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PROJECTED RED PINE YIELDS FROM ALDRIN-TREATED AND UNTREATED STANDS DAMAGED BY WHITE GRUB (COLEOPTERA: SCARABAEIDAE) AND OTHER AGENTS AT STAND AGE TEN YEARS

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ABSTRACT

White grubs affect pine plantations by killing some trees and by reducing vigor and growth of others. Light to moderate mortality only slightly affects timber yields and financial returns if the level of trees remains at the number required for full utilization of the site. Reduced height growth, however, lowers apparent site quality and substantially affects yields and financial returns. The 10-year projections suggest that greater product volumes, financial returns, and higher interest rates on the investment will be gained by grub control before tree growth is reduced.

During the first few years after planting, red pines, *Pinus resinosa* Ait., are vulnerable to several injurious agents including white grubs, the larvae of May beetles, *Phyllophaga* spp. (Kittredge 1929). To protect seedlings from white grubs, more than 12,000 acres of National Forest land in the Lake States were treated with aldrin.[3] Almost 10,000 of these acres were on the Hiawatha National Forest in Michigan (Fowler 1973).

To assess white grub injury and to determine the effectiveness of different aldrin treatments on white grub populations, studies were begun on the Hiawatha National Forest in 196". White grubs killed many trees and suppressed others in the research areas. More than half of the total tree mortalty during the first five years after planting, however, was attributed to disease organisms, improper planting practices, and other agents (Fowler and Wilson 1971a, 1974). The overall impact of the white grubs and other agents was assessed and then growth and yield projections of the red pine were made after five years (Fowler and Wilson 1975). Growth and yield projection made from the trees after 10 years are presented here; direct comparisons to the five-year projections are not possible due to changes made in some of the assumptions in the 10-year growth and yield program projections.

MATERIALS AND METHODS

Four white grub infested research areas (designated Bird, Raco, Townhall, and Townline Lake) were machine-planted with 3-0 and 2-1 nursery stock red pine in 1967 on the Hiawatha National Forest. Because terrain and obstacles differed, initial tree stocking ranged from 450 to 1037 trees per acre in the four study plantations. The Townline Lake area had the lowest stocking because it was a conversion of a poorly stocked hardwood stand.

Three aldrin treatments were evaluated by using a randomized complete block design replicated five times in each planting. Aldrin was applied both as a liquid solution and as a granular formulation by a dispenser on the planting machines, and as a liquid solution with a

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[3]This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registerd by appropriate state or federal agencies before they can be recommended.

backpack pump and wand. Further details of the results of the tests are found in Fowler and Wilson (1971b, 1974).

For the first three years after planting, the trees were monitored for height growth, causes of injury, and mortality. Height growth and mortality of the pines were also measured in the research plots after five years, and then growth and yield projections were made from the five-year data. After the 10th growing season, tree height and mortality were again recorded for all trees in all study plots. Site index values were calculated from the height of three dominant or codominant trees from each plot. Growth and yield projections were then made from 10-year data. The Raco granular aldrin treatment was excluded from the 10-year projections because of heavy mortality from Scleroderris canker, *Gremmeniella abietina*.

GROWTH AND YIELD PROGRAM

Growth and yield volumes and values for the study plantings were projected by using a computer program called REDPINE.[4] The management provisions in the Timber Management Plan of the Hiawatha Natinal Forest were used in the projections. Basic inputs to the program included (1) nature of each stand (new plantations); (2) site index of each stand (from Table 1); (3) age of trees at the time of establishment (3 years at planting); and (4) number of trees an acre alive at 10 years after planting (from Table 2).

At the start, all plantations were considered to be age 0 and the planting stock to be age 3. Projections were made at five-year intervals, from stand-age 0 to rotation-age 120 years. The stands were thinned to 90 square feet basal area, beginning at age 30 when possible, and every 10 years thereafter to age 100. Final harvest was made at age 120. The model assumes a varying distribution of tree diameters within the stand (Lundgren 1981).

Cubic-foot volume is the total stem volume under bark, not limited by a merchantable top. Board foot volume is the volume of sawtimber in trees 9.0 inches d.b.h. and larger using the International 0.25-inch rule. Cordwood volume includes all merchantable volume in trees 5.0 to 9.0 inches d.b.h.

White grubs and most other injurious agents kill trees in a contagious distribution and not randomly, usually resulting in distinct pockets of dead trees. The dead trees, however, were not sufficiently clumped in the study plots to cause concern, and we assumed that the little uneven distribution would be evened out during early thinings.

The economic analysis of the alternative treatments was made using the investment analysis program RETURN (Lundgren and Schweitzer 1971, Schweitzer et al. 1967). Assumed planting costs were $94 per acre direct and $38 per acre indirect. Sales administration costs were $0.0029 per cubic foot harvested. The costs of the chemical and application were not included in the basic inputs into the computer program. Cost of the chemical was less than $1 per acre, and except for occasional filling of the dispensing apparatus in the planting machine, no extra time or effort was expended in applying the chemical when the granular aldrin was used. Liquid applications added to the cost.

Stumpage values of expected products used were $20 per thousand board feet (MBF) for sawtimber. Cordwood values were $5 per cord for Townhall and Raco and $7.92 per cord for Bird and Townline Lake. These are 1975 values used to keep the five-year and 10-year projections similar.

The Internal Rate of Return (IRR) was computed for each stand for a wide range of rotation ages. The IRR is a measure frequently used to indicate when a stand should be harvested in order to maximize financial returns. It is the rate of interest earned over an investment period on all invested capital and the rate of interest that would make the sum of all compounded costs equal to the sum of all compounded incomes (Lundgren 1966).

[4]Developed by A. L. Lundgren. The computer program, not yet published, is based on growth and yield equations developed by Buckman (1962) and Wambach (1967). The growth model is briefly described by Lundgren (1981).

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RESULTS AND DISCUSSION

Site index values calculated from 10-year heights differed somewhat from the five-year values, which were estimated from soil characteristics alone because of small tree size (Table 1). Site index values were reasonably close between the five- and 10-year data for Bird and Townhall, but the five-year indexes for Raco and Townline Lake appeared to overestimate the site. Also, mean 10-year site index calculations from the aldrin-treated plots were consistently and significantly ($P < 0.05$) higher than those from the untreated plots. The significantly higher index values and taller trees in the treated plots suggest that the aldrin affected the outcome. We know that aldrin killed many of the grubs and thus lessened root injury in the treated areas. The response from this lessened injury apparently is greater height growth. Also, site indexes calculated for the aldrin-treated plots would thus be the most realistic for each research area as height growth of trees in the untreated plots is affected by grub feeding injury.

Between the fifth and 10th years, tree mortality averaged 1–11% in the aldrin-treated plots and 2–12% in the untreated plots (Table 2). One aldrin-treated plot at Raco, which was eliminated from analysis, had 17% mortality but most of that was caused by Scleroderris canker. No mortality between the fifth and 10th years was attributed to white grub feeding as we had predicted previously (Fowler and Wilson 1975). A few trees weakened by grubs during the first five years may have died during the latter period, but as losses were proportionately the same for treated and untreated plots, the effect from grubs must have been small.

Table 1. Five- and 10-year site index values for aldrin-treated and untreated plots for white grub research areas, Hiawatha National Forest.

Research area	Site index[a] 5th year	Site index[b] 10th year	
	Treated and untreated plots	Treated plots	Untreated plots
Bird	55	59	51
Raco	55	46	39
Townhall	65	70	61
Townline Lake	65	58	53

[a]Estimated by soil characteristics of each research area.
[b]Calculated from height of three dominant or codominant trees in each lot. Treatments were pooled because there were no significant differences in tree heights among treatments.

Table 2. Mean number of trees per acre for aldrin-treated and untreated plots for white grub research areas at plantation ages 5 and 10 years.

Research area	Trees per acre (treated)		Percent loss	Tress per acre (untreated)		Percent loss
	5 yrs	10 yrs		5 yrs	10 yrs	
Bird	628	615	2	459	427	7
Raco	737	656[a]	11	609	536	12
Townhall	829	821	1	745	730	2
Townline Lake	346	332	4	252	237	6

[a]Pooled data for only two aldrin treatment plots instead of three. Data from the granular aldrin treatment were omitted because of excessive mortality from Scleroderris canker.

Table 3. Volume yields of cordwood and sawtimber over a 120-year rotation in aldrin-treated and untreated plots for white grub research areas, using site index values for both treated and untreated plots.

	Volume removed				Volume removed			
	Treated		Untreated		Treated		Untreated	
Age	Cords	MBF[a]	Cords	MBF	Cords	MBF	Cords	MBF
	BIRD				RACO			
30	8.0	0.04	1.1	0.01	1.3	0.00	—	—
40	7.0	1.24	5.7	0.87	6.7	0.10	2.7	0.00
50	3.4	3.59	3.2	2.44	5.0	0.76	4.3	0.32
60	0.0	6.31	0.3	4.48	3.0	1.74	3.0	0.82
70	0.0	6.42	0.0	4.93	1.1	2.81	1.8	1.33
80	0.0	5.53	0.0	4.41	0.0	3.47	0.8	1.73
90	0.0	4.76	0.0	3.86	0.0	3.35	0.0	1.92
100	0.0	4.11	0.0	3.38	0.0	3.06	0.0	1.69
120	0.0	31.30	0.0	27.08	0.0	23.33	0.0	16.34
Total	18.4	63.30	10.3	51.46	17.1	38.62	12.6	24.15
%dif[b]	79	23			36	60		
	TOWNHALL				TOWNLINE LAKE			
30	18.7	0.17	8.6	0.00	1.5	0.11	—	—
40	8.5	2.05	7.8	1.13	4.5	2.48	2.3	1.74
50	2.8	5.95	4.1	3.51	0.4	5.67	0.0	5.19
60	0.0	9.00	0.0	6.55	0.0	6.64	0.0	5.57
70	0.0	8.39	0.0	6.88	0.0	5.83	0.0	4.92
80	0.0	7.00	0.0	5.90	0.0	5.03	0.0	4.30
90	0.0	5.92	0.0	5.05	0.0	4.34	0.0	3.74
100	0.0	5.07	0.0	4.35	0.0	3.76	0.0	3.27
110	0.0	37.72	0.0	32.33	0.0	30.97	0.0	28.27
Total	30.0	81.27	20.5	65.70	6.4	64.83	2.3	57.00
%dif[b]	46	24			178	14		

[a]Thousands of board feet.
[b]The percentage difference is the increase in volume of the treated product over the corresponding untreated product.

Volume yields of sawtimber and cordwood were projected over the length of the 120-year rotaton by using calculated site index values from aldrin-treated and untreated plots (Table 3). In all research areas more sawtimber and cordwood were produced in the aldrin-treated than in the untreated plots. The increase in sawtimber ranged from 14 to 60%; the cordwood increase ranged from 36 to 178%. The untreated Raco and Townline Lake plots could not be thinned at age 30 because of insufficient basal area.

Projected stumpage values were estimated for the products produced over the 120-year rotation (Table 4). Total values for aldrin-treated trees ranged from 16 to 57% higher than those for untreated trees.

The calculated internal rates of return (IRR) reached maximum at age 80 for the treated areas except for Raco where the maximum was reached at age 110 (Table 5). The IRR's reached maximum at age 90 for the untreated areas except for Raco where again it was reached at age 110. Based on an economic rotation then, all the stands except Raco could be

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Table 4. Stumpage value[a] of red pine cordwood and sawlogs over a 120-year rotation in aldrin-treated and untreated plots for white grub research areas, using site index values for both treated (T) and untreated (U) plots for growth projections.

	Stumpage value ($/acre)								
	Site index		Cordwood		Sawlog		Total		%
Research area	T	U	T	U	T	U	T	U	diff.
Bird	59	51	146	82	1266	1029	1412	1111	27
Raco[b]	46	39	86	63	772	483	858	546	57
Townhall	70	61	150	103	1625	1314	1775	1417	25
Townline Lake	58	53	51	18	1297	1140	1348	1158	16

[a]1975 prices.
[b]One aldrin treatment omitted from the pooled data because losses from disease were heavier than in other plots, yielding a significant difference in number of trees per acre.

Table 5. Internal rates of return over a range of rotation ages for aldrin-treated and untreated lots by research areas and 10-year site index values.

Rotation age	Internal rate of return (percent)					
	Treated		Untreated	Treated		Untreated
	BIRD			RACO		
	SI 59	SI 51	SI 51	SI 46	SI 39	SI 39
60	3.04	2.15	2.25	1.17	0.26	0.32
70	3.21	2.45	2.50	1.65	0.73	0.84
80	3.24	2.57	2.59	1.91	1.05	1.16
90	3.24	2.61	2.61	2.01	1.24	1.36
100	3.22	2.61	2.61	2.05	1.36	1.42
110	3.19	2.59	2.59	2.06	1.39	1.44
120	3.16	2.57	2.56	2.05	1.38	1.43
	TOWNHALL			TOWNLINE LAKE		
	SI 70	SI 61	SI 61	SI 58	SI 53	SI 53
60	3.60	2.72	2.79	2.91	2.46	2.52
70	3.72	2.98	3.01	3.04	2.66	2.67
80	3.73	3.05	3.07	3.07	2.72	2.71
90	3.71	3.06	3.08	3.05	2.73	2.70
100	3.69	3.04	3.06	3.03	2.71	2.68
110	3.66	3.02	3.03	3.00	2.68	2.65
120	3.63	2.99	3.00	2.96	2.65	2.62

harvested at least 30 years earlier than the planned rotation of 120 years. And early aldrin treatments for white grubs could reduce the rotation age by 10 years. For untreated areas the maximum IRR's ranged from 1.44% at Raco to 3.08% at Townhall. Aldrin treatments raised the IRR's to 2.08% at Raco to 3.73% at Townhall. These rotation ages and IRR percentages, except for the Raco area, compare favorably with the five-year projections presented by Fowler and Wilson (1975).

CONCLUSION

White grubs affect pine plantations in at least two ways; they kill some trees and reduce the vigor and subsequent growth of others. Provided the number of living trees is not reduced below the level required for relatively full utilization of the site (perhaps as few as 200 to 300 trees per acre), the effect of mortality alone is small on timber yields and financial returns in red pine plantations. White grubs, in reducing the vigor and hence the height growth of red pine trees, lower the apparent site quality and substantially affect yields and financial returns.

Based on the projections presented here and an assumption that the relationships will continue to rotation age, greater product volumes, financial returns, and higher interest rates on the investment will be gained by preventing the grubs from destroying part of the root system and decreasing tree growth.

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