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FINANCIAL COMPARISON OF ACCELERATED-OPTIMAL-GROWTH TO BARE ROOT SEEDLINGS IN SIMULATED RED AND JACK PINE PULPWOOD PLANTATIONS IN MICHIGAN

presented by

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has been accepted towards fulfillment
of the requirements for

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Major professor

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FINANCIAL COMPARISON OF ACCELERATED-OPTIMAL-GROWTH TO BARE ROOT SEEDLINGS IN SIMULATED RED AND JACK PINE PULPWOOD PLANTATIONS IN MICHIGAN

By

Ronald E. Gockowski

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ABSTRACT

FINANCIAL COMPARISON OF ACCELERATED-OPTIMAL-GROWTH
TO BARE ROOT SEEDLINGS IN SIMULATED RED AND
JACK PINE PULPWOOD PLANTATIONS IN MICHIGAN

By

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A comparison of the profitability of Accelerated-Optimal-Growth red and jack pine seedlings to bare root seedlings was conducted over 1440 simulated red pine and 288 simulated jack pine plantations. Accelerated-Optimal-Growth seedlings have the potential for increased growth and improved survival. The increase in growth required to warrant the use of Accelerated-Optimal-Growth seedlings as an alternative to bare root seedlings in 40 year pulpwood plantations was determined over a range of site indices, planting densities, survival improvements, real interest rates, planting stock costs, and stumpage prices using a form of the cash flow discounting model. Accelerated-Optimal-Growth seedlings will most likely be the preferred alternative at lower interest rates, higher site indices, and lower planting densities. The jack pine results are less confident but the author believes they are equally as promising as red pine. Recommendations were made for future studies.

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I would also like to thank Drs. L. M. James and J. W. Hanover for all the assistance they have given me while at Michigan State.

I wish to dedicate this thesis to my mother, Marlene, for her love and confidence throughout my college career.

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INTRODUCTION

Accelerated-Optimal-Growth or Accel-O-Gro (AOG) is a relatively new concept in seedling production. In contrast to conventional outdoor nurseries, the system involves producing seedlings within protective cultures (greenhouses) and manipulating important growth variables to optimize growth. Light or photoperiod is the most important growth variable. By controlling light duration, quality, and intensity, dormancy can be inhibited and continuous seedling growth achieved. Temperature, moisture, carbon dioxide, and nutrients are also controlled to provide an optimum growing environment for a particular species. The result is the production of large, healthy, and vigorous seedlings in months rather than years (Hanover, 1976).

In reaction to a possible softwood fiber scarcity (USDA, 1980), many forest managers are intensifying softwood plantation management and are considering the use of AOG seedlings as part of this management scheme.[1] The purpose of this study was to assess the economic feasibility of using AOG seedlings for outplanting in red and jack pine pulpwood plantations. AOG seedlings have many advantages in comparison to conventional outdoor nursery seedlings (bare root seedlings), the more important being the potential for increased growth and increased survival.

[1]Personal communication with forest industry representatives.

A seven year study by Hanover (1977) compared growth and survival of blue spruce planted with AOG techniques to those planted with conventional nursery practices. The results showed that survival in the AOG plantation was 95.4 percent versus 84.5 percent for the non-AOG plantation. Better survival in AOG plantations can be attributed to larger and more vigorous seedlings. Hanover also found that an 81 percent increase in height growth resulted after seven years when AOG methods were used to produce these seedlings.

Although there is this biological evidence that the use of AOG seedlings will improve survival and growth, the magnitude of these improvements and the exact economic benefit of them for 40 year red and jack pine plantations, if any, still remains unanswered. It is the purpose of this thesis to begin to address some of these questions.

Studies on the costs and returns of tree improvement programs for loblolly pine in the south and white spruce in Canada have found that an increase in yield (growth volume) of 2 percent to 5 percent is required to justify an investment in improved seed, while published expectations of yield increases range from 5 percent to 15 percent (Davis, 1969; Carlisle and Teich, 1970). In order to determine whether the benefits of AOG seedlings can offset their increased cost, similar relationships are analyzed herein. Also included are implications and recommendations for future study.

STUDY METHODS

Analytical Model and Technique

The most popular decision model to use in evaluating investment alternatives is the cash flow discounting model (Van Horne, 1980). In using this model, the analyst estimates all cash flows (costs and returns) during the project time horizon and adjusts these cash flows to a common point in time, usually the present. A measure of project worth in this model is net present value (NPV), which is defined as the sum of the discounted revenues less the sum of the discounted costs.

The decision rule is to accept the project or investment if the NPV is positive, otherwise reject it. A positive NPV means that the discounted revenues exceed the discounted costs, and the project rate of return is greater than the guiding rate of return used in discounting.

The decision whether to use AOG planting stock, rather than bare root stock grown in conventional outdoor nurseries, assumes that the above analysis has been completed for a particular bare root plantation, and the profitability of that plantation confirmed. Now, the decision is whether the plantation can be made more profitable by using AOG seedlings. This will be the case only if the additional cost of the AOG seedlings is more than offset by additional revenue. This type of analysis is called an incremental or marginal analysis:

only additional costs and additional revenues are considered; costs and revenues equal between both alternatives are ignored.

An incremental analysis can be incorporated into the cash flow discounting model. When this is done, the only cash flows considered are the additional costs of AOG seedlings, over those of conventional bare root seedlings, and the resulting additional revenues, if any. Thus, if the NPV of this incremental analysis is positive (the time-adjusted additional revenues exceed the time-adjusted additional costs) the overall profitability of the plantation can be increased by using AOG planting stock. If the NPV of the incremental analysis is negative, i.e., if the increased cost of AOG seedlings is not offset by a sufficient increase in revenues to improve the overall profitability of the plantation, then conventional bare root planting stock should be used.

This analysis assumed that the only relevant incremental cost is the cost differential between AOG and bare root planting stock. All the investment costs of protective culture are embodied in this differential. Other costs such as site preparation, planting, weed control, annual maintenance, and taxes are all assumed to be the same no matter if AOG or bare root seedlings are planted.[2] Thus, they can be eliminated from the analysis.

To warrant an investment in AOG planting stock, additional revenues must be generated. It is assumed that they will come from higher yields than those expected with bare root stock. Knowing that

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[2]Personal communication with forest industry representatives.

revenue contains both a price and a quantity component, the required increase in revenue can be expressed algebraically as:

$$\frac{(PQ^{*} - PQ)}{(1 + i)^{n}} - C_{i} \geq 0 \qquad (1)$$

where, P = the price per unit of pulpwood (AOG and conventional) in year n.

Q^{*} = the quantity (yield) of pulpwood harvested in year n, AOG.

Q = the quantity (yield) of pulpwood harvested in year n, conventional.

C_{i} = the incremental investment cost of AOG seedlings in year 0.

n = the rotation age.

i = the rate of interest, as a decimal.

Assuming the same stumpage price (P) and the same rotation age (n) for both AOG and bare root plantations, it can be seen that the additional revenue required to warrant the incremental investment cost (C_{i}) of AOG seedlings must come solely from increased yield.[3] Since the magnitude of yield increases from using AOG seedlings is not yet known, the problem is one of identifying the gain in yield necessary to offset this additional investment cost. This can be expressed algebraically by solving equation (1) above for ($Q^{*} - Q$):

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[3]It is assumed there are no quality differences in the wood fiber produced by AOG and bare root stock that would affect price.

$$(Q^* - Q) = \frac{C_i(1 + i)^n}{P} \qquad (2)$$

This equation computes the minimum additional yield required to break even on an AOG investment; it identifies the yield increase which sets the NPV of the AOG investment just equal to zero. Note that the incremental investment cost is compounded to year n, the rotation age. Thus, all cash flows are adjusted to a common point in time, as is required. The compounded incremental investment cost is then divided by the stumpage price in year n to give the increase in yield necessary to break even on the AOG investment. Any yield increases above this minimum would make AOG seedlings the preferred alternative. If expected yield increases are below this minimum, bare root seedlings would be preferred.

To summarize, the compounded incremental investment cost must be offset by incremental revenues at rotation age to warrant the use of AOG seedlings. Since incremental revenues contain a price and quantity component, dividing by the stumpage price will give the quantity (yield) increase required.

To standardize and facilitate comparison of the required yield increases across the variables studied, they can be expressed as a percentage of the expected bare root yield. Equation (2) can be rewritten to reflect this step in the analysis. Dividing equation (2) by the projected bare root yield and multiplying by 100 gives the percentage yield increase required to warrant the use of AOG seedlings. The following equation results:

$$\frac{(Q^* - Q)}{Q}(100) = \frac{C_i(1 + i)^n}{PQ}(100) \qquad (3)$$

This analysis was conducted for red pine over a range of site indices, planting densities, survival differentials, real interest rates, stumpage prices, and incremental investment costs. For jack pine the analysis was more limited in that the effect of differential survival was not considered.

Data Collection

Cost and return data were collected from various forest industries in Michigan, Wisconsin, and Minnesota, and from the U.S. Forest Service and Michigan Department of Natural Resources. The relevant data included the parameters of equation (3): namely, Q, growth and yield data for bare root plantations; P, stumpage price projections to rotation age; and C_i, incremental investment costs which have earlier been defined as the difference in cost between AOG planting stock and bare root planting stock. The rotation age, n, used in the analysis was 40 years. Real interest rates, i, of 2, 4, 6, and 8 percent were considered.

Red pine growth and yield were projected over a range of site indices, planting densities, and survival rates using the formulas developed by Buckman (1962). The study considered site indices 45, 55, 65, and 75; planting densities of 400, 800, and 1200 trees per acre; and bare root planting survival of 60, 70, 80, 90, and 100 percent. In total, red pine growth and yield were projected for 60 combinations of these three variables (Table 1).

TABLE 1.--Yield for 40 year old bare root red pine plantations, in cords per acre.[a]

Site Index	Planting Density (Trees/Acre)	Percent Planting Survival 60	70	80	90	100
45	400	14.5	15.6	16.9	17.8	18.9
	800	20.6	21.9	23.0	24.0	24.8
	1200	24.0	25.2	26.0	26.8	27.4
55	400	21.6	23.4	25.1	26.6	27.8
	800	30.2	32.1	33.7	35.0	36.2
	1200	35.0	36.7	37.7	38.9	39.7
65	400	30.6	33.2	35.4	37.6	39.3
	800	42.4	45.0	46.8	48.6	50.2
	1200	48.6	50.7	52.2	53.5	54.4
75	400	40.7	44.0	46.8	49.1	51.3
	800	55.3	58.4	61.0	63.0	64.8
	1200	63.0	65.5	67.3	68.7	69.7

[a]From Buckman (1962):

$$\text{BA growth} = 1.6889 + 0.041066(\text{BA}) - 0.00016303(\text{BA})^2 - 0.076958(\text{AGE}) + 0.00022741(\text{AGE})^2 + 0.06441(\text{SITE INDEX})$$

$$\text{Cords} = 0.003958(\text{BA} \times \text{HEIGHT})$$

For jack pine, growth and yield were projected over four site indices (40, 50, 60, and 70), and three planting densities (500, 1000, and 1500 trees per acre), using the tables developed by Laidly (1976), and the formulas developed by Buckman (1962). Due to limited information on plantation growth and yield, the jack pine analysis did not consider less than perfect survival (Table 2).

TABLE 2.--Yield for 40 year old bare root jack pine plantations, in cords per acre.[a]

	Planting Density (trees per acre)		
Site Index	500	1000	1500
40	6.8	8.9	10.0
50	11.6	14.8	17.3
60	18.2	24.0	26.8
70	26.3	33.1	36.2

[a]Basal area growth from table by Laidly (1976).

Cords = 0.003958 (BA x HEIGHT), from Buckman (1962).

Stumpage price and volume cut data were collected for the Hiawatha and Ottawa national forests of the Upper Peninsula and the Huron and Manistee national forests of the Lower Peninsula from red and jack pine pulpwood cut and sold reports for fiscal years 1975 through 1979. This data was also collected from the eight districts of the Michigan Department of Natural Resources for the years 1978

and 1979. From this, weighted average red and jack pine stumpage prices were computed (in 1979 dollars) for both the Upper Peninsula and for all of Michigan (Appendix A).

Future stumpage prices were projected from 1980, the assumed year of establishment, to rotation age 40 years hence (Table 3). These projections assumed an average 2 percent real annual softwood stumpage price increase (USDA, 1980). These prices are in real or constant dollars, net of inflation. The 2 percent real price increase reflects a projected softwood fiber scarcity in that such price increases will be necessary to bring pulpwood demand and supply into equilibrium.[4]

TABLE 3.--Projection of weighted average 1979 red and jack pine stumpage prices to rotation age 40, in dollars per cord.

	Red Pine		Jack Pine	
Year	Michigan	Upper Peninsula	Michigan	Upper Peninsula
1979[a]	6.62	11.24	8.92	13.76
1980[b]	6.75	11.46	9.10	14.04
2020	14.91	25.31	20.09	30.99

[a]Derivation in Appendix A.

[b]Year of assumed plantation establishment.

[1]Note that these are not what the actual prices will be in current dollars since the annual rate of inflation will surely be above 0 percent. However, these prices are valid for the analysis so long as the other cash flows are also in a real context (net of inflation), as will be the case.

The bare root planting stock costs used in the analysis were $40 per thousand for red pine and $20 per thousand for jack pine.[5] Three AOG planting stock costs ($135.00, $142.50, and $150.00 per thousand) were assumed to account for variations in the cost of planting stock production that may occur.[6] These AOG planting stock costs were used for both the red pine and jack pine analyses. The incremental investment costs (C_i) resulting from these cost estimates are presented in Tables 4a and 4b.

Data Analysis

Recall that growth and yield (Q) were projected for bare root red pine plantations over four site indices, three planting densities, and five survival rates resulting in yield projections for 60 hypothetical red pine plantations (Table 1). Similarly, yield was projected for 12 bare root jack pine plantations across four site indices, and three plant densities (Table 2). Also recall that the analysis considered four real interest rates (i), three incremental investment costs (C_i), and two stumpage prices (P) for each of these plantations. Thus, the percentage yield increase required to warrant an AOG investment was computed, using equation (3) across the range of variables, for a total of 1440 red pine plantations and 288 jack pine plantations.

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[5]Michigan Department of Natural Resources 1980 nursery price list.

[6]Chippewa Farms Horticultural Enterprises, Minnesota, and Michigan Cooperative Tree Improvement Program quotations.

TABLE 4a.--Incremental investment costs for AOG red pine planting stock over a range of planting densities and AOG stock costs, in dollars per acre.

Cost per 1000 Seedlings		Incremental Investment Cost per Acre[a]		
Bare Root	AOG	Trees per Acre		
Dollars	Dollars	400	800	1200
40.00	135.00	38.00	76.00	114.00
	142.50	41.00	82.00	123.00
	150.00	44.00	88.00	132.00

[a]Incremental investment cost

= (AOG cost per 1000 seedlings - BR cost per 1000 seedlings)

x (planting density per acre/1000)

TABLE 4b.--Incremental investment costs for AOG jack pine planting stock over a range of planting densities and AOG stock costs, in dollars per acre.

Cost per 1000 Seedlings		Incremental Investment Cost per Acre[a]		
Bare Root	AOG	Trees per Acre		
Dollars	Dollars	500	1000	1500
20.00	135.00	57.50	115.00	172.50
	142.50	61.25	122.50	183.75
	150.00	65.00	130.00	195.00

The method of analysis can best be explained by considering a particular plantation. Assume a forest manager is considering the use of AOG seedlings for a site index 65 red pine plantation planted at 400 trees per acre. Further assume that the cost for AOG planting stock is $142.50 per thousand and the relevant real rate of interest is 4 percent. Finally, assume that the plantation is located in the Upper Peninsula and the projected stumpage price is $25.31 per cord.

The first step in the analysis is to compound the incremental investment cost to rotation age, 40 years hence, at 4 percent per year. Note that the interest rates used in the analysis are in real terms, net of inflation. Market rates of interest, on the other hand, are normally expressed in current terms, which includes components for the time value of money, risk, and inflation. To avoid estimating an uncertain rate of inflation it is often easier to conduct a financial analysis in real terms, as was done here. Recall that stumpage prices (and thus revenues) were projected using an estimated real annual price increase. The incremental investment costs will also be compounded using the investor's real interest rate or guiding rate of return.[7] Since most decision makers are more familiar with using current interest rates (e.g., cost of borrowing from a bank), Table 5 shows some equivalent current rates for the four real rates used in this analysis. For example, if the prime lending rate (which is expressed in current terms) is 20 percent and the annual rate of

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[7]It is essential that all cash flows be expressed in real terms or all expressed in current terms and not to compare real cash flows with current interest rates (Gregersen, 1975).

TABLE 5.--Relationship of current and real interest rates for a range of annual inflation rates, in percent.

Current Rate of Interest	Rate of Inflation	Real Rate of Interest[a]
20.0	17.6	2.0
15.0	12.7	2.0
10.0	7.8	2.0
20.0	15.4	4.0
15.0	10.6	4.0
10.0	5.8	4.0
20.0	13.2	6.0
15.0	10.6	6.0
10.0	3.8	6.0
20.0	11.1	8.0
15.0	6.5	8.0
10.0	1.9	8.0

[a] $$i = \left[\frac{(1 + k)}{(1 + j)} - 1\right] 100$$

Where, i = real interest rate

j = annual rate of inflation

k = current interest rate

inflation is 15.4 percent, the equivalent real interest rate is 4 percent.

Returning to the example, the incremental investment cost (C_i) for AOG seedlings is $41 per acre (Table 4a). By compounding this value at 4 percent per year for 40 years, a compounded incremental investment cost of $197 per acre is accrued. Thus, in order for AOG seedlings to be a financially feasible alternative to bare root planting stock, incremental revenues of at least $197 per acre must be generated at rotation age. With a projected stumpage price of $25.31 per cord, this corresponds to a required yield increase of 7.8 cords per acre, or 20 percent.[8]

Recall that two important benefits of using AOG seedlings are the potential for increased growth and improved survival. Thus there are two potential sources from which this required yield increase may possibly accrue: increased yield from better survival and increased yield from better growth.[9] If the forest manager can estimate the improvement in survival that may result from using AOG seedlings, then the resulting increase in yield can easily be obtained from growth and yield data, such as that in Table 1. If this yield increase is greater than or equal to the minimum yield increase required to warrant the use of AOG seedlings, then AOG seedlings

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[8] From equation (3) and Table 1: $\frac{Q^*-Q}{Q}(100) = \frac{7.8}{39.3}(100) = 20\%$

[9] The yield increase due to better survival assumes more growing trees per acre will produce more yield per acre at rotation age. It is also assumed that in a 40 year rotation mortality losses due to crowding will be minimal.

would be financially feasible even if no growth increase occurred. More commonly, however, the increase in yield from better survival will not fully offset the total required, and some yield increase from better growth will also be necessary. Also, if no improvement in survival is expected, the entire required yield increase must come solely from increased growth.

This analysis assumed a 100 percent survival rate for AOG seedlings. Consequently, if bare root survival is expected to be 100 percent, there would be 0 percent improvement in survival; if bare root survival is expected to be 60 percent, there would be a 40 percent survival improvement by using AOG seedlings; and so on.

Since the required yield increase may be a function of increased growth and/or increased survival, the results are expressed as the percent increase in growth required given a certain expected improvement in survival. That is, the yield increase required from improved growth is the total yield increase required less the yield increase expected from improved survival.

Continuing with the example, if no improvement in survival is expected, the required 7.8 cords per acre of increased yield must come entirely from increased growth. This translates to a 20 percent increase in growth requirement given that no improvement in survival is expected. If, on the other hand, a 10 percent improvement in survival is anticipated, only 6.1 cords per acre of additional yield from better growth need be generated. The remaining 1.7 cords per

acre of increased yield will come from better survival.[10] So with a 10 percent improvement in survival, only a 16 percent increase in growth is required to warrant the use of AOG seedlings in this particular plantation.[11]

In the case of an expected 40 percent improvement in survival, no increase in growth would be required: 8.7 cords per acre of additional yield results from better survival, and only 7.8 cords per acre in total are required. Or put another way, improved survival increases yield at rotation by 22 percent (8.7/39.3). Since a total yield increase of only 20 percent is required, no yield increase need come from improved growth.

A summary of the results for this particular plantation across a range of expected improvements in survival is presented in Table 6. Notice that as the improvement in survival due to the use of AOG seedlings increases, less yield increase is required from better growth. The total yield increase required will always be at least 7.8 cords per acre (or 20 percent) to warrant using AOG seedlings for this plantation. However, this can come from better survival, better growth, or a combination of the two.

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[10]From red pine yield data in Table 1. With a 10 percent improvement in survival there are 39.3 cords per acre at rotation rather than 37.6, a 1.7 cord increase.

[11]Percent growth increase required = total percent yield increase required - percent yield increase expected from improved survival.

$$\frac{7.8}{39.3}(100) - \frac{1.7}{39.3}(100) = 20 - 4 = 16$$

TABLE 6.--Required yield increases for a sample analysis.

Expected Survival Improvement	Resulting Yield Increase from Better Survival	Required Yield Increase from:		
		All Sources	Better Growth	
Percent	Cords/Acre	Cords/Acre	Cords/Acre[a]	Percent[b]
40	8.7	7.8	0.0	0
30	6.1	7.8	1.7	4
20	3.9	7.8	3.9	10
10	1.7	7.8	6.1	16
0	0.0	7.8	7.8	20

[a]Total yield increase required - Yield increase expected from improved survival.

[b]Required yield increase from better growth ÷ Bare root yield expected with 100 percent survival.

The above example explains the method of analysis for all red pine plantations. The final result for each plantation is the required increase in growth necessary to warrant the use of AOG seedlings, given an expected improvement in survival. The jack pine analysis differed only in that the possible benefit from improved survival was not included due to lack of data. Consequently, the jack pine results are very conservative.

RESULTS AND DISCUSSION

A total of 1440 red pine plantations and 288 jack pine plantations were analyzed. A full disclosure of the results appears in Appendix B, with a cross-section of the results for each species presented below. These cross-sections show the relationships between the variables studied. They are useful in drawing conclusions on the use of AOG seedlings in 40 year old red and jack pine pulpwood plantations.

Red Pine

The percent increase in growth required to warrant the use of AOG seedlings in selected red pine plantations is presented in Table 7. Important relationships between the variables studied are also presented in Figures 1, 2, and 3.

Figure 1 shows the effect expected survival improvement and site index have in the percent growth increase required, ceteris paribus.[12] It can be seen that as survival improves due to the use of AOG seedlings, less growth increase is required. Also, the better the site, the less the percent growth increase required.

In Figure 2 the effects of planting density and AOG planting stock costs on the requirement for an increase in growth are

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[12] Ceteris paribus - given that all other variables remain constant.

TABLE 7.--Cross-section of red pine results showing percent increase in growth required to warrant the use of AOG seedlings.[a]

Site Index	Planting Density	Expected Survival Improvement	Required Growth Increase			
			Real Rate of Interest (in percent)			
	Trees/Acre	Percent	2	4	6	8
55	400	40	0*	4*	38	104
		30	0*	12*	44	111
		20	3*	18*	50	117
		10	9*	24*	56	122
		0	13*	28*	60	127
65	400	40	0*	0*	20*	67
		30	0*	4*	27*	74
		20	0*	10*	32	80
		10	5*	16*	38	85
		0	9*	20*	42	90
65	800	40	0*	15*	51	125
		30	4*	21*	59	130
		20	7*	24*	60	133
		10	11*	28*	63	137
		0	14*	31	66	140
65	1200	40	9*	32	81	183
		30	13*	36	85	187
		20	16*	39	88	190
		10	18*	41	90	192
		0	20*	43	92	194

[a]Using AOG stock cost of $142.50 per thousand, and Upper Peninsula stumpage price of $25.31 per cord.

*Financially feasible AOG plantation.

Figure 1.--Required percent growth increase to warrant the use of AOG red pine seedlings across a range of site indices and expected survival improvements, given 400 trees planted per acre, a 4 percent real rate of interest, AOG stock costs of $142.50 per thousand, and Upper Peninsula stumpage prices.

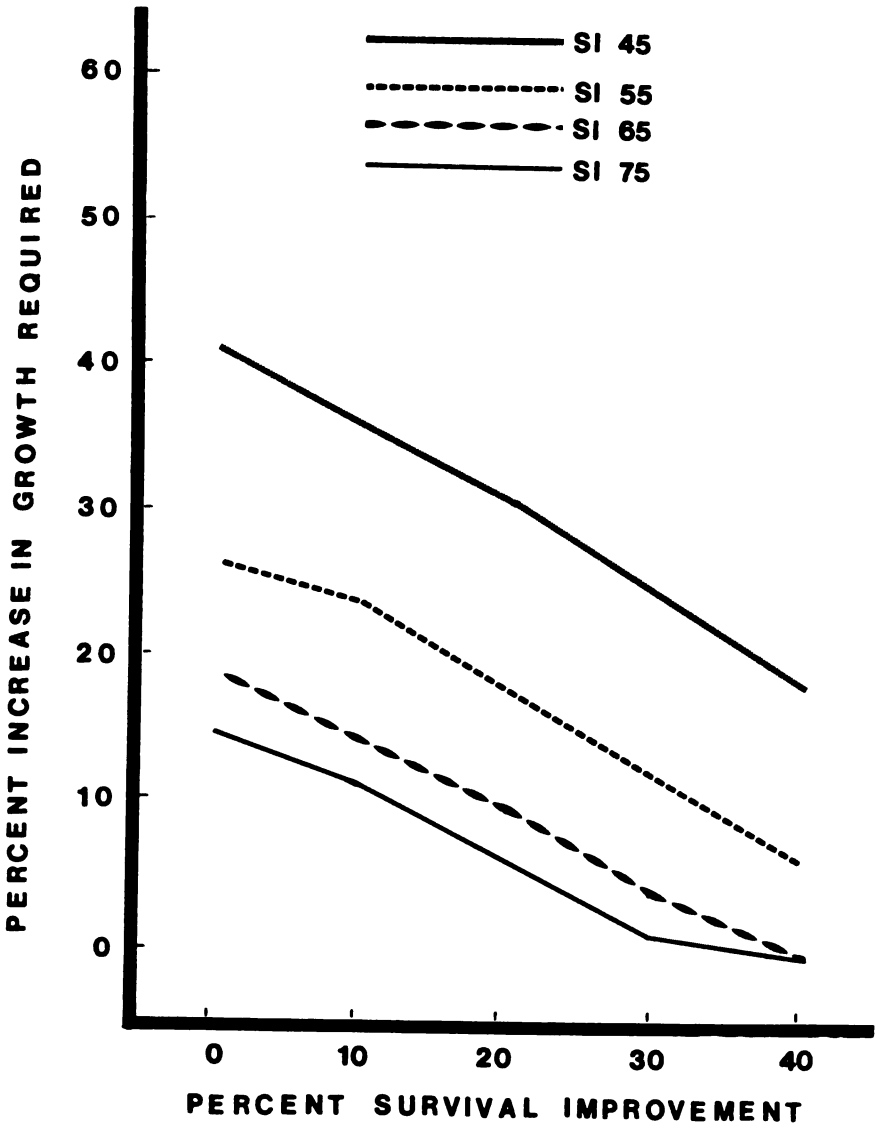
SI 45
SI 55
SI 65
SI 75
60
50
40
30
20
10
0
PERCENT INCREASE IN GROWTH REQUIRED
0
10
20
30
40
PERCENT SURVIVAL IMPROVEMENT

FIGURE 1

Figure 2.--Required percent growth increase to warrant the use of AOG red pine seedlings across a range of planting densities and AOG stock costs, given a site index of 65, a 4 percent real rate of interest, 20 percent survival improvement, and Upper Peninsula stumpage prices.

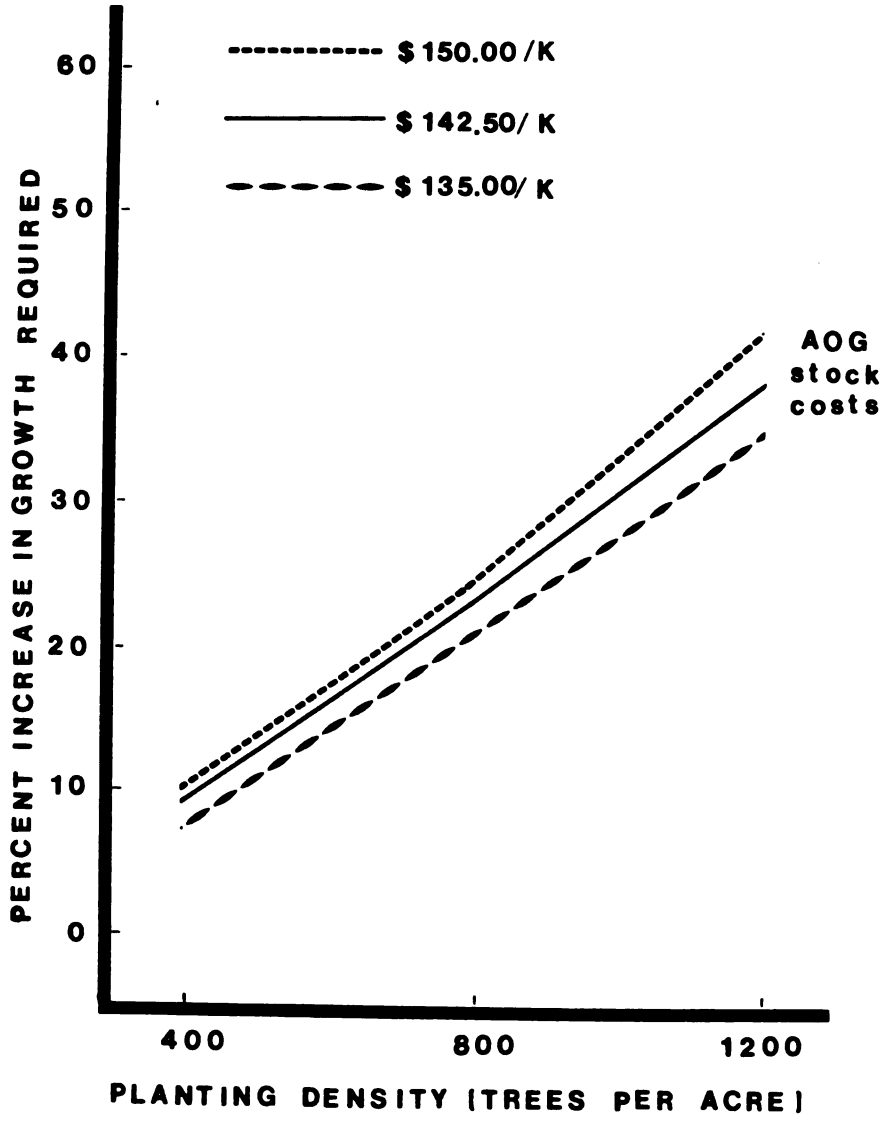
$ 150.00 /K
$ 142.50/ K
$ 135.00/ K
AOG
stock
costs
PERCENT INCREASE IN GROWTH REQUIRED
60
50
40
30
20
10
0
400
800
1200
PLANTING DENSITY (TREES PER ACRE)

FIGURE 2

demonstrated, ceteris paribus. It is evident that as planting density increases and as AOG planting stock costs rise relative to bare root stock costs, the required percent increase in growth also increases. An increase in either of these two variables increases the incremental investment cost (C_i) of AOG seedlings (see Table 4). With an incremental increase in costs comes the requirement for an incremental increase in revenues and, thus, an incremental increase in yield.

Finally, Figure 3 shows the relationship between interest rates and stumpage prices to the percent increase in growth required, again ceteris paribus. At high interest rates, the compounded incremental investment cost is greater than at low rates. Therefore, more incremental revenue (and thus more incremental yield) is required at rotation age. Also evident from Figure 3 is that with higher stumpage prices, less growth increase is required to warrant the use of AOG seedlings. Recall that two weighted average stumpage prices were considered in the analysis: one for all of Michigan, and one for the Upper Peninsula only. Since the Upper Peninsula stumpage prices are consistently higher than the state average, less growth increase is required if Upper Peninsula stumpage prices are relevant. Given any required incremental revenue (to offset any given compounded incremental investment cost), as the stumpage price increases, the associated incremental yield requirement decreases.

From these relationships it is quite evident that an AOG investment will be more profitable when:

Figure 3.--Required percent growth increase to warrant the use of AOG red pine seedlings across a range of real interest rates and stumpage prices, given a site index of 65, 400 trees planted per acre, 20 percent survival improvement, and an AOG stock cost of $142.50 per thousand.

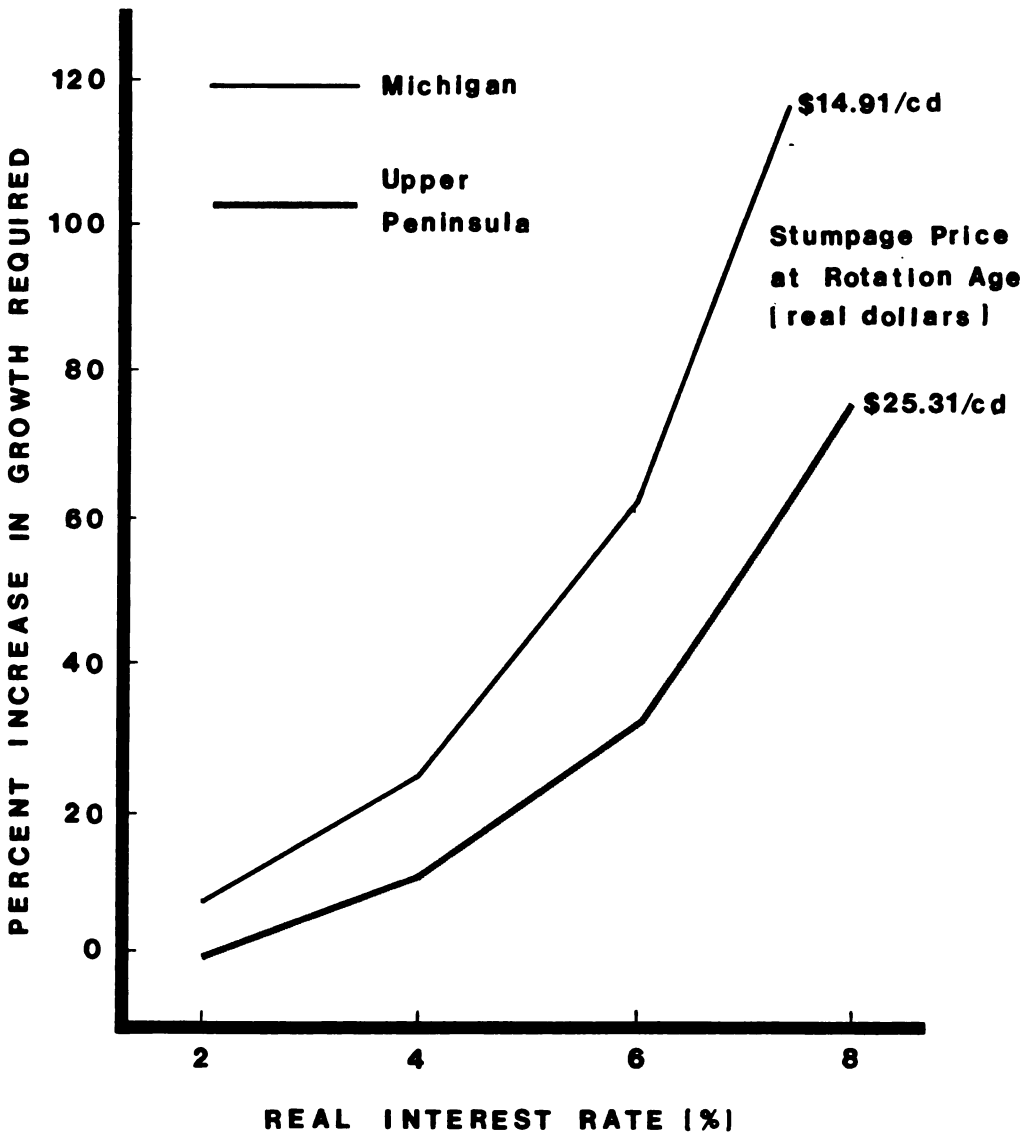
120
100
80
60
40
20
0
PERCENT INCREASE IN GROWTH REQUIRED
Michigan
Upper
Peninsula
$14.91/cd
Stumpage Price
at Rotation Age
[real dollars]
$25.31/cd
2
4
6
8
REAL INTEREST RATE [%]

FIGURE 3

- Planting density is at a minimum.
- The AOG planting stock cost is lowest relative to the cost of bare root planting stock.
- Interest rates are at a minimum.
- Projected rotation age stumpage prices are at a maximum.
- The site index is high.
- Anticipated improvements in survival are at a maximum.

This is not to say that all of the above conditions need be present for AOG seedlings to be preferred over bare root seedlings, but it is evident from Table 7 and Figures 1 through 3 that at least one or two need to be. For example, assume that it has been determined that AOG seedlings will increase growth and yield of any red pine plantation by 30 percent. If the guiding rate of return for plantation investments is relatively low, say 2 or 4 percent, then AOG seedlings will be preferable to bare root seedlings over most site indices, planting densities, and possible improvements in survival (see plantations with asterisks in Table 7). Thus, even though all the variables are very important in estimating the relative profitability of AOG seedlings to bare root seedlings, not all of them need to be entirely favorable.

Note from the above example that the decision whether to use AOG seedlings necessitates a judgment as to what the potential growth increase will be. As of now the expected increase in growth from switching to AOG planting stock is unknown. Nevertheless, the results of this analysis can identify those cases where the use of AOG

seedlings will surely not be financially preferable to bare root seedlings. The results also allow us to make judgments as to where and when AOG seedlings may be feasible.

If an optimistic estimate is made that the threshold for any possible growth increase from the use of AOG seedlings is 30 percent, then many situations can be identified where it will be more profitable to continue using bare root planting stock in pulpwood plantations. Of those plantations presented in Table 7 it is evident that bare root seedlings would be preferred in most cases when real interest rates are 6 or 8 percent, or when the desired planting density is 1200 trees per acre. This is consistent with the overall red pine results which showed that in most cases bare root seedlings should be used when real interest rates are 6 to 8 percent, when higher planting densities of 800 to 1200 trees per acre are desired, and when plantations are located on moderate to lower sites of 45 to 55.

However, the results also show that AOG seedlings are preferred in most cases when real interest rates are 2 or 4 percent, when planting densities of 400 (and in some cases 800) trees per acre are desired, and with site indices of 65 and 75.[13] Since most intensive forest management practices are more likely to be located on better sites and planted at lower planting densities, AOG seedlings appear practical in many situations.

As mentioned earlier, many forest managers consider the establishment and management of red pine plantations to be a hedge

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[13]Assuming a 30 percent expected increase in growth.

against possible future softwood fiber scarcities. This practice reflects a willingness to forgo current consumption or more profitable short term investments for future security. Such an objective also reflects a relatively low time value of money or real rate of interest. The real interest rates of 2 and 4 percent used in this analysis appear appropriate for these managers.[14] Recall that at these interest rates, the outlook for AOG seedlings looks very promising.

In conclusion, the use of AOG seedlings for red pine pulpwood plantations is contingent on the potential improvement in survival and increase in growth that may result. Since research into the exact survival and growth of AOG seedlings is yet to be completed, judgment must be used by forest managers as to when AOG seedlings should be planted. This study identifies the economic yield increase that is required to warrant the use of AOG seedlings, but the actual use of AOG seedlings is dependent on whether these yields can be attained biologically. The answer to this question is beyond the scope of this study.

Jack Pine

At first glance the jack pine results, presented in Table 8, may not seem as promising as the red pine results. However, recall that these results do not include the potential benefit of improved survival. Although there are no data to confirm this, it could be

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[14]Remember that these interest rates are real rates. With an annual inflation rate of 13 percent, they correspond to current interest rates of approximately 15 and 17 percent, respectively.

TABLE 8.--Cross-section of jack pine results showing percent increase in growth required to warrant the use of AOG seedlings.[a]

Index	Planting Density	Required Growth Increase			
		Real Rate of Interest (in Percent)			
	Trees/Acre	2	4	6	8
40	500	64	140	299	632
	1000	98	213	457	965
	1500	131	285	610	1288
50	500	38	82	175	370
	1000	59	128	275	580
	1500	76	165	353	745
60	500	24*	52	112	236
	1000	36	79	169	358
	1500	49	106	228	242
70	500	17*	36	77	163
	1000	26*	57	123	259
	1500	36	79	168	356

[a]Using AOG stock cost of $142.50 per thousand, Upper Peninsula stumpage price of $30.99 per cord, and excluding potential benefits from improved survival.

*Financially feasible if 30 percent growth increase is expected.

inferred from the red pine results that these yield increase requirements would decrease sufficiently to make a number of the plantations feasible if improved survival benefits could be included.

The jack pine results exhibit the same relationships to site index, planting density, interest rates, stumpage price, and incremental investment cost as red pine. Therefore, it can be concluded that the jack pine results also show that AOG seedlings will probably be feasible only at lower planting densities, and interest rates, and higher site indices. Again, however, feasibility requires a judgment by the forest manager as to expected survival improvement and percent growth increase.

IMPLICATIONS FOR FUTURE STUDY

Although they are not as easily incorporated into a financial analysis as are improved growth and survival, it is important to recognize that there are other benefits from using AOG seedlings that have definite financial implications. Two of the more important benefits are improved availability and flexibility of planting stock, and more efficient use of available labor and equipment (Hanover, et al., 1976).

Since AOG seedlings are grown in months rather than years, production planning is simplified where AOG methods are employed, planting stock is more readily available, and adjustments can be easily made to sudden changes in demand for planting stock. A major limitation of bare root stock is that outplanting can only be done during a short period of the year when soil conditions are optimal. With container grown AOG seedlings, soil conditions can be less than optimal and the planting season can be extended. This allows for better utilization of available labor and equipment. Quantifying the above benefits opens up a broad area for further economic research.

Another area of possible future research would be to analyze the potential benefits of a reduction in rotation lengths from using AOG seedlings in pulpwood plantations. This could also include identifying the optimal financial rotation age for AOG plantations.

A final area of possible future research for AOG seedlings is that of wood fiber quality. Is the wood fiber produced in AOG plantations of better quality? Should there be a price premium for such quality? Or do faster growth rates reduce wood quality? These are both biological and economic questions.

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APPENDICES

APPENDIX A

DERIVATION OF WEIGHTED AVERAGE STUMPAGE PRICES, IN 1979 DOLLARS

TABLE A-1.--Weighted average stumpage price for red pine in Michigan, in 1970 dollars.

Agency	Year	Total Volume Sold	Weighted Average Stumpage Price per Cord	Adjustment Factor[a]	Weighted Average Stumpage Price per Cord[b]
		Cords	Current Dollars		1979 Dollars
USFS	1975	10,572	4.45	1.33	5.92
	1976	--	--	1.26	--
	1977	4,673	5.99	1.18	7.07
	1978	1,595	7,46	1.10	8.21
	1979	--	--	1.00	--
		16,840			6.46
MDNR	1978	3,580	6.16	1.10	6.78
	1979	4,587	7.07	1.00	7.07
		8,167			6.94
MDNR+USFS	Total	25,007			6.62

[a]Adjustment Factor = $\frac{\text{Wholesale Price Index for 1979}}{\text{Wholesale Price Index for Adjustment Year}}$

[b]Stumpage Price in 1979 dollars = adjustment year price (adjustment factor). From Averill, et al. (1977).

TABLE A-2.--Weighted average stumpage price for red pine in the Upper Peninsula, in 1979 dollars.

Agency	Year	Total Volume Sold	Weighted Average Stumpage Price per Cord	Adjustment Factor	Weighted Average Stumpage Price per Cord
		Cords	Current Dollars		1979 Dollars
USFS	1975	2,111	8.96	1.33	11.92
	1976	--	--	1.26	--
	1977	382	13.51	1.18	15.94
	1978	378	9.97	1.10	10.97
	1979	--	--	1.00	--
		2,871			12.20
MDNR	1978	2,282	7.70	1.10	8.47
	1979	1,373	13.83	1.00	13.83
		3,655			10.48
MDNR+USFS	Total	6,526			11.24

TABLE A-3.--Weighted average stumpage price for jack pine in Michigan, in 1979 dollars.

Agency	Year	Total Volume Sold	Weighted Average Stumpage Price per Cord	Adjustment Factor	Weighted Average Stumpage Price per Cord
		Cords	Current Dollars		1979 Dollars
USFS	1975	47,905	5.61	1.33	7.46
	1976	62,570	4.84	1.26	6.10
	1977	20,835	7.83	1.18	9.24
	1978	19,970	9.14	1.10	10.05
	1979	18,388	10.65	1.00	10.65
		169,668			7.83
MDNR	1978	71,219	8.72	1.10	9.59
	1979	70,614	10.85	1.00	10.85
		141,833			10.22
MDNR+USFS	Total	311,501			8.92

TABLE A-4.--Weighted average stumpage price for jack pine in the Upper Peninsula, in 1979 dollars.

Agency	Year	Total Volume Sold	Weighted Average Stumpage Price per Cord	Adjustment Factor	Weighted Average Stumpage Price per Cord
		Cords	Current Dollars		1979 Dollars
USFS	1975	19,142	8.02	1.33	10.67
	1976	16,452	7.58	1.26	9.55
	1977	7,618	11.49	1.18	13.56
	1978	4.947	14.23	1.10	15.65
	1979	4,475	20.43	1.00	20.43
		52,634			12.04
MDNR	1978	30,826	12.05	1.10	13.26
	1979	22,884	18.41	1.00	18.41
		53,710			15.45
MDNR+USFS	Total	106,344			13.76

APPENDIX B

COMPLETE RESULTS OF RED AND JACK PINE ANALYSIS

TABLE B-1.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 45, 400 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	6	9	11	0	0	0
	4	41	46	51	15	18	21
	6	115	126	137	59	65	71
	8	270	293	316	149	163	177
30	2	12	15	17	0	2	3
	4	47	53	137	21	24	27
	6	121	132	143	64	71	77
	8	276	299	322	155	169	182
20	2	19	22	24	7	9	10
	4	54	59	64	18	31	34
	6	128	139	150	71	78	84
	8	282	306	329	162	176	189
10	2	24	25	28	12	13	15
	4	59	64	49	32	36	38
	6	133	144	155	71	83	89
	8	287	310	333	167	181	194
0	2	30	32	34	18	19	20
	4	65	70	75	38	41	44
	6	139	150	161	82	88	95
	8	293	316	339	173	186	200

TABLE B-2.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 45, 800 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	28	32	35	10	12	14
	4	82	90	97	41	46	50
	6	194	211	228	108	117	127
	8	429	465	500	246	267	288
30	2	34	37	41	15	17	19
	4	87	95	102	46	51	55
	6	200	216	233	113	123	132
	8	435	470	505	251	272	293
20	2	38	42	45	19	22	24
	4	91	99	107	51	55	60
	6	204	221	237	117	127	137
	8	439	474	510	256	276	297
10	2	42	46	48	23	25	28
	4	95	103	111	55	59	64
	6	208	225	242	121	131	141
	8	443	478	514	260	280	301
0	2	45	49	52	27	29	31
	4	99	107	114	58	63	67
	6	211	228	145	125	134	144
	8	446	482	517	263	284	305

TABLE B-3.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 45, 1200 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	49	54	59	24	27	30
	4	121	132	143	66	73	79
	6	275	297	320	157	170	183
	8	594	642	690	345	373	401
30	2	54	59	63	28	31	34
	4	126	137	147	71	77	83
	6	279	302	324	161	174	188
	8	598	646	694	349	377	406
20	2	57	61	66	31	34	37
	4	129	140	150	74	80	86
	6	282	305	327	164	177	191
	8	601	649	497	352	380	409
10	2	59	64	48	34	37	40
	4	132	142	153	77	83	89
	6	285	307	330	167	180	194
	8	604	652	700	355	383	411
0	2	62	67	71	36	39	42
	4	134	145	155	79	85	91
	6	287	310	332	169	182	196
	8	606	654	702	357	385	414

TABLE B-4.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 55, 400 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	0	0	1	0	0	0
	4	22	25	29	4	6	8
	6	72	80	87	33	38	42
	8	177	193	208	95	104	114
30	2	5	6	8	0	0	0
	4	28	32	35	10	12	1 4
	6	79	86	94	40	44	48
	8	184	199	215	101	111	120
20	2	11	12	14	2	3	4
	4	34	38	41	16	18	20
	6	85	92	100	47	50	55
	8	190	205	221	108	117	140
10	2	16	18	19	8	9	9
	4	40	43	47	21	24	26
	6	90	98	105	51	56	60
	8	195	211	117	113	122	131
0	2	20	22	23	12	13	14
	4	44	48	51	26	28	30
	6	94	102	109	56	60	64
	8	199	125	231	117	127	136

TABLE B-5.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 55, 800 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	14	17	19	2	3	5
	4	51	56	62	23	26	29
	6	128	140	151	69	75	83
	8	289	313	338	164	178	192
30	2	20	22	25	7	8	10
	4	56	62	67	28	32	35
	6	134	145	156	74	81	87
	8	295	319	343	169	183	197
20	2	24	26	29	11	13	14
	4	61	66	71	33	36	39
	6	138	149	161	78	85	92
	8	299	323	347	173	188	202
10	2	28	30	33	15	16	18
	4	64	70	75	37	40	43
	6	142	153	164	82	89	96
	8	303	327	351	177	191	205
0	2	31	34	36	18	20	21
	4	68	73	78	40	43	47
	6	145	156	168	85	92	99
	8	306	330	354	180	194	209

TABLE B-6.--Growth increase required to warrant an investment in AOG red pine seedlings, site indes 55, 1200 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	31	34	37	13	15	17
	4	81	88	95	43	47	51
	6	186	202	218	105	114	123
	8	407	440	473	235	254	274
30	2	35	38	42	18	20	21
	4	85	92	100	47	51	55
	6	191	206	222	109	118	128
	8	411	444	477	239	258	278
20	2	38	41	44	20	22	24
	4	87	95	102	49	54	58
	6	193	209	224	112	121	130
	8	413	446	479	241	261	280
10	2	41	44	47	23	25	27
	4	90	98	105	52	57	61
	6	196	212	227	115	124	133
	8	416	449	481	245	264	283
0	2	43	46	49	25	27	29
	4	92	100	107	54	59	63
	6	198	214	229	117	126	135
	8	418	451	485	247	266	285

TABLE B-7.--Growth increase required to warrant an investment in AOG red pine seedlings, site index, 65, 400 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	0	0	0	0	0	0
	4	9	11	14	0	0	0
	6	45	50	55	17	20	23
	8	119	130	141	61	67	74
30	2	0	0	1	0	0	0
	4	16	18	20	3	4	6
	6	51	56	62	24	27	30
	8	125	137	148	67	74	81
20	2	4	6	7	0	0	0
	4	21	24	26	8	10	11
	6	57	62	67	29	32	36
	8	131	142	153	73	80	86
10	2	10	11	12	4	5	5
	4	27	29	32	14	15	17
	6	62	68	73	35	38	41
	8	137	148	159	79	85	92
0	2	14	16	18	8	9	10
	4	31	34	36	18	20	21
	6	67	72	77	39	42	46
	8	141	152	163	83	90	96

TABLE B-8.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 65, 800 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	7	9	10	0	0	0
	4	33	37	41	13	15	18
	6	89	97	105	46	51	56
	8	205	222	236	114	125	135
30	2	12	14	16	3	4	5
	4	38	42	46	18	21	23
	6	94	102	111	51	59	61
	8	210	228	245	120	130	140
20	2	16	18	19	6	7	8
	4	42	46	50	22	24	26
	6	98	106	114	55	60	64
	8	214	231	349	123	137	147
10	2	19	21	23	10	11	12
	4	46	50	53	26	28	30
	6	101	110	118	58	63	68
	8	218	235	252	127	137	147
0	2	22	24	26	13	14	15
	4	49	53	56	29	31	33
	6	104	113	122	62	66	71
	8	221	228	255	130	140	150

TABLE B-9.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 65, 1200 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	20	23	25	8	9	10
	4	57	62	68	29	32	35
	6	134	145	157	75	81	88
	8	295	319	343	168	183	198
30	2	24	27	29	11	13	14
	4	61	66	71	33	36	39
	6	138	148	161	78	85	92
	8	299	323	347	173	187	201
20	2	27	29	32	14	16	17
	4	63	68	74	36	39	42
	6	141	152	163	81	88	95
	8	301	325	350	176	190	204
10	2	29	32	34	17	18	19
	4	66	71	77	38	41	44
	6	144	154	166	84	90	97
	8	304	328	352	178	192	107
0	2	31	34	36	18	20	21
	4	67	73	78	40	43	46
	6	145	156	167	85	92	99
	8	305	329	354	180	194	208

TABLE B-10.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 75, 400 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	155
40	2	0	0	0	0	0	0
	4	3	5	7	0	0	0
	6	30	35	39	9	12	14
	8	87	96	104	43	48	53
30	2	0	0	0	0	0	0
	4	10	12	13	0	1	2
	6	37	41	45	16	18	21
	8	94	102	111	49	54	49
20	2	2	3	4	0	0	0
	4	15	17	19	5	6	8
	6	42	46	50	21	24	26
	8	99	108	116	55	60	65
10	2	7	8	8	2	3	3
	4	19	21	23	10	11	12
	6	47	51	55	26	28	31
	8	104	112	121	59	64	69
0	2	11	12	13	6	7	7
	4	24	26	28	14	15	16
	6	51	55	58	30	33	35
	8	108	116	125	64	69	74

TABLE B-11.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 75, 800 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	3	4	5	0	0	0
	4	23	26	29	8	9	11
	6	66	73	79	33	37	41
	8	156	170	183	86	94	102
30	2	8	9	10	0	1	2
	4	28	31	34	12	14	1 6
	6	71	77	84	38	42	46
	8	161	175	188	91	99	107
20	2	12	13	14	4	5	6
	4	32	35	38	16	18	20
	6	75	81	88	42	46	49
	8	165	179	192	95	103	111
10	2	15	16	17	7	8	9
	4	35	38	41	20	21	23
	6	78	84	91	45	49	51
	8	168	182	195	89	106	114
0	2	17	19	20	10	11	12
	4	38	41	44	22	24	26
	6	81	87	94	48	51	55
	8	171	184	198	101	109	117

TABLE B-12.--Growth increase required to warrant an investment in AOG red pine seedlings, site index 75,1200 trees per acre (in percent).

Expected Survival Improvement (percent)	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		14.91			25.31		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	15	17	18	5	6	7
	4	43	47	51	21	24	26
	6	103	112	121	57	62	67
	8	229	247	266	131	142	153
30	2	18	20	22	8	9	10
	4	47	51	55	25	27	30
	6	107	116	125	60	66	71
	8	232	251	270	134	145	157
20	2	21	23	25	11	12	13
	4	49	53	58	28	30	32
	6	109	118	127	63	68	74
	8	235	254	273	137	148	159
10	2	23	25	27	13	14	15
	4	51	55	60	30	32	35
	6	111	120	129	65	70	76
	8	237	256	275	139	150	161
0	2	24	26	28	14	15	16
	4	53	57	61	31	34	36
	6	113	122	131	66	72	77
	8	238	257	276	140	151	163

TABLE B-13.--Growth increase required to warrant an investment in AOG jack pine seedlings, 500 trees per acre (in percent).

Site Index	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord: 20.09 AOG Cost, $/1000: 135	143	150	Stumpage Price, Dollars per Cord: 30.99 AOG Cost, $/1000: 135	143	150
40	2	93	99	105	60	64	68
	4	202	215	228	131	140	148
	6	433	461	490	280	299	317
	8	914	974	1034	592	632	670
50	2	54	58	62	35	38	40
	4	118	126	134	77	82	87
	6	254	270	287	164	175	186
	8	536	571	606	347	370	393
60	2	35	37	39	23	24	26
	4	75	80	85	49	52	55
	6	162	172	183	105	112	119
	8	342	364	386	221	236	250
70	2	24	26	27	16	17	18
	4	52	56	59	34	36	38
	6	112	119	127	73	77	82
	8	236	252	267	153	163	173

TABLE B-14.--Growth increase required to warrant an investment in AOG jack pine seedlings, 1000 trees per acre (in percent).

Site Index	Real Rate of Interest (percent)	Stumpage Price, Dollare per Cord					
		20.09			30.99		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	142	151	161	92	98	104
	4	309	329	349	200	213	226
	6	662	705	748	429	457	485
	8	1397	1488	1579	906	965	1024
50	2	85	91	97	55	59	63
	4	186	198	210	120	128	136
	6	398	424	450	258	275	292
	8	840	895	950	545	580	616
60	2	53	56	60	34	36	39
	4	114	122	129	74	79	84
	6	245	261	277	159	169	179
	8	518	552	586	336	358	380
70	2	38	41	43	25	26	28
	4	83	88	94	54	57	61
	6	178	189	201	115	123	130
	8	376	400	425	244	259	275

TABLE B-15.--Growth increase required to warrant an investment in AOG jack pine seedlings, 1500 trees per acre (in percent).

Site Index	Real Rate of Interest (percent)	Stumpage Price, Dollars per Cord					
		20.09			30.99		
		AOG Cost, $/1000			AOG Cost, $/1000		
		135	143	150	135	143	150
40	2	190	202	215	123	131	139
	4	412	439	466	267	285	302
	6	883	942	999	572	610	647
	8	1866	1987	2109	1209	1288	1370
50	2	110	117	124	71	76	80
	4	238	254	269	254	265	275
	6	510	544	577	331	353	374
	8	1078	1149	1219	699	745	790
60	2	71	75	80	46	50	51
	4	154	164	174	100	106	113
	6	329	351	373	214	228	242
	8	696	741	787	451	481	510
70	2	51	56	59	34	36	38
	4	114	121	129	74	79	83
	6	244	260	276	158	169	179
	8	515	549	582	334	356	378