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.

Figure 1. — Young slash pine in seed orchards 5 years after work began. — *Left,* pollinations to produce these seedlings were made in the spring of 1958. The seedlings were in nursery beds one year and were outplanted in the spring of 1961. Cone production will not begin for several years. — *Right,* field grafts made the same year as the pollinations have begun producing conelets. Grafted seed orchards of slash pine come into production while very young.

Pollinating selected parent trees, scattered over a wide geographic area, entails a number of problems. The first, of course, is the production of "flowers" on the selected parents. Selected trees growing under dense stand conditions may require several years to produce adequate "flowers" for pollinations. These "flowers" would be exposed to climatic conditions, animals, diseases, and insects, so a protection program would be needed to insure a harvest of adequate seed. Under the best of conditions, one could expect to spend two or more years and visit each selection several times to complete the control pollinations. Then, in the case of pines, a wait of 2 years to obtain the seed, followed by another year in the nursery before establishment in the field. At this point, seedling orchards are already a minimum of two to three years behind clonal orchards *(figure 1).* For some species, such as the oaks, adequate hand pollinations to produce seedlings for an orchard may be impractical because a large number of seedlings must be produced from each parent in order to allow a high selection differential in roguing.

The same high cultural levels and site preparation should be used for both types of orchards to insure rapid early growth and to shorten, if possible, the period of time until seed production. Transplanting grafts into a clonal orchard may be somewhat more expensive than planting seedlings but the cost of pollination, seed collection, and nursery production must be balanced against grafting costs.

Progeny Tests

Progeny tests in some form are needed at present for both types of orchards. For adequate evaluation, progeny should be grown under conditions as similar as possible to those of the land management program under which the seed will be used. This requires sampling sites and geographic locations throughout the area of application. Planting spacing and cultural measures should be in line with the management policies of the landowner.

Progeny tests for clonal orchards are separate and can be carried on independent of orchard management. At present, we feel that all clones should be progeny tested, but in the future, as additional heritability information becomes available and after we have had an opportunity to establish correlations between clonal performance and progeny performance, the progeny testing phase of clonal orchards may be reduced considerably. The testing problem is not so difficult with clonal orchards because progeny tests are designed to furnish reliable estimates of the clones' genotype up to harvest age.

In the case of seedling seed orchards, the orchard itself is a progeny test of the parents. From the beginning, these seedling orchards-progeny tests must compromise both phases. In order to have the best designs for random pollination in a seed orchard, we have to compromise progeny test design and forego estimates of yield that might be obtained from multiple tree plots. Site restrictions must be applied in order to have these seedling orchards on good sites for high seed production and conveniently located for management.

A feature of seedling seed orchards is the advantage of several opportunities for applying selection pressure within generations as well as recurrent selection in different generations. The effectiveness of selection within the combined progeny test and seed orchard depends both on the number of trees that can be culled and the accuracy with which the genotype of trees left to produce seed at a later date, when sexually mature, can be estimated in seedling or sapling age classes. While roguing may take place at various periods, it should be done with considerable accuracy if maximum gains are to be obtained. The process is not reversible and after trees are cut the seed orchard manager can only work with what is left. Although the juvenile-mature correlations may be reasonably high for some traits in a group of slash pine, they do not necessarily hold for individual trees. Error can occur in two ways: average or below average seedlings can improve their rating, and above average seedlings can fail to maintain their high standing. If juvenile-mature correlations are not high, or predictions cannot be made with accuracy for individual trees, roguing should be delayed, which loses time; or more trees should be left after roguing, which lowers the selection differential and reduces seed production per tree because the stand is more closely spaced; or more trees should be planted, which increases costs, if the progeny test-seed orchard covers a large area and requires higher than normal planting density. Considerable research effort is being expended on juvenile-mature relationships in slash pine, but we are far from establishing reliable data for all economically important traits. After each roguing, we have changed the environmental-competitive complex for the trees and thus further complicated future evaluation.

In orchards from seedlings the orchard itself is the only progeny test area. This denies the tree breeder an opportunity to test his strain on various sites, in other geographic areas, or where certain pests are prevalent. This is important in breeding slash pine because the species is widely planted geographically, where soils, climate, and pests vary. Sites suitable for optimum seed production may not be representative of lands to be reforested with the seed.

Inasmuch as seed orchards are a large investment, it is common practice to protect them from certain insect or disease pests that may influence growth; they may be heavily fertilized or the crowns "pruned" to increase growth and production of seed. These measures bias the results of the progeny testing feature of the slash pine seedling orchards. This is a very important point.

Starting Seed Production

Time is an expensive commodity in any production job and must be considered, along with genetic quality of seed produced in evaluating seed orchard methodology. In loblolly and slash pine grafted clonal orchards in the state of Georgia, we have obtained initial flowering at 3 to 5 years and expect appreciable cone production by 12 to 15 years. In trees from seedlings, we expect flowering during ages 10 to 15 years, but appreciable cone production is not expected before 15 to 20 years. Young slash pine grown at close spacing, as recommended for seedling orchards, may be even older before flowering in abundance. These estimates are based on a slash pine seedling seed orchard in Georgia planted with 1-year-old seedlings by the Ida Cason Callaway Foundation in 1955, and on control-pollinated slash pine progeny in Florida planted in 1945. Grafted slash pine seed orchards were started in Georgia after 1955 and rooted cuttings of slash pine in Florida were planted during 1944 and 1947. All plantings are within a region where slash pine blooms well.

Genetic Gain

Individual trees in seedling orchards are not progeny tested; thus, estimates of the genetic quality of their seed are difficult. The seed may be well above unimproved seed in quality, but it will be difficult to identify precisely. Proper estimates of genetic quality are required for seed certification and would be highly desirable in other cases if a high price is asked. In clonal orchards, on the other hand, this situation need not exist because each clone will be evaluated when combined with other clones by controlled pollination.

Reports in the literature for some species indicate severe depression in vigor from selfing, a criticism often leveled at clonal orchards. This inbreeding depression from selfing, if as serious as many believe, may only reduce the number of seedlings available and not lower the quality, because the self-seedlings would be stunted in the nursery and could be easily culled at that step (SQUILLACE and KRAUS 1962). In the case of seedling orchards, it is likely that we will have many related individuals in the orchard so that we will have a considerable portion of our seed coming from half-sib and full-sib crosses. The results of crosses such as these in terms of inbreeding depression have not been reported, but we may have only moderate depression in vigor which would not be detectable at early stages. The seed orchard trees with some degree of inbreeding may produce a considerable portion of seed that will give us a lower net growth in planted stands.

One of the arguments put forth favoring seedling orchards is the amount of gain that might be expected in future generations as the result of recurrent selection. Unfortunately, many of the theoretical approaches to seedling orchards have considered only one or two traits in estimating the amount of gain that might be expected. Let us assume, for example, that we wish to select for four traits; this is a very modest number for most tree improvement programs. If we assume that these four traits are independent and we wish to apply a selection differential of the top 10 percent for each trait, we can see that only one of each 10,000 trees would be expected to fall in the top 10 percent for all four traits. In a seedling seed orchard this would leave us, at most, about 1 tree for each 5 acres, a totally unreasonable approach to seed production. If we wish to retain 100 trees per acre for seed production, we must lower our selection differential in order to maintain seed production and in so doing, we lose a great deal of the expected theoretical gains. So we encounter a vast area of scientific darkness in seedling seed orchard methodology. Much needs to be done to determine how many plus trees should be available before work is started, what characteristics they should have, how they should be mated, how the initial planting is to be made, and how and when the orchard is rogued, to give the most gain over a long period of time.

In the case of clonal orchards, our second cycle would also be vegetatively propagated and the material for these orchards would be selected from among a great many trees in progeny tests, as well as any other suitable sources, such

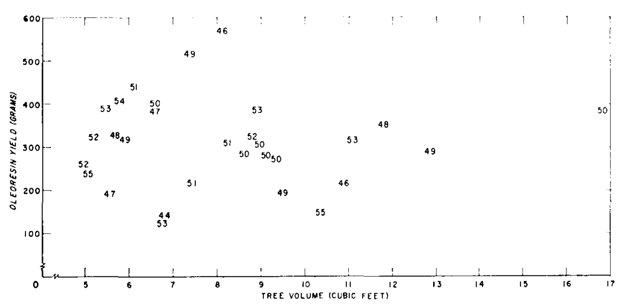

Figure 2. — Oleoresin yield, wood specific gravity (indicated by the number at plotting points), and stem volume in a 30-tree group, full sibs of slash pine parents (G4 × G1) that were twice average for oleoresin yield, and about average for volume growth and wood specific gravity. Mean oleoresin yield of the progeny is about twice average for the species, while volume growth and wood specific gravity are about average. The largest tree (16.8 cu. ft.) in the progeny group has 106 percent higher volume, 25 percent higher oleoresin yield and average (0.50) wood specific gravity. The tree with the highest gum yield (570 grams) is 84 percent above average for the group, has average volume (8.10 cu. ft.), and below average wood specific gravity. A tree with high wood specific gravity (0.55) has above average stem volume and below average oleoresin yield. Oleoresin yields are based on a test period of several months with micro-faces. The absence of a high correlation between three important traits is evident.

Table 1. — Range among individual trees for traits of oleoresin yield, wood specific gravity, and volume in slash pine control pollinated progeny.

Parent trees	Oleoresin yield				Wood specific gravity				Stem volume			
	Low	High	Difference: High as percent of — Low	Difference: High as percent of — Mean	Low	High	Difference: High as percent of — Low	Difference: High as percent of — Mean	Low	High	Difference: High as percent of — Low	Difference: High as percent of — Mean
	Gms.	*Gms.*	%	%	*No.*	*No.*	%	%	*Cu. ft.*	*Cu. ft.*	%	%
G 4 × G 1	124	570	460	183	0.445	0.557	+ 124	+ 111	4.96	16.83	+ 340	+ 206
G 1 × G 2	156	498	320	182	.439	.551	+ 125	+ 110	4.12	12.67	+ 310	+ 162
G 1 × G 7	41	386	940	192	.417	.541	+ 129	+ 112	4.62	12.66	+ 274	+ 145

Table 2a. — Variation of three traits in seven families in a slash pine seedling seed orchard — total trees.

Maternal parent	Total trees	Height: Average height	Height: Standard deviation	Height: Coefficient of variation	Diameter: Average d. b. h.	Diameter: Standard deviation	Diameter: Coefficient of variation	Crown width/tree height × 100: Average ratio	Crown width/tree height × 100: Standard deviation	Crown width/tree height × 100: Coefficient of variation
	No.	*Ft.*	*No.*	%	*Ins.*	*No.*	%	%	*No.*	%
C-10	58	24.22	4.15	17.1	4.86	1.04	21.4	29.0	5.03	17.3
C-37	115	23.67	3.32	14.0	4.89	.79	16.2	30.9	4.97	16.1
C-50	75	24.48	4.17	17.0	4.96	.99	20.0	32.1	4.81	15.0
C-63	27	23.24	2.72	11.7	4.77	.87	18.2	30.8	5.14	16.7
C-134	105	24.15	3.59	14.9	5.04	.93	18.5	30.7	5.21	17.0
C-56	23	23.72	3.04	12.8	5.00	.65	13.0	31.4	4.51	14.4
C-58	24	24.00	2.63	11.0	4.83	1.00	20.7	30 0	4.26	14.2
Population mean		24.00	3.62	15.1	4.93	.91	18.5	30.8	5.00	16.2

Table 2b. — Variation of three traits in seven families in a slash pine seedling seed orchard — selected trees only.

Maternal parent	Total trees	Height: Average height	Height: Difference between selected average and total average	Height: Selection differential in standard deviations	Diameter: Average d. b. h.	Diameter: Difference between selected average and total average	Diameter: Selection differential in standard deviations	Crown width/tree height × 100: Average crown-width ratio	Crown width/tree height × 100: Difference between selected average and total average	Crown width/tree height × 100: Selection differential in standard deviations
	No.	*Ft.*	*Ft.*	*No.*	*Ins.*	*Ins.*	*No.*	%	*No.*	*No.*
C-10	2	26.75	2 53	0.61	5.20	0 34	0.33	30.0	1.0	— 0.20
C-37	6	26.68	3.01	.91	5.65	.76	.96	31.7	.8	— .16
C-50	9	26.42	1.94	.47	5.28	.32	.32	32.2	.1	— .02
C-63	3	24.50	1.26	.46	4.93	.16	.18	33.3	2.5	— .49
C-134	6	25.77	1.62	.45	5.23	.19	.20	30.8	.1	— .02
C-56	0	—	—	—	—	—	—	—	—	—
C-58	0	—	—	—	—	—	—	—	—	—
Population mean		26.13	2.13	.59	5.31	.38	.42	31.7	.9	— .18

as other tree breeding projects. Because we are dealing with individual trees that will be vegetatively propagated, we can still maintain our very high selection differentials and achieve near maximum gains.

Contributing Data

Unfortunately, because few seedling orchards have been established, records of performance and expectation are limited and little information is available for various species on the correlation of characteristics for individual trees between juvenile and mature ages.

Figure 2 shows the range in oleoresin yield, wood specific gravity, and stem volume in control-pollinated slash pine progeny 15 years old. *Table 1* gives numerical data for individual trees in the same progeny group plus two other groups, and the range of variation in percent. The wide range in oleoresin yields among progeny groups and between trees within groups, the wide range in stem volume between trees within progeny groups, and the moderate range in wood specific gravity between trees is especially noteworthy in view of the high economic importance of these traits. There were 30 to 42 trees in the progeny groups. In addition to the three traits illustrated, slash pine varies widely in several traits in the general category of "form", in chemical composition of oleoresin, and in resistance to fusiform rust (*Cronartium fusiforme* Hedgc. et Hunt), an important disease.

These data ilustrate the problem of keeping the selection differential high for multiple traits.

One of the first slash pine seedling seed orchards established in the South was planted near Pine Mountain, Georgia, by the Ida Cason Callaway Foundation in March 1955. Open-pollinated progenies from seven slash pine trees — selected on the basis of 3-year performance trials — were used in the orchard. Each progeny was planted in rows randomly distributed over the orchard area. The seedlings were planted at a spacing of 12 × 12 feet, and after 7 years in the field individual trees were measured and scored on approximately 2 acres of the orchard area. The year before measurement, a number of trees had been eliminated from the orchard because of stem cankers of fusiform rust.

Of the original 641 trees planted, 427 were measured and scored and 26 found acceptable for seed production. The major reasons for eliminating trees were fusiform rust, which accounted for 220, and sweep or crook, which eliminated 86 additional trees. Other trees were eliminated because of poor growth, forking, excessive limbiness, etc. Any tree which was reasonably straight, free of fusiform rust, and above average for its individual row in height diameter and branching characteristics was kept.

Tables 2 a and 2 b give figures on total height, d. b. h., and crown width for the individual progenies. Probably the most interesting figures are the right hand column of each section in *2 b* which express the differences between the means of the "selected" trees and the means for all trees in each progeny in terms of standard deviations. In no case did the means of the "selected" trees exceed the means of the total progeny by one standard deviation. In the case of crown width, the means of the "selected" trees are actually below average for the progenies.

Figure 3 shows the distribution of the 26 "selected" trees for d. b. h. and total height. Trees to remain after the first thinning were selected on the basis of stem form, crown form, resistance to fusiform rust, stem diameter, and height. Two of the seven families were removed from the orchard. Grouping of trees by family is evident and increased selection pressure could remove certain families.

Figure 4 expresses the variation in d. b. h and total height for all the trees of a single progeny; in this case, C-37. The six "selected" trees are indicated on the figure and it is notable that whereas all of the trees exceeded the progeny mean for both height and diameter, only one of them lies near the extreme end of the distribution, in the top ten percent for both characteristics.

Although these data given in *figures 3 and 4* are based on open-pollinated progenies and the number of progenies is limited, they still point up some of the problems involved with seedling seed orchards. First of all, the 26 "selected" trees were insufficient for stocking the area. Second the number or percent of trees of each progeny was not uniform, with two progenies having been eliminated completely. Third, the selection differential for several of the traits was much below that needed to achieve the gains which are theoretically credited to the seedling seed orchard approach. Had we selected for wood quality characteristics also, such as specific gravity and tracheid length, we would have further reduced the selection differential for all of the traits to retain sufficient trees for seed production.

It should be recalled that the choice of these progenies was based on 3-year performance in the Callaway Foundation test area. Those progenies performed above average initially and have continued to do so. Thus, seed from the orchard should be above average in genetic quality.

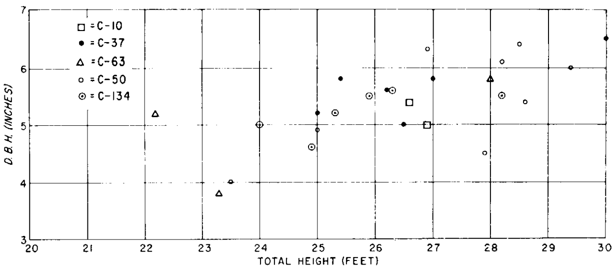

Figure 3. — Stem diameter and height of selected trees of five families in a slash pine seedling seed orchard.

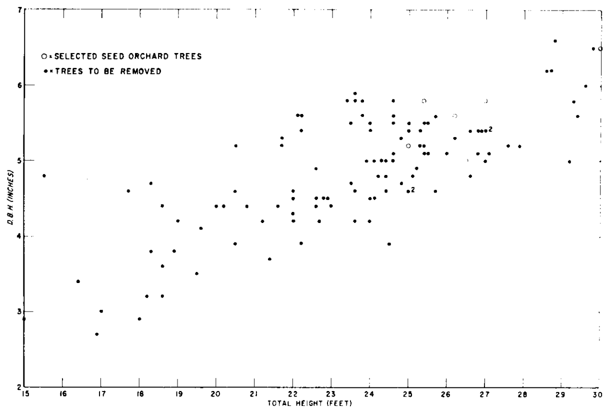

Figure 4. — Stem diameter and height of 115 wind-pollinated offspring in C-37, one of seven families in a seedling seed orchard. When rated for volume growth, stem form, crown form, and freedom from disease only one tree in the top ten percent for volume growth was retained. The other five trees selected for seed orchard use were only slightly above average in diameter and height growth.

Discussion

Applied tree breeding is a relatively new field of work, and seed orchard management is newer still. Considerable discussion of the theory and practical implementation is to be expected. If we are to move forward, the theories should be followed by research and the possibilities and limitations of various theories clearly defined.

There are several important considerations in the establishment of seed orchards. With the present limited supply of seed of improved genetic quality, the most important consideration is the time interval involved from the start of a seed orchard program until the orchard is producing appreciable quantities of seed. Costs of establishment and operation, of course, must be considered, but estimates of increased value of seed (Perry and Wang 1958) have shown that substantial amounts of money can be justified to achieve rather modest amounts of timber production increase. In planning, the relative degree of improvement expected from seed orchards must be balanced against the time to obtain production and the costs involved. Many of the aggressive tree improvement programs have recognized the importance of time and have established seed production areas in the best of natural stands to provide seed until orchard production can satisfy all needs.

A seed improvement or seed orchard program should be dynamic. While each orchard stands as an entity and as only one step toward maximum potential gains, long-term plans should include provision for continued parental selection and breeding and the establishment of additional seed orchards in later years as improved material becomes available. Elite trees may come from natural stands or plantations and from progeny tests and populations derived by planned breeding; each generation of seed-producing trees should contain the best material available from all possible sources. Long-term gains are dependent upon the degree of improvement obtained in each generation, the selection differential used, and the time interval between generations.

The importance of continued selection and breeding in subsequent generations will vary a great deal for the many individual traits to be considered. We can expect continued improvement in growth and yield over many generations of selection. Some traits, such as stem straightness or forking tendencies may reach a plateau after one or two cycles of selection and leave little possibility of gain in the long-term. The individual traits to be considered and the amounts of improvement that can be expected must be examined on the basis of individual species and even races, e. g. the possibilities of improving form and branching characteristics in loblolly pine (*Pinus taeda* L.) are certainly much greater than with a species such as red pine (*Pinus resinosa* AIT.). Each species and the requirements of the timber producer who will use the seed must be considered equally in planning individual seed orchards.

No one establishes seed orchards as a separate and isolated job — they are established under specific conditions for specific purposes. Inasmuch as these purposes vary according to the species concerned and the owners involved, it is to be expected that no one type or kind of orchard will meet all requirements. Because we have emphasized some of the problems involved in developing seedling orchards at this time does not mean we think orchards of other types are easy to establish, cheap to operate, or highly efficient in production of genetically improved seed. We do not think any one kind of orchard will meet all conceivable situations.

The tree breeder and the production forester are entitled to question the theorist and to suggest that he follow up his ideas with actual field tests to work out details. The theorist should not expect the production forester to rush enthusiastically to the woods or to his superiors with a request for large amounts of money with only an outline of the work involved, a vague notion of the time schedule needed, and an even more vague estimate of benefits. He needs detailed blueprints and accurate budgets.

The forester can expect differences of opinion in theory among geneticists and tree breeders until research data or experience accumulate to the point where facts outweigh guesses. Differences still exist about the relative merits of basic breeding methods, such as tree introduction, intraspecific selection, and species hybridization. Some geneticists unfamiliar with tree species of the southern pine region and applied forest tree breeding problems have questioned the effectiveness of selection as a method of breeding — a method upon which both seedling and clonal seed orchards are based. Somewhat similar differences of opinion occurred in the field of progeny test design

A comparison of seed orchard types under highly controlled conditions will be very difficult, expensive, and require a long time to complete. Certain features can be tested, however, and separate research studies may clarify problems. The best policy at present seems to be to identify the conditions, the objectives desired, and establish the type of orchard deemed most practicable.

A seedling seed orchard combines breeding method, progeny testing, and seed production into one project. At our present stage of ignorance, we feel we are far from competent in any one of the three jobs, to say nothing of trying to do a highly refined job of all three combined.

We feel some of the basic theory of seedling seed orchards is sound. We are using them ourselves but only under research or very special conditions. In our opinion, orchards of this type are still in the experimental stage and a great many procedures of establishment and management are still to be developed. In the meantime, we feel it is prudent to keep breeding methods, progeny testing, and seed orchards as separate jobs, doing the best possible with current information, and improving methodology on the basis of research and experience as the opportunities occur.

Which type of orchard is best? This will depend on your particular situation. We have recommended both types of orchards to our cooperators and they have been established. Only time and diligent research can tell us which will be best for any given situation. To supply the immediate needs for southern pine tree seed of improved genetic quality, we feel that the first step should be seed production areas from the best stands, followed by clonally established orchards to obtain seed from the best parents we can select in the shortest possible time.

Summary

Various aspects of seedling and clonal seed orchards are discussed in relation to breeding problems and genetic characteristics of *Pinus elliottii*, an important species in southeastern United States. It is pointed out that seedling orchards are slower than clonal orchards to reach seed production stage, may not provide adequate progeny testing, make cultural measures for seed production difficult to apply, make it very difficult to estimate the genetic quality of seed produced, and make it extremely hard to achieve very much gain through roguing in species that have wide inherent variation in several economically important traits. It is pointed out also that there are important problems still unsolved in determining juvenile-mature relationships in *P. elliottii* and in estimating the genotype of trees in the thinning operation characteristic of the seedling seed orchard concept. It is concluded that at present clonal seed orchards offer several advantages over seedling seed orchards but that no one type of orchard may be satisfactory for all conditions and all species.

Résumé

Titre de l'article: *Vergers à graines de clones ou de semis?*

Divers aspects des vergers à graines de semis ou de clones sont examinés en liaison avec les problèmes d'amélioration et les caractéristiques génétiques de *Pinus elliottii*, espèce importante au sud-est des Etats Unis. On fait remarquer que les vergers de semis présentent les inconvénients suivants: ils mettent plus de temps à atteindre le stade de production de graines que les vergers de clones; ils ne permettent pas toujours de tester convenablement les descendances; les techniques culturales pour augmenter la production des graines sont d'application difficile; l'estimation de la qualité génétique des graines produites est très difficile; l'obtention d'un gain important par élimination des géniteurs indésirables chez des espèces présentant de larges variations héréditaires de plusieurs caractères importants du point de vue économique est extrêmement difficile. On souligne aussi que d'importants problèmes n'ont pas encore été résolus dans la détermination des relations entre individus jeunes et arrivés à maturité chez *P. elliottii* et dans l'estimation du génotype des arbres dans l'éclaircie caractéristique de la conception du verger à graines de semis. On en conclut qu'à l'heure actuelle, les vergers à graines de clones présentent plusieurs avantages par rapport aux vergers à graines de semis, mais qu'aucun de ces deux types de vergers n'est satisfaisant pour toutes les conditions et toutes les espèces.

Zusammenfassung

Titel der Arbeit: *Klon- oder Sämlings-Samenplantage?*

Verschiedene Aspekte der Sämlings- und Klonsamenplantagen werden im Zusammenhang mit Züchtungsproblemen und genetischen Eigenschaften von *Pinus elliottii*, einer im Südosten der Vereinigten Staaten wichtigen Art, diskutiert. Es wird gezeigt, daß Sämlings-Samenplantagen das Stadium der Saatguterzeugung langsamer erreichen, daß sie keine angemessene Nachkommenschaftsprüfung

darstellen dürften, daß sie die Anwendung von Kulturmaßnahmen für die Saatgutproduktion erschweren, daß sie weiter die Einschätzung der genetischen Qualität des Saatgutes sehr erschweren und es schließlich zu einer sehr schwierigen Aufgabe machen, sehr viel Züchtungsfortschritt durch negative Auslese in Species zu erreichen, die große erbliche Variation in verschiedenen wirtschaftlich wichtigen Merkmalen zeigen. Auch wird darauf hingewiesen, daß bei der Bestimmung der Zusammenhänge zwischen Merkmalen junger und alter Bäume bei *Pinus elliottii* und bei der Einschätzung des Genotyps von Bäumen bei der für das Konzept der Sämlings-Samenplantage charakteristischen Durchforstung wichtige Probleme noch ungelöst sind. Es wird geschlossen, daß heute Klonsamenplantagen verschiedene Vorteile gegenüber Sämlings-Samenplantagen besitzen, daß aber kein Plantagentyp für alle Situationen und Species ganz befriedigen dürfte.

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Tree Distribution in a Seedling Seed Orchard Following Between and Within Family Selection

By R. E. GODDARD

The possibility of substantial economic gain through use of genetically improved forest planting stock has been shown by numerous studies throughout the world. In areas of intensive forest management and large scale artificial reforestation, there has developed among forest managers a sense of urgency in obtaining improved planting stock in the shortest period possible. Among the many methods of obtaining genetic improvement, perhaps the most widely adopted other than use of correct geographic sources, has been individual tree selection. It is obviously impossible to obtain sufficient seed from the few truly outstanding individual trees selected to regenerate the thousands of acres planted annually. Thus, the situation demands, simultaneously, mass seed production and substantial genetic improvement.

In the southern United States, the breeding technique most widely adopted has been vegetative reproduction of selected individuals and establishment of clonal seed orchards. It is stated, or at least implied, that each clone so established will be progeny tested so that clones not producing a desired level of improvement may be eliminated from the orchards. To date, approximately 2500 acres of such clonal orchards have been established in the southern states. Alternative methods have been suggested (for example, GODDARD and BROWN, 1961) whereby sexual progeny of the same selected trees would be used for mass production of improved seed. Variations of this method have received limited application. While there are several reasons for this, most important is probably the less vigorous development and promotion of seedling orchards by those in charge of the southern tree improvement programs. As progeny tests must be conducted in conjunction with established clonal orchards and there is strong probability that these orchards will not produce sufficient seed for all future needs, especially if direct seeding is expanded, seedling orchards developed from progeny tests offer a potential source of a vastly increased supply of improved seed. The purpose of this paper is to explore one possible procedure for the conversion of a progeny test into a seedling seed orchard. The discussion deals primarily with southern pines but should apply to other species which flower at a relatively early age.

Some Comparisons Between Clonal and Seedling Orchards

There can be little doubt that both clonal and seedling seed orchards can result in a substantial improvement of the genetic quality of planting stock. The theoretical gains to be obtained by several variations of both general types have been thoroughly discussed by WRIGHT (1959, 1960). As experimental evidence of actual gains achieved through application of any of the proposed methods is not available for many tree characteristics, there is little to be gained by a repetition of theoretical calculations. It is sufficient to say that selection of the best individuals within the best families should achieve genetic improvement in the following generation at least equal to and probably superior to the progeny of a clonal seed orchard. This is praticularly true with moderate heritabilities and a substantial portion of the genetic variance attributed to additive effects. If most genetic variance is due to epistasis, neither multiclone orchards nor first generation seedling orchards should be expected to be very effective.

The costs of establishing a clonal orchard by grafting, as is required with southern pines, were briefly discussed by GODDARD and BROWN (1961). Since that paper was prepared, the cost of grafting has no doubt been reduced because of increased efficiency and wider experience in this type of work. Also, seedlings produced as a result of controlled