Economic Considerations of the Genetic Approach

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I feel that the following quote, from a company forester in the proceedings of a tree improvement conference, is apropos: "We have spent considerable time and money on a tree improvement program. We have no assurance that this will pay off; however, we believe in it firmly enough to continue every effort in this direction." I must admit I view this quote with mixed feelings. However, this forester may be speaking for many others and is honest enough to express his true feelings. I do not happen to agree with his statement concerning whether or not the tree improvement program will pay off because I happen to believe that all this work being done in the field of tree improvement is worth the time and money. I would like at this time to present some facts and figures to substantiate why I so believe.

At the outset the speaker wants to point out that the genetic approach used and referred to in this talk will be the so-called clonal seed orchard approach widely used in the South today whereby good phenotypes are selected for parents and grafted into the seed orchards. It is assumed that progeny testing will start immediately so that the genetic worth of these selected parents may be tested and assessed as soon as possible. The progeny test results will then be used to remove or rogue those parents proven inferior. Quite frankly if it were not for a direct action program such as this it is doubtful whether or not the organization I work for would be involved in a tree improvement program. We have a critical need for seed right now and want production orchards *as soon as possible*. We recognize that the immediate gain or improvement from these production orchards will not be as great as later gains. However, by moving ahead with these production orchards we will be producing seed at an earlier date and in the speaker's opinion this seed will offer considerable improvement over the seed in present day use. Quality improvement in seed orchards is really a never ending job and as time goes on we will be continually upgrading the genetic quality of our seed produced by our seed orchards.

We do know that establishing and managing seed orchards is not an inexpensive operation. Most of us have learned a long time ago that we do not get something for nothing, so costs attendant to seed orchard establishment and management must be expected. I will elaborate no further on seed orchards costs; each organization must figure its own. However, it should be remembered that seed orchard costs must be prorated over the entire life expectancy of the orchard and since this may be as long as 60 years (Dimpflmeier 1954) this will reduce the cost of seed per pound considerably.

Scarcity of Seed

We in the Virginia Division of Forestry are becoming increasingly aware of seed shortages. Each year, for us, loblolly pine seed is becoming more difficult to obtain. Let me cite our experience in 1962. Our reforestation division, in order to supply loblolly pine seed for our nursery (we have a loblolly pine nursery production of approximately 30 million seedlings annually) and direct seeding needs, wanted to collect a minimum of 7,000 bushels of loblolly pine cones. In order to secure these cones the State Forester asked that cone collection be placed second in work priority only to fire. An all out effort was made to secure these cones but in spite of this we were only able to collect a disappointing 1,200 bushels of loblolly pine cones. Seed yield per bushel of these cones was only 0.8 pound whereas normally we expect a seed yield of approximately 1 pound per bushel. Not only were loblolly pine cones scarce in Virginia last year but what seed was available was eagerly sought by other organizations. Competition for existent seed is keen in Virginia and from all indications will continue to be keen for many years to come. Our reforestation division estimates that our loblolly pine seed needs for Virginia Division of Forestry use alone projected for the next 5 years will be nearly 10,000 pounds each year. Nursery demands and direct seeding demands have made it necessary to carefully limit seed sales and as a result many Virginia landowners are unable to buy local seed from our organization for direct seeding. You may be interested to know that we sell repellant-treated loblolly pine seed for $6 per pound (based on dry weight) and that last year we were unable to fill orders for hundreds of pounds of seed. One alternative for those persons wanting local seed but unable to obtain it is to buy and use non-local seed, which many Virginia landowners did last year. We do not think this advisable and I personally shudder at not only the immediate but long-term implications of using non-local seed, but this is what is happening. I should like to make a point: for us, local seed is scarce and is in strong demand. Seed orchards, once in production, will assure ample supplies of *local* seed for our use.

Cone Collection Costs

Once seed orchards are established and producing seed, will it prove costly to collect cones? Evidence is accumulating which indicates that seed orchard cone collection costs will not be exorbitant and may compare favorably with seed collection under present-day methods. This evidence is provided by those who have kept seed production area seed collection costs. Before mentioning these costs, I would like to tell you of our Virginia Division of Forestry present cone collection and purchase method. We buy from local cone collectors and pay $2.50 per bushel for loblolly pine cones. Under normal conditions a bushel of loblolly pine cones will yield us 1 pound of seed. However, this $2.50 per bushel or per pound of seed, exclusive of extraction costs, etc., does not represent a true cost of seed per pound, which in some instances is much more. Not included in this cost are certain overhead costs, cost of locating cuttings and securing permission from the owner to collect, cost of inspecting the tops for cone ripeness and quality (used only in the sense of the cones not being damaged), inspection costs at pick-up points and cone transportation costs. Also, oftentimes it has been our experience that cones will be collected before ripe enough, thereby increasing extraction cost and decreasing seed yield per bushel of cones. I should like to emphasize that we try to maintain rigid standards with respect to our cone collections and that this adds to our costs. In 1962, exclusive of other costs mentioned above, loblolly pine seed cost us $3.12 per pound for what seed we could obtain.

Seed collected from seed production areas has not proven to be overly costly and provides us with some notion of what seed orchard seed collection costs may be. Quoted below are collection costs from standing trees; the cones were collected by climbing. Goddard (1958) reports that in Texas the average cost of collecting from tall standing loblolly pines was $4.77 per bushel of cones and that these cones yielded approximately 1 1/2 pounds of seed. Therefore, the cost of seed per pound was $3.18. Cole (1962) reports that in collecting from standing loblolly pines in a seed production area in Georgia, seed cost was $3.88 per pound from certified areas and $4.58 per pound from uncertified areas. Cole further points out that superior seed yields from slash seed production areas were obtained versus cones purchased on the open market. Sweetland in private communication reported that in 1961 from a 65-acre seed production area in Prince George County, Va., 520 bushels of loblolly pine cones were collected from 311 pines. The seed yield was 679 pounds, and the cost per pound of clean seed amounted to $5.41. This cost figure includes charges for picking (through contract with a tree expert company), measuring, sacking, threshing and cleaning, supervision, and transportation incidental to the harvesting. Sweetland went on to say, "we think these costs can be lowered considerably by improving harvesting techniques." It should be remembered that the costs reported above are for climbing pines of considerable height and that the seed production areas had remaining some 18 to 20 trees per acre. Within our seed orchards many more trees per acre will be available for climbing and collecting purposes, thereby travel time to the tree should be less. Also, we should be able to better control when to start collection so that cones will be mature when harvested and this, in turn, should result in lower seed extraction costs and higher seed yield per bushel of cones collected. These are all very real economic considerations for us to keep in mind. Furthermore, I have confidence that we will develop and devise more efficient and easier means of collecting cones from standing pines. This will tend to lower seed costs even more.

Gains or Improvements

What basis do we have for making any claims for immediate gains through seed orchards? Evidence is accumulating daily which indicates that considerable improvement may be expected through seed orchards. Some means of providing improvement are:

1. Through better adaptation.— In a classic loblolly pine study (Wakeley 1944) it was found that stock from seed collected within 50 miles of the planting site produced 1.8 to 2.7 times as much merchantable pulpwood in 22 years as did stock from seed collected 350 to 450 miles from the planting site. The potential growth lost by using Arkansas seed instead of local Louisiana seed was 1.2 cords per acre per year.

Zobel and Goddard (1955) demonstrated the presence of pronounced differences in seedling survival among local strains of loblolly pine. Anything which affects tree survival must be considered economic. If a seedling fails to live it certainly will not produce wood and it costs as much money to plant this seedling which doesn't live as the one which does.

So that seed might be better adapted to its proper site most of us in the seed orchard business are establishing separate orchards for different geographic areas. This will enable us to use local seed and capitalize on these benefits mentioned.

2. Through improved disease resistance.—Barber (1961) found in Georgia open pollinated slash pine progenies highly significant differences in freedom of fusiform rust canker when comparing parents. The 1952 plantings varied from 19 to 88 percent of the trees free of rust comparing various parents. Wakeley (1961) also found significant differences in susceptibility to fusiform rust; the Georgia seed source had a much higher degree of infection than the other sources represented. Derr (1963) found that wind pollinated seedlings from a brown-spot resistant longleaf pine growing in central Louisiana have demonstrated a high level of resistance to the disease. This finding indicates the genetic control of this trait, and suggests the possibility of selection for resistant strains of longleaf pine. There are other references in the literature pointing toward the fact that susceptibility or resistance to disease appears to be hereditary and that by selecting disease-resistant parents the chances of producing disease-free offspring are improved considerably. If a tree dies before it becomes merchantable it costs us money, and every merchantable tree which can be added to our harvest cut adds income. The selection of disease-resistant parent trees for seed orchard use is an important economic consideration.

3. Through wood quality improvement.—Zobel and Haught (1962) found that the total merchantable volume of moderately straight trees contained less than 10 percent compression wood (compression wood affects the properties of both pulp and lumber), while more crooked trees commonly had over 15 percent of the total volume as compression wood. In excessively crooked trees compression wood exceeded 50 percent of the total bole volume. Compression wood lowers actual pulp yield and also lowers quality for sawtimber purposes. Several studies on inheritance of bole straightness have been reported; some of these will be mentioned later. The substance of these studies is that straightness is controlled genetically. Straight parent trees in seed orchards should produce straighter offspring which in turn result in improved wood quality. I believe that all of us are stressing straightness in the selection of trees for our seed orchards.

Evidence is accumulating concerning the heritability of wood specific gravity. Fielding and Brown (1960) and Dadswell et al. (1961) found definite evidence of heritability of wood specific gravity in Monterey pine. Brown and Klein (1961) by regression analysis found a real association between parent tree wood specific gravity and progeny wood specific gravity in the crosses of loblolly pine tested.

Squillace et al. (1962) found high heritability of specific gravity in slash pine comparing specific gravity of parent and specific gravity of 14-year-old controlled and open pollinated progeny.

A high specific gravity correlation between 6-year-old open pollinated loblolly pine progeny and the female parent was found by van Buijtenen (1962). From one selection for specific gravity he had an estimated progress of approximately 4 percent, based on a selection differential of one standard deviation.

Zobel points out in a private communication that we should be able to increase specific gravity by about 50 to 300 pounds a cord green weight from seed orchards. Assuming an increase of 150 pounds per cord this amounts to approximately a 3-percent improvement for weight alone.

4. By increasing growth, form and yield.—Mergen (1955) found that certain slash pine parents produced better stem form than others. One female slash pine parent's progeny included 51.6 percent trees with sweep; another female slash parent's progeny included 40.9 percent with sweep.

Barber (1961) found that trees containing stem crook varied from 30 to 89 percent among progenies of different slash parents; that "parents that had a greater amount of crook had progenies that were among those having the greatest percentage of crooked stems." For young trees of loblolly pine Perry (1960l found that bole straightness has a fairly strong inheritance pattern. Progeny from crooked parents were significantly more crooked than those from straighter parents. Try as we might we cannot escape the importance of having straight trees. Too much depends upon it and evidence indicates that straightness is genetically controlled.

Peters and Goddard (1961) report a heritability of vigor of very roughly 15 percent in slash pine based on measurements 5 years after the progeny were outplanted.

McWilliam and Florence (1955) tested slash pine progeny in Australia in which open pollinated progeny were selected from the outstanding slash pine phenotypes in 1932 plantations. A limited number of controlled pollinated progeny were also included. For comparison purposes, a routine planting (representing the general plantation stock, resulting from seed collected from the best 160 pruned trees per acre) was included in the study. These progeny were assessed for both vigor and form. Vigor included both height and volume. Form included all other visual characteristics of the tree such as straightness, branch size and angle, and appearance. A difference of 5 percent in form represents a big improvement.

The results of the open pollinated progeny test were as follows:

Parent	**Best**	**Routine**	**Worst**
Acceptable stems per acre	272	112	80
Form percent	47	40	36
Plus stems	21	1	—
Minus stems	43	151	248

The results of the controlled pollinated progeny were as follows:

Parent	Acceptable stems per acre	Form (percent)	Plus stems per acre	Minus stems per acre
CB 74 selfed	520	62	184	--
CB 76 selfed	496	56	80	24
CB 74 x CB 76	440	56	64	32
CB 74 open pollinated	216	46	21	45
CB 76 open pollinated	176	44	7	63
Routine	112	40	1	151

Note the superiority of the controlled pollinated progeny over the routine progeny. Not including the "selfs" the controlled pollinated cross CB 74 x CB 76 progeny exhibited a difference of 16 percent in form compared to routine progeny and had 64 plus stems per acre versus 1 for the routine progeny.

McWilliam and Florence further found that a considerable improvement in the straightness of stems was obtained in comparing controlled pollinated progeny with routine plantings. They had twice the number of acceptable stems per acre comparing controlled pollinated with routine progeny. Because of its great economic importance in forest management stem form must be of considerable concern to forest managers. An undesirable tree of poor form not only yields less usable wood substance but also occupies just as much space in a forest (perhaps more) than a straight, well-formed tree.

Nikles (1962) in Queensland reports that volume production of slash pine was increased by at least 30 percent by crossing superior phenotypes. Nikles compared the controlled pollinated trees with routine plantings (routine plantings were progeny of trees selected for high pruning) and found nearly three times as many acceptable trees (trees having superior growth and straightness) among the controlled crosses versus the routine trees. A tabular summary prepared by Nikles comparing volume production and numbers of acceptable trees in 7½ -year-old slash pine progeny follows:

Progeny	Mean volume '	Mean number acceptable trees
G 11 x 15	60.9	16.5
G 34 x 16	57.9	12.5
G 15 x 13	57.7	20.0
G 34 x 11	56.2	12.0
G 8 X 9	53.4	18.0
G 9 x 15	51.3	16.0
G 17 x 15	49.1	16.75
Routine "	40.5	6.5
G 3 self x G 2 self	37.6	10.0

' Total volume of 25 trees in cubic feet; means of four plots per treatment.
A tree scoring at least a certain minimum of points for straightness as well as reaching a minimum level of volume production.
Progeny of trees selected for high pruning.

Nikles further points out that these crosses by producing a larger number of straight offspring will result in a higher recovery of sawn timber. Juvonen (1961) corroborates this. Nikles sums up, "in view of this, and evidence from other trials up to 16 years of age, it would be conservative to claim an increase in recoverable volume of more than 30 percent by the 10th year as a result of selection and cross breeding."

Economic Implications of Expected Improvement

Just a few studies have been mentioned which indicate the many different areas in which improvement is possible through genetic control. Considering these studies and improvements noted it seems most reasonable that we may expect at least a 5-percent improvement as a result of our seed orchard programs. It is assumed that this 5-percent improvement will manifest itself in 5 percent more wood substance or yield than is being obtained today using routine nursery stock grown from seed collected by present-day collection methods.

A 5-percent improvement in yield might not sound impressive to some but the economic implications are tremendous. Here is what a 5-percent improvement could mean to my organization's tree planting program in Virginia assuming that the planted pines would be harvested by a clear-cutting operation 20 years after being planted. We found that our loblolly pine plantations were growing, on the average, 1.64 cords of pulpwood per acre per year. Using this 1.64 cords per acre per year as a base growth rate, in 20 years the average acre would contain 32.8 cords of pulpwood. If a $6 per cord pulpwood stumpage price is assumed at the end of 20 years the average acre would have a gross pulpwood value of $196.80. If a 5-percent improvement in yield is realized as a result of using improved planting stock from our seed orchards 20 years after being planted the average acre would have a gross pulpwood value of $206.64 or an increase of $9.84 per acre. Each year the Virginia Division of Forestry distributes for planting approximately 30 million loblolly pine seedlings. Our average planting space is 6 by 8 feet or approximately 900 seedlings per acre. We, therefore, plant approximately 33,333 acres of loblolly pine annually in Virginia. If a 5-percent increase in total pulpwood yield results at the end of the first 20-year period (assuming all 33,333 acres were planted using improved planting stock) landowners stand to gain $327,996.72 over what their returns would have been had routine nursery planting stock been used. Once our seed orchards are producing enough seed to fully supply our nurseries it should be remembered that each year improved planting stock is used thereafter in a planting program that these benefits will accrue and become available at harvest time. It should be kept in mind that it costs just as much to plant a routine nursery stock seedling as it does an improved seedling; and it costs just as much to prepare land for planting routine nursery stock seedlings as to prepare land for planting improved seedlings. It also costs just as much to release an acre planted with routine planting stock seedlings as it does an acre on which improved planting stock has been planted. As a matter of fact, presupposing a $9.84 increase per acre in 20 years as a result of planting improved planting stock and charging a 5-percent interest rate we could afford to spend an additional $3.70 per acre for site preparation, release, etc.

Some of us may be concerned with seed orchard establishment costs because they may seem high. However, since we expect to gain considerable improvement in seed used for our reforestation programs this should not unduly concern us. An example is provided using the same set of conditions as mentioned earlier, i.e. assuming a 5-percent increase in yield and clearcutting plantations 20 years after planting, which would result in a total *increase* of $327,996.72 realized from an annual planting program of 33,333 acres. Let us assume that it will take 15 years before our seed orchards furnish enough seed for our reforestation programs (planting only) and that an additional 20 years will elapse before we are able to harvest our first pulpwood by clearcutting. We will further assume that we will recover $327,996.72 each year for a total of 6 years. Therefore, from the time of seed orchard establishment to time of harvesting our sixth successive annual pulpwood crop a period of 40 years will have elapsed. At the end of 40 years, using a 5-percent interest rate, $2,230,377.70 will have accumulated which represents the *increase* in returns alone resulting from using improved planting stock. Therefore, again charging a 5-percent interest rate one could afford to spend some $316,815.01 in seed orchard establishment and development costs and still break even 40 years after beginning the seed orchard program. In practice this will not be the case, however, since we will be collecting some quantities of improved seed from our seed orchards before the end of 15 years and this presents a more favorable financial picture because we could start to amortize our investment sooner. Also, once our seed orchards are in production, each year we use improved seed our benefits accrue and it is reasonable to expect these benefits to be available for many years to come—more years than in the example above. Furthermore, the cost of our seed orchards should be prorated over the entire life expectancy of the orchard, which may be 50 years or longer.

In all of the calculations used above only expected gains or improvement in plantations are noted. It is assumed that until seed becomes abundant in seed orchards the first seed produced will be used for planting and not for direct seeding. It should be remembered that economic gains will be realized using improved seed in direct seeding programs as well.

Cole (1962) computes improvement in another manner using slash pine on sawtimber rotations. Cole states that on an "average" slash pine site (site index 70 feet at 50 years) a 1-percent increase in volume yield over a 35-year rotation would mean that the cost of seed could be increased about 5 times and the planter would still break even (this assumes all of the increase is considered to be in sawtimber at $35 per M bd. ft. at the end of the period and 5-percent interest is charged).

Perry and Wang (1958) provide evidence that genetic improvements of as little as 1 or 2 percent more than justify the extra costs involved in programs of seed orchard establishment. They point out that frequently because of improper geographic origin or inferior genetic quality, the only seedlings available for planting will yield growth rates and profits 4 percent or more below average.

Percent improvements of a small magnitude may seem small and inconsequential. However, when one considers all the wood harvested each year in our respective states and the economic implications of using improved seed in our direct seeding programs and using genetically improved planting stock for our planting programs these small percentage figures become very impressive indeed. I have heard one company forester make the statement that if only a 1-percent improvement is realized that this would amount to more than a million dollars a year to one mill!

In summary I believe our seed orchards, once in production, will assure us of ample supplies of seed to supply our reforestation programs. It will cost no more to collect this seed and we will be able to verify its origin.

The different types of improvement possible and noted by others and reported were: (1) better adaptation of seed to site, (2) better disease resistance, (3) better wood quality, and **(4)** straighter, more vigorous trees of better form. In view of these I believe it entirely realistic to expect at least a 5-percent overall improvement from our seed orchard programs—this 5-percent improvement to manifest itself in increased wood yields.

It should be remembered that a small percent gain or improvement has tremendous economic implications. We stand to be amply repaid many times over for our time and expense spent on our seed orchard programs. We must be careful not to oversell our seed orchard programs but we must not be guilty of underselling either!