ABSTRACT

PAUL SHANNON. Evaluation of Financial Returns for Different Seed Orchard Establishment Options (Under Direction of Drs. Bailian Li and Robert Weir).

The loblolly pine (*Pinus taeda* L.) seed orchard managers of the North Carolina State University-Industry Cooperative Tree Improvement Program (NCSU-ICTIP) are faced with a choice of roguing existing 2nd generation orchard, establishing 2.5 generation seed orchards, establishing 3rd cycle mixed orchard (with both 2nd generation clones and their offspring) or 3rd cycle offspring seed orchards. The 3rd cycle orchards may be established immediately in 1999 or delayed to 2004 when all the progeny test information and selections are available.

Using both the genetic gains and the economic factors, the Net Present Value were examined for each of the above seed orchard establishment options, establishment time, and roguing options for the Piedmont and Coastal Plain regions of the Southeastern USA. The genetic gains for parent clone selections were based on 2nd generation breeding values of the loblolly pine breeding program. The genetic gain for 3rd cycle selections was predicated with the variance components, heritability and selection intensity. Cost and other information were collected from both state and private members of the cooperative. This information was used to calculate the Net Present Value for each option on the Piedmont and Coastal plain for both private and state members of the cooperative. The sensitivity of each option to changes in the interest rate, annual change in timber prices, seed yield, and accuracy of genetic gain estimates was also examined.

The results from this study showed that genetic improvement of loblolly pine was very profitable. The financial benefits were high and overwhelming in certain cases, for example, exceeding $100 million for merchandized timber from a state agency on the Coastal plain region. The Net Present Values (NPVs) of the two 3rd cycle options were higher than unrogued 2nd generation orchard. Additionally, it was more profitable to wait to establish the 3rd cycle orchards in 2004 to take advantage of all 3rd cycle selections available. The sensitivity analyses showed that financial returns from all the options were quite robust. The NPVs stayed positive in all cases except when all timber was used for pulpwood only and double digits discount rates were used for the rogued 2nd generation orchard in the Piedmont region. Merchandising the timber was in every case more profitable than harvesting all the volume for pulpwood, due to the premium market price for saw timber versus the low market price for the additional pulpwood volume. In conclusion, the 3rd cycle mixed orchard was recommended to seed orchard managers because NPVs were similar to the 3rd cycle offspring orchard, but it has the added advantage of known and tested clones that could provide operational efficiency and reliable gain in an applied tree improvement program.

EVALUATION OF FINANCIAL RETURNS FOR DIFFERENT SEED ORCHARD ESTABLISHMENT OPTIONS

By

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BIOGRAPHY

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TABLE OF CONTENTS

Page

List of Tables

Page

List of Figures

1. INTRODUCTION

The North Carolina State University-Industry Cooperative Tree Improvement Program (NCSU-ICTIP) has completed two cycles of breeding and is now implementing the 3rd cycle of breeding for improving loblolly pine (*Pinus taeda* L.). Second generation seed orchards are providing over 50% of the total seed harvest in the region. Genetically improved planting stock has an estimated average genetic gain of 13-21% in volume per acre at the end of a 25 year rotation compared to trees grown from unimproved seeds (Li et al. 1998) (Li et al. (1999)

The 1st generation selection of loblolly pine was started in 1950 by selecting superior (plus) trees from natural populations. The selection of the trees was based on growth, stem form, and freedom from rust diseases and insects (Talbert, 1982). The selection intensity of plus trees ranged from 0.97 to 1.89. Scions from selected trees were grafted to start 1st generation seed orchards. Then, plus trees were progeny tested with unimproved wild seeds in order to estimate genetic gains. A factorial mating design (tester) was used for breeding, in which four to five parents were used as tester and crossed with the all the other trees in the orchards (Talbert, 1982). The field experimental design was a randomized complete block.

By 1982, some of the field tests were old enough to estimate realized genetic gain from progeny trials. Genetic gains for height at various ages averaged about 3%. In order to estimate gain for volume at the end of a 25-year rotation, the improved trees were assumed to have a three-percent higher Site Index (SI) than unimproved stock. Then, using growth and yield models, the gain at the end of the rotation was estimated to be 6.4 % from the original orchards. When these orchards were rogued by removing the poor performing clones, the genetic gain increased to 12.7%. Talbert (1982) also reported improvement for stem straightness and fusiform rust disease resistant besides vigor. Superior trees from these 1st generation progeny tests were also used as the material for the next cycle of tree improvement.

The 2nd cycle of improvement began at the end of the 1970's with selections being made from 1st generation progeny tests. The orchards established from these were producing seeds by the end of the 1980's and by 1999 were responsible for more than half the seeds harvested by the cooperative. (Li et al. 1999)

With each successive generation of improvement, it has become vital to take full advantage of the gains. There are at least four options for fully utilizing genetic gain from breeding cycles. One option would be to rogue existing second-generation seed orchards, leaving only the best clones for seed production (rogued 2nd generation orchard). The Next option would be to select the best 2nd generation clones based on their breeding value information and use them to establish a new 2.5 generation seed orchard (Zobel and Talbert, 1984). Another option would be to select the best 2nd generation clones and the very best performing progenies from 2nd cycle parents. These selections would then be grafted to establish new 3rd cycle mixed seed orchards. The final option would be to select only the best progenies of best 2nd generation families in progeny tests to establish 3rd cycle offspring seed orchards. The first option could and probably would be used in conjunction with the other options.

The results from progeny test data are not available at once, but due to different establishment years, different test series are evaluated at different years. With each passing year, more progeny tests data become available (McKeand et al. 1997). Thus, the establishment time of new seed orchards adds a complexity to make a decision. Results from 2nd generation progeny tests of the NCSU-ICTIP will culminate in 2004 when all 2nd generation progeny tests will have been assessed. The process of breeding and testing suggests that more genetic gain can be realized by using higher selection intensity in a larger population when all the progeny test results become available (Falconer and Mackay 1996). Since economic return is also a function of the number of years to realize it, a longer generation means smaller value return due to the delay. These different options would provide different genetic gains and would have different costs. Choosing the economic option is a dilemma that cooperative members and tree improvement managers commonly face.

There are several reasons for why many options are available. First, many of the second-generation orchards are now in full seed production. That gives an opportunity to rogue seed orchards intensely without causing considerable seed shortage. Additionally, as the breeding and testing work culminates, the cooperative will have more information on family performance from 2nd generation progeny tests. Not only can this information guide orchard managers on what families can be rogued out of the 2nd generation orchard, but these tests also provide trees to start 3rd cycle seed orchards.

1.1. Objectives

The objectives of this study are:

1. To provide a comparative analysis of genetic gains, costs, and financial returns associated with each of four seed orchard options; 2nd generation rogued, 2.5 generation, 3rd generation mixed, and 3rd generation offspring.
2. To determine the sensitivity of each option's net present value when the discount rate, timber prices, seed yield, and the accuracy of the genetic gain predictins are varied.
3. To develop recommendations for genetic program managers applicable to their operational tree improvement programs.

1.2. Literature Review

Porterfield (1974) used goal programming to provide recommendations to different agencies on how to make the improvement programs more efficient. He examined genetic gains and costs for different programs for industry, state, and private land owners.

Ledig and Porterfield (1974) estimated the amount of volume gain that is needed to produce a profit for two West Coast species, Ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engel.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Using a sensitivity analysis, they found that the interest rate, seed yield, and length of rotation all had large effects on the break-even point. They also examined the long rotations of these species (up to 120 years) and found that intermediate thinnings may be needed to realize a return.

Buford and Burkhart (1987) demonstrated that the growth curves of unimproved and improved trees only differ in their height, not in the actual shape of the curve. This means that the volume of an improved stand can be predicted with a growth and yield model that accurately models the growth of unimproved trees (Talbert 1982).

Talbert (1982) summarized the genetic gain from the 1st generation of Loblolly pine improvement. The gain for tree height at age 12 was used to estimate the gain in volume at rotation age with a growth and yield program for predicting height and volume. Using this gain data Talbert et al. (1985) described how the added cost of the improvement program can be more than made up for by the gain achieved from the improved trees. They showed that depending on the amount of seed produced, the real rate of return ranged between 14.3 and 18.7 percent (Talbert et al. 1985). The investment cost per pound of seed was shown to depend on the seed yield in pounds per acre.

McKenney et al. (1989) studied the returns of black spruce (*Picea mariana* L.) improvement using cost-benefit analysis. By comparing the returns from approaches using seed orchards and rooted cuttings, they indicated that either approach was not profitable at the current stumpage prices in the region but the seed orchard approach could realize returns at lower stumpage prices than rooted cuttings. They assumed a fixed research cost, regardless of the scale of the program. It was also assumed that as the tree improvement program becomes larger, the research costs would make up a smaller percentage of total cost.

Using earlier gain data, McKeand et al. (1997) used the present value of the 2nd cycle genetic gain to suggest an optimum time to establish a 2.5 generation seed orchard. They also recommend a 2.5 generation seed orchard over a 3rd generation seed orchard for several reasons, including the fact that the characteristics of 2nd generation clones are well known so that problems associated with orchard clones can be eliminated. However, unlike this study, the net present value for the orchard was not calculated.

2. MATERIALS AND METHODS

2.1. Second generation genetic gain

More than 2000 progenies were selected by the NCSU-ICTIP from 1st generation tests and were available to use in second-generation seed orchards (Li et al. 1998). In order to estimate genetic gain for second-generation families, open-pollinated progeny tests were established using a randomized complete block field design. With the data collected in these tests, breeding values of families were then calculated using the best linear unbiased predictions (BLUP) method (Little et al. 1996). The genetic gains in volume at 25 years were estimated using the gain in height at 8 years and are presented in Table 1 (Li, et al. 1998).

Table 1. Genetic gains for loblolly pine 2nd cycle improvement program in the different regions of the southern U.S. (from Li, et al. 1998). Note, VA = Virginia and NC = North Carolina.

	Avg. For all Families		Avg. for best 30% of families	
Region	%Height	%Volume	% Height	%Volume
VA/NC	8.1	17.0	12.7	27.0
Atlantic Coast	6.1	12.8	12.4	26.3
Lower gulf	7.7	16.0	14.6	31.2
Piedmont	9.9	20.7	16.0	34.9
Average	8.0	16.5	13.9	29.9

In this table, the average for all families indicates the gain of the 2nd generation orchards at establishment, while the average for the best 30% of families is representative of the gain that is possible after these orchards are heavily rogued. These gains were found by averaging the breeding values of all and 30% of the families, respectively for the different regions.

2.2. Genetic gains from third generation selection

Genetic gains from forward selection of third generation selections were estimated using the variance components and heritabilities from disconnected-half-diallel tests as described by Xiang and Li (2000). Genetic gains for height at age 6 were estimated using the following equation (Falconer and Mackay, 1996).

[1] $G = i \, \sigma_p \, h^2$

Where G is genetic gain, h^2 is heritability of interest (family or within family), i is selection intensity, and σ_p is phenotypic standard deviation of family means or within family.

2.3. Rogued 2nd Generation Seed Orchard

Genetic gain calculations for the rogued 2nd generation seed orchards were based on breeding value estimates of height at age 6 for the appropriate regions. This hypothetical 2nd generation orchard was then rogued as follows.

Age of seed orchard	Best families left
8	70%
12	50%
16	40%
20	30%

To calculate genetic gain for height at age 6, all the breeding values were ranked in descending order and then, the average of the top families for a given seed orchard was calculated. For example, when the orchard is eight-years old, it is rogued to the top 70% of families. The approximate genetic gain for the orchard would be the average of breeding values of the top 70% families.

Genetic gains for height at age 6 were then converted to the genetic gain in volume at age 25. This was done using a loblolly pine growth and yield model that takes the trees to the end of 25-year rotation age (Hafley et al. 1982). The first step of the model required the establishment of some baseline to compare the improved trees and to simulate the genetic gain of the rogued trees at the end of a 25-year rotation. Running the model with a site index (at base age 25) did this. The site index of loblolly pine in the model was then set to a value that represents the typical site in the zone of interest. In this study, a loblolly pine site index of 70 for the Coastal Plain and a site index of 65 for the Piedmont were used.

The growth and yield model would only simulate the height and volume of a 10-year old stand or older. However, the breeding values used for this analysis were estimated at age 6. In order to estimate gain for age 10, It was assumed that the genetic gain in height at age 10 is the same as it is at age 6. The validity of the extrapolation was shown by Li et al.

(1996). They showed that both genetic gain and selection efficiency for 20-year volume is similar at both ages 6 and 10.

The first step in transforming the height gain at age 6 into a volume gain at age 25 was to run the growth and yield model at the baseline site index. The average height of this stand at age 10 was then considered to be the height of the appropriate commercial check. Since the breeding values listed in the Cooperative database are in terms of the gain over the commercial check, finding the average height of the improved trees at any roguing intensity could be done by a formula,

[2] $$h_{Im} = h_b(1+(b_a/100))$$

Where h_{Im} is the height of the improved trees, h_b is the height of the commercial check trees, and b_a is average breeding value of trees in the orchard. Once the average height of the second generation trees were found, the Site $Index_{25}$ in the growth and model was raised until the average height of the trees matched the height calculated above. Then, the growth and yield model was run to age 25 for both of the site indexes. The volume gain at age 25 for the rogued second-generation orchard was calculated using the following formula:

[3] $$G_{25vol}= 100(1-(V_{r2nd} / V_{SI70}))$$

Where G_{25vol} is genetic gain in volume at age 25, V_{r2nd} is volume per acre of the improved trees, and V_{SI70} volume of the commercial check trees.

2.4. 3rd Cycle mixed seed orchard

Genetic gains of all the orchard options in this study were based on the second-generation breeding values. For the rogued second-generation orchard, the average breeding value for all the families in the appropriate region was used as the genetic gain of the orchard at establishment it was then successively rogued as described above down to 30 %.

A pure 2.5 generation seed orchard would be equivalent to the rogued 2nd generation orchard. This option was not simulated in this study because the top ranked parents would need to be grafted into a new orchard and if a member was going to establish a new orchard, it would be logical to establish a mixed orchard with the best 2nd generation parents and a few outstanding 3rd generation selections to create a 3rd cycle mixed seed orchard.

Sorting the database in the following ways simulated 3rd cycle mixed seed orchards. First, only selections that did not share common parents were used. This reduced the gain of the orchard because many of the highest performing clones shared common parents. Also, the clones selected met the following requirements: a) any family that was not of at least better than average stem straightness was eliminated. b) If the clone's progeny has a rust infection rate of higher than 40% when the combined commercial check had a infection rate of 50% it was also excluded. This meant that the selection intensity was lower than it could have been otherwise. c) In addition to the second-generation clones that were used in this orchard, several third cycle selections (best performing progenies of 2nd generation parents) were also used. Since less information was available for 3rd cycle clones, only those clones whose parents were also selected were included in the mixed orchard. d) Those third generation clones that were selected replaced both 2nd generation parents. However, since less information was known about 3rd generation selections, their total number in the mixed orchard was kept to four or five out of a total of 25 clones that were included in the seed orchard at establishment. So for example in the Coastal plain, the 3rd cycle mixed seed orchard that was established in 1999 had 25 clones selected by the above criteria. There were then rogued according to the regime outlined above. For the orchards established in 2004, the breeding values of the top 13 clones were used to simulate the higher selection intensity that could be used at this time.

2.5. 3rd Cycle offspring seed orchard

Genetic gain for the 3rd cycle offspring trees was predicted using variance components, heredity, and selection intensity as described in the genetic gain equation (1). The same methods were used for selecting the clones included in the 3rd cycle offspring orchard as was used in the 3rd cycle mixed orchard. But in this case only the offspring of 2nd generation parents were used, not the parents themselves.

2.5. Cost Estimates

Since the NCSU-ICTIP has both private companies and state agencies as members, the costs for each were analyzed separately as in Porterfield (1974). The types of costs involved in seed orchard establishment can be divided into two main categories, fixed and variable. These can be further divided into annual, periodic, and one-time costs. A fixed cost is one that does not change with the scale of the seed orchard. Mckenny et al. (1989) put the cost of research and progeny testing in this category.

Porterfield (1974) gives the cost of selection per clone. Other fixed costs of orchard establishment include the salary of the manager, the cost of the necessary buildings, and the costs of any equipment needed for maintenance. The size of the orchard will be assumed to be 25 acres.

Variable costs are those that depend on the scale of the orchard. There are both annual costs and periodic costs in this category. The costs of establishment are one-time costs. Porterfield (1974) recognizes site preparation per acre and orchard establishment per clone as one-time variable costs. He proceeds to divide these two further. Site preparation includes land clearing and burning, and orchard establishment includes root stock planting and grafting. Roguing would be ether a periodic or one-time cost depending on how many times it is performed during the life of the orchard. The cost of the land would also be a one-time cost. Porterfield (1974) recognizes the following annual costs: fertilization, mowing, pest management, and supervision. The cost of harvesting seed and growing seedlings in the nurseries also depends on the size of the seed orchard. It would be considered an annual cost. Other costs include plantation establishment and maintenance. All the above costs tend to increase due to inflation, which was taken into account in cost estimation.

2.6. Collecting Cost Information

In this study, both fixed and variable cost information was solicited from members of the NCSU-ICTP Cooperative by surveying selected members of the Coop. The content of the survey was modified from the categories suggested by Porterfield (1974).

The data was collected confidentially and anonymously, especially for the private industries, and was differentiated based on only whether it was from a state agency or a private industry from the Piedmont or Coastal Plain. The data in each was averaged before being used for analysis.

Financial information collected by the survey of selected NCSU-ICTP members

Fixed Costs

1.Orchard establishment costs (Roads, equipment storage, irrigation, etc.)

2. Annual tree improvement budget (breeding, testing and selection and applied research)

Variable Costs (Per acre)

1. Orchard establishment costs (Site prep, root stock, grafting, ect.)

2. Management costs

3. Land value per acre

4. Roguing cost

Other financial info

1. Information on cost capitalization

2. Information on roguing and seed production

3. Information on the life of the seed orchard

4. Information on the alternative rate of return.

2.7. Financial Returns Estimates

The financial returns for each of the options depends on the amount of seed produced per year, the location, and the time of the orchard roguing (Porterfield, 1974). The seed yields were estimated using the numbers provided by the cooperative. Another factor in determining the financial return is the length of the rotation. For this study, a rotation length of 25 years was used since it is a good average value of different cooperative members. The last factor that affects the return is the value of the timber produced. This was determined using prices in 1999 from “Timber Mart South” (University of Georgia, 1999) for both the Piedmont and the Coastal Plain and adjusted over time by assuming annual price changes.

Another possible return from a seed orchard is by the sale of seed or seedlings. This has the advantage of providing an immediate return compared to waiting 25 years for a return from the planting of seedlings. The Cooperative members were surveyed about how important seedling sales are for the company before it was decided to include this in the financial return estimates.

One of the main differences between the returns of the rogued 2nd generation and the 3rd cycle orchards (both mixed and offspring) is the time these returns are realized. This is because the rogued 2nd generation seed orchards will produce seed immediately since they already consist of mature trees. On the other hand, the 3rd cycle seed orchards will be established with new grafts and therefore will take several years to start producing seed. For this study, it was assumed that it takes five years for seed production to start and an additional three to five years after that for full seed production.

2.8. Collecting Information on Financial Returns

In this financial analysis, revenue came from two activities. Some seed was either sold or grown as seedlings. Most of the returns from the seed orchard were from the additional volume of wood produced by the genetically improved seeds. Information for these financial returns was collected in the following ways. For the portion of the seed that was sold a price per pound of seed was determined based on the amount of roguing that had been done on the orchard at the time of harvest. The price of seed from an unrogued seed orchard and a fully rogued one were based on information from the Cooperative. The price of seed from the intermediate stages of roguing was interpolated from the above.

For the volume returns of improved seed, revenues were based on the values of the different products from Loblolly pine. The products used in this analysis are the ones that are produced in the plantations of the cooperative members from the appropriate region as reported by “Timber Mart South” (University of Georgia, 1999).

2.9. Analysis of Genetic Data

The genetic gain data was analyzed to determine how the gain from each option affects the yield of plantations established with that option’s progeny. A growth and yield model was used to estimate the volume produced per acre and the value at harvest was determined. In order to simulate additional volume from genetic gain, the model was adjusted following the method by Hamilton and Rehfeld (1994). They used multipliers to adjust the model so stand height at a particular time matched what the genetic gain suggested it should be.

2.10. Production Costs

Seed orchard establishment and production costs were acquired by sending a survey to nineteen cooperative members in the fall of 1998. These members included four state agencies and fifteen private companies.

Responses were received from all four state-agencies and nine of the fifteen private companies. Some companies were concerned with the privacy of the information and decided not to answer certain questions. It is important to note that some of the Cooperative members went beyond what the survey asked for. Several members included worksheets that scheduled out the orchard establishment and management regime. The relevant cost information is shown in Table 2 and Table 3.

Table 2. Cost information from state agencies replies on the survey

Cost data	Fixed establishment costs	Variable establishment costs per acre	Management costs years 1-5. per acre	Years 6-10	Years 15+	Real discount rate	Years Till full Production
# of responses	4	4	4	3	3	2	4
mean	$50,000	$612	$450	$417	$450	5	11
median	$50,000	$450	$450	$450	$450	5%	11
mode	$50,000	$450	$350	#N/A	#N/A	#N/A	#N/A
Standard Deviation	$0	$431	$115	$153	$200	3%	2.8
range	$0	$950	$200	$300	$400	4%	6.5

Cost data	Seed Yield per acre	Land Value/acre	Productive life of orchard	% tree imp costs used for research and testing	. Annual Tree imp costs	Roguing costs	Roguing intensity
# of responses	4	4	4	4	4	4	4
mean	50	$1,113	22	44%	$212,500	($138)	36%
median	50	$1,250	20	30%	$225,000	($100)	35%
mode	50	$1,250	18	25%	$275,000	#N/A	#N/A
Standard Deviation	0	$275	5	31%	$75,000	$151	11%
range	0	$550	11	65%	$150,000	$350	25%

Table 3. Cost information from private industries replied on the survey

Cost data	Fixed estab. costs	Variable estab. costs per acre	Management costs years 1-5. Per acre	Years 6-10	Years 15+	Real discount rate	Years Till full Production	Seed Yield per acre	% prod. On company land.
number of responses	9	9	9	8	8	9	9	8	8
Mean	$150,278	$800	$472	$568	$744	8.11%	11.1	71.6	76%
Median	$87,500	$700	$450	$500	$650	8.00%	10	70.5	75%
mode	$50,000	$350	$550	$450	$650	8.00%	10	70.5	100%
standard deviation	$110,365	$551	$83	$189	$361	2.57%	3.1	13.6	21%
range	$300,000	$1,700	$200	$550	$1,150	9.00%	11.5	40.5	50%

Cost data	Land Value/acre	Productive life of orchard	% tree imp costs used for research and testing	. Annual Tree imp costs	Roguing costs (Return)	Roguing intensity
number of responses	9	9	8	8	8	9
Mean	$1,178	24	42%	$259,375	($31)	28.3%
Median	$900	23	35%	$250,000	($75)	30%
mode	$900	23	35%	$225,000	($75)	30%
standard deviation	$506	4.7	17%	$66,732	$156	7.1%
range	$1,300	12.5	55%	$225,000	$475	25%

2.11. Summary and discussion of costs information

Production costs were originally considered to be categorized not only according to whether they were from private companies or state agencies, but also on whether the seed orchard was going to be established on the Piedmont or the Coastal Plain. However, once the surveys were examined, it was decided to assume that any new orchard would be established in the Coastal plain region. This is because with very few exceptions, both the states and the private industries had timberland in both the Piedmont and the Coastal Plane. Coastal Plains are preferred for new seed orchard establishment. Environmental conditions in the Coastal Plains are more favorable for seed production than the Piedmont (Jett, 1986). The Piedmont region is more susceptible to late spring frosts and more prone to glaze storms that can damage tender flowers and reduce seed production (Jett, 1986).

2.12. Net present value of all options

Since genetic gain is predicted for rogued 2nd (Li et al. 1998), and genetic gain information is available for the 3rd cycle mixed and offspring seed orchards, the Net Present Value (NPV) for each of them can be estimated. NPV can be calculated by discounting all the costs back to the present value and then summing as suggested by Fox (1988).

$$[4] \qquad PV_{\text{costs for opt. X}} = \sum_{k=0}^{c} C_k/(1+i)^k$$

Where C_k= cost at year k, i = Discount rate, c= total number of years in the life of the orchard. The total PV of the financial returns can be found similarly.

[5] $$PV_{\text{returns for option x}} = \sum_{k=0}^{c} R_k/(1 + i)^k$$

Where: R_k = return at year k, i = Discount rate, c= total number of years in the life of the orchard. The NPV of the option was calculated by subtracting the total PV of the costs from the total PV of the return. Since roguing the existing 2nd generation orchard can easily be done alongside the other two options, 3rd cycle mixed and offspring seed orchards NPV's includes the costs and returns for the rogued 2nd generation.

2.13. Sensitivity Analysis

A sensitivity analysis was performed to investigate how the net present value and the break-even genetic gain of the above options are affected by changing the factors involved. Table 4 shows what factors are used to judge the sensitivity of the NPV functions.

Table 4. Variables examined for effect on Net Present Value in sensitivity analysis

Variable	Base Value	Range of variation
Alternative Rate Of Return	8.11 % for Private industry, 5% for State agencies	5% to 15%
Seed Yield	71.6 lbs per acre for Private industry, 50 lbs per acre for State agencies	50 to 100 Lbs. Per acre
Annual change in timber prices	No annual change	2% annual inflation to 2% annual deflation
Genetic gain	Breeding Value for age 6 height	Breeding Value ±1 STD

3. RESULTS AND DISCUSSIONS

3.1. Financial Analysis

The Net Present Values for each option in each region for both private industry and state agencies were evaluated for different establishment times and products (Table 5.) The full Net Present value for each option (for the whole time frame) is underlined.

Table 5. Net Present Value (x1000) of each seed orchard establishment option for a Private and State Agency Cooperative member operating on the Coastal Plain and Piedmont

a) Private Industry

Full NPV of option	Rogued 2nd	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cycle offspring 2004
C. Plains					
Merchandized					
For 15 years	*$17,195*	$21,074	$19,881	$18,817	$18,950
For 30 years		*$34,176*	$35,799	*$29,000*	$30,485
For 35 years			*$38,304*		*$32,297*
Pulpwood					
For 15 years	*$4,188*	$4,474	$4,330	$3,847	$4,052
For 30 years		*$7,750*	$8,254	*$6,296*	$6,913
For 35 years			*$8,894*		*$7,375*
Piedmont					
Merchandized					
For 15 years	*$10,459*	$11,188	$11,324	$10,487	$11,095
For 30 years		*$16,537*	$17,798	*$15,957*	$17,887
For 35 years			*$18,834*		*$18,970*
Pulpwood					
For 15 years	*$2,176*	$1,456	$1,751	$1,376	$1,739
For 30 years		*$2,381*	$2,934	*$2,367*	$2,984
For 35 years			*$3,124*		*$3,182*

b) State Agencies

Full NPV of option	Rogued 2nd	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cyclle offspring 2004
Coastal Plains					
Merchandized					
For 15 years	*$36,783*	$46,092	$42,671	$41,182	$40,846
For 30 years		*$89,512*	$95,569	*$74,930*	$79,233
For 35 years			*$106,954*		*$87,474*
Pulpwood					
For 15 years	*$10,541*	$12,583	$11,761	$11,060	$11,146
For 30 years		*$25,277*	$26,929	*$20,645*	$22,326
For 35 years			*$30,293*		*$24,782*
Piedmont					
Merchandized					
For 15 years	*$24,911*	$27,994	$27,624	$26,302	$27,142
For 30 years		*$47,717*	$51,578	*$46,496*	$52,297
For 35 years			*$56,817*		*$57,766*
Pulpwood					
For 15 years	*$5,581*	$5,137	$5,532	$4,959	$5,507
For 30 years		*$8,905*	$10,257	*$8,983*	$10,458
For 35 years			*$11,285*		*$11,525*

These tables show the Net Present Value of the options for the first 15, 30, and 35 years. Net Present Values for each option were calculated assuming that the harvested timber would be fully merchandised or used only for pulp. The values are marginal values, which include the costs and benefits directly associated with the roguing of the 2nd generation orchards and the establishment and roguing of the 3rd cycle orchards.

The most important finding of this study was the profitability of a tree improvement program. The extra money spent for research, selection, and establishment of seed orchards was more than compensated by the added value (both in quantity and quality) of the timber from improved trees. The Net Present Values ranged from $2 million for a rogued 2nd generation orchard (pulp, Piedmont, Private company) to $107 million for a 3rd cycle mixed orchard (Merchandised, Coastal Plain, State agency).

3.2. Sensitivity analysis

The profitability of Tree improvement can be further demonstrated by changing the alternative rate of return that affect the Net Present Value (Figures 1 and 2).

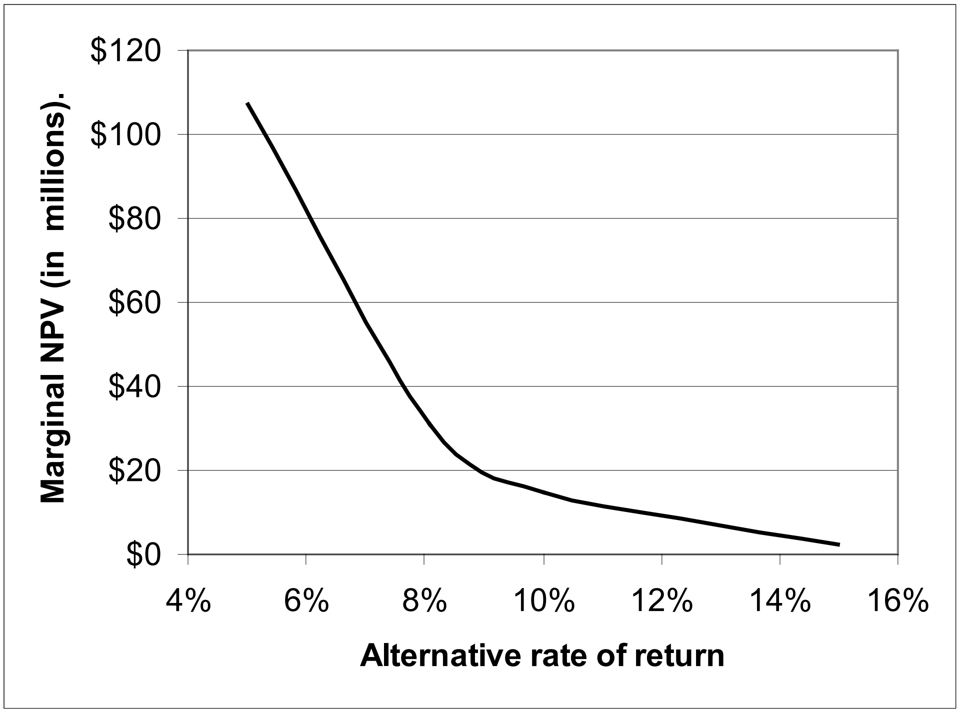

Figure 1. Net Present Value for various alternative rates of return at 35 years for a 3rd cycle mixed orchard established in 2004 on the Coastal plane by a state agency and harvested for all merchandize. The default alternative rate of return for this option is 5%

This option's Net Present Value stays positive even with the alternative rate of return set to fifteen percent. This means that this option has an Internal Rate of Return (interest rate where the NPV equals zero) at least 15%, a rate that is higher than used by any Cooperative members. This demonstrates that the risk of either option becoming unprofitable because of a change in company priorities (i.e. They change the rate of return that they use to evaluate projects) is low. Even the option with one of the lowest NPV's has a Internal Rate of Return of almost fifteen percent (Figure 2).

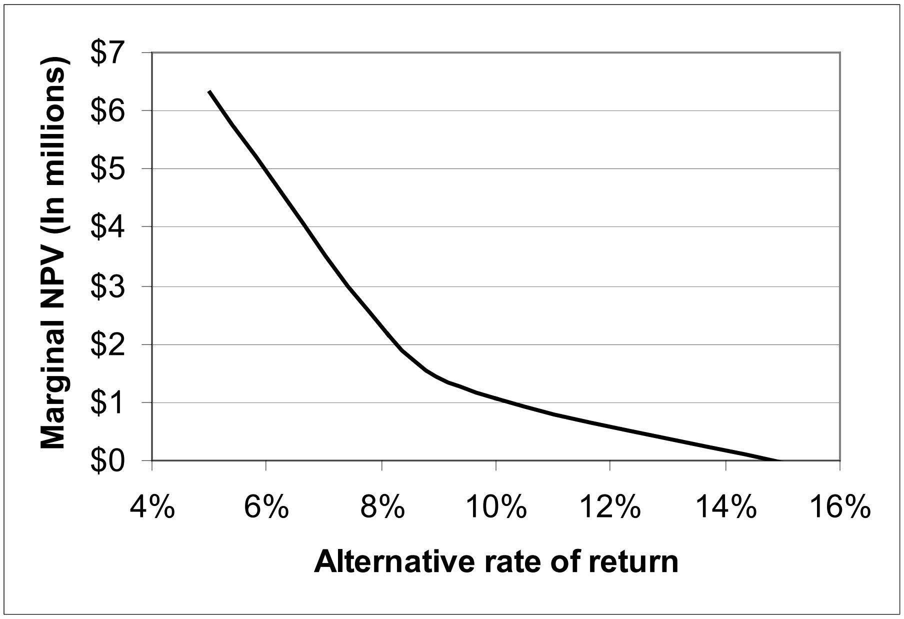

Figure 2. Net Present Value for various alternative rates of return at 15 years for a rogued 2nd generation orchard established in 1984 by private industry and harvested for pulp only. The default rate of return for this option is 8.1 %

While the returns for all options of tree improvement were positive, there are many factors that went into determining the Net Present Value of these options that could affect the amount of the returns. The most important variables were: the discount rate, any change in timber price over time above and beyond inflation, the seed yield of the orchard, and any deviation from the estimated gain. How the Net Present Value of a 3rd cycle mixed orchard established on the Coastal Plain by private industry in 1999 and fully merchandized changes as the above variables are changed is shown (Figures 3 thru 6).

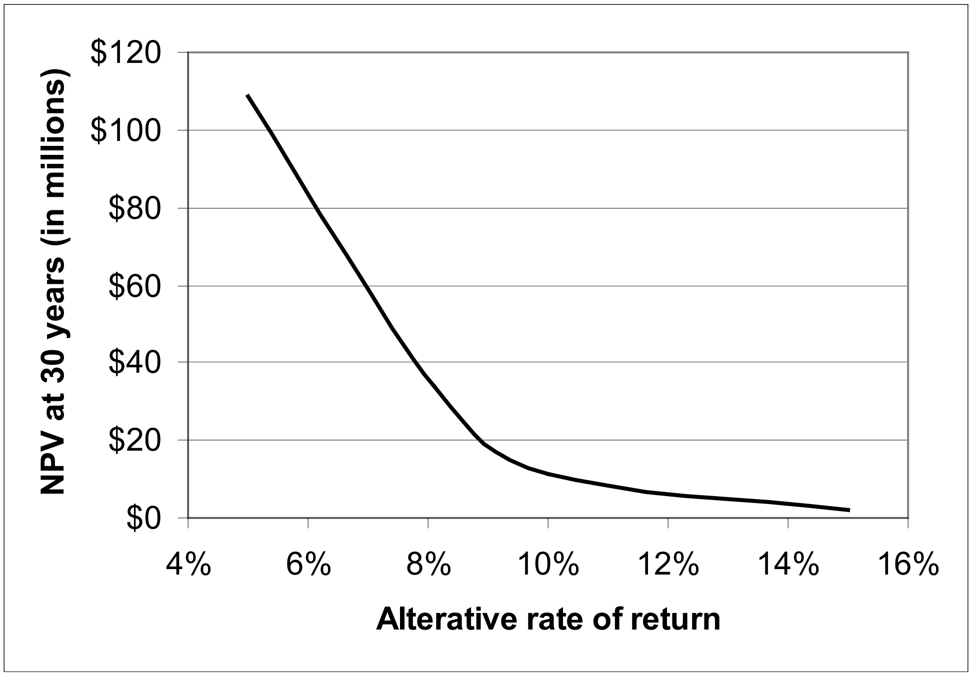

Figure 3. Net Present Value at 30 years of a 3rd cycle mixed orchard established in 1999 by private industry on the Coastal Plain and fully merchandized based on the alternative rate of return.

The Alternative rate of return had a large effect on its value (Figure 3). However even at 15%, the option still had a positive value. The other variables changed the Net Present value by a smaller degree. The Net Present Value was also affected by how timber prices behave in the future (Figure 4). For comparing with overall rate of inflation, the values are affected if the prices change faster or slower than the general rate of inflation.

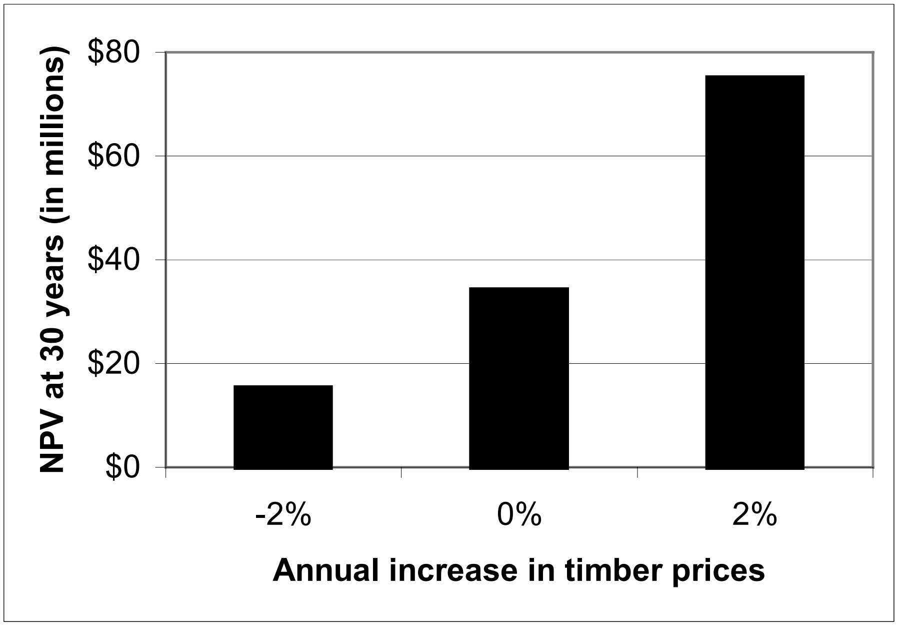

Figure 4. Net Present Value at 30 years of a third cycle mixed orchard established in 1999 on the Coastal Plain and fully merchandized based on the change in annual timber prices

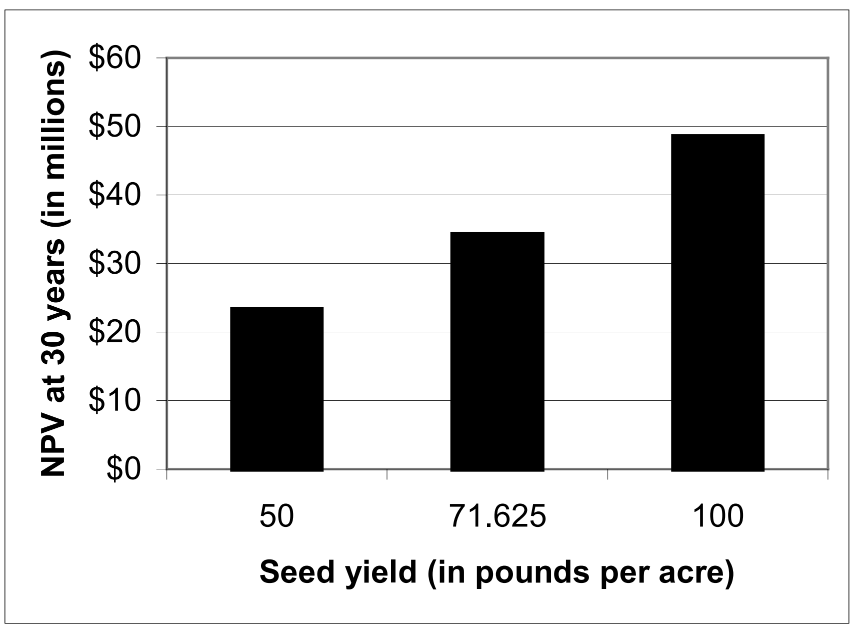

Figure 5. NPV at 30 years of a third cycle mixed orchard established in 1999 on the Coastal Plain and fully merchandized based on different seed yields

The Net Present Value of the orchard can be affected by how well seed production is managed as shown in Figure 5. The center value is the average production expected by the private cooperative members. It is clear that any improvements in seed production are very profitable. While the value gain of these tree improvement options comes from the increased genetic gain from improved trees, the total profits depend on factors completely different from the genetic gains of the orchard.

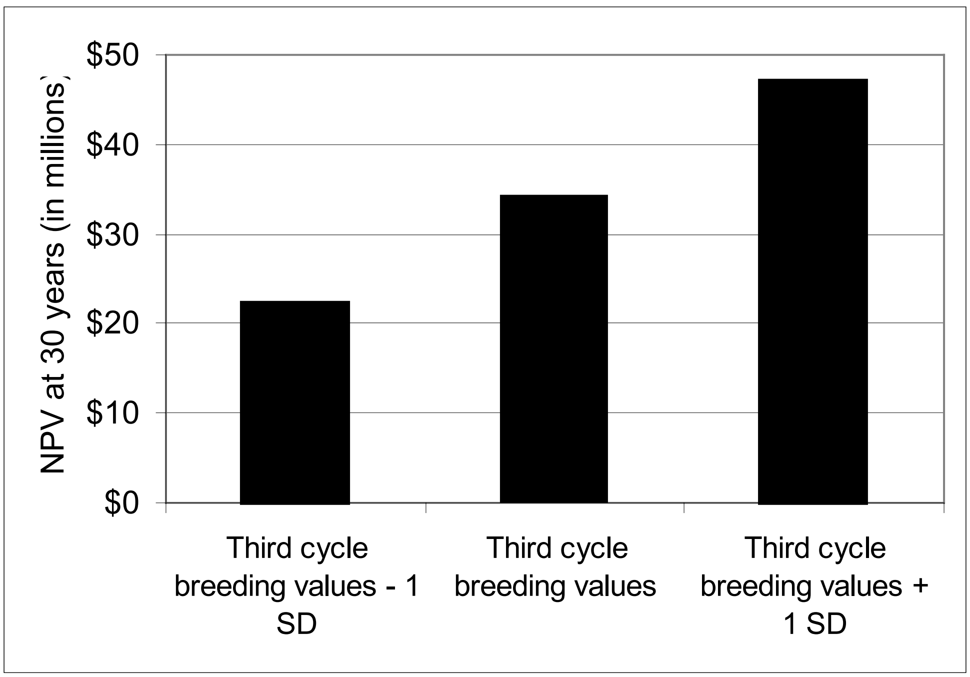

Figure 6. Net Present Value at 30 years of a 3rd cycle mixed orchard established in 1999 on the Coastal Plain and fully merchandized as affected by the accuracy of 3rd cycle gains

The uncertainty of the 3rd cycle gain was considered by changing the estimated breeding values of the third cycle options up and down one standard deviation (Figure 6.). The results make it apparent that increasing the accuracy of genetic gain estimations will help the decision makers.

While the gain in total volume is impressive, the increase in value is even higher. This increase in value is because as the genetic gain of the advanced generation orchards increases, an increasingly large proportion of the total volume of the timber would be high value saw timber. Figure 7 shows this by showing the volume of the different products and the total volume from different seed sources.

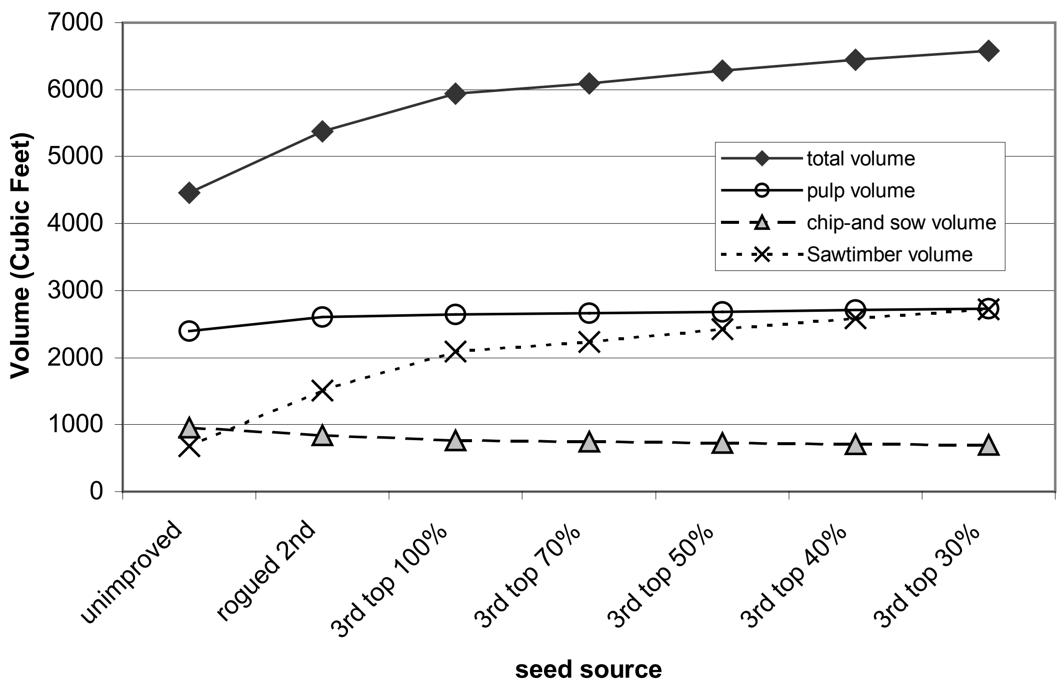

Figure 7. Total volume and volume of each product for unimproved, fully rogued 2nd generation and 3rd cycle mixed at various roguing levels for the coastal plain (3rd cycle established in 1999)

The amount of total volume that is saw timber is increasing at a much higher rate than the other products as an increasing number of trees in the plantation cross the threshold size to be considered saw timber. This is coupled with stumpage prices for saw timber, which are much higher than the price of pulp. This explains why the NPV of each of the options are much higher when they are merchandized (Tables 3 to 7). Therefore, if timberland owners planting the improved seedlings can merchandise the timber at harvest, tree improvement is even a better investment.

Net Present Value of the options is consistently higher in the Coastal Plain than the Piedmont (Tables 3 to 6). There are several reasons for this. First, Coastal Plain sites are generally more productive than Piedmont sites (Via personal communication from Dr. Zobel). This was taken into account by assuming that the Site Index (SI) at base age 25 for the commercial check in the Piedmont was 65 as opposed to 70 for the Coastal plain. Another explanation for the value difference is that timber prices are higher on the Coastal Plain than on the Piedmont.

The results suggested that in the Coastal Plain, establishing a 3rd cycle mixed orchard was more profitable than a 3rd cycle offspring orchard. However, the reverse was true for the Piedmont. An explanation for this can be seen by comparing the selections for both orchards in the piedmont.

Although the 3rd cycle mixed orchard starts out with higher gain, as each is rogued more intensely, the offspring orchard's gain becomes higher (Figure 8). This is because two or three families in this orchard that have very high breeding values.

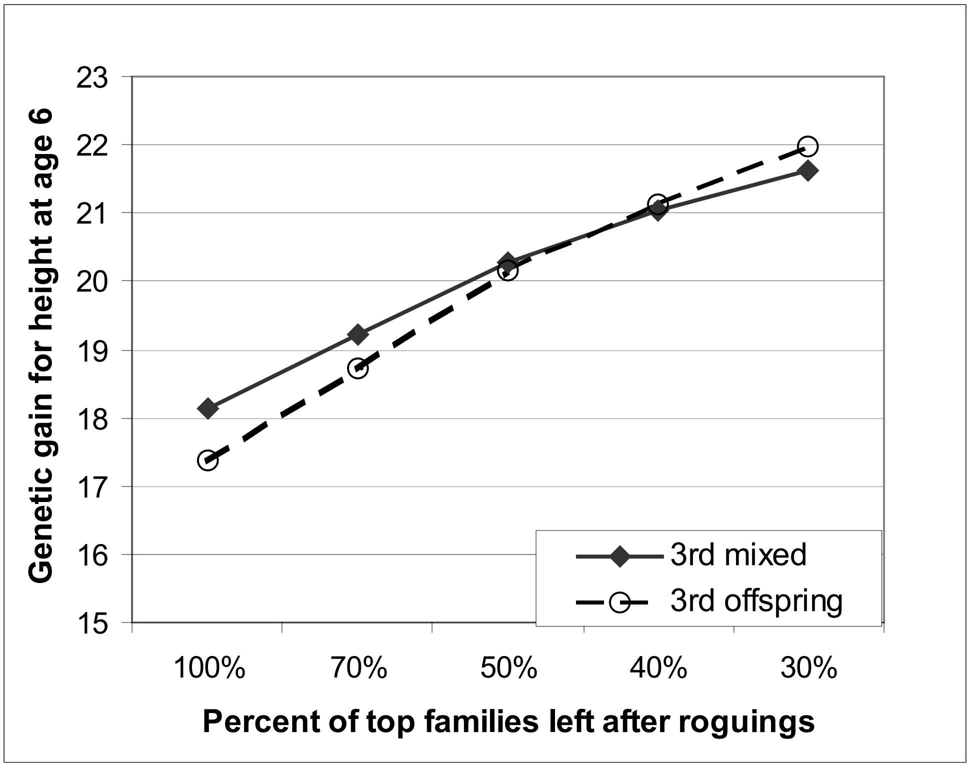

Figure 8. Comparison of genetic gain for height between a 3rd cycle mixed orchard and a 3rd cycle offspring orchard established on the Piedmont in 1999 after successive roguings

The results show that the returns from establishing advanced generation orchards compensated more than the cost of their establishment and management. Tree improvement has been an economical investment for a long time. Perry and Wang (1958) showed that even gains as small as one or two percent paid for any costs incurred in tree improvement. The volume gains predicted for the 3rd cycle orchards for all the scenarios in this study were much higher. The option with the smallest amount of gain (4.5%) over the alternative was roguing the 2nd generation seed orchard in the Piedmont. The amount of gain increased with the other options. The Net present value for each pound of seed harvested for each option is presented at Table 6.

Table 6. The NPV per pound of seed for each seed orchard establishment option for a tree improvement program run by private industry in the Coastal Plain

	2nd cycle Rogued	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cycle offspring 2004
Merchandized					
NPV per Pound seed	\$600	\$615	\$594	\$522	\$501
Pulpwood					
NPV per Pound seed	\$146	\$140	\$138	\$113	\$114

It is important to note that since this is the Net Present Value of each pound of seed, the cost of producing that seed has already been factored in. So for example, each pound of seed from the option of roguing the 2nd generation orchard and then establishing a 3rd cycle orchard in 1999 has a value of \$615. This is the marginal return of that pound of seed over the option of just roguing the 2nd generation orchard. Another way to look at the returns is to put the Net Present Value in terms of the amount per acre of pine planted. Since some of the seed crop is sold in the private industry scenarios, Table 7 illustrates this for a state run seed orchard.

Table 7. The NPV per acre reforested for each orchard establishment option for a tree improvement program run by a state agency in the Coastal Plain (Total gain per acre)

	2nd cycle Rogued	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cycle offspring 2004
Merchandized					
NPV per acre	$123	$154	$158	$129	$130
Pulpwood					
NPV per acre	$35	$43	$45	$36	$37

Thus, for example, the option of roguing the 2nd generation seed orchard and then establishing a third cycle offspring orchard in 2004 will return $129 on each acre of pine plantation. This is the return over the alternative option of just roguing the 2nd generation orchard.

A fact that stands out is that the 2nd generation rogued option looks better on the basis of pound per seed produced than on acre of plantation established. One reason for this could be that since it a pound of seed will plant more than one acre of plantation, the establishment and management, costs have more of an effect. Since the establishment costs do not occur in the rogued 2nd generation orchard, this helps its value per pound of seed Also the 3rd cycle options produce more seed and more plantations and this is not accounted for in ether figure.

One thing to note with these two tables is that they make the assumption that every pound of seed produced or acre of plantation established during the entire life of each option are the same. However this is not really the case since the ones produced closer to the present time are more valuable.

Comparing the results with economic analysis done in other regions could reveal some of the advantages of tree improvement in the Southeast. Ledig and Porterfield (1978) analyzed Ponderosa pine and Douglas-fir in the Southwest, while Lundgren and King (1966) analyzed jack pine (*Pinus banksiana* Lamb.) and red pine (*Pinus resinosa* Ait.) in the Northeast. In both studies, the long rotations of the species were included. Ledig and Porterfield stated that Ponderosa pine improvement was not economical without the income of thinnings during the rotation. In contrast, loblolly pine improvement has a large return even without thinnings as shown by this study. This return could probably be increased with mid rotation thinnings.

Two of the above species also had other factors that could negatively affect the possible returns of any improvement program. The problem with Douglas-fir is that the terrain of the Pacific North-West causes the environment to be much more varied than in the Southeast. Therefore, while the NCSU-ICTIP divides the Southeast into only seven different breeding regions, douglas-fir grows in dozens of different microclimates. If different programs had to be initiated for each one, tree improvement practices could prove uneconomical (Ledig and Porterfield 1978).

The major problem with red pine on the other hand is genetic. Red pine for a species with its range has relatively little genetic variation. Since any attempt to achieve genetic gain requires genetic variation (Falconer and Mackay, 1996), the gains from any improvement program for red pine could be limited in comparison to loblolly pine.

Even though the economic returns are high for each of the options, there is a drawback in investing in tree improvement (Figure 9).

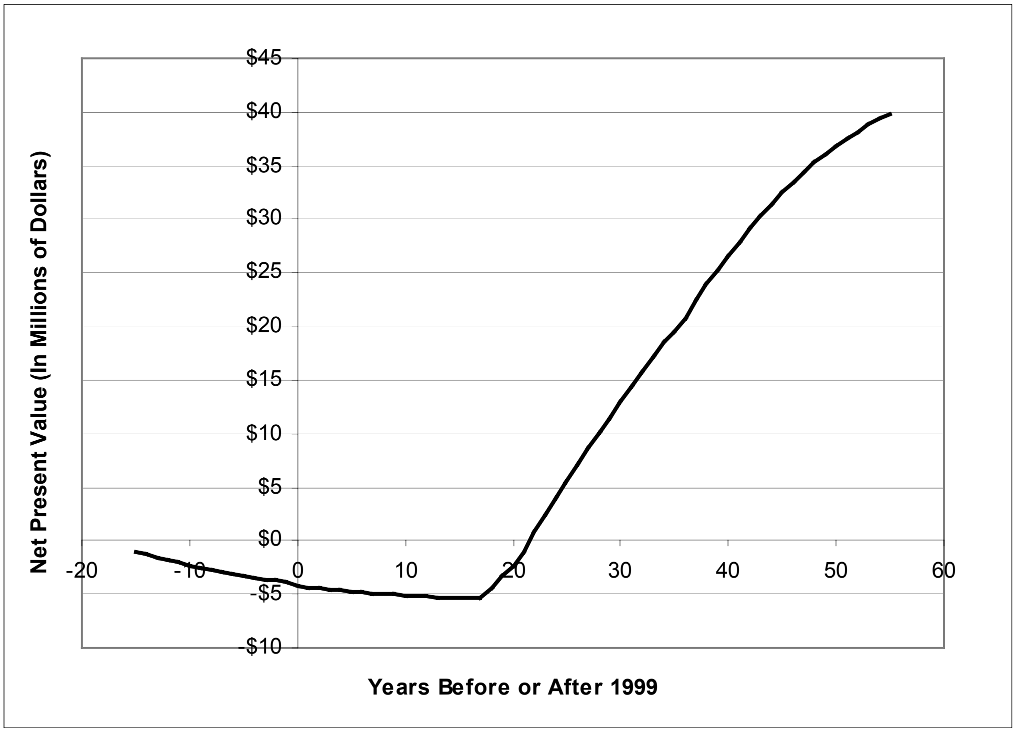

Figure 9. Cumulative Net Present Value from the option of roguing the 2nd generation seed orchard and establishing a third cycle mixed orchard in 1999 for private industry on the coastal plain

The final Net Present Value of the option is almost 40 million dollars. However, the option does not start to show a positive Net Present Value until over 20 years after 1999. This could make this option unattractive as compared to investments that promise immediate return. One way to take this into account would be to increase the Alternative Rate of Return.

The Net Present Value of each of the options for each type of cooperative member in each region was strongly positive. The outcome of the sensitivity analysis was the next most important result of this study. This analysis was needed to see if the returns could be adversely affected by any of the variables. Almost none of the changes in the main variables (discount rate, change in timber price over time, seed yield, and accuracy of gain estimates) made the Net Present value of any of the options negative. It can be stated with some certainty, the return of the tree improvement programs will be positive.

This apparent stability of tree improvement in the Southeast, like its high Net Present Value, shows it strength as compared tree improvement programs in other regions of the USA. This could be done by comparing each aspect of the sensitivity analysis done in this study with similar ones done in other studies.

3.3. Alternative Rate of Return

Table 8 shows how varying the discount rate affects the Net Present Value of private industry roguing a 2nd generation orchard and then establishing a 3rd cycle offspring orchard in 1999 on the Costal Plain.

The Net Present Value of this option is positive, except when the plantations are harvested only for pulp. At the highest discount rate of 15%, this starts to show negative Net Present Values. The alternative rate of return is used as one of the most important factors in determining if a project is profitable. It is usually one of first factors examined in a sensitivity analysis.

Table 8. Net Present Value (x 1000) of a 3rd cycle seed orchard established in 1999 on the Coastal plain by private industry at various alternative rates of return

Full NPV	**Rogued 2nd**	**3rd cycle mixed 1999**	**3rd cycle mixed 2004**	**3rd cycle offspring 1999**	**3rd cycle offspring 2004**
Merchandized		**Discount Rate**	**5%**		
For 15 years	*$44,366*	$56,656	$53,022	$50,203	$50,149
For 30 years		*$108,882*	$116,587	*$90,902*	$96,386
For 35 years			*$130,264*		*$106,306*
Pulpwood					
For 15 years	*$11,349*	$13,619	$12,930	$11,836	$12,074
For 30 years		*$27,131*	$29,057	*$22,063*	$23,987
For 35 years			*$32,632*		*$26,601*
Merchandized		**Discount Rate**	**8.11%**		
For 15 years	*$17,195*	$21,074	$19,881	$18,817	$18,950
For 30 years		*$34,176*	$35,799	*$29,000*	$30,485
For 35 years			*$38,304*		*$32,297*
Pulpwood					
For 15 years	*$4,188*	$4,474	$4,330	$3,847	$4,052
For 30 years		*$7,750*	$8,254	*$6,296*	$6,913
For 35 years			*$8,894*		*$7,375*
Merchandized		**Discount Rate**	**10%**		
For 15 years	*$9,782*	$11,575	$11,005	$10,362	$10,528
For 30 years		*$17,351*	$18,020	*$14,836*	$15,591
For 35 years			*$18,931*		*$16,248*
Pulpwood					
For 15 years	*$2,242*	$2,064	$2,064	$1,726	$1,921
For 30 years		*$3,456*	$3,740	*$2,750*	$3,124
For 35 years			*$3,967*		*$3,286*
Merchandized		**Discount Rate**	**15%**		
For 15 years	*$2,183*	$2,080	$2,100	$1,829	$2,013
For 30 years		*$2,773*	$2,947	*$2,355*	$2,610
For 35 years			*$3,013*		*$2,657*
Pulpwood					
For 15 years	*$271*	-$266	-$126	-$336	-$152
For 30 years		*-$139*	$36	*-$256*	-$50
For 35 years			*$50*		*-$41*

The effects of varying discount rates have been discussed by some other studies. Lundgren and King (1966) had similar estimates of the Net Present Value of a tree improvement program as in this study. They examined, long and short term improvement in Jack pine and red pine. The sensitivity analysis in this case showed that in both programs Net Present Values are strongly affected by what discount rate is used. However, in both species, the short-term program always had the higher value. In the same study, Lundgren and King (1966) only used discount rates up to 10 % and all of the programs NPV's were markedly reduced at this point. Even the program with the highest Net Present Value (the short-term Red Pine program) the value dropped from $1,689,300 to only $16,500 at the highest expected increase in Site Index. In this study, all the options still have a positive Net Present Value at 15% if their timber is fully mechanized.

However, the objective of Ledig and Porterfield's (1978) study was to determine what amount of genetic gain is required for Douglas-fir and Ponderosa pine programs to break even. In their paper, changing the alternative rate of return affects the amount of the increase in volume that is required to offset the costs of the program. How the break-even amount of genetic gain is affected by several other factors is also examined. The percent increase in volume needed is as follows. For an alternative rate of return of 5% a volume increase of .9% in the Ponderosa pine program is needed. This small amount of gain is almost guaranteed. If the discount rate rises to 8%, there needs be at least a 6.3% increase in volume to make up the costs. The Douglas-fir program was much less sensitive to changes in the variables although not having pre-harvest thinnings still adversely affected the program. According to Ledig and Porterfield (1978), this amount of gain is also obtainable. However, if the alternative rate of return climbs to 11%, then a volume increase of 35.4 % is needed to break even. This amount of gain is highly unlikely (Ledig and Porterfeild 1978). This study still has positive returns at 15% and that shows the advantages of tree improvement in the Southeast.

The sensitivity analysis (changing interest rate) in this study did not affect the optimum time to establish the 3rd cycle orchard. It always paid to wait until 2004 for all the progeny data to be available. This is in contrast to McKeand and Bridgwater's (1985) paper. They determined the optimum time to establish the next generation seed orchard by finding the discounted value of expected gain. Their calculation was based on dividing the gain of the early-established orchard by the gain of the orchard established using all the selections. This is then discounted back to the year when the first tests are established. The results of this paper show that the number of years into the selection period that the orchard should be established ranges from 8 years at a discount rate of 4% to 5 years at a discount rate of 15%. The difference between the above paper and this study can be explained by different methodology. In this study, several steps were taken in order to simulate the returns from 3rd cycle orchards as realistically as possible while McKeand and Bridgwater's (1985) paper was more theoretical. The paper determines the time to establish the next orchard by a method that does not take into account any of the costs of orchard establishment. In this study, marginal costs are accounted for. Also while their paper uses genetic gain, it is only for increases in breeding value and does not take into account additional gain from larger amounts of higher value forest products (Chip and saw and saw timber versus pulpwood).

Another difference between McKeand and Bridgewater's paper and this study is while tree improvement managers are waiting to determine the optimum time to establish their 3rd cycle seed orchard; they were still reaping gain from roguing their 2nd generation orchards. Even though varying the discount rate did not change the profitability of the orchard establishment in 2004 compared to establishing in 1999, the relationship between the two NP Values was affected (Figure 10). The NPV of a 3rd cycle orchard established in 1999 becomes larger in comparison to establishing the same orchard in 2004.

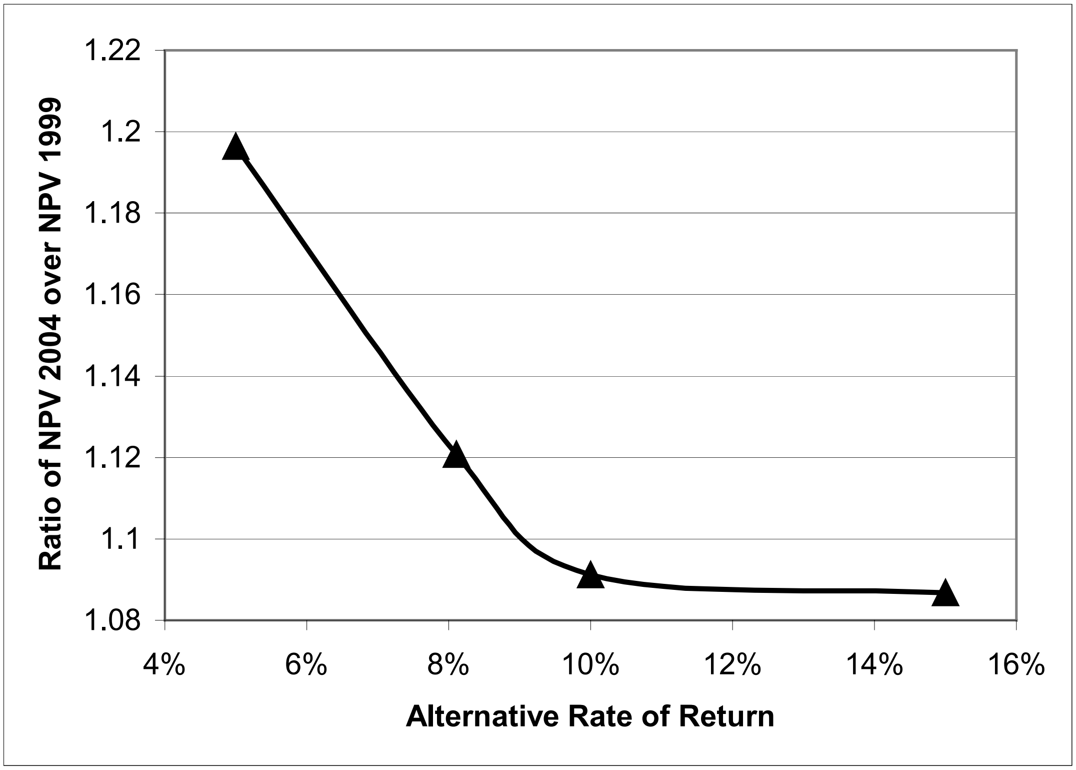

Figure 10. Ratio (NPV 2004 / NPV 1999) for the option of roguing a 2nd generation orchard and establishing a 3rd cycle mixed orchard on the Coastal Plain by private industry at various alternative rates of return for merchandized timber

3.4. Change In Timber Prices.

Table 9 shows how a annual change in timber price affects the Net Present value of all the options for private industry on the Coastal Plain. The rate change in the timber prices affects the return of starting a 3rd cycle mixed orchard in 1999 as compared to 2004 (Figure 11). The results seem counterintuitive; suggesting that annual decrease in timber prices would make the early establishment of the orchard more advantageous. However, as shown in the figure 11, a decrease in timber prices would give an advantage to the late establishment of the orchard. This can be explained by the effects of the change in annual rate of timber price on the return of the Net Present Value function and not the costs. Therefore, when there is a 2% annual decrease in timber prices, the return is reduced, the time of orchard establishment becomes a factor. All the establishment costs take place five years later when the 3rd cycle mixed orchard is established in 2004. The costs are then discounted five years in comparison to the 1999 option. In addition, the 2004 option has five more years of seed sale that is also not affected by the price change. When the annual rate of timber price increases from 0 to 2%, the ratio between the two prices behaves as expected. The five extra years that the 2004 option produces timber, has a larger effect because the price at that time would be higher.

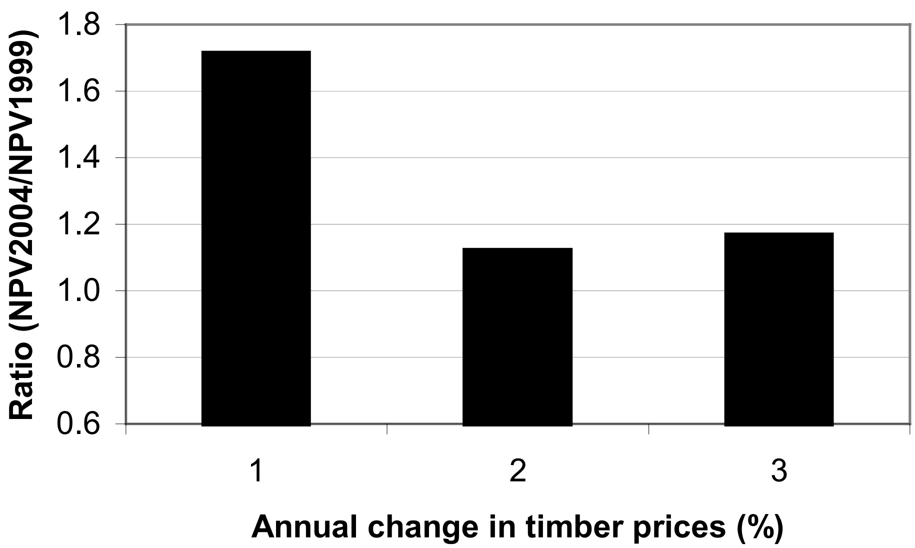

Figure 11. Ratio (NPV 2004/NPV 1999) for the option of roguing the 2nd generation orchard and then establishing a 3rd cycle mixed orchard on the Costal Plain by private industry as affected by the annual change in timber price

Table 9. Net present Value for each of the orchard establishment options for private industry on the Coastal Plain as affected by annual increases or decreases in the price of timber (x1000)

Full NPV	Rogued 2nd	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cycle offspring 2004
Merchandized			**-2%**		
For 15 years	*$8,843*	$10,319	$9,823	$9,224	$9,396
For 30 years		*$15,261*	$15,846	*$13,029*	$13,713
For 35 years			*$16,598*		*$14,249*
Pulpwood					
For 15 years	*$1,952*	$1,644	$1,663	$1,339	$1,535
For 30 years		*$2,751*	$3,018	*$2,125*	$2,477
For 35 years			*$3,190*		*$2,593*
Merchandized			**0%**		
For 15 years	*$17,190*	$21,066	$19,874	$18,810	$18,943
For 30 years		*$34,163*	$35,784	*$28,989*	$30,473
For 35 years			*$38,288*		*$32,283*
Pulpwood					
For 15 years	*$4,187*	$4,472	$4,329	$3,845	$4,050
For 30 years		*$7,747*	$8,250	*$6,293*	$6,910
For 35 years			*$8,890*		*$7,372*
Merchandized			**2%**		
For 15 years	*$32,756*	$41,422	$38,855	$36,825	$36,856
For 30 years		*$75,007*	$79,670	*$63,014*	$66,558
For 35 years			*$87,628*		*$72,336*
Pulpwood					
For 15 years	*$8,339*	$9,815	$9,359	$8,543	$8,763
For 30 years		*$18,543*	$19,753	*$15,166*	$16,456
For 35 years			*$21,848*		*$17,994*

3.5. Changes in Seed Yield

The next factor varied in the sensitivity analysis was per acre seed yield of the orchard. The effects of seed yield in the orchard on the Net Present Value of all options for a tree improvement program run by private industry on the Coastal Plain are presented in Table 10.

Unlike the first two factors (Interest rate and annual change in timber price), changing the seed yield does not have a time effect. Its impact is to change the number of acres of pine plantation that could be planted annually from the seed produced from the orchard. It also increases the amount of seed that is sold (Table 10). However, this is a small factor in the total Net Present Value of the orchard. Also unlike the other two factors, changing the seed yield had a direct linear effect on the Net Present Value.

Seed yield was also considered as factor by Ledig and Porterfield (1978) to determine its effect on the amount of volume gain needed to break even. In the Ponderosa pine improvement program, doubling the seed yield reduced the volume gain needed to break even from 6.3 to 4.6%. Seed yield was taking into account in the Douglas-fir improvement programs.

Table 10. Effects of seed yield (per acre) of seed orchard on the NPV of the various establishment options for a tree improvement program run by private industry on the Coastal Plains

Full NPV	Rogued 2nd	3rd cycle mixed 1999	3rd cycle mixed 2004	3rd cycle offspring 1999	3rd cycle offspring 2004
Merchandized		**Seed Yield:**	50 Lbs/acre		
For 15 years	*$11,741*	$14,203	$13,426	$12,628	$12,661
For 30 years		*$23,235*	$24,422	*$19,623*	$20,600
For 35 years			*$26,155*		*$21,848*
Pulpwood					
For 15 years	*$2,664*	$2,618	$2,574	$2,181	$2,350
For 30 years		*$4,795*	$5,202	*$3,780*	$4,236
For 35 years			*$5,632*		*$4,543*
Merchandized		**Seed Yield:**	71.6 Lbs/acre		
For 15 years	*$17,190*	$21,066	$19,874	$18,810	$18,943
For 30 years		*$34,163*	$35,784	*$28,989*	$30,473
For 35 years			*$38,288*		*$32,283*
Pulpwood					
For 15 years	*$4,187*	$4,472	$4,329	$3,845	$4,050
For 30 years		*$7,747*	$8,250	*$6,293*	$6,910
For 35 years			*$8,890*		*$7,372*
Merchandized		**Seed Yield:**	100 Lbs/acre		
For 15 years	*$24,309*	$30,072	$28,335	$26,922	$27,185
For 30 years		*$48,500*	$50,692	*$41,277*	$43,427
For 35 years			*$54,208*		*$45,975*
Pulpwood					
For 15 years	*$6,155*	$6,903	$6,631	$6,029	$6,281
For 30 years		*$11,620*	$12,250	*$9,590*	$10,417
For 35 years			*$13,164*		*$11,083*

Table 11. The Net Present Value of all seed orchard establishment options by private industry on the Coastal Plain as affected by varying all 3rd cycle breeding values (BV) by one standard deviation

Full NPV	**Rogued 2nd**	**3rd cycle mixed 1999**	**3rd cycle mixed 2004**	**3rd cycle offspring 1999**	**3rd cycle offspring 2004**
Merchandized		**Average BV :**	Value - 1 SD		
For 15 years	*$17,190*	$14,401	$18,242	$13,271	$17,953
For 30 years		*$22,349*	$29,969	*$20,117*	$27,426
For 35 years			*$31,949*		*$29,083*
Pulpwood					
For 15 years	*$4,187*	$2,626	$3,822	$2,432	$3,757
For 30 years		*$4,546*	$6,713	*$4,048*	$5,998
For 35 years			*$7,217*		*$6,385*
Merchandized		**Average BV :**	Value		
For 15 years	*$17,190*	$21,066	$19,874	$18,810	$18,943
For 30 years		*$34,163*	$35,784	*$28,989*	$30,473
For 35 years			*$38,288*		*$32,283*
Pulpwood					
For 15 years	*$4,187*	*$4,472*	$4,329	$3,845	$4,050
For 30 years			$8,250	*$6,293*	$6,910
For 35 years			*$8,890*		*$7,372*
Merchandized		**Average BV :**	Value +1 SD		
For 15 years	*$17,190*	$28,866	$22,249	$24,623	$20,278
For 30 years		*$47,070*	$42,958	*$37,780*	$34,882
For 35 years			*$46,190*		*$37,135*
Pulpwood					
For 15 years	*$4,187*	$6,437	$4,887	$5,316	$4,424
For 30 years		*$10,938*	$9,976	*$8,661*	$7,966
For 35 years			*$10,762*		*$8,511*

Talbert et al. (1985) examined the affects of seed produced in the orchards on the financial return for a tree improvement program. In this study, the costs and benefits from the cooperative's first generation tree improvement were examined. The returns in this paper are expressed as a rate of return after tax. The rate of return varied from 14.3% to 19.75% depending on whether the orchard produced 10 pounds or 75 pounds per acre. The return on higher seed yields was lower because the net investment per pound of seed increased. Since in this study, the cone harvesting costs were fixed regardless of the yield, the cost per pound of seed will only decrease because of increased production. While this is not entirely realistic, all the costs of production are overwhelmed by the returns, which indicates small changes in the cone harvesting costs will not affect the results significantly.

3.6. Accuracy of genetic gain predictions

The next varied factor was the expected genetic gain from the 3rd cycle orchards. It is important to have an accurate estimate of genetic gain in order to be able to predict the Net Present Value of a tree improvement program. If the predicted improvement from the next cycle of tree breeding is not reliable, it would be very difficult to assess the cost efficiency of a tree improvement program.

This issue was addressed in detail by Ledig and Porterfield (1978) and by Lundren and King (1966). For a ponderosa pine improvement program in the western US, depending on the assumptions made about the program, the break-even amount of volume gain varied from less than 1% up to over 100% (Ledig and Porterfield 1978). Thus, the greater gain needed for a program to be profitable, the more important is the accuracy of gain estimate. If not, the returns in later years could be seriously misstated.

The NPV of all the seed orchard establishment options proved very rugged when breeding values varied to simulate uncertainty in expected genetic gain (Table 11). The method of varying the breeding value of each of the 3rd cycle seed orchards for this part of the sensitivity analysis was to find the standard deviation of all the clones in that particular orchard. A better method would be to calculate the standard deviation for the estimated breeding value of each of the clones used in each particular orchard and then use these to vary the average breeding value of the orchard. However, this information was not available for this study. The cooperative should consider including this information in its next report on its progeny tests, as it would be helpful for tree improvement managers. As shown in Table 11, the lowest Net present Value is still profitable even at the lowest amount of gain expected from the seed orchard.

The results suggested that the program still could provide a positive return. It is important to note that it is necessary to fully merchandize the timber harvested from improved stock in order to fully capture the genetic gain. The reasoning for this is shown in Figure 6. When the timber is merchandised, the value gain is from more timber produced in the higher DBH classes. This leads to more of it being classified as high value saw timber.

Burkhart and Matney (1981) studied the effect of genetic improvement on growth and yield, and on models to account for genetic gain in growth and yield models. They also raised concerns that gain could have an unintended consequence. If for example, increasing the mean diameter of the trees, while decreasing the variance of the diameter, the amount of volume that is high value saw timber could actually be reduced. They argued that the possibility of reducing high value saw timber could be high. If this is proven true, it might have implications on the genetic improvement of Loblolly pine. This is because, genetic gain is possible if there is genetic variation in the population (Falconer and Mackay, 1996). However, the opposite seems more probable as suggested by the results of this study. As the genetic gain continues to increase, a larger part of the total volume would be in high value saw timber. At the same time, the volume that is in pulpwood also increased.

The genetic gain in volume was estimated using Hafley et al. (1982) Managed Pine Plantation Growth and Yield Simulator. The model was developed for stand growth and thus may be subject to inaccuracies. The way that genetic improvements actually affects stand growth is probably more complex. The results from this study are only estimates and should be interpreted accordingly.

Another important fact about this study is that even with the large returns from the advanced generation orchards, the analysis was conservative in many ways. First, the plantations that were simulated using the NCSU Growth and Yield model were not thinned. These were planted at a density of 600 trees per acre and grown to a rotation age of 25 years. A thinning before final harvest would improve the return in two ways. First, a mid-rotation thinning would provide income earlier in the growth cycle. Even though the income from this thinning would probably be small, the fact that it occurs closer to the present increases its importance. In addition, thinning the stand (especially a top down thinning) early would lessen the competition for the remaining trees. This would increase the amount of higher value saw timber at the end of the rotation.

Another factor making the return estimates conservative is that the analysis only took into account the gain in volume. Tree improvement also makes gains in qualitative traits like rust resistance, straightness, and limb size, etc. One of the criteria for selecting clones to be included in the third cycle orchards is the expected rust infection level when stands have a 50% infection level (R-50 value). This index must be less than 40%. Many clones with high breeding values were excluded because their higher R-50 values. Since the growth and yield model does not take into account rust resistance, this tends to underestimate the volume gains of the orchard. Finally, gains in qualitative traits can also reduce tree-harvesting costs. Trees that are strait and do not have many large branches are easier to handle on site (via personal communication with Dr. Zobel).

All the options have a higher Net Present Value when carried out for the Coastal Plain than in the Piedmont. There are two reasons for this; one is biological and the other is economic. The biological reason is that sites on the Coastal plain tend to be more productive than sites in the Piedmont due to better soil structure, temperatures, and rainfall. The microenvironment differences were outlined in detail by Myers et al. (1986). Even though the annual amount of rain is not much different in the two regions, the Coastal plain gets more rain during the summer. The Piedmont is more susceptible to drought. In addition, the Piedmont is more likely to get later frosts and damaging ice storms. The Coastal Plain is more susceptible to hurricanes than the Piedmont; however, most serious ones tend to be few and far between (Myers et al. 1986).

In addition, the Coastal Plain has more favorable temperatures for growth of loblolly pine and soil characteristics are also better than the Piedmont region. The soils in the Piedmont are predominantly Ultisoils and Alfisoils, soils with high clay content at shallow levels. This decreases their ability to retain water. Even worse, in most places in the Piedmont, the soils have been severely eroded by agriculture. Many of the areas have almost totally lost their top fertile layer. The middle Coastal Plains, on the other hand, include some of the best soils in the region. These soils have the right texture, depth, and permeability (Myers et al., 1986). The flatness of the Coastal Plain also makes the soils less susceptible to erosion that the Piedmont. These differences are accounted for in this study in two ways. First, a base SI of 70 was used for the Coastal Plain while a SI of 65 was used for the Piedmont. In addition, different growth curves were used in the growth and yield models.

The Economic reason for the difference in the Net Present Value between the Piedmont and the Coastal Plain is the difference in timber prices between the two regions (Figure 12). The price is higher on the Coastal Plain than it is on the Piedmont. The price of timber seems to decrease further inland Hunter (1982), He explained the price change using a multiple regression model. Some of the factors that may cause the price decline in the Piedmont were, less demand for timber due to fewer mills, larger distances between stands and the mills, the smaller size of forest stands, and less productive land. However, even though tree improvement in the Piedmont is not as profitable as on the Coastal Plains, its Net Present Value is still considerable.

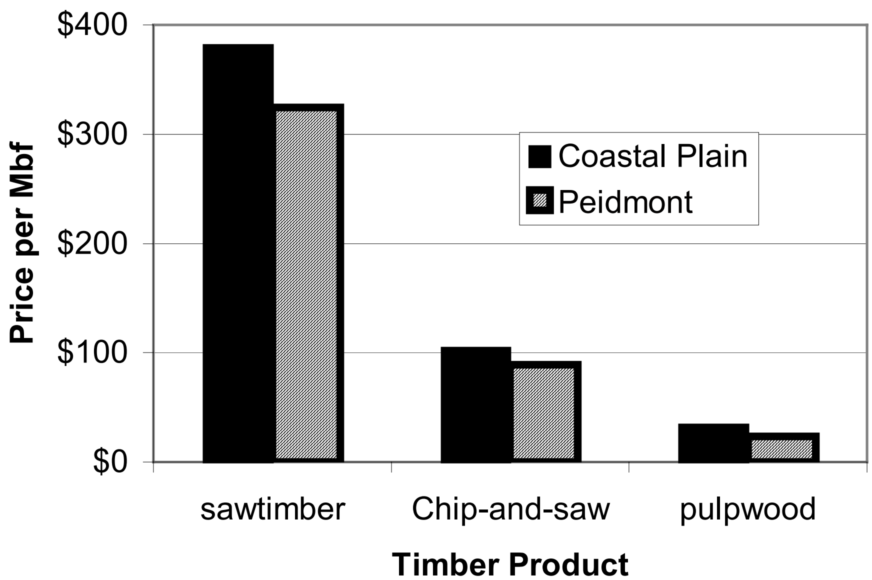

Figure 12. Timber prices for saw timber, chip-and-saw, and pulpwood for the Coastal Plain and Piedmont from "Timber-Mart-South" (University of Georgia, 1999)

The 3rd cycle offspring orchard had a higher Net Present Value than the mixed orchard. This could be explained by using few 3rd generation families to estimate gains of the orchard. However, the difference can be neglected since it is small (a couple of thousand dollars). Moreover, there are definite advantages in using clones whose performance is well documented in the progeny tests. As suggested by McKeand and Bridgewater (1985), using 3rd cycle mixed orchards still is applicable and profitable.

4. CONCLUSIONS

The economic benefits from Loblolly pine genetic improvement programs were considered based on the three seed orchard establishment options in this study. The return is more than offset by the added costs of research, orchard establishment and roguing. The research and application have made the improvement programs more attractive to both companies and agencies in the southeastern United States. The main conclusions from the study are as follows:

1. The genetic improvement of loblolly pine is <u>VERY</u> profitable. The benefits are overwhelming in certain cases, for example exceeding $100 million for merchandized timber from a state agency on the Coastal plane..
2. The NPVs of the two 3rd cycle options are higher than unrogued 2nd generation orchard.
3. In all cases it is more profitable to wait to establish the orchard in 2004 to take advantage of the fact that all the selections will be available.
4. Positive Net Present Values are quite robust. They are positive in all cases except when all timber is used for pulp and double digits discount rates are used.
5. Merchandized timber options were in every case more attractive than pulpwood, due to the premium market price for saw timber versus the low market price for the additional pulpwood volume.
6. The 3rd cycle mixed orchard is recommended because The NPVs similar to the offspring orchard and known and tested clones provide for operational efficiency and reliable gain.

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