plus efficace dans les cas généraux. Cet article consacre plus d'attention à 'l'importance des relations entre individus jeunes et adultes que tous les autres articles présentés.

Zusammenfassung

Titel der Arbeit: Ein kurzer Rückblick und *Schlußfolgerungen aus der Diskussion über Samenplantagen.*

Dieser Aufsatz sollte die Ergebnisse der Diskussion über Klon- und Sämlings-Samenplantagen in Silvae Genetica zusammenfassen. Es ist weder möglich noch notwendig zu sagen, welches der beiden Systeme im großen und ganzen besser ist als das andere. Die relative Wirksamkeit, ausgedrückt in Einheiten des Züchtungsfortschritts und der Kosten, streuen in breitem Rahmen je nach Heritabilitäten, Schwierigkeiten vegetativer Vermehrung und kontrollierter Bestäubung usw. Die einzelnen Beiträge geben eine ausführliche Diskussion. Vf. möchte jedoch Klonsamenplantagen als die im allgemeinen zuverlässigere Methode empfehlen. Die Bedeutung der Merkmalskorrelationen zwischen jungem und späterem Alter erfuhr in diesem Aufsatz mehr Beachtung als in den übrigen.

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Seed Orchards for the Production of Genetically Improved Seed

By BRUCE ZOBEL and R. L. MCELWEE[1])

Recent emphasis on forest tree breeding has posed the questions, "How can improved seed be economically produced in sufficient quantities for large scale forestry programs?" and, "How can the greatest genetic improvement be achieved?" New varieties of forest trees can be produced but they will not be of significance in improving yields and quality of wood until they can be produced economically on a commercial scale. Foresters and scientists in related fields have considered these problems and all suggest producing quality seeds in seed orchards. The seed orchard concept is being accepted and already widely used in forestry; it is a term frequently heard at technical forestry meetings or referred to in forestry journals. Even though seed orchards are recognized as one of the few workable methods now available to economically mass-produce improved forest tree seeds, many do not understand their objectives. In some forest regions, new varieties can be developed without having immediate use, while in others the problem is one of putting improvements to immediate use through standard forest management operations.

Where forestry practice is intensive there is a wide gap between the silvicultural improvements that have been made and the development of better trees to take advantage of the improved cultural methods. Forestry has not developed along agricultural patterns where cultural practices and genetic improvement proceed together and complement each other; instead, the plant improvement part in forestry is well behind. Because of the long-term nature of all forest management research, progress to bring culture and plant improvement to the same level will be slow and "crash programs" will not be too effective to bring about rapid narrowing of the gap between the two. Therefore, we need to take immediate action which may involve considerable dependence on ideas that have not as yet been proven.

Production seed orchards are a good example of activities involving some unproven ideas. Large sums of money are being spent in establishing such orchards, and it is necessary to critically analyze the objectives and philosophies involved. Such a situation is present in the Southeastern United States, an area of rapid tree growth, large forest industries and intensive forest management practices. This region is ideal for applying genetics in forestry practices; the current large regeneration programs have produced an urgent need for mass-producing genetically improved seed.

This paper deals with the philosophy, not the techniques. of seed orchard management and will be based upon experience and ideas gained in the N. C. State-Industry Cooperative Tree Improvement Program. This Cooperative Program is supported by 18 organizations located in ten southeastern states, mostly members of the pulp and paper industry. Rather than cover this program in detail, *Figs.* 1 *and* 2 and Tables 1 *and* 2 have been prepared to describe the scope of the Cooperative Tree Improvement Program. All cooperating organizations have one thing in common – they all have great and urgent need for improved seed

The Generai Seed Orchard Concept

The forest manager is faced *each* year with the problem "Where shall I get seed?" One way to satisfy this need is to establish seed orchards. Data on inherent differences on a racial or individual basis is simply too impressive to ignore, and it is obvious that progeny will be better when both parents are good than if only one or neither of the parents is good. A seed orchard is used to take advantage of both known and suspected areas of inheritance and gain. Despite the present sketchy knowledge of techniques as well as the degree of improvement possible to achieve, there is as yet no satisfactory alternative to a seed orchard program; it is simply this or continuation of use of unimproved seed.

Seed orchards are established to produce seed for trees having specially desired characteristics. They are but one step in the succession of practices necessary to improve seed; they can be established to multiply seed from special provenances, from certain desirable trees within a given provenance or for hybrids. Seed orchards usually contain

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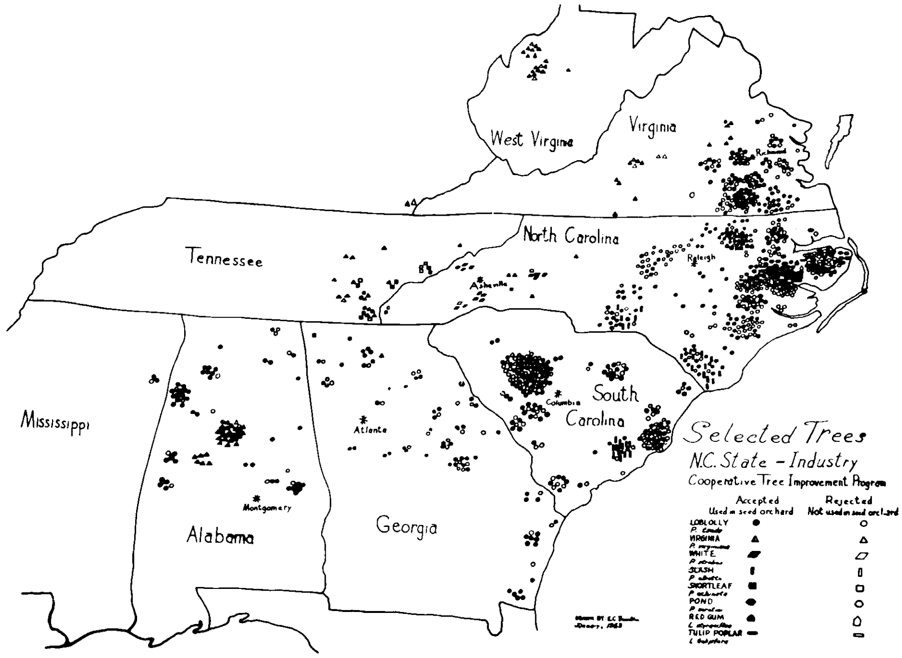

Fig. 1. — Trees selected in the N. *C.* State-Industry Cooperative Tree Improvement Program to Feb. **1, 1963** are indicated by species. Eight species are shown but, in addition, five trees have since been selected in pitch pine *(Pinus rigida).* Also, preliminary selections have been made in Fraser fir but are not indicated on the map. Trees established in seed orchards are indicated by solid symbols — those not used were rejected mainly for undesirable wood properties.

parent trees obtained from a specific physiographic region and most seed orchards include as parents those trees within a given provenance that have been specially selected for one or several characteristics. Almost without exception the selected parent trees are from relatively wild or previously unselected populations of trees; this means thst the early production seed orchards consist of individual; from the first, or at most, the second cycle of selection. Especially in the Southern Pinr Region, parent trees selected for use in seed orchards are almost always from native wild populations, or from plantations established with mixed seed collected from such wild populations.

Maximum genetic improvement for forest trees cannot be expected from the first seed orchard established but will depend on additional selection, controlled crossing, or both. This need for additional selective breeding is at the

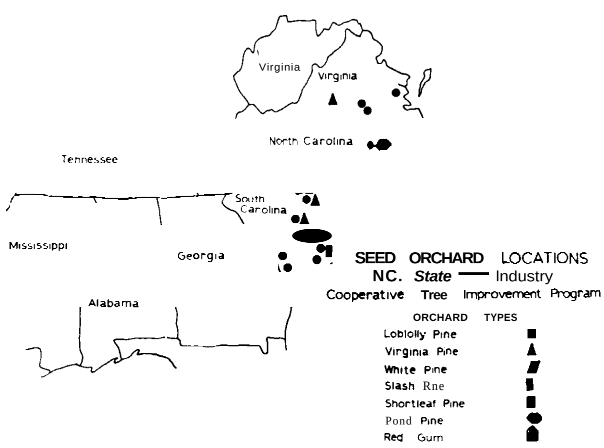

Fig. 2. — **Seed** orchards are indicated in **23** different locations. They include 40 orchards when categorized by species alone, and actually **constitute 56** separate orchards, based on location, species, wood qualities and physiographic source of the clones. The orchards total **679** acres, with **985** different clones being represented.

***Table** 1.* — Selected Trees Used in the Industry-N. C. State Tree Improvement Program[1]).

State	Species	Selected Trees	Trees Established in the Seed Orchards	Trees Rejected[2]) or not yet Established
Alabama	Loblolly Pine	65	50	15
	Virginia Pine	25	22	3
Georgia	Loblolly Pine	85	59	26
	Virginia Pine	1	1	0
	Shortleaf Pine	1	0	1
	White Pine	1	0	1
Kentucky	Virginia Pine	2	1	1
Mississippi	Loblolly Pine	3	2	1
North Carolina	Loblolly Pine	293	154	139
	Virginia Pine	14	10	4
	White Pine	25	17	8
	Slash Pine	19	14	5
	Shortleaf Pine	10	7	3
	Pond Pine	36	26	10
	Red Gum	22	18	4
	Tulip Poplar	34	18	16
South Carolina	Loblolly Pine	213	118	95
	Virginia Pine	1	1	0
	Slash	12	11	1
Tennessee	Loblolly Pine	3	2	1
	Virginia Pine	16	14	2
	Shortleaf	11	6	5
Virginia	Loblolly Pine	140	84	56
	Virginia Pine	27	22	5
West Virginia	Virginia Pine	18	15	3
	Pitch Pine	4	0	4
	Total	1081	672	409

[1]) See the map, ***Fig.*** 1, for locations of trees selected before Feb. **1, 1963.** ***Table* 1** included trees selected up to April **1, 1963.**

[2]) Usually rejected for wood quality or poor grade. Only those trees are graded that, in the judgment of the grader, stand a chance of being accepted. Many trees are rejected for inferior wood qualities (specific gravity, tracheid length or other properties, the desired qualities depending on the objectives and wood usage of the company).

Table 2. — Seed Orchards in the Industry-N. C. State Tree Improvement Program[1]).

Species	State Where Established	Acres of Seed Orchard[2])		Number of Grafts		Number of Clones	
Loblolly Pine (Coastal Plain)	Alabama	15		3,000		20	
	Georgia	21		3,250		34	
	North Carolina	176		22,400		171	
	South Carolina	73		10,750		59	
	Virginia	28		1,400		21	
Total			313		40,800		305
Loblolly Pine (Piedmont and Mountain)	Alabama	30		6,000		21	
	North Carolina	100		12,600		206	
	South Carolina	35		6,000		101	
	Tennessee	22		4,400		44	
	Virginia	28		1,500		23	
Total			215		30,500		395
Virginia Pine	Alabama	20		4,000		22	
	North Carolina	6		1,200		15	
	South Carolina	3		600		15	
	Virginia	2		400		19	
	Tennessee	12		2,400		25	
Total			43		8,600		96
Slash Pine	North Carolina	30		4,000		35	
	South Carolina	10		500		12	
Total			40		4,500		47
Shortleaf Pine	Alabama	15		3,000		15	
	North Carolina	5		1,200		15	
	Tennessee	3		600		15	
Total			23		4,800		45
Pond Pine	North Carolina		7		1,400		31
White Pine	North Carolina		20		4,000		30
Yellow Poplar	North Carolina		10		800		18
Sweetgum	North Carolina		8		600		18
Grand Total			679		96,000		985

[1]) Already established or to be completed by June, 1964.

[2]) Most orchards are established at a spacing of 15' × 15' or 15' × 30', although one or two are 30' × 30' or 20' × 20'.

bottom of many of the questions raised about seed orchards, i. e., how many clones need to be included, how should they be outplanted, how should they be progeny-tested, and should their progeny be used as a base for further improvement?

A distinction between the production seed orchard and the tree bank (sometimes called a research orchard) needs to be made. It is sometimes assumed that the few parents included in a production orchard will serve as the ultimate source or base for all future genetic improvement in the following cycles of selection and breeding. Although serious consideration should reveal the error of such restrictive thinking, numerous discussions have been held, statistical formulae produced and papers written to point out that the numbers of clones used in early production seed orchards are too few for extensive improvement in later generations. On several occasions it has even been recommended that mediocre phenotypes be used in the original production orchard in order to obtain the large number of parents deemed necessary for future generatioris of selection and breeding. Certainly, too restricted a number of parents is highly undesirable if the orchard is to be used as a research tool to produce material for future selections, but arguments regarding clone numbers necessary for future selection become meaningless if the objective of the production orchard is kept separate from the objective of the tree bank.

In a region of intensive forest management, vast acreages are planted and direct-seeded each year. Better seed is needed immediately for these operations — not 10 years, or 20 years from now. On such large acreages even modest gains mean large total benefits to the forest industries. The urgency for seed is a declsive consideration in planning a production seed orchard program. To supply this need, a production orchard must be considered as a source of seed which will give the very maximum improvement as soon as *possible*. Conversely, the tree bank is used for refinement, development and production of progeny for future selection and breeding. It should contain many different genotypes from which can be obtained those most suitable to take advantage of new knowledge and the changed management practices of the future.

A well-planned tree improvement program, then, must have both short-term seed production objectives and long-range, developmental plans. The latter involve considers tion of silvicultural and management practices considerably different from those currently in use. Forest management practices will need to change if forestry is to continue existence as a competitive source of industrial raw material. Currently, change in management practices is very rapid in regions of intensive forestry, with cultural measures already in use that were never even dreamed of by past generations of foresters. In order to produce trees which can take full advantage of the more intensive forest practices, the seed orchard program must include research tree banks as well as the production orchards necessary for immediate seed supply.

Considerable criticism has been leveled at the seed orchard approach because the orchards usually have been established from individuals which are good phenotypes, with nothing known about thcir genotypes. Such criticism is certainly justified if: (1) no testing is to be done to prove the genotypic worth and combining ability of the parents· (2) sites are so variable and are so poorly understood that phenotypic-genotypic relationships cannot be estimated; or (3) there is no immediate need for large amounts of seed of the species, ecotype or hybrid to be produced. Certainly the ideal procedure is to first test the parents through their progeny and, if time is not limited, to complete several selection cycles before establishing the proven genotypes in a production seed orchard.

In areas such as the Southern Pine Region the urgent needs of forest management preclude this leisurely approach. It often is said that seed orchards should not be established until problems in their management are solved and thcir yields and degree of tree improvement are known. The lack of early flowering in certain grafted spruce orchards and trouble from incompatible clones in the southern pines are used as example of what happens when orchards are established before sufficient basic knowledge is available. It seems clear that we must take one of two attitudes: (1) work only with known facts. not taking any chances on new concepts that have not been proven; or (2) look at forestry as a dynamic industry that needs progress and change for its very existence and he willing to try promising but unproven concepts. The latter approach requires imagination first and foremost; it also requires operations in aress of insufficient knowledge and entails considerable risk. Mistakes will be made when operating in this manner – they are inevitable in any progressive approach. In the South, the criticisms still ring clearly in our ears about those who first tried site preparation. "Of course it can't pay," it was said, and furthermore "Trees are suited to grow under wild conditions." But now site preparation in some form is a standard practice. indispensable to intensive forest rnanagement, not, however. until many techniques of site preparation costing hundreds of thousands of dollars were tried in the ever-evolving process that has resulted in the methods and equipment currently in use. The same arguments are leveled against "radical" techniques such as planting at wide spacing, mechanical harvesting and fertilization, with the implication that such radical management practices have no place in practical forestry and, therefore, should not have a prominent place in the thinking and planning for the future.

Since improved trees are developed for future use, those concerned with tree improvement and genetics must be the most forward-looking of all. Every possible effort must be made to anticipate future needs. The inclusion of wood specific gravity in company ceed orchards in the N. C. State-Cooperative Program is a prime example. A decade ago practically nothing was known about the inheritance of wood specific gravity in the southern pines. Despite this void and at considerable expense and trouble, specific gravity of wood was included as a vital characteristic in the choice of parents for use in seed orchards. This decision was not made on facts but on an intimate knowledge of variation within the species and breeding practices with other organisms. Recent research results shows that this inclusion of wood will pay handsomely. because wood specific gravity has strong enough genetic control and has enough variation to yield real dividends from a production orchard. The cooperating industries could have had seed orchards that would produce several hundred million seedlings a year with no improvement in wood quality (the safe, cautious approach); but by taking a risk, they now have seed orchards that will produce seedlings with considerably improved wood quality.

Gains from a seed orchard will be larger than those determined strictly from inheritance data based on individual tree characteristics. Of primary importance, a seed orchard assures that seed will be from the desired, or designated provenance. This assurance is especially important in countries where cxotic trees are being extensively used; for species such as Douglas fir, ponderosa pine, Scotch pine, and certain of the southern pines, control of the correct geographic source alone may constitute the greatcst gain from a seed orchard. Lacking strict seed certification. one is never sure that he has the desired provenance when buying seed on the open market. There is still a strong tendency to purchase seed of the desired species for the most reasonable price, regardless of source, with resultant heavy losses from drought, freezing, pests or poor growth. Seed obtained from a properly established production orchard prevents such losses due to improper geographic source.

One of the least understood, but most important, problems in tree improvement is that of crossing between related individual~Parent trees used for most production seed orchards will not be related since they are usually obtaincd from many different stands growing many miles apart. This consideration, although not commonly recognized, is most important, especially for species such as loblolly pine, where forests have resulted from invasions of old fields It is not unusual to have many acres established from seeds of a very few parents, such as those growing along an old fence or road. In the South, these old field stands are commonly used as a commercial source of seed and large amounts of seed are collected from relatively small areas. These seeds may be half sibs, or full sibs, or inbreds and are often from parent trees that were themselves half sibs, full sibs, or selfs, with resultant poorer survival or growth.

It is tacitly assumed that seed from a seed orchard invariably will have a narrower genetic base than seed from a wild stand. This outcome is assured for certain desired characteristics such as straightness, wood properties or limb angle, but not so for physiological characteristics of survival. Since the parents come from many widely separated stands, seed produced will have a wide physiological diversity, and the fear of catastrophe in growth or adaptability from allegedly narrowed "genetic bases" appears to be without foundatinn. Indeed, only if the desired form and wood characters are strongly tied to adaptive characters is such narrowing in physiological adaptability possible.

The Production Seed Orchard - The Short-Term Approach

Seed from a seed orchard will produce seedlings suitable to grow under certain environments and to produce a desired product. Most industries in the Tree Improvement Program require trees that will grow well on either the Coastal Plain or Piedmont under moderate to intense site preparation, with wood suited for either kraft paper, high grade paper, or newsprint. One kind of tree will be best for each physiographic area and product, but no single tree will be best for all. To assure that the seed from a given orchard are the best, progeny tests must be made under conditions similar to those in which the trees will be grown commercially.

Forest management practices and products desired will change with time so no one type of tree (or seed orchard) will permanently remain the most suitable. A production seed orchard is created specifically for a given set of conditions or products, either currently present or foreseeable in the future, and it cannot be expected to be completely satisfactory as forest management and wood use practices change in the future; a good example of such a possible change is the use of fertilizers. Although fertilization has not attained the status of a standard silvicultural "tool", except in nurseries or for stimulation of seed production, eventually it might become a common practice in stand management. In this eventuality, parent trees in the present seed orchards may not be the best, since their worth was judged by progeny tests under conditions of site preparation without fertilizatiori. It is known that some trees respond to fertilizer better than others; therefore, it will be necessary to obtain trees of a different kind from the seed orchards if we are to obtain the maximum benefit from fertilization. Management practices of using both fertilization and site preparation will then require either an alteration of the old orchard or construction of a new one to obtain new parents and parentsl combinations necessary to produce seed best for the new conditions.

One of the best sources of material for the new conditions will be plantations from the original orchard, but sometimes this source will not prove feasible. For example, a number of production seed orchards have been established for trees of high wood specific gravity. If it should become necessary to switch to lower specific gravity wood because of a change in product or quality specifications, the parents or progcny from the original high specific gravity orchard would not be very useful. In this case a completely new source of genetic material is necessary to best satisfy the new needs. These probable interim dilemmas point up one of the major objectives of this paper; i. e., the need to *recognize* that a production orchard cannot be considered as thc solc source *of* future seed supply *or* as the only *source of genetic* material for future seed orchards. Yet this point is usually overlooked in discussions about seed orchards, and criticism is leveled at the design or number of parent trees included in a production orchard because it does not provide a broad enough base for future selection. *Production* seed orchards are not primarily established as a base for future selections; what they are established for is *to* provide the maxinzum possible improvement in the shortest possible time.

The Tree Bank — The Long-Term Approach

Since the current production orchards will not serve as the sole base for future improvement, it is necessary to have available additional genetic material from which new orchards can be developed. This can be maintained in tree banks ready for use in a seed orchard as needed. New production orchards established from tree banks will yield good genetic gains since there has been time to breed and sclect and test more intensively, perhaps through several generations, a process not possible for the first production orchards. Considerable imagination and prognostication is required on the part of the researcher to estimate future management practices and product requirements when testing tree banks for possible future use. Genetic material for the tree bank from which new production orchards can be established will be drawn from the following sources:

(1) Plantations from seeds of the production orchard. These trees will have undergone more than one selection cycle, and, provided they will do well under the new conditions, should give considerable genetic improvement depending on the quality and characteristics of the original production orchard.

(2) Established tree banks. Many industries use trees with specific characteristics and reject, for immediate use, trees that may be highly desirable in all but one characteristic. For example, an industry desiring high specific gravity wood rejects over half of their best phenotypic selections bccause of low specific gravity. Instead of discarding the low specific gravity trees, the temporary "rejects" could be retained in a tree bank and progeny tested with the expectation that in the future, low specific gravity as well as high spccific gravity wood might be desired. Such dual specific gravity requirements are, in fact, already a reality because products and technology have shifted and certain desircd papers are best obtained from low spccific gravity wood.

(3) New "genetic combinations" and trees with different and useful characteristics from wide crosses within the species. In the Industry-N. C. State Tree Improvement Program there are over 800 select loblolly pines in nine southeastern states (see Fig. 1). These trees are growing under widely differing conditions: from nearly frost-free climates to those with considerable annual snowfall, from below sea level to nearly 2,000 feet in elevation, and in deep organic soils, deep droughty sands and heavy clays, both in bottoms and hills. Crosses among trees growing under these widely divergent conditions will yield many new and potentially useful genetic combinations.

(4) Crosses between species. The possibility of obtaining valuable genetic combinations from interspecitic crosses is eonsiderable, although present knowledge and techniques are inadequate to obtain maximum improvement by hybridization.

From the varied genetic combinations in the tree bank, it will be possible to obtain trees suited to grow in many different situations and with wood good for diverse products. Direct establishment of a production orchard from the tree bank depends upon the intensity of testing and on the researcher's ability to foresee future requirements in forest management and utilizaticn.

Clonal **Production** Seed **Orchards**

Thcre has recently developed a lively controversy regarding seedling vs. clonal seed orchards, and their respective advocates have spoken eut sharply on the advantages and disadvantages of each. In most instances such discussions have not been well presented and sometimes have consisted simply of tirades emphasizing how wrong the opposing idea is. Even worse, these differing opinions have been heatedly debated before lay forestry groups who have neither the training, the basic background, nor the interest to judge which is best. In at least two instances administrators of tree improvement programs have stated that they will take no action regarding tree improvement until the controversy regarding seedling or clonal orchards has been resolved. Reactions of this sort to mere differences of opinion are not only discouraging, they are positively damaging to progress, since advocates of seedling orchards and clonal orchards both have the same ultimate objectives — i.e, improvement of forest trees. The difference is one of technique, with costs and hypothetical gains at some future time usually considered as the criteria of success. Usually. experimental proof of the superiority of one approach over the other is lacking, so arguments must be based on speculation of what might happen; the lack of proof is especially true of seedling seed orchards of which very few have been established or tested on a production basis, and data demonstrating the intrinsic value are not yet available.

The point to emphasize is that neither is absolutely right or wrong; either may be desirable depending on given conditions and species. It is not the objective of this paper to directly discuss the pros and cons of seedling vs. clonal orchards but to present the reasons for using clonal orchards in the N. C. State-Industry Tree Improvement Program. It is axiomatic that some of the disadvantages of seedling orchards will be brought out in the discussion.

Listening to arguments regarding the best approach, it often becomes evident that critics themselves lack a clear-cut philosophy and a positive understanding of seed orchards. It should be evident to everyone that one of the major points of difference is the genetic gain possible at some time in the future. This point may become quite academic, however, if the seed orchard approach is considered in the light of (1) the short-term, immediate-gain production orchard teamed with (2) the long-term, developmental tree bank. Additionally, very long-term predictions may be pointless when dealing with species under dynamic forest management, where silvicvlture, management practices and products are constantly evolving and undergoing changc.

Another point often overlookcd is that gain from a production orchard must be calculated as the total gain *accrued* between *now* and some given time in the future although a valid measure of long-term *progress* may be based upon the gain possible at some future date. If it is possible to get a 5% improvement soon, compared to a 10% gain not obtainablc until 25 years from now, it certainly is not sensible to forego the 5% gain for all the intervening 25 years, just because it is less than thc predicted future improvement. While the smaller short-term improvcmenl is being utilized, development of trees for the larger future gain must be under way. This is the philosophy of the short-term production orchard (get the 5% now) and long-term research tree bank (take 10% when developed). To argue whether one or the other is right is mcaningless — maximum improvement can only be obtained by a combination of the two methods.

Grafted, or clonal, seed orchards have certain specific adventages that have been regarded as compelling enough to adopt their use in the N. C. State-Industry Tree Improvement Program:

1. If adequately progeny-tested, all seed produced is from parents of known "genotype" and combining ability Some persons have erroneously assumend that progeny-testing of the grafted clones would not be done — yet all 600 established clones in our industry orchards will soon be under test, and we know of no production orchards where such testing is not under way or anticipated. The progeny test tells us what is expected when certain clones are mated, — thus, the reference to a "dam-sire" mating scheme. In contrast, seed from a seedling orchard is always obtained only from phenotypes and the combining ability of each parental tree is never known because one works only with families of trees. This approach has been most successful with crops that have beeen selected for manv generations and thus are quite homozygous. Fnr the most part, forest trees are very heterozygous, and they will not react in the same manner as selected inbred families, and the same formulae to predict gain cannot be accurately used on both. When a good individual seedling of a good progeny is left to crossbreed with a good seedling of another good progeny, one is still working only with good phenotypes and the resultant progeny may, or may not, be as good as the calculations indicate; just as the progeny of any cross between good phenotypes (clones) in a vegetative orchard may, or may not, be good. Until more is known only testing will indicate gains by use of either the clonal or seedling orchard.

2. In the clonal seed orchard there will be no crossing among relatives, since parental trees are obtained from widely separated stands, often many miles apart. There will always be some danger of selfing between ramets of the same clone, although this hazard can be mostly avoided by careful designs. Danger from related matings in a seedling seed orchard is considerable if a pollen mix or open-pollinated seedlings are used. If one or two of the parents have exceptional general combining ability, trouble will develop, either with or without strict family selection. Seedlings from the good combining mother tree or trees would tend to be saved in the seedling orchard, no matter which pollen effected fertilization. Additionally, within anv family it would be found that in roguing to obtain the number of trees required for the seed orchard the good combining males would be chosen much more frequently than those with a poorer combining ability. This will result in a number of the trees left for the seedling orchard having either a common mother, father, or both. Certainly the danger of having considerable numbers of inbred progeny from a production seed orchard is a chance that cannot be taken and one that will be more easily avoided in a clonal orchard.

3. Grafts of most species flower well at an early age. Horticulturists cite the rule that a graft will flower in half the time required for a seedling. This earliness has proven to be the case in loblolly and slash pines - both male and female flowering builds up rapidly and quite heavily on some clones at three and four years of age. Most clonal orchards of southern pines can be considered to be coming into commercial production at six years of age. Seedlings sometimes flower at that age but not if planted at a spacing suitable for a progeny test. Additionally, one must be careful in using early flowering trees because, as several workers point out, these may be the fast starters and short-lived individuals; the most desirable seedling plants may delay flowering for many years

In a clonal orchard most of the early flowers are used for making controlled crosses, planting of which normally can start five years after grafting. Economy of crossing in the orchard is obvious — for example, in 1963 nearly 40,000 cones were control pollinated in our Cooperative Program by technicians, including women. If one has to go to parent trees in the natural stands to do such crossing, as suggested for seedling seed orchards, a large number of skilled persons would be required to cross on trees usually many miles from each other and from headquarters. Early flowering of the clones enables the making of early, relatively inexpensive crosses for progeny tests, and seed will be obtained nearly as early as crossing selected parents in the field. Field and nursery bed grafting techniques have been developed to the extent that an orchard of moderate size can be completed within two years.

4. A clonal orchard can be established on an area of maximum operational efficiency. on suitably good soils. near headquarters or in conjunction with a nursery. It can also be developed south of the species range if this promotes flowering, but if the seedling orchard is to be properly progeny tested it must be located in an area similsr to that where the trees are to be grown; also the proper sitc for an orchard often is not the same as that for a suit able progeny test. This limitation cancels the one main feature of a seedling orchard; i. e., it should serve the dual function of progeny test and seed production at one time.

5. Opportunity for rapid genetic improvemenl is available in a clonal orchard. The first phenotypic selection results in a given amount of improvement, but some clones will not prove to be good genotypes. Removal of these following progeny testing results in an additional upgrading of quality of seed from the orchard. In later generations, further improvements will take place by intensive selection from large acreages of commercially outplanted pregeny, from the tree bank, wide crosses, etc. Selection differential will be large from the commercial outplanting – certainly much larger than the 10 or 15% possible by selecting the trees to be left in a seedling seed orchard.

6. Improved seed is available while progeny-testing of the clones is in progress. Although the seed Irom the unrogued orchard will not be the best possible, it will be an improvement over commercial collections. Progeny tests can be made under conditions of spacing and site similar to those in which they will be grown commercially. Conversely, to properly progeny test a seedling seed orchard. planting must be at a spacing too close to foster proper crown development or early seed production, or a wider spacing must be used which nullifies much of the value as a progeny test.

7. The cost of establishing a grafted plant is not so great as claimed, and efficient methods of obtaining scions and grafting have been developed. Making control-pollinations for progeny tests in the orchard is much less expensiv? than making them in the field. Commonly, 20 to 40 clones are used in a clonal orchard, while recommendation for 100 or more parental trees are made for use in a seedling orchard; this larger number plus the necessity of crossing on the parent trees in the natural stands markedly increases costs of seedlings in a seedling seed orchard. If a production clonal orchard is combined with a tree bank approach, the need for initially large numbers of clones is not present.

8. The pressures to rogue early in a clonal orchard are not so great as in a seedling orchard. Certain characteristics such as disease resistance, ctraightness and wood quality can be assessed in the progeny at an early age but others such as volume growth, height growth and pruning ability cannot be determined from young plants. Removal of undesirable clones will be started as they begin to com pete and as progeny tests give positive answers concerning the most desirable parents. A seedling orchard must be rogued early if it is to serve its function of seed production, and too early roguing can yield poor results because the trees have not as yet had a chance to express their potential growth.

Grafted orchards present a number of difficulties, the most serious of which are (1) loss of graft following plant establishment by such things as graft incompatibility, a very serious phenomenon under certain circumstances; (2) failure of certain species to form a graft unicn, or when grafted failure to develop a genuine tree form; (3) occasional failure of flowering to occur in the desired manner following grafting; (4) loss of the stock plant to insects or diseases such as Cronartium fusiforme; (5) the necessity for planting more grafts than ultimately desired because of clonal removal for incompatibility, disease of the stock plant, or genetic undesirability.

All questions considered, it has appeared to us that for most purposes clonal orchards are the best under conditions and pressures of the N. C. State-Industry Tree Improvement Program. Seedling orchards are occasionally used for special purposes, such as for Fraser fir for Christmas trees.

Summary

(1) Some type of seed orchard is needed to obtain genetically improved seed in quantity. This paper was written to explain the reasoning behind the seed orchard approach used in the N. C. State-Industry Cooperative Tree Improvement Program.

(2) The philosophy of the short-term, production seed orchard combined with longer-term developmental tree bank is discussed in detail. Causes for errors and misunderstanding, as well as discussions of weaknesses and strengths, are brought out.

(3) Reasons why the decision to use clonal orchards in the N. C. State-Industry Tree Improvement Program arr briefly discussed, with some reference to the alternative seedling seed orchard approach.

(4) There is an implication throughout the paper, tantamount to a plea, to the advocates of different methods to present their case in a positive manner, pointing out signiPicant values and strengths, not emphasizing mainly the faults of the othcr approaches or dressing up their ideas in complex formulae that look impressive but really do not apply to the problem under discussion. Advocates of all methods want the same thing – maximum improvement in minimum time.

Résumé

Titre de l'article: Vergers *à* graines pour *la* production de graines *améliorées.*

(1) Un certain type de verger a graines est necessaire pour obtenir en grandes quantités des graines génétiquement ameliorees. Le but de cet article est d'expliquer par quel raisonnement le probleme des vergers a graines a été aborde dans le Programme d'Amélioration des Arbres en cooperation entre l'Etat de Caroline du Nord et l'Industrie.

(2) La philosophie du verger à graines de production a court terme combine a une réserve d'arbres au développement a plus long terme est étudiée en detail. Les causes d'erreurs et de malentendus, ainsi que l'etude des points faibles et des points forts sont mises en évidence.

(3) Les raisons pour lesquelles on a décidé d'utiliser les vergers a graines de clones dans le Programme d'Amélioration des Arbres en cooperation entre l'Etat de Caroline du Nord et l'Industrie sont exposées brievement en faisant allusion aux differentes manieres d'aborder le problerne des vergers a graines de semis.

(4) Cet article iaisse entendre aux partisans des differentes méthodes qu'ils devraient presenter leurs arguments d'une maniere positive, mettant en évidence ses qualités et avantages significatifs et non en insistant surtout sur les défauts des autres moyens d'approche ou en enveloppant leurs idées dans des formules compliquées qui sont impres-

sionnantes, mais ne s'appliquent pas vraiment au problème debattu. Les partisans de toutes les méthodes desirent la même chose: le maximum d'amélioration dans le minimum de temps.

Zusammenfassung

Titel der Arbeit: *Samenplantagen* für die Erzeugung genetisch verbesserten Saatguts.

(1) Samenplantagen sind notwendig, um genetisch verbessertes Saatgut in Mengen zu erhalten. Dieser Aufsatz soll den theoretischen Hintergrund des Wegs erklären, den man hinsichtlich der Samenplantagen im „N. C. State-Industry Cooperative Tree Improvement Program" (Gemeinsames Programm von Staat und Industrie in North Carolina) beschreitet.

(2) Das Gedankengebäude der Kombination zwischen der kurzfristig der Saatguterzeugung dienenden Samenplantage und der langfristigen, der Verfolgung der Weiterentwicklung dienenden „tree bank" wird ausführlich erörtert. Die Gründe für Irrtümer und Mißverständnisse wie auch die Diskussion von Stärken und Schwächen werden vorgebracht.

(3) Gründe für die Entscheidung zugunsten der Klonsamenplantagen im „N. C. State-Industry Cooperative Tree Improvement Program" werden in Kürze diskutiert unter Bezugnahme auf den anderen Weg, die Sämlings-Samenplantagen.

(4) Durch den ganzen Aufsatz zieht sich die Aufforderung an die Vertreter verschiedener Methoden, ihren Fall unter Hinweis auf Vorteile und Stärken positiv darzustellen, und nicht die Schwächen anderer Verfahrensweisen anzuprangern oder ihre Ideen in eindrucksvollen Formeln wiederzugeben, die mit dem diskutierten Problem wahrhaftig nichts zu tun haben. Die Befürworter aller Methoden wollen das Eine – ein Höchstmaß an Züchtungsfortschritt in einem Mindestmaß an Zeit.

Clonal or Seedling Seed Orchards?

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Introduction

The production of seed In sufficient volume for field planting is a logical extension of a successful applied tree breeding program. A planted area of genetically improved trees managed for seed production is one of the more intensive methods proposed for producing such seed; in other words, a forest tree seed orchard.

The purpose of a seed orchard is to supply seed of improved genetic quality for the generation of forest stands. The orchard stands as an entity and the genetic quality of the seed produced is determined by the parent trees used in its establishment. Roguing may change the average genetic quality of the seed produced, but the orchard has a ceiling determined by the best materiai used in its establishment. Although orchards may be used for a number of purposes, they should not be considered primarily as breeding areas or as steps "leading" to future gains.

Inasmuch as we are still in the early stages of applied forest tree breeding, the considerable interest in methods of seed orchard establishment and management is only natural. Various authors have dealt with the subject at length (Zobel et al. 1958; Zar 1956; Larsen 1956; Klaehn 1960; Driver and Cech 1960; Marquardt 1956).

Recently there have been discussions of a refined method of seed production based on a combination of breeding method, progeny testing, and seed production with stands started from seedlings (Schreiner 1962; Wright 1959 a, 1959 b, 1960; Goddard and Brown 1961).

We would like to discuss and compare some of the various features of orchards started with seedlings and with clonal material. To make the discussion more meaningful, we will restrict it largely to slash pine *(Pinus elliottii* Engelm.), an important species in the tree breeding programs of the southern and southeastern United States. We feel that only by considering specific species with thcir inherent traits and problems can we advancc a discussion beyond the theoretical considerations published heretofore.

When considering seed orchard methods it should be kept in mind that a seed orchard is very specific and real. An orchard consists of one species or variety; its genetic characteristics and the local environment are determining factors. Seed orchards cost money and local financial budgeting and work scheduling apply. They are generally production jobs, not research, and production methods apply. Also, all details have to be worked out for the specific orchard from start to finish; generalities can't be applied. One weakness in theory in the whole chain of events may result in failure of the whole project. These are very important factors but they haven't always been recognized by some writers when presenting the theory of seed orchards started with seedlings.

Selection of Parents

Regardless of which type of orchard is chosen. a selection program must be startod to locate the parents used in establishment. Selection criteria will be determined by individual needs and a certain minimum number of selections must be made, depending on the orchard requirements. In this phase, neither the seedling or clonal method has any advantage, but fewer selections may be safely used in a clonal orchard without creating undesirable effects.

Seed Orchard Establishment

As soon as selections are made. the clonal orchard can be started. Grafts can be made immediately if suitable rootstocks are available and at most, a delay of one year to grow rootstocks would be encountered for the southern pines. If a small orchard, say 10 acres, were being established, it is conceivable that the establishment phase of a clonal orchard would be completed in 2 years. In contrast, pollinations for a seedling orchard, as proposed by Goddard and Brown (1961), would require a delay in control pollination until all selections were made so that pollen could be bulked for the crosses.