PROGRESS AND PROBLEMS IN FOREST TREE SELECTION

By

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INTRODUCTION

The following paper will be limited to forest tree selection in the southern United States, keeping the discussion within the framework of this meeting. Although most of the forest tree improvement work in the South has been done with pines, the discussion will not be restricted to them but will include hardwood species as well, which present many problems of their own. Since Dr. Stonecypher covered the topic of second-generation selection thoroughly, I will concentrate on first-generation selection.

OBJECTIVES OF SELECTION

Although selection objectives may differ in detail as much as the people doing the selecting, they can be grouped roughly into two categories: increase in the quantity of wood produced and improvement of its quality.

For a given age and number of stems per acre quantity production is largely controlled by the following characters: height, DBH, form class, and wood specific gravity. Here already a divergence of viewpoints exists. To the producer of lumber and plywood, volume is the most significant measure of quantity; wood specific gravity is primarily a quality factor,affecting such properties as strength, shrinkage, and adhesiveness. To the pulp and papermaker, however, specific gravity has both quantity and quality components, affecting pulp yield and fiber wall thickness, and therefore other properties, such as tear factor, tensile strength, bursting strength, refining energy in groundwood production, and so on. There are many other properties which in a similar way affect both quantity and quality: natural pruning, stem form, branch habit, fiber wall thickness, fiber length, amount of compression wood, and summerwood content.

Where quality is concerned, selection objectives may differ widely from organization to organization. With the advent of stress grading a lumber mill may be very much interested in an increase in specific gravity, while at the same time a groundwood mill may be primarily interested in wood of low specific gravity, resulting in deduced refining energy and better pulp and papermaking properties.

METHODS OF SELECTION

The rating systems currently being used in the South for superior tree selection can be grouped under three headings. The method of selecting pines most commonly accepted in the South is by means of a rating system based

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on a comparison of the selected tree with a number, usually five, of the best dominant trees within the vicinity. Vicinity is defined fairly loosely, but may include as much as a one-acre plot with the selected tree at the center. The selected tree is given a point score for individual characters based on its superiority over the comparison trees. An example of such a point score is given in Table I.

TABLE I

EXAMPLE OF POINT SCORE ON LOBLOLLY PINES [1)]

	Score	
	Minimum	Maximum
Height	0	15
Volume	0	7
Crown	-2	5
Form point	-3	3
Straightness	0	5
Pruning ability	-3	3
Branch diameter	-2	2
Branch angle	-2	2
Specific gravity	-2	10
Age	0	3
Total possible points		55

1) Scoring system used by International Paper Company.

This method is satisfactory in plantations and even-aged natural stands but loses most of its value in uneven-aged stands. In contrast to the method discussed below, no measure of selection intensity is obtained, since the check trees themselves are considerably above the average of the stand.

Another system in use can be called a base-line or regression system. It requires considerable knowledge of the growth of a given species on the sites where it is usually found,and-consists of predicting the range of value to be expected of a given species on a given site and rating the selected tre against these values. In this case it can be rated as a certain percentage o a certain number of standard deviations above the average. The system is applicable under most stand conditions, but may be subject to more error than the comparison tree system.

The method of selection is always dependent on the biology of the species selected and should be developed with this in mind. A case in point is the selection of hardwoods. Many of these are extremely different from pines, and the selection system developed for pines simply cannot be adopted uncritically. To give an extreme example: selecting quaking aspen or sweet-gum by the comparison system would be meaningless, since both frequently occur in clones. Since all trees in a clone would be of the same genetic constitution, the difference between the selected trees and the check trees could be entirely a reflection of the environment.

Many hardwoods are found in uneven-aged stands. As a consequence they have to be graded against absolute standards rather than on the basis of a comparison with check trees. An example of such a scoring system is given in Table II.

TABLE II

EXAMPLES OF POINT SCORE ON' HARDWOODS

(Developed by R. farmer for selection of cherrybark oak)

	Score	
	Minimum	Maximum
Straightness	0	5
Crown	0	5
Epicormic sprouting	-3	3
Pruning ability	-3	3
Branch angle	0	2
Leader dominance	0	5
Total possible points		23

MULTIPLE TRAIT SELECTION

Because of the long generation span in forest trees, it is not practical to improve only one trait in one generation. Instead, it becomes desirable to improve several traits simultaneously. One approach to so doing is to select for each trait individually. As the number of traits increases it becomes of course increasingly difficult to find the type of tree desired. Selecting for instance, the best tree out of one hundred for each trait, and assuming no correlation between traits we would find one out of a hundred for one trait, one out of ten thousand for two, one out of a million for three traits, and one out of a thousand billion for six traits. This last figure somewhat exceeds the number of trees available.

Another approach is to weight each character by a score depending on its inheritance and economic value and to select the trees with the highest score. Theoretically this is the most efficient approach, although in practice it leaves something to be desired. The index could be used in conjunction with the comparison tree system or with a base-line system, where a tree's selection index would have to exceed a certain value to be accepted. Two examples are given in Table III.

The comparison tree system of selection is somewhat of a combination of a true selection index and selection using independent culling levels, with a point score being given to a tree for various characteristics, while at the same time the selected tree does have to meet certain minimum criteria of freedom from disease and insects, of form, and in some cases of specific gravity.

TABLE iII

EXAMPLES OF SELECTION INDEX[1)]

EXAMPLE ONE

Selection index = .6 X height + 2.5 X DBH - 50 X s.g. - .2 sweep - .5 X[2)] crook + 1.3 X spiral - 2.6 X lean.

Range of Selection Index Scores if Calculated on the Basis of the Comparison Tree System

	Score	
	Minimum	Maximum
Height	0	10
Diameter	0	15
S.G.	-1	4
Sweep	-5	.5
Crook	-.5	.5
Spiral	-2	2
Lean	-4	4
Total possible score		36

EXAMPLE TWO

Selection index = -1.4 X stemform + .67 dry weight (kg).

Range of Selection Index Scores if Calculated on the Basis of the Comparison Tree System.

	Score	
	Minimum	Maximum
Form	-4	4
Dry weight	0	20
Total possible score		24

1) Based on data obtained from 10-year-old open pollinated progeny test of loblolly pine.
2) Stem form, sweep, crook, spiral, and lean were rated on a 4-point scoring system, as follows:

1 = Superior tree quality
2 = Above average
3 = Below average
4 = Dismal

USE OF MATHEMATICAL PROGRAMMING

Another approach to tree selection, one which to my knowledge no one has tried so far, is the use of mathematical programming methods. Mathematical programming is used in many industries to optimize operations and might very well have application in this field. ft is applicable in a situation where a number of limited resources have to be utilized to either minimize cost or maximize profit. In the case of tree improvement, for instance, one could define the manpower, land, and budget available, and then maximize the profit obtainable by selecting for certain characteristics. It is an extremely powerful method, one forcing a person to analyze his operations critically and to keep always in mind such matters as facilities, budget, manpower, and expected returns. A very simple hypothetical example is given in Table IV. Value produced is given in dollars per acre for each unit of selection. In this case a selection differential of one standard deviation is defined as the unit.

The constraints (limiting resources) are given in terms of man-years required to produce one unit of genetic improvement in volume or one unit of genetic improvement in wood specific gravity. The right-hand column gives the number of man-years available. The bottom row shows the limits put on the selection intensity to keep the model realistic.

The solution shows that maximum value production is obtained when laboratory and field personnel are fully occupied. It also shows that the grader and supervisor have extra time available and that the "production" is limited by the manpower available in the laboratory and in the field.

The model can be made extremely revealing by describing the system in more detail and in actual budget terms.

SELECTION FOR RESPONSE TO INTENSIVE CULTURE

In agriculture the experience has been that as much or more improvement is obtained by more intensive culture practices, resulting from the use of improved seed, as is obtained from the genetic improvement itself. We can expect the same thing to happen in forestry and many signs are indicating already that this is happening. Practices such as fertilization, bedding, and even irrigation, which were practically unheard of ten years ago, are being applied on varying scales right now. it is important therefore that in tree selection we take these changes into account and select for individuals which are capable of responding to intensive cultural practices. (Pritchett and Goddard, 1967). Early indications obtained on pines have been promising, but the greatest opportunities in this area are probably in hardwoods. Many of these species are inherently more demanding than pines and more capable of responding to high fertility levels.

PROGRESS OBTAINED BY SELECTION

Good data are becoming available on the inheritance of volume growth, height, DBH, and wood specific gravity. As a rule of thumb the lower herit-

TABLE IV

EXAMPLE OF MATHEMATICAL PROGRAMMING

Constraints		Volume	SG	Total
Type	Name			
N	Value	15.00	7.5	
L	Fieldwork	1.0	.2	2.0
L	Grader	.2	.05	1.0
L	Laboratory	.01	2.00	2.0
L	Supervision	.05	.01	.3
Bounds	Upper	3.0	3.0	
	Lower	1.5	.5	

Solution

Row	At	Activity	Slack Activity	Lower Limit	Upper Limit
Value	BS	34.46	-34.46	none	none
Field work	upper limit	2.0	--	none	2.0
Grader	BS	.41	.59	none	1.0
Lab. work	upper limit	2.0	--	none	2.0
Supervision	BS	.1	.2	none	.3

Column	At	Activity	Input Cost	Lower Limit	Upper Limit
Volume	BS	1.8	15.0	1.5	3.0
SG	BS	.99	7.5	.5	3.0

abilities are found in the more variable characteristics. Values reported in the literature and results obtained in the Texas Forest Service program indicate that the heritability of wood specific gravity may be around 50%, of height about 20% of diameter around 15%. Since the increased variability compensates for the lower inheritance, the expected gain varies only moderately among characteristics and runs between ten to twenty percent in one cycle of selection. Branch size and amount of knotwood have been shown to be definitely inherited, (van Wedel et al.,1967). Straightness and natural pruning show genetic differences, although it is much harder to put definite values on this, since they are rated by a scoring system rather than measured.

One of the most important benefits of genetic improvement is through the reduction of losses. Breeding for resistance to drought, rust, insects, and brown spot, for instance, offers good opportunity for improvement. This has already been borne out by considerable experimentation. (Jewell, and Mallett, 1961; van Buijtenen, 1966).

Wood properties are also inherited to a considerable extent. The genetic gains to be expected are of the order of 10% in one generation of selection. For some properties, such as wood specific gravity, it is quite meaningful, for other properties, such as fiber length and fiber wall thickness, this may be small in comparison to modifications obtainable through technology. There is much data available on this subject, but the interpretation is not clear and the matter is under study at present by one of the sub-committees of the TAPPI Forest Biology Committee.

ANALYSIS OF RETURNS ON INVESTMENT

In considering the investment returns from tree improvement in detail one cannot completely separate the selection for various properties, but rather has to look at groups of related activities. I would like to single out a number of groups for somewhat closer consideration, specifically field selection, selection involving laboratory testing, selection involving tests that can be carried out at an early age in the nursery or a similar setting, and selection involving progeny testing under field conditions.

Field Selection

At this stage one can select for growth rate, stem form, crown form, and freedom from diseases and insect. The cost of selection at this level is dominated by two general principles. 1) The major cost is in locating a promising tree to start with. Once one has found a tree worth looking over in detail, the cost of checking additional traits is relatively small, so one might as well describe the tree as accurately as possible. 2) The more traits are considered the more difficult and therefore the more costly it is to find a tree which is acceptable in all respects. To keep cost down, one has to either limit the number of traits selected for or to allow excellence in one trait to compensate for a deficiency in another.

Present indications are that the improvement obtainable in quantity production alone is from 10% to 20%. It is impossible to make estimates of increase in value through quality improvement without specifying particular products involved. Even for any given end product, one could do no more than make an educated guess.

Selection Involving Laboratory Testing

In this category we find mostly wood properties and chemical properties. At present it is clear that wood specific gravity can be improved by selection and that this can be dose cheaply. The cost of determining the specific gravity on one sample runs somewhere around a dollar. The determination of other properties such as summerwood percent, fibril angle, fiber length, and fiber wall thickness is much more expensive. Somewhere in this region we are near the point where it would be as economical to improve the quality of the end product by technological means as it is to improve them by genetic means. This is, however, no more than a guess and urgently reeds to be studied in depth.

Selection Invoiving Early Procenies

In this category fall testing for disease resistance and testing for drought resistance. In both cases the gains to be made are considerable and can be obtained quickly. in the case of resistance to fusiform rust, it may mean an increase in productivity of 25% or more. In the case of resistance to brown spot or drought resistance, it may mean the difference between being able to practice forestry on certain sites or with certain species and not being able to do this at all.

Selection Involving Pro eny Testing Under Field Conditions

Progeny testing in the field serves actually two purposes, the evaluation of the progenies of the selected trees, giving the information necessary for seed orchard roguing, and the establishment of stands of trees from which second-generation selections can be made. Both goals are equally important. In this discussion we are primarily concerned with the improvement obtained through roguing of seed orchards. If the methods outlined by Namkoong et al. (1966), are used and assuming that it will be possible to remove half of the clones out of an orchard by roguing, the progress by roguing will be approximately half of that obtained by the initial selection.

Some Investment Considerations

The chief investment considerations of the seed orchard can be summed up as follows:

1. The cost of setting up a seed orchard contains a fixed portion, determined by the number of clones in the orchard and the progeny-testing scheme adopted, and a variable portion, which is dependent on the size of the orchard.

2. The return to be expected on the orchard will depend on the number of acres that will eventually be planted in improved seedlings raised

from seed obtained from the orchard. This is therefore controlled by the size and the productivity of the orchard. The situation becomes more favorable in the larger orchards, since the fixed cost remains the same while the return increases.

3. The various activities in a seed orchard program do not promise equal investment returns.

4. The smaller the seed orchard the less elaborate the selection procedure one can afford, perhaps only including the most profitable steps in the selection process, until the orchard becomes so small that its operation Is no longer profItable.

FUTURE SEED ORCHARDS

I would like to conclude with some comments on the developments one can expect in seed orchards. Taking the development of second-generation seed orchards for granted, the key question to be raised is whether the cycle of selection, seed-orchard establishment, progeny testing, and selection among progenies needs to be repeated indefinitely in this order. The answer is a very definite no. Seed orchard establishment is independent of selection and progeny testing, and the present procedure is to some extent a stopgap measure necessitated by the lack of previous experience and the urgent need for the availability of large quantities of improved seed on rather short notice. There are, however, other alternatives, such as the separation of seed-orchard establishment from breeding per se. This would open up the possibility of setting up orchards from clones which already have been tested, thus doing away with the need for goguing. In addition it will be possible to anticipate some of the problems that might occur with particular clones, such as incompatibility or inherently poor flower production, so remedial measures can be applied before the problem becomes serious. One would pay for increased productivity per acre of seed orchard by a delay in time of the availability of particular improved materials. However once the immediate need for seed is less urgent there may be a real opportunity in this type of approach.

SUMMARY

1. Selection for characters affecting quantity is quite straightforward. Many characters, however, affect both quantity and quality or quality alone. In these cases selection objectives may differ widely from organization to organization, since quality has to be defined in terms of the end use.

2. Because of practical considerations some form of multiple-trait selection has to be practiced in forest trees We no longer have to rely on empirical schemes, but are getting enough information to construct selection indexes based on genetic principles.

3. In devising a selection system for forest trees, the most crucial consideration is the biology of the species. It is not desirable to devise a generalized selection scheme for all species.

4. A tool which has not been used so far in forest tree genetics is mathematical programming. This extremely powerful technique can be adapted to tree improvement problems and its use is strongly advocated.

5. A detailed scrutiny of the likely investment returns from tree improvement reveals that it is difficult to consider the selection for individual properties separately. One must rather look at groups of related activities. Some of the main principles are: a) the cost of setting up a seed orchard contains a fixed portion, determined by the number of clones in the orchard and the progeny-testing scheme adopted, and a variable portion, which is dependent on the size of the orchard. b) The return to be expected on the orchard will depend on the number of acres that will eventually be planted to improved seedlings raised from seed obtained from the orchard. The return is therefore controlled by the size and the productivity of the orchard. The situation becomes more favorable in the larger orchards, since the fixed cost remains the same while the return increases. c) The various activities in a seed-orchard program do not promise equal investment returns. d) The smaller the seed orchard the less elaborate the selection procedure one can afford, perhaps only including the most profitable steps in the selection process, until the orchard becomes so small that its operation is no longer profitable.

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