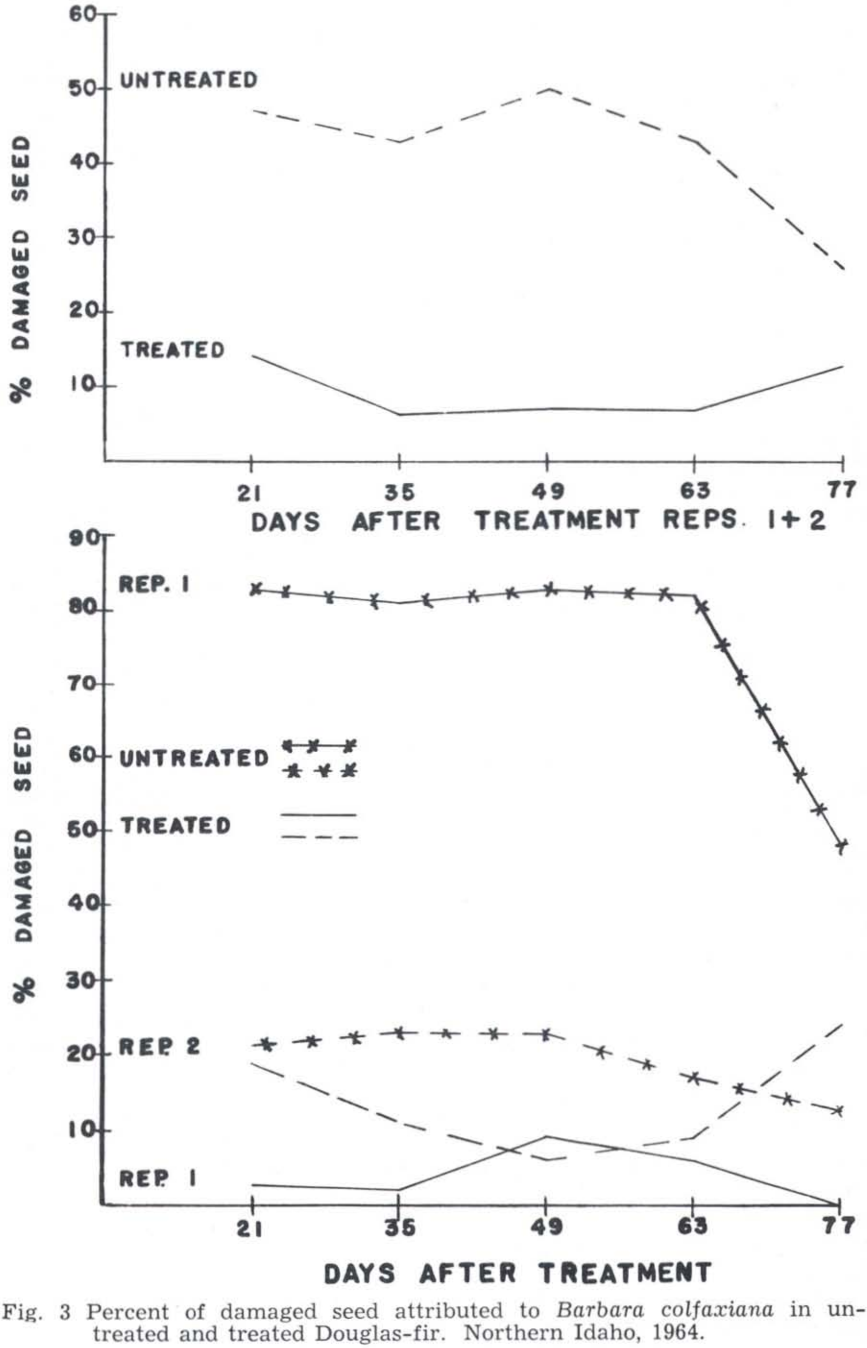

Fig. 3 Percent of damaged seed attributed to *Barbara colfaxiana* in untreated and treated Douglas-fir. Northern Idaho, 1964.

Table 7. Seed losses by casual agent on treated (T) and untreated (C) Douglas-fir based on sample seed counts. Northern Idaho, 1965. Asterisks indicate significance level between treated and untreated trees.

Days after trtmt.	Rep. & Trt.	% seed damaged	Percent of available seed lost due to casual agent: B. colfax.	D. abiet.	Contar-inia	M. spermo.	all insects	un-known
7	1 C	8.9	2.6	0.0	2.0	0.0	4.7	4.2
	2 C	11.8	7.3	0.0	0.0	0.0	8.2	3.6
	Average	10.3	4.9	0.0	1.1	0.0	6.4	3.9
	1 T	5.2	1.7	0.0	0.0	0.0	1.7	3.5
	2 T	7.2	5.1	0.0	0.0	0.0	5.1	2.1
	Average	6.2*	3.4	0.0	0.0	0.0	3.4	2.8
21	1 C	17.9	12.0	0.0	0.0	0.0	12.0	5.9
	2 C	38.0	30.4	0.2	0.0	0.4	31.4	6.6
	Average	27.2	20.5	0.1	0.0	0.2	21.0	6.2
	1 T	8.3	0.5	0.0	0.0	0.0	0.4	7.9
	2 T	34.1	24.7	0.0	0.0	0.6	25.5	8.6
	Average	20.5	11.8	0.0	0.0	0.3	12.2	8.3
35	1 C	22.4	8.5	1.6	0.5	2.5	15.3	7.1
	2 C	53.0	38.8	1.1	1.1	2.1	44.9	8.1
	Average	36.6	22.5	1.3	0.7	2.3	29.0	7.6
	1 T	7.9	0.9	1.8	0.0	0.0	2.6	5.3
	2 T	33.1	22.0	2.6	0.0	1.7	26.2	6.9
	Average	21.8**	12.5	2.2	0.0	0.9	15.7	6.1
49	1 C	57.5	13.0	9.2	2.0	2.7	27.7	29.8
	2 C	70.7	22.9	4.5	1.9	6.1	35.9	34.8
	Average	63.5	17.5	7.0	1.9	4.3	31.4	32.1
	1 T	29.6	0.0	0.3	3.3	0.0	3.6	26.0
	2 T	67.4	23.8	9.6	1.2	0.0	37.5	29.9
	Average	50.5**	13.1	5.4	2.2	0.0	22.3	28.2
63	1 C	69.7	11.3	4.5	5.2	7.5	29.4	40.3
	2 C	77.8	17.3	16.1	1.0	6.1	45.9	31.9
	Average	73.0	13.8	9.3	3.5	6.9	36.2	36.8
	1 T	67.4	0.0	2.1	0.4	1.4	3.9	63.5
	2 T	74.5	9.4	12.3	2.4	0.5	31.5	43.0
	Average	71.6	5.6	8.2	1.6	0.9	20.3	51.3

losses due to all causes increased with each collection period to mean maxima of 73 percent and 71.6 percent in the untreated and treated trees, respectively.

Another cone moth, *Dioryctria abietella,* was not observed until July 15 (21 days after treatment) when it was recorded in small numbers in occasional cones from untreated trees. Treated trees were not infested until July 29 (35 days after treatment). Losses in both the untreated and treated trees tended to increase to a maximum in late August (9.3 and 8.2 percent, respectively).

Galls of *Contarinia* sp. were first observed in untreated cones collected July 29, but not in treated cones until the collection of August 12. Losses from this species in the untreated trees tended to increase to a mean maximum of 3.5 percent in late August; whereas losses in the treated trees were maximal (2.2 percent) in mid-August. Seeds infested by *M. spermothrophus* were first recorded from both treated and untreated cones collected July 15. Seed losses due to this species were negligible in treated trees, but attained a mean maximum of 6.9 percent in the untreated trees.

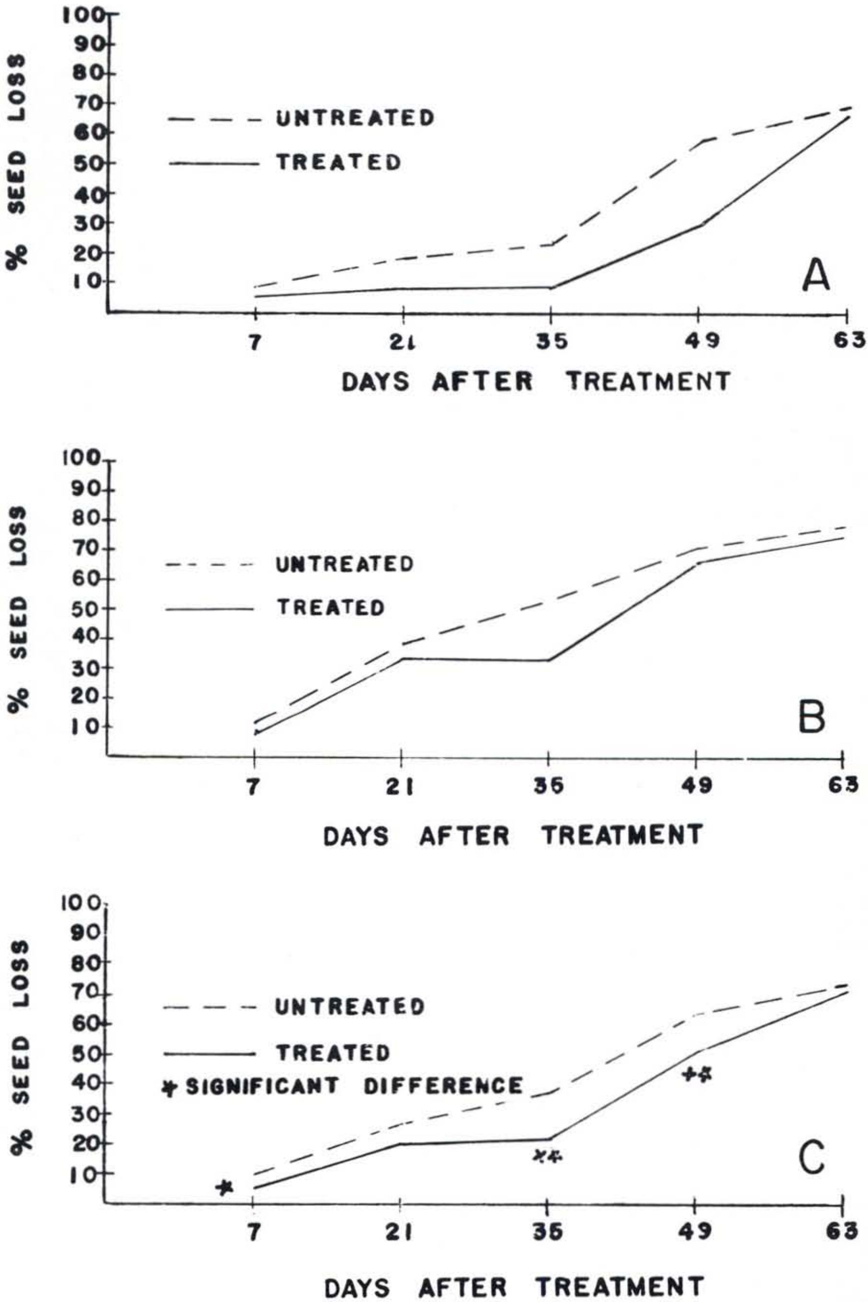

Fig. 4. Seed losses from all causes in untreated and treated Douglas-fir. Northern Idaho, 1965. A. Replicate 1; B. Replicate 2; C. Combined replicates.

Losses in the untreated trees from unknown causes ranged from an average of 3.9 to 36.8 percent of the available seed, while these losses in treated trees ranged from 2.8 to 51.3 percent (Table 7). The substantial increase in seed loss from unknown causes between the 35th and 49th days may be due, in part, to the increasing difficulty in distinguishing between causal agents late in the season.

Insufficient insect population in the western white pine treated in 1965 precluded statistical analysis; however, the data suggest that treatment of this tree species at 1 gm per diameter inch did not effect control of either the cone beetle, *Conophthorus monticolae* Hopk., or the cone moth, *Eucosma rescissoriana* Hein.

Insect mortality. In 1964, highly significant differences in mortality of *B. colfaxiana* were obtained between the untreated and treated cones of Douglas-fir (Table 6). There also were substantially fewer larvae of this species recovered from the treated than from the untreated cones, probably due to the rapid disintegration of the small early-instar larvae killed by the insecticide. Sample counts of dead and living midge larvae (*Contarinia* sp.) within the galls indicated that mortality of this species also was very high, which was reflected in the substantially fewer galls produced in the treated cones. The effectiveness of the treatment on other insect species could not be statistically determined; however, it was apparent that little or no control of the seed chalcid, *M. spermothrophus,* or the cone moth, *D. abietella,* was achieved. In the latter case, the reason may be the appearance of the insect after maximum effectiveness of the insecticide (late July). The parasitic species associated with *B. colfaxiana* also were adversely affected, with consistently fewer species and individuals emerging from treated than untreated cones placed in rearing.

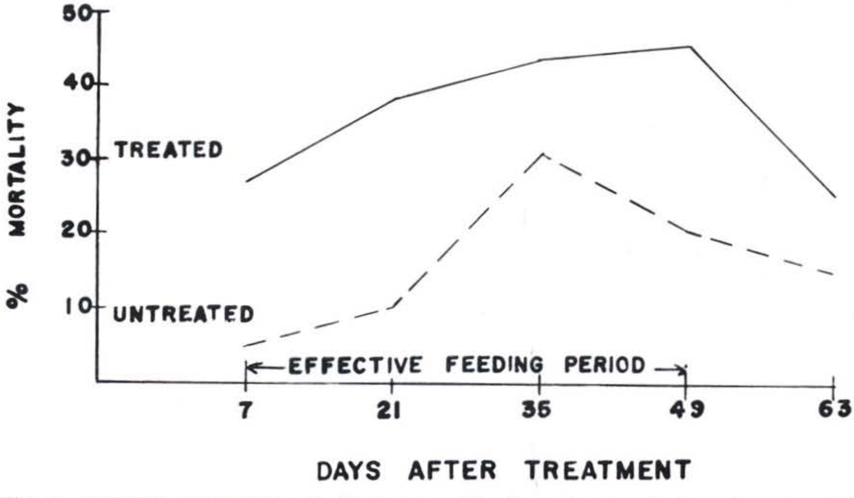

Fig. 5. Percent mortality of *Barbara colfaxiana* in treated and untreated Douglas-fir cones. Northern Idaho, 1965.

The results of the 1965 treatment were not as conclusive as those of 1964, primarily because of insufficient data due to extremely low insect populations and to the reduced dosage of systemic. Significant differences in percent mortality of *B. colfaxiana* occurred only in the first and second cone collections, 7 and 21 days after treatment, respectively; however, there was lower mortality recorded at each collection date in the untreated cones (Figure 5). The seed chalcid and the gall midges were not killed by the low dosage, although there were fewer midges recovered from the cones of treated trees in all collections. Data on parasite emergence were insufficient.

Seed germination and seedling growth. Germination percentages of treated and untreated seed were virtually identical. Of the 450 seeds sown in each treatment, 74 percent of the treated and 75 percent of the untreated seed successfully germinated. The elimination of empty seeds and the relatively small sample may have been influential in the uniformity of germination obtained.

Seedlings were carefully examined twice-weekly, and weekly height measurements were taken for the first two months. They were examined and measured once a month thereafter. In mid-May, when germination was almost complete, the flats were set out in dappled shade under field conditions. No abnormalities of color or growth pattern were observed. Seedling development was followed through two growing seasons and then terminated.

Mammalian toxicity. No differences in general conditions, behavior, mortality, fecundity, or survival of young were recorded between either deer mice or white mice fed treated cones and those fed only untreated food. Continuous contact with "contaminated" material in the cages also had no adverse effect. Dermal toxicity tests were discontinued after extreme variability in effects occurred with weight, age, and condition of the treated animals. The deer mice, however, were less affected than the white mice.

Summary and Discussion

Introduction of a systemic insecticide into the trunks of Douglas-fir by means of "Mauget Tree-Injector Units" was proved feasible. Injections of oxydemetonmethyl at 24 gms per tree (ca 2 gms per diameter inch) significantly reduced insect-caused seed losses in open-growing, pole-sized trees in 1964. Percent seed losses in treated trees averaged approximately one-fifth the losses in untreated trees. In 1965, injection of the systemic at 1 gm per diameter inch failed to produce consistent, significant reductions in seed losses; however, losses in the treated trees were slightly less than those in the untreated trees at each examination date.

Highly significant differences in mortality of *Barbara colfaxiana* were obtained between untreated and treated cones in 1964. Sample counts of dead and living midge (*Contarinia* sp.) larvae within the galls indicated that mortality of this species also was very high, and was reflected in the substantially fewer galls produced in the treated cones. The effectiveness of the 1964 treatment on other insect species could not be statisictally determined due to low population numbers; however, little or no control of the seed chalcid, *Megastigmus spermotrophus*, or of the cone moth, *Dioryctria abietella*, was achieved. With the reduced dosage in 1965, significant differences in percent mortality of *B. colfaxiana* occurred in only two collections, although there was lower mortality in the untreated cones at each collection date.

Oxydemetonmethyl at either dosage did not produce discernible phytotoxic symptoms in treated Douglas-fir, did not affect geminative capacity, and had no apparent effect on seedling growth or development. Test colonies of white mice and deer mice fed treated cones showed no difference in behavior, fecundity, and survival of young from those colonies fed untreated material.

It is believed that an experienced, 2-man crew, using an efficient carrying device for the insecticide-filled injector units, could reduce treatment time substantially below the 8.75 minutes per tree required in this study. Units of larger capacity also would be advantageous, particularly in the treatment of large diameter trees. Excessive displacement of the tube during insertion, or positioning of the unit on the tube, may result in the loss of insecticide externally. Some leakage of insecticide from the injector units occurred during storage and handling. Subsequent modifications in unit construction by the manufacturer may have eliminated this problem.

Although more detailed investigation of the effects of different dosages of oxydemetonmethyl on the tree and its seed, and on the various insect species contributing to seed loss in Douglas-fir would be desirable, the results of this study show the feasibility and effectiveness of "selective treatment" by use of trunk-injected systemics. If only genetically superior cone bearing trees in a seed production area or forest stand were treated, the impact of the cone and seed insects could be utilized to establish a more productive stand by destroying seed (reproduction) from inferior trees. This practice would be less costly than broadcast application and less distrupting to the faunal ecology. Returns from marketable material and increased yield might further justify the practice if it was done in conjunction with commercial thinings or sanitation cuts.

Acknowledgements

The authors express their appreciation to Chemagro Corporation, Kansas City, Missouri, for supplying the test insecticide and the injector apparatus. We are also indebted to Dr. Jack Warren, Chemagro Technical Representative, and Dr. Dale O. Everson, Professor and Statistician, Idaho Agricultural Experiment Station, Moscow, for their assistance in planning and data analyses. The field and laboratory assistance of Mr. G. B. Hewitt and Mr. J. R. Gosz is acknowledged.

Literature Cited

1. Beckman, C. H. and J. E. Kuntz. 1951. Translocation of poisons, dyes and radioiodine and its relation to oak wilt. Phytopath. 41:2-3.

2. Ferrell, W. K., F. D. Johnson, and C. E. Michelsen. 1960. Movement and distribution of radiophosphorous in crowns of healthy and pole-blighted western white pine (*Pinus monticola* Dougl.). Plant Physiol. 35:414-417.

3. Ferri, M. G. 1945. Preliminary observations on the translocation of synthetic growth substances. Contr. Boyce Thompson Inst. 14:51-68.

4. Fraser, D. A. and C. A. Mawson. 1953. Movement of radioactive isotopes in yellow birch and white pine as detected with a portable scintillation counter. Canad. Jour. Bot. 31:324-333.

5. Giese, R. L., D. M. Benjamin, and J. E. Casida. 1958. Results of trunk implantation of systemic insecticides. Jour. Econ. Ent. 51:400-401.

6. Johnson, N. E. and J. H. Rediske. 1964. Tests of systemic insecticides for the control of the Douglas-fir cone midge, *Contarinia oregonensis* Foote. Weyerhauser Co. For. Res. Note 56. 13 pp.

7. Kinghorn, J. M. 1955. Chemical control of the mountain pine beetle and Douglas-fir beetle. Jour. Econ. Ent. 48:501-504.

8. Leedy, D. L. 1959. Pesticide-wildlife problems and research needs. 24th Trans. N. Amer. Wildlife Conf. Washington, D.C. :158-165.

9. Moreland, D. E. 1950. A study of the translocation of radioactive phosphorous in loblolly pine (*Pinus taeda* L.). Jour. Elisha Mitchell Sci. Soc. 66: 178-181.

10. Rudd, R. L. 1964. Pesticides and the living landscape. Univ. Wis. Press. Madison. 320 pp.

11. ———— and R. E. Genelly. 1956. Pesticides: Their use and toxicity in relation to wildlife. Calif. Dept. Fish and Game. Game Bull. 7. 209 pp.

12. Vite', J. P. 1955. Der Versuch einer gleichzietigen Bekampfung von Larchenblasenfub und larchenminiermotte, seine Grundlagen und Aussichten. Hofchen-Briefe, Bayer-Phlanzenschutz-Nachr. 8:35-53.

13 ————. 1956. Weitre Versuche zur Bekampfung von Forstschädlingen mit dem Einbandverfarhen. Anz. schadlingsk 29:11.

14. ————. 1957. Trial controls of larch insects by injecting trees with systemic insecticides. Hofchen-Briefe, Bayer-Pflanzenschutz-Nachr. 10:-61-94.

15. ———— and J. A. Rudinsky. 1959. The water conducting systems in conifers and their importance to the distribution of trunk-injected chemicals. Contrib. Boyce Thompson Inst. 20:27-38.

16. Wachtendorf, W. 1954. Uber die Einsatzmöglichkeiten innertherapeutischer Präparate im Forstschutz. Anz. schadlingsk 27:116-167.

17. Wedding, R. T. 1953. Plant physiological aspects of the use of systemic insecticides. Jour. Agri. Food Chem. 1:832-834.