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INJURY TO ALDRIN-TREATED AND UNTREATED RED PINE BY WHITE GRUBS (COLEOPTERA: SCARABAEIDAE) AND OTHER AGENTS DURING FIRST FIVE YEARS AFTER PLANTING

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Freshly planted red pine (*Pinus resinosa* Ait.) seedlings are vulnerable to injury by several agents. White grubs–the larvae of May beetles (*Phyllophaga* spp.)–are among these agents and sometimes must be controlled in areas scheduled for pine planting. A study was begun in 1967 to evaluate the effectiveness of applying three levels of aldrin for controlling white grubs in the Upper Peninsula of Michigan. After two years white grubs were satisfactorily suppressed by the three treatments tested (Fowler and Wilson 1971a). Reported here is a continuation of that study for five years following planting. We wanted to learn the effect of the aldrin treatments on the subsequent growth and survival of young red pine trees and to what extent white grubs and other agents injured or killed the red pine during the five years after treatment.

METHODS

Five white grub-infested areas were selected for planting and aldrin tests in the Hiawatha National Forest in Upper Michigan. These areas were machine-planted in the spring of 1967 with bed-run 3-0 red pine seedlings or 2-1 red pine transplants. Four of the research areas were suitable for red pine growth based on soil types and pH levels (Fowells, 1965). They also satisfied the requirements for white grubs in terms of soil types (Graham, 1958), soil pH (Hammond, 1948), and availability of adult and larval host vegetation (Graham, 1958). These four areas, designated Raco, Townhall, Townline Lake, and Bird, were observed for a five year period; the fifth area was abandoned because of low grub populations.

A randomized complete block design, replicated five times in each test planting, was used to evaluate the aldrin treatments. Each of the four treatments in a block included 15 trees in six adjacent rows or 90 trees per block (Fig. 1). The treatments were as follows:

Treatment 1–Aldrin solution applied with a dispenser attached to the planting machine (aldrin-machine).

Treatment 2–Aldrin solution applied with a backpack pump and wand (aldrin-pump).

Treatment 3–Granular aldrin applied with a dispenser attached to the planting machine (aldrin-granular).

Treatment 4–Check plots (untreated).

Each seedling was spot treated. Details of the equipment and application methods have been reported by Fowler and Wilson (1971a). Liquid aldrin concentrations varied from 0.3 to 1.2% and the dosage rates from 8.8 to 11.3 ml. per seedling. Granular aldrin was applied at 9.3 gm. per seedling (Table 1).

The plots were examined in the autumn of 1967 and 1968 and each spring (late May and early June) from 1968 to 1972. All dead seedlings were excavated and examined for white grub root feeding and other causes of death. In the autumn of 1967 and again in 1968, eight to ten living seedlings per plot were randomly selected, dug, roots examined,

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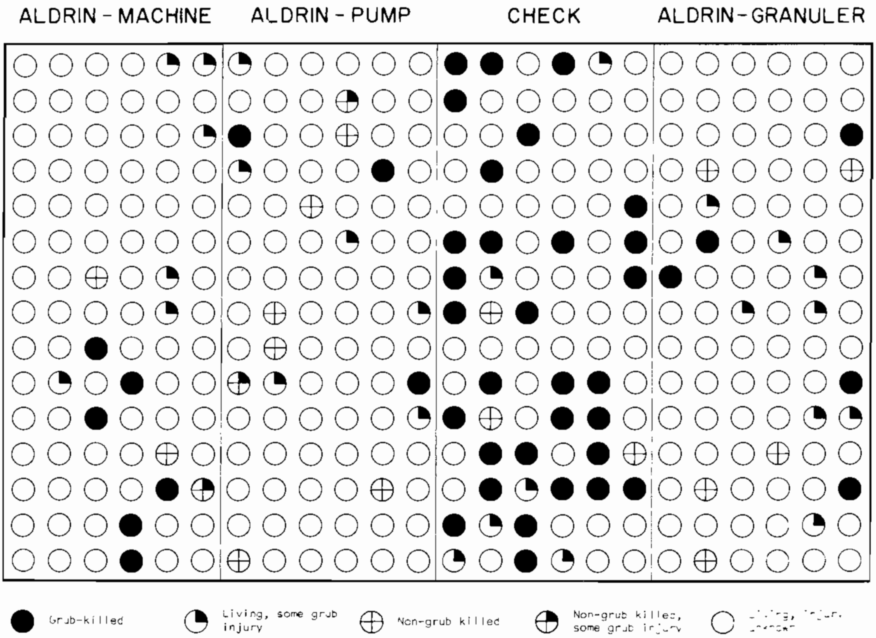

Fig. 1. Schematic diagram of typical plots showing location of seedlings with injury from white grubs and other causes. Data presented from Block II at Townline Lake plantation 5 years after planting. (Irregularities in planting and spaces are omitted.)

Table 1. Dosage rate of aldrin applied per seedling per plantation, based on 1% solutions and 20% granulars.*

Study area	Liquid		Granular
	Machine	Pump	
	ml.	*ml.*	*gm.*
Raco	13.7	10.6	9.3
Townhall	13.7	10.6	9.3
Townline Lake	5.8	4.6	9.3
Bird	5.8	3.7	9.3

*From Fowler and Wilson (1971a).

Table 2. White grub (*Phyllophaga* spp.) populations and feeding indexes for all research study areas.

Study area	1968		1971	
	Number grubs	Feeding index	Number grubs	Feeding index
Raco	11	70	3	16
Townhall	36	122	16	116
Townline Lake	40	218	26	155
Bird	7	26	2	16

and inspected for other potential causes of mortality. The root damage from grubs was visually scored one to five, depending on the degree of injury. Scoring criteria have been defined by Fowler and Wilson (1971b). Seriously damaged seedlings dug alive were considered as dead in analysis. Most of these were off-color or stunted or both. Past experience indicated such unhealthy trees would soon die.

Terminal shoot growth was measured after the first, second, and fifth growing seasons and tree height after the fifth growing season (spring 1972) on living seedlings as an indicator of sublethal injury.

White grub populations were sampled by examining thirty 1-cubic-foot soil samples in each research area as described by Fowler and Wilson (1971b). Larval instars were determined, and feeding indexes computed by the formula: $FI = (N_1 + 2N_2 + 4N_3 + 8N_4)$ where FI is the feeding index and N_1, N_2, etc., are the numbers of larvae in instars 1, 2, etc.

MORTALITY FROM WHITE GRUBS

The highest seedling mortality from white grubs occurred in the period between the first and second years—from May 1968 to June 1969 in all of the test plantings (Fig. 2). Mortality occurred in most aldrin treated plots but was highest in the untreated plots. After the third year, mortality leveled off in all plots. Few seedlings were killed after three years, even though the grub populations and feeding indexes (Table 2) were high enough to cause serious damage (Fowler and Wilson, 1971b).

In the aldrin-treated plots, white grubs killed some seedlings, but in general significant control was accomplished early in the study and remained effective throughout the five year period. We thought the seedlings might become more susceptible to attack in the year following treatment as the roots grew out of the chemically treated zone, but this was not the case. The aldrin-treated plots lost 6% or less of their seedlings to white grubs after five years, the only exceptions were the machine-treated plots at the Townline Lake and Bird Areas, which suffered losses of 16 and 13%, respectively. These higher mortalities were expected because these plots received less than one-half the amount of aldrin that the machine-treated plots in the other two areas received due to misformulation and miscalibration of the dosages (Fowler and Wilson, 1971a). Even so, the untreated Townline Lake and Bird Area plots had considerably more grub-caused mortality than the treated ones—an average of 25% for the four areas during the five year period.

MORTALITY FROM OTHER CAUSES

Several agents other than white grubs killed seedlings during the five year study period. Definitive nongrub mortality occurred each year at all locations (Fig. 3); by the end of the fifth year it varied from 11 to about 18% per area. Out of 7,200 seedlings in all plots and areas, 967 or 13% died strictly from nongrub causes. Most mortality occurred between the first and second years, the same period when grub-caused mortality occurred.

Seedling mortality was not always a clear-cut grub-caused or nongrub-caused situation. Of the 1,206 dead seedlings examined, 20% were clearly grub killed and 53% were clearly killed from other agents. But, the remaining 27% had grub-injured roots and injury from other agents simultaneously, either of which were capable of causing mortality (Fig. 3).

Agents other than white grubs causing mortality are listed in Table 3. Scleroderris canker (*Scleroderris lagerbergii* Gremmen) was the most important disease observed. It destroyed about 7% of the seedlings by 1972, mostly in the Raco Area. This diesase was identified by the characteristic yellow-green discoloration beneath the bark. Specimens examined by a forest pathologist indicated that our field identification was more than 95% accurate.

Canker-like damage was observed on 6% of the dead seedlings, especially on the 3-0 stock. Because no fungus was observed it could possibly have been mechanical injury from handling the seedlings. Most of this mortality occurred the year after planting. This canker was also found on some living seedlings.

Armillaria root rot (*Armillaria mellea* (Vahl ex Fr.) Kummer) killed 2% of the seedlings, mostly at Townline Lake where hardwoods were abundant. We identified this disease by its distinctive white mycelial mat under the bark at the ground line.

About 2% of the dead seedlings at three locations had a fine, irregular, discolored line completely encircling the stem just above the ground line. This "cambial ring" was usually blue, but a few were pink or brown. Forest pathologists could not identify it as a pathogen, but suggested it may be due to high temperature near the soil surface.

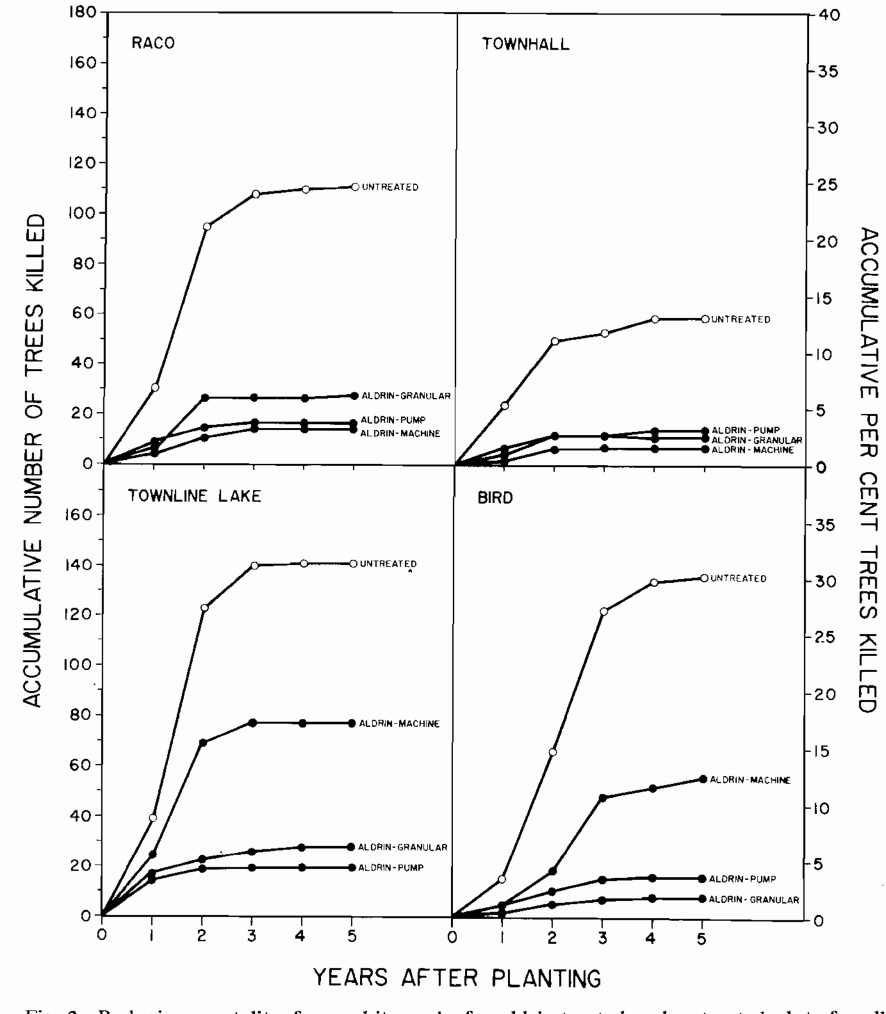

Fig. 2. Red pine mortality from white grubs for aldrin-treated and untreated plots for all research areas.

During the first and second winters, snow breakage of the main stem occurred on 3% of the seedlings. After the second year some branch breakage occurred from snow, but it caused little seedling mortality.

J-rooting caused by inadequately excavating a hole for the tree when it was planted was found on nearly 33% of the seedlings that died, and of these 66% showed no other evidence of injury. Most J-rooting of 3-0 stock occurred in the field at planting; however, serious J-rooting of 2-1 stock occurred both in the nursery and during field planting. Seedlings planted deep, i.e., root collar buried 1 or more inches below the soil surface, were frequently J-rooted because their roots were forced into a horizontal position on the bottom of the trench during planting. Although deep planting has been shown to be beneficial to red pine survival (Mullin, 1964), white grubs killed more J-rooted seedlings than those with roots spread out, because the rootlets are readily accessible to the insect.

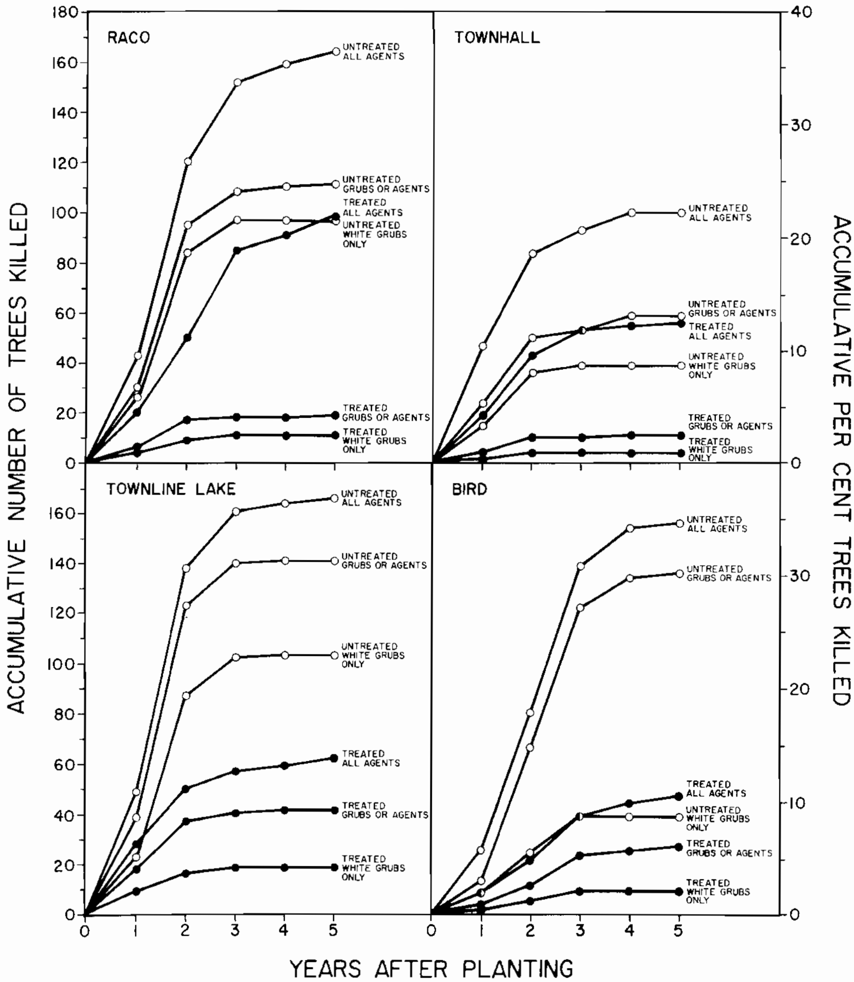

Fig. 3. Red pine mortality from white grubs and other agents for aldrin-treated and untreated plots for all research areas. *All agents* refers to mortality from all causes including white grubs; *grubs or agents* refers to seedlings having white grubs and another agent simultaneously—either of which, were capable of mortality; and *white grubs only* refers to mortality from just *Phyllophaga.*

A few seedlings also apparently died from shallow planting.

Of the mortality not caused by grubs, 40% was due to other, mostly unknown, causes (Table 3). Animals, especially deer, severed a few seedlings in the Townline Lake and Bird Areas shortly after planting. Seedlings sometimes vanished from the plots between examination periods, and deer may have nipped these, too. Trees that were smaller than those usually recommended for planting size often died for undetermined reasons. Some seedlings apparently died from competition; weeds choked out a few while others became sodbound when the lay of the furrow fell back against the seedlings at planting time. Other seedlings died from no apparent causes.

Table 3. Red pine mortality from agents other than white grubs 1967-1972.

Agent	Dead Trees at:				Total	
	Raco	Townhall	Townline Lake	Bird		
	Number					Percent
Scleroderris canker	59	7	1	5	72	7
Unknown canker	24	19	13	4	60	6
Armillaria root rot	2	1	13	1	17	2
Cambial ring	4	6	5	3	18	2
Snowbreak	8	9	4	11	32	3
J-root	83	51	38	142	314	33
Planting depth	24	19	15	6	64	7
Other*	126	103	104	57	390	40
TOTAL	330	215	193	229	967	100

*Includes trees missing, animal nip, competition, sub-standard planting size, and unknown causes.

Stem aphids were observed on a few seedlings in all but the Townhall Area. These aphids were as common in treated as in untreated plots. At Raco, however, root aphids were observed only in the untreated plots; those in the treated plots were probably killed by aldrin. No seedling mortality was ascribed to aphids.

SEEDLING GROWTH

Aldrin-treated seedlings were significantly taller and had longer terminals ($P > 0.05$) than untreated seedlings 5 years after planting (Table 4). The treated seedlings averaged 3

Table 4. Seedling height and terminal length in 1972 for all treatments and research study areas.

Study area	Treatment			
	Aldrin-machine	Aldrin-pump	Aldrin-granular	Untreated
	Height in feet			
Raco	1.9	1.8	1.8*	1.5
Townhall	2.5	2.4	2.8*	2.0
Townline Lake	2.4*	2.2	2.3	1.9
Bird	2.0*	2.1*	2.2*	1.8*
Mean	2.2	2.1	2.5	1.8
	Terminal Length in inches			
Raco	5.8	5.4	6.3*	3.8
Townhall	7.9	7.3	9.8*	6.1
Townline Lake	8.3*	7.5	8.1	6.0
Bird	7.5*	8.3*	9.6*	6.2*
Mean	7.4	7.1	8.5	5.5

*2-1 stock. All other stock is 3-0. 2-1 stock averaged 0.5 foot and 3-0 stock averaged 0.7 foot at time of planting.

to 7 inches taller than the untreated ones, an increase of nearly 25%. The treated 2-1 transplants averaged slightly greater height and longer terminals than treated 3-0 stock in all cases except for the seedlings at Raco. In the Bird Area, where all 2-1 stock was used, seedlings treated with granular aldrin were taller and had longer terminals than those treated with liquid aldrin.

We thought that aldrin may have stimulated growth. Simkover and Shenefelt (1952) showed that chlordane (up to 50 pounds per acre) benefited growth by causing root elongation. Shenefelt *et al.* (1961) used liquid aldrin (e.c.), and suggested it may also act as a root simulant for red pine, eventually increasing vigor and height growth. However, Lane and Shearin (1972) applied granular aldrin around loblolly pine seedlings and found no increase in height growth. We are not able to tell if aldrin stimulated growth in this study, and thus have assumed for the most part that differences in height between aldrin-treated seedlings and the untreated ones have been due to injury by white grubs.

DISCUSSION

White grubs are often blamed for pine seedling mortality following planting in old fields. White grubs do cause significant mortality and loss of vigor, but diseases, planting practices, and other agents accounted for more than half of the seedling mortality especially during the first three years after planting. Also seedling mortality is not just a white grub-caused versus nongrub-caused situation. Some seedlings that were severely grub injured showed evidence of damage by other agents which in the absence of grubs would have died anyway. Nevertheless the three aldrin treatments tested, which were equally effective in alleviating mortality by white grubs (Fowler and Wilson, 1971a), reduced white grub-caused mortality by 83% and surviving seedlings attained greater vigor than untreated seedlings. Whether this increased vigor, measured as a growth differential, is biologically significant must yet be determined. Perhaps differences will be more evident at thinning or harvesting time. It is certain, however, that some of the untreated seedlings still living at the end of the test will never reach merchantable size as they had not grown appreciably since they were planted. Many were seriously root damaged from white grubs, and for all practical purposes should be considered dead.

Aldrin had no obvious effect on the nongrub agents in this study because mortality from other causes was as great or greater in the aldrin-treated plots as in the untreated plots. Also, there was no evidence of a phytotoxic effect of aldrin on the red pine seedlings. This is not surprising because Simkover and Shenefelt (1952) reported no phytotoxic symptoms on red pine at a dosage rate of ten pounds of aldrin per tree.

Scleroderris canker and J-rooting were the predominant nongrub agents injurious to the seedlings. Although the trees outgrew most of the problem agents after three years, Scleroderris remains a potential threat because it readily attacks young saplings and most likely would cause additional mortality in the future. However, J-rooting might be lessened in future plantings by modifying existing planting practices.

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