TREE SELECTION TECHNIQUES IN THE NORTHEAST: SOME PROBLEMS AND QUESTIONS

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Abstract

Four techniques of plus-tree selection (ocular, comparison trees, base line, absolute standards) are considered in relation to the application of mass selection - clonal orchard; and family selection - seedling orchard breeding methods for *Picea glauca* (Moench) Voss, *P. rubens* Sarg., *P. mariana* [Mill.] B.S.P., *Larix laricina* [Du Roi] K. Koch, and *Pinus banksiana* Lamb. The comparison-tree technique is most commonly used, often in combination with a point score, but the other techniques also deserve consideration as a pilot study indicates. A survey of time requirements and costs based on eight organizations revealed higher costs than expected and the need to recognize more clearly how the two breeding methods differ and to distribute efforts accordingly.

Introduction

Most selection programs begin with the identification of individual trees in wild stands or plantations, and the subsequent propagation of these individuals vegetatively or generatively from seed.

Many theoretical and practical problems attend such programs. This paper is only concerned with one of them, namely the techniques of plus-tree selection and their current application in northeastern North America. Surprisingly little work has been done in this problem area (Dorman 1976). Results of a recent survey and of a pilot study will be used as a basis for discussing the issue, and to shed some light on a number of problems. Five major conifer species will be considered.

Breeding Methods and Selection Techniques Applied in the Northeast

Characteristics of Breeding Methods

There are two breeding methods that are commonly applied in the Northeast and need to be discussed here, namely mass selection with clonal seed orchards and family selection with seedling seed orchards. Choice of the most appropriate method is based on species characteristics such as flowering age, the characters to be improved and their genetic parameters such as heritabilities, as well as the skills and facilities needed to apply them.

Mass selection to establish clonal orchards is a method useful for species that flower late so that grafting makes it possible to achieve earlier seed production. The method is devised to achieve rapid and substantial improvement in genetic quality of planting stock in the first generation. Selection here is individual-tree selection which is considered effective in modifying traits that are easily seen and strongly inherited such as the morphological traits of stem and crown form (Shelbourne 1969). For physiological traits related to growth and yield, individual-tree selection in natural stands is probably only marginally effective as measured by the genetic gain per unit of time or dollars invested (Ledig 1973). This view is supported by results from southern pines where volume improvements based on seed from unrogued orchards are in the order of 4% (Snyder 1969, Talbert 1982). The clonal orchard also requires grafting skills and greenhouses, i.e. personnel and facilities not available to all organizations. This method is considered promising for white spruce (*Picea glauca* [Moench] Voss), red spruce (*P. rubens* Sarg.) and eastern larch (*Larix laricina* [Du Roi] K. Koch). These species are utilized for both lumber and pulp (Teich 1975, Coles 1981).

In contrast, family selection to establish seedling seed orchards is well adapted to species that flower earlier, and which are selected to improve primarily growth and yield. Individual-tree selection is needed to start the program, but because of the low heritability of these traits, the emphasis then shifts to family selection in the affiliated open-pollinated tests. The efficiency of family selection rests on the principle that when a number of individuals contribute to a family mean, the average phenotype will approach the mean genotype of the family (Lerner 1958, Wright 1976). Of course, randomization and replication are also used to improve selection and measure genetic parameters. In this approach, many parents need to be selected initially and selections are done more rapidly than for clonal selection. Although greenhouses are now commonly used to produce seedling families, this is not really necessary. There is no need for grafting unless a clone bank constitutes part of the program for breeding in advanced generations. Most likely this breeding method can be successfully applied to black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) which are primarily used for pulp (Morgenstern 1975, Yeatman 1975, Coles 1981). It was shown that in longleaf pine (*Pinus palustris* Mill.), family selection for height growth was almost three times more effective than individual-tree selection in wild stands (Snyder 1969).

The Four Selection Techniques

Plus-tree selection as first initiated in Sweden about 40 years ago was based on a comparison of one phenotypically outstanding tree and its nearest neighbors (Plym Forshell 1964). Variations of that approach are still widely used but other methods have been devised since then. Three techniques were listed by van Buijtenen (1969) and four by Morgenstern et al. (1975) namely, (1) ocular selection, (2) comparison trees, (3) the the base-line system, and (4) absolute standards. A brief description of each of these follows; for a more detailed consideration readers should refer to the 1975 publication mentioned.

Ocular selection. A rapid survey of a given stand is made and individual trees are chosen without measurements or ratings. This simple technique has been found to be surprisingly effective in a number of cases. For example, when we carried out a selection exercise in white spruce for demonstration purposes at Petawawa with each of the three technicians working independently, all chose the same tree out of 25.

The comparison-tree technique consists of finding an exceptional tree which is then compared with its nearest neighbors in characteristics such as height, diameter, crown diameter, etc. The chosen tree must be better in at least one trait. This technique is often used in combination with a point score for qualitative characters such as stem and crown form (Sayward 1980). It is easily taught to technical staff and widely used, but as Ledig (1974) points out, may be ineffective when neighbors are related. It is less subject to error in plantations where a genetic relationship among neighbors rarely exists. It is then also more effective than in natural stands because of uniform age and spacing (Webb and Barber 1966).

Base-line system. Based on measurements of a dependent and independent variable (e.g. height and age) on 10 - 20 dominant and codominant trees in a particular stand, a regression equation is calculated. Trees that exceed mean values (i.e. lie above the regression line, say by 10% or 1 - 2 standard deviations) may be selected. In this system height/age ratios could even be used without a regression. The technique is adaptable to many situations but has been rarely applied in practice.

Absolute standards in given tree variables (e.g. height, diameter) may be set by volume tables, yield tables, or site-index curves for specific site classes in certain regions. After the site class has been established for a given stand, promising candidates can be measured to see if they exceed table values. The candidate trees would have to meet minimum standards in other characteristics (e.g. stem form, branch angle) to be accepted. A variation of this technique was described by van Buijtenen (1969) in which a minimum point score based on several traits must be reached before a tree could be chosen. This method is not widely used but has been adopted in Ontario.

Applications in the Northeast

An overview of selection programs and affiliated techniques is given in Table 1. This is a rapid survey and makes no claim to being complete. It covers the State of Maine and the Provinces of Ontario, Quebec, New Brunswick, Prince Edward Island and Nova Scotia; and is concerned only with white spruce, black spruce, red spruce, jack pine and eastern larch.

As indicated by Table 1, the two breeding methods mentioned earlier are used. The first method involves a high intensity of selection followed by grafting to establish the conventional clonal orchard. The second method is based upon seed collection from open-pollinated trees selected at a lower intensity, with subsequent planting of seedling orchards and associated half-sib family tests. The table shows that this method is used only for black spruce and jack pine. Organizations responding to my questions indicated that most selection work is done in natural stands but in some cases plantations were searched, particularly in Maine where some

50 - 60-year-old plantations are found.

The table reflects the predominance of the comparison-tree technique which is used almost everywhere except in Ontario and Quebec. It is often supplemented by a point score based on several tree measurements and morphological characteristics, particularly when applied to white spruce and eastern larch (Sayward 1980). A point score is normally not used for black spruce since that species usually has acceptable stem and crown form and is primarily utilized for pulp. Ocular selection is used in a few cases as well.

A Study of Cost and Time Requirements

Survey Results

Eight organizations with active selection programs in New Brunswick and Quebec (including pulp and paper companies and provincial forest services) supplied information on man-days required to select individual plus-trees and make scion or cone collections (Table 2). With two exceptions, the data were kept separate for the mass and family selection breeding methods. In some cases cost data for technical staff were not supplied and I then calculated an approximate figure on the basis of $75 per man-day (M.D.). The cost figures also include travel, accommodation, food and equipment expenditures (such as ammunition, snowmobile rental, etc.).

Table 2 indicates that total input per selected tree ranged from 1.6 M.D. (or $200) to 4.1 M.D. ($409) for family selection. The equivalent range for mass selection is 4.0 and 9.6 M.D. ($484 - $1118).

For comparison, several figures are given from the literature (Table 3). Here, too, costs per tree for the mass selection are about twice as high as for family selection.

Pilot Study of Selection Techniques

General procedures.

In the summer of 1981 the application of all four plus-tree selection techniques was studied in natural stands at Acadia Forest Experiment Station and the University of New Brunswick Forest. Study methods were adapted to a situation comparable to the family selection - seedling seed orchard breeding method where relatively large numbers of trees are selected rapidly. The sample included 7 stands of black spruce and 3 of eastern larch. The general procedure common to all techniques was to establish a base-line of about 120-400 m along roads, power lines or trails, and then select 2 - 3 trees along each line using in random order each of the 4 techniques for black spruce and 3 techniques for larch (the method of absolute standards was not applicable in this species). All selected trees came from the dominant or codominant class and were spaced at least 40 m apart. Measurements included total height, diameter and age at breast-height. The proportion of trees selected was calculated from the number of trees per ha given in yield tables (Plonski 1956) and verified by counts. The phenotypic improvement achieved was measured in terms of the change in height/age ratio from the mean value discovered through the base-line system. The time needed for each selection technique was recorded.

Specific procedures.

Ocular technique. The trees were rapidly selected and height and age determined.

Base-line system. Fifteen to 20 trees were measured, and the 2 or 3 selected trees had to exceed the regression line by at least 10%. A pocket calculator was used to develop the regression equation in the field.

Absolute standards. The Lake States site index curves for black spruce (Gevorkiantz 1957) were found to agree most closely with local productivity. They were used to establish the site class for each stand and for the evaluation of selected trees. The technique involves a number of trial-and-error measurements until acceptable trees are found.

Comparison trees. Five comparison trees were measured from dominant or codominant trees surrounding the candidate tree.

Results

The 10 stands sampled (7 black spruce, 3 larch) ranged in age from 37 - 84 years, and the proportion of trees selected was from approximately 1 in 500 to 1 in 1000.

For black spruce (Table 4), the results were obtained under ideal conditions and the time requirements were small. However, not the absolute values but the relative differences among techniques are important. Phenotypic improvement is measured in terms of changes in the height/age ratio per unit of time spent to make the selection. The table indicates that greatest improvement per unit of time is made by means of ocular selection, followed by absolute standards, base-line and comparison trees.

For larch (Table 4), the ocular technique is again most efficient. The comparison-tree technique is next and base-line last, but the difference between the latter two is only 1% per hour of effort.

General Discussion

Application of Techniques

Table 1 shows that selection of plus trees is based primarily on the comparison tree technique and that it is often supplemented with a point score. The absolute standards approach as used in Ontario does not utilize a point score but in some southern hardwoods it is based exclusively on a point score (van Buijtenen, 1969). Ocular selection is used for several species in Quebec, but together with a point score for white and red spruce. This indicates that the rigid definitions used here are not necessarily followed in the field.

In spite of these attempts to adapt suitable techniques to the species, the comparison-tree method is perhaps used more often than it should be in view of Ledig's (1974) valid criticisms. Also, Snyder (1969) found that it proved to be fairly ineffective in selection for height growth.

The pilot study of time requirements (Table 4) supports the view that the other three techniques should be more frequently used. For black spruce, the comparison-tree technique yields the lowest returns per hour of effort. However, this result is conditioned by the sampling procedure adopted here, where up to three trees were selected in each stand. If a single tree was selected (a procedure more likely to be adopted for mass selection and the clonal orchard), the relationship would differ because the number of comparison trees measured in a stand would be smaller.

Cost Data

In a previous section, reasons for using clonal vs seedling orchards have been given. The two methods differ in several operations and because this survey has focussed only on selection techniques, it therefore precludes overall cost comparison. However, it has indicated some problems. Not only is the actual time required to select one tree for seedling orchards and family tests much higher than anticipated but in some cases there is only a small difference between the two methods in selection intensity and cost. This trend should be corrected in view of the fact that, based on the family tests, about 80% of the families will be removed from seedling seed orchards.

Porterfield and Ledig (1977) presented an economic analysis of several breeding methods based primarily upon data of the Petawawa group (Morgenstern et al., 1975). They considered tree selection costs to be very low and felt that these could probably be increased. However, this argument has its limitations; it is difficult to know when the point of diminishing returns has been reached. It is doubtful that a three- or four-fold increase in cost is justifiable. Furthermore, in a recent study at the University of Maine (Kenlan 1981), it has again been shown that identification of superior black spruce parent trees based on growth in natural stands is difficult. Family selection probably would have been more promising.

Finally, as the pilot study indicates (Table 4), there is no reason why techniques other than the comparison-tree technique should not be more widely applied, particularly for the family selection - seedling orchard method.

Conclusions

1. A variety of selection techniques is used in eastern North America of which the comparison-tree technique is most common. This pre-eminence appears to be questionable. Other techniques should be investigated by organizations which do not use them, particularly when the family selection - seedling orchard breeding method is used.

2. Time requirements and costs between organizations are not easily comparable but there are indications that some initial tree selection costs may be too high. Because many organizations have not been involved in selection programs longer than 2 - 3 years, there is hope that cost can be reduced. A detailed economic analysis of this problem is difficult because the cost-benefit ratio depends largely upon seed orchard areas established and actual seed production (Porterfield and Ledig 1977).

3. It is important that distinctions between mass selection and family selection breeding methods are maintained. The available funds should be applied where the greatest gains can be made.

4. As soon as figures are available on orchard areas established and gains are calculated from family tests, comprehensive economic analyses should follow.

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Table 1. Summary of selection practices by breeding method as applied in the Northeast.

Breeding method	Species and Abbrev.	Plus-tree selection technique	Geographical area
Mass selection and clonal orchard	White spruce (wS)	Comparison-tree, usually combined with point score.	Maine, New Brunswick, Prince Edward Island, Nova Scotia
		Absolute standards based on yield tables or site index.	Ontario
		Ocular, with point score.	Quebec
	Red spruce (rS)	Comparison-tree, with point score.	Nova Scotia
		Ocular, with point score.	Quebec
	Black spruce (bS)	Comparison-tree.	Maine, New Brunswick, Prince Edward Island, Nova Scotia
		Absolute standards.	Ontario
	Eastern larch (eL)	Comparison-tree, often combined with point score.	Maine, New Brunswick, Prince Edward Island
Family selection and seedling orchard	Black spruce (bS)	Comparison-tree, usually of lower intensity than in mass selection.	Maine, New Brunswick, Prince Edward Island, Nova Scotia
		Ocular.	Ontario, Quebec
	Jack pine (JP)	Comparison-tree, usually combined with point score; low intensity.	Maine, New Brunswick, Nova Scotia
		Ocular.	Maine, Quebec, Ontario

Table 2. Time and cost figures supplied by eight organizations.

Breeding method	Species[1/]	Organization	Year	Man-days per tree: Tree selection	Man-days per tree: Scion or cone collection	Cost per tree[2/] $
Mass selection and clonal orchard	wS	A	81	9.1	0.5	1118
	wS	B	81	4.0	1.0	379
	wS	C	81	3.0	1.0	484
	wS	D	81	4.7	1.0	616
	wS	E	80-81	6.6	1.0	723
	wS	H	80-81	1.0	1.0	165*
	rS	H	80-81	1.0	1.0	160*
	eL	E	80-81	5.0	1.0	585
	eL	A	81	4.1	(incl. in selection)	713
	eL	B	81	4.0	1.0	379
	eL	D	81	6.4	1.2	818
Family selection and seedling orchard	bS	A	79-81	4.1	(incl. in selection)	409
	bS	C	80-81	1.3	0.3	200
	bS	E	79-80	4.0	(incl. in selection)	348
	bS	E	80-81	3.0	(incl. in selection)	277
	bS	H	80	1.0	0.3	125*
	jp	E	80	3.3	(incl. in selection)	305
	jp	H	80-81	1.0	0.3	118*
Both methods (data not separate)	wS, bS, jP	F	80	4.2	0.9	525
		F	81	7.4	1.1	884
	wS, bS, jP	G	80	8.2	0.8	785
	eL		81	10.2	0.8	958

[1/] Abbreviations as in Table 1.

2/Figures that do not include travel, equipment and accommodation are marked by *.

Table 3. Black spruce time and cost data for the two breeding methods from several authors. All costs have been updated to 1982 assuming a 10% annual inflation rate.

Breeding method	Per Tree Time (M.D.)	Per Tree Cost ($)	Authors
Mass selection & clonal orchard	2.0	117[1/]	Morgenstern 1975
Mass selection & clonal orchard	4.0	293[2/]	Carlisle and Rauter 1979
Family selection & seedling orchard	0.7	39[1]	Morgenstern 1975
Family selection & seedling orchard	0.7	43[2/]	Carlisle and Rauter 1979
Family selection & seedling orchard	1.6	220[3/]	Coles 1981

1/ Estimated cost; travel, lodging and equipment not included.

2/ Actual cost. See authors for details.

3/ Estimated total cost.

Table 4. Phenotypic improvements achieved per unit of effort by each selection technique.

Technique	Average height/age of selected tree (m/year)	Average time per tree (hours)	Improvement over stand mean (%)	Improvement per hour of effort (%)
		A. BLACK SPRUCE		
Ocular	0.325	0.38	14	37
Base-line	0.348	1.50	22	15
Absol. Std.	0.331	0.69	16	23
Comparison	0.331	1.43	16	11
		B. EASTERN LARCH		
Ocular	0.380	0.47	8	17
Base-line	0.404	1.56	15	9
Comparison	0.387	1.03	10	10