SEED PRODUCTION AREAS AND SEED ORCHARDS IN CALIFORNIA

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I thank you for giving me the chance to talk briefly to you. I began to make notes about problems that you people were having and questions that I had of you. Soon I realized that many things were not being asked and many things were not being said. I wondered if an ad lib comment about the philosophy of seed production are and seed orchards as we have developed them in California might not be appropriate.[2]

I think a contrast exists between our philosophy in California and what I will call the "Swedish philosophy" that many people operate under. Let me define what I call the Swedish philosophy. Foresters spend a great deal of time making very intensive selections of a few trees without much idea about the selection differential, the importance of characters, or the heritability of characteristics. A great many man-years are spent in this process. Then comes the establishment of seed orchards of selections. Very much later progeny tests are established. When I first thought about this whole philosophy and about our problems in California, I was disturbed.

Now let me tell you our problem and what Region 5 of the U. S. Forest Service is doing with the technical guidance of geneticists at the Pacific Southwest Forest and Range Experiment Station. I don't want to get into any arguments, but I do want to expose you to my thinking. Some of what I have to say may apply to your problems.

Our problems are very much like yours; we need seed yesterday. The State of California has four million acres of brush fields that have to be put back into timber production. The Chief of the Forest Service has given us twenty years to put two million acres back into production; we have to plant a hundred thousand acres a year. Three years ago we celebrated planting the one hundred thousandth acre in California. You can see we have a tremendous job ahead. If somebody had only told us of this problem twenty years ago, we could have started then, but we have to start now to supply the seed. Our need for seed is immediate. Where can we get it? On trees that are producing seed. That's the only place you can get it in the next twenty years.

Our first step is a seed production area program. Region Five of the Forest Service has inaugurated this. Their plan calls for something like a thousand acres of seed production areas to supply the required seed. They have immediate plans for or have established several hundred acres of seed production areas. Seed from these areas will supply our short-range need. Seed production areas are being established in young-cone-bearing stands. They must be on level to gentle slopes operable with tracked vehicles. Stands are thinned by silviculturists' selections to leave forty to seventy trees per acre. Selection is variable, but it means, first, removing trees not spaced at the right intervals in order to maximize spacing, second, taking

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[2]This has been edited by Dr. Callaham; he has not changed the contents of his recorded "ad lib" remarks. Editor.

out the obviously defective trees, and, third, making sure that we leave only trees that have a history of bearing cones. These seed production areas are being established in stands of our native species as fast as possible. We know that before we have a thousand acres of seed production area we probably will have already switched to the seed orchard phase.

Our second step is to establish seed orchards to produce genetically improved seed for planting programs 15 or 20 years from now, But let me digress and explain to you some of the problems influencing our seed orchard program. You probably have similar problems here in the Northeast. We do not fully understand the geographical variation in the many species growing in our forests. We have very steep and high mountains. We have a very wet coast and a very dry interior. We don't know the influence of site variation from a dry ridge to a wet bottom at the same elevation. We think that all of these things had influences on the heredity of the trees that grow there, but we can't prove them all. We probably have the best information on inherent variation associated with elevation in the world. We know that elevation is very important, but we do not know enough about elevational variation in each species in each mountainous area, In short, we do not know the range of variability in our species, We do not know the heritability of important characters. We do not even know which characteristics are economically and technically important, but we have some ideas. We have the further complication of not having extensive, even-aged, pure stands on relatively uniform sites. We are plagued with mixed species, all ages, and highly diverse sites. For example, site index might change from 80 to 180, as you drive three hundred yards around a ridge from a south slope to a north slope.

With this perspective on our ignorance of patterns of inherent variation and of the heritability and importance of tree characters, let me outline our seed orchard program. Here are six essential features:

1. Select 200 to 400 plus trees throughout each seed zone;
2. Collect open-pollinated seed from each selection;
3. Select 100 or more families having fastest height growth in nursery progeny tests;
4. Outplant selected families in progeny tests on a number of sites throughout their seed zone;
5. Reserve the tallest 5 percent of seedlings in each outplanted family for planting at close spacing on a seed orchard site;
6. Rogue families from the orchard on the basis of family performance in field progeny tests after ten or 15 years.

Here is more detail on plus tree selection. The objective briefly is to provide 200 to 400 selections broadly representative of unknown inherent ecological adaptations in each zone. The number of selections is large to keep the genetic base broad. From these selections we will want to select for characters like stem form, wood quality, pest resistance, and adaptation to micro-sites within the broad seed zone. The intensity of the search to find 200 to 400 trees will be moderate. Something like finding the best one in 100 to the best one in 1,000 trees. The procedure is simple. Foresters drive the roads in the seed zone looking for even-aged, patches of trees about one-third to one-half rotation age, 30 to 50 years. When they spot a group of trees, they hop out and measure up 3 or 4 of the tallest trees and several adjacent codominants. If a dominant is about the same age as the codominants and does not have disagreeable branch angle, sinuosity or other visible defects, it is selected. In the beginning I understand that Region 5 crews averaged 2 to 4 selections per man day. They anticipate more selections per day with experience. This depends on knowledge of and easy access to the stands of the proper age class for selection.

The next step will be to collect seed from these selections. Open-pollinated seed should be available on a majority of selections in years of good cone crops. Let me emphasize that the number of selections is high because we know many will not bear cones Sexless trees can be discarded at little cost to the program. Bagging of cones may be needed to prevent loss of seeds as cones ripen. Subsequent progeny tests will require that seed be fully ripened on the tree before collection. Bagging also should reduce losses to insects and squirrels, Comparatively, few cones will be needed. We will need only enough seed to produce 500 seedlings for progeny tests.

Nursery progeny tests are the crux of this program. These one-parent progenies must be grown in carefully designed tests. Numerous replications must be made to permit assessment of environmental influences in the nursery. Seed size, germination time and other factors influencing height growth must be accounted for.

Families will be selected in the nursery for better height growth. We know for some species that selection for superior height growth in the second *year* in the nursery will give us genetic improvement. The level of selection intensity should be low, The family correlation between nursery height growth and later height growth is significant but not extremely high, We plan to rogue half of the two hundred to four hundred one-parent progenies. Half of the families will be selected on the basis of better height growth in the second year.

Most seedlings of selected families will be outplanted into progeny tests in their seed zone. Designed progeny tests must be conducted at several locations in each seed zone. Probably 5 to 8 locations will be chosen to represent the major soils, climatic patterns, and site variations in the zone. Genotype-environment interactions are expected. They probably will lead to particular selections for particular environments. The key feature is testing of progenies in the zone where seed would ultimately be used.

Representatives of each outplanted family will be planted on a seed orchard site. In our rugged mountains seed orchard sites are rare. Most of our progeny tests will be established on ground that is sloping or steep. We probably will be unable to combine progeny testing with seed orchard development, as some flatland geneticists have proposed. We are planning orchard development on agricultural type land close by our tree nurseries. Needed labor and equipment are available there.

The tallest five percent of the seedlings in each family will be reserved for these seed orchards. We have growing evidence that tallest seedlings in one-parent progenies will maintain their superiority in height growth in later years. Chances are we will achieve some additional genetic improvement by this selection. Ultimately trees in the seed orchard will be progeny tested when they begin to produce cones.

The present plan for orchard design is to use a systematic arrangement of progenies at close spacing. One seedling of each progeny would be planted in each block. Location could be chosen systematically or randomly. Chances of inbreeding would be small with 100 to 200 progenies in each block. Spacing would be 8 or 10 feet between seedlings. Field survival of bare-root seedlings is generally high, and failures would not be replanted.

Progenies, not individual trees, would be thinned from the orchard after 10 to 15 years. Field progeny tests should begin to show superiority and inferiority of one-parent progenies after 10 years. All seedlings of inferior progenies could be rogued from the orchard as a first thinning. Probably 30 to 40 percent of the

poorer progenies plus defective individuals of the reserved progenies would be removed in the first thinning. This probably would be done just before crowns start to close. Subsequent thinnings would rogue progenies judged to be inferior in the field tests at that time. Actually this thinning takes trees more or less randomly from the orchard. If spatial arrangement of trees after thinning would not be desirable, cuttings from progenies to be retained could be top-worked into trees of inferior parentage. Ultimately the best trees of the best 10 to 15 percent of the progenies should make up an orchard of trees at 25 or 30 foot spacing.

Following this procedure, we should have an orchard producing faster growing trees and having a genetic base as broad or as narrow as our field tests warrant. The procedure should provide flexibility in the thinning process. Fickle foresters undoubtedly will change their concepts of a good looking tree, and geneticists will have to shift to favor progenies having desired characters. I believe that geneticists in the future will welcome the flexibility this plan provides. They will have answers to the questions we can not resolve today.

Thank you for giving me this moment to give you a different philosophy on a tree improvement program which involves seed production areas for immediate need and seedling seed orchards for the period fifteen to thirty years ahead.

DISCUSSION

SCHREINER -Bob, could you define, a little more clearly, the difference between the California and the Swedish concept, and between the concept in our southern states. And how does your California philosophy differ from what we have been talking about as seedling seed orchards for a number of years?

CALLAHAM - This concept varies, Ernie, in this respect. The Swedes spend, I would estimate, thousands of man-hours to find one tree; this is one in a million selection, plus or minus several hundred thousand. What I'm talking about is selection of one in a hundred or one in a thousand, the best tree on an acre, let's say; the best tree that natures put on that acre at half of rotation age.

SCHREINER - You're still establishing seedlings not grafted stock.

CALLAHAM - But the points are that we will work with a broad genetic base, with progeny testing concurrent with seed orchard establishment, and with progressive roguing of the orchard on the basis of successive results of progeny tests. The last two points are those which most people haven't thought about. I think its a serious mistake to talk as some people were doing today about establishing orchards that will be progeny tests. From what I've seen, I don't think you can do it. Maybe your ground is such that you can put your orchard right out where the field test should be. Ours isn't. Neither will the spacings and treatments of orchards be suitable for progeny tests.

SCHREINER - Well, that's the difference; we can.

CALLAHAM - If you can, then you can put these in an orchard location. If you can afford to rogue them, make a progeny test, and develop an orchard simultaneously, then you can do as you say. But I wonder if you can. If you rogue seventy-five to eighty percent of your progenies and you only had twenty-five selections in the beginning, you're down to a genetic base of five, six, seven tree. I think your genetic base will be too slim.

SCHREINER - For black cherry we're starting out with larger numbers. We hope to get 320 candidate plus trees and select 90 of these for nursery selection. It still seems to me that you're talking about a seedling approach quite similar to what Wright and I have had in mind since before he moved on to Michigan. But of course on a much broader scale; on a California scale.

GENYS - I wish to refer to Dr. Callaham's outline of work in California because I feel his views are right and because some aspects of his report were similar to those I presented. Apparently, some colleagues were strongly interested in learning to what extent we can use and trust the results from the nursery tests. I would appreciate it if Dr. Callaham would extend some more views on this question.

CALLAHAM - We have fair juvenile-mature correlations for many characters; excellent juvenile-mature correlations for others, like blister rust resistance for example. I think that we will have many ways of short-circuiting the wait to evaluate characteristics. For example, take Zobel's studies of the wood characteristics of lower branches on seedlings to evaluate mature tree wood characteristics; and take the results you'll hear later in this longer meeting, that we are close to predicting the bark beetle resistance of a seedling from one drop of oleoresin without waiting until it was thirty, sixty, or eighty years old. As such information accumulates, we will be able to do more and more in the nursery. At the present time we can do many things. What you say has considerable merit.

HUBBES - I would like to ask Dr. Callaham, did I understand that you take your cones in certain areas from trees which you can reach very easily? Is there not already a danger for the selection in small trees?

CALLAHAM - The selections that we propose will be made in trees that are about one-third rotation age, let's say twenty-five to fifty years. They must be climbable and bearing cones. Selection will be made in even-aged stands. Our stands often occur in groves or groups of even-aged trees. For example, in a half acre stand, they might pick one tree; in a two-acre stand, they might pick the best two trees. We are selecting the best volume producers and trees without obvious sinuosity of the stems or multiple forking. The heritability of traits used in selection has been estimated for us by the geneticists in the Pacific Northwest. We merely use their criteria. Cones will be collected from these trees when they bear, and only as they bear can they be brought into the program. There'll be no big grafting program to bring them into orchards.

GABRIEL - I have a question for anyone who may have an answer. At what age would you think that it would be safe to say that a definite correlation has been established between juvenile and mature performances of trees. Perhaps I used the wrong term in "mature", but where in the life of the tree would the correlation with juvenility be significant and have meaning? How do you know when you've passed the effects of nursery which might have been carried into the outplanting phase? Snyder, Wakeley, and others have pointed out that this nursery effect can last for quite awhile. Is it safe to say that correlations between performances at 3 years of age and at 14 years are meaningful? Even though these correlations may be there, they may reflect nursery effects that are still hanging on. I would be a trifle reluctant to make selections among seedling progenies without data from more mature trees to back them up.

SCHREINER - Bill, I gave my opinion in a previous discussion. I would prefer half-rotation age as a time for my final judgment. Bob Callaham has just mentioned both half rotation and one-third rotation for selection of parent trees. I don't remember what age he mentioned for selection of seedling progenies.

CALLAHAM - Its impossible to respond to the question directly; rather I'll talk around it. But first of all, you have to realize that very strong correlations can be established between some traits at one year and at maturity. If this is the case, at any time after one year you can use this as a basis for selection. You cant categorically say "one year" or "eleven years" or "half rotation". This problem of nursery-genotype interaction is one that Snyder and Wakeley showed existed for a prolonged period of time for something like longleaf pine. For those species that get out of the nursery bed and get up in the air real quickly, for example ponderosa pine, we know that all the nursery effects are gone after about seven years in the field; this has been well demonstrated by Fowells and by me. For western white pine, Squillace and Bingham have shown that second-year height growth is not influenced by seed size. I think we merely have to learn more about how to use these juvenile trees in increasing the precision of juvenile-mature correlation estimates.

ZARGER - The T.V.A. began a super-seedling study in 1952 which involved the selection of outstanding seedlings from regular nursery production. This varies from the type of seedling selection Dr. Callaham reported on, in that ours was from quantity production, and he selected within one-parent progenies. We now have data on eastern white pine selections up to ten years of age. Correlating age classes with annual height measurements we found real differences in height between super-seedlings and their controls. Over eighty percent of the super-seedlings are outgrowing the average control, while less than 0.8 percent of the controls are outgrowing the average super-seedling. Loblolly and shortleaf are under study too, but I believe the white pine, selected as 2-0 stock, shows the best response to this type of selection, When you look at the trees in the outplanting, its difficult to visualize how seed size plays a part. There is no evidence to indicate that seed size still effects the growth rate or had an influence on the early rapid growth associated with juvenile vigor. I think there are numerous studies that show seed size no longer plays a part after seven or eight years.

HUNT - Dr. Callahan, would you comment on the technique or the mechanism for applying your progeny test data to the orchard area on an individual basis. Are you still going to rogue your orchard area and retain individuals of a particular progeny on their own merits?

CALLAHAM - Let me answer the second question first and then make a comment on the point made about the super-seedlings a moment ago. As we envision it, the roguing in the orchard would be done strictly on the basis of performance in the field trials. Roguing would be done on a progeny basis and not on an individual tree basis. An exception would be the obviously deformed tree. It would be rogued too. Now, back to the point that I wanted to make about super-seedlings. What was said is true. I am talking about seedling selection from one-parent progenies not super-seedling selection. The contrast has been made in my paper published in the Proceedings of the Forest Genetics Workshop at Macon in 1962.

HUNT - Then you're going back to your progeny tests for the next generation, either by controlled or open-pollinated progeny, to select your next parent generation.

CALLAHAM - These would be second generation selections and orchards.

ROLLINS - Dr. Callahan, what is your basis for making two-year selections? Why wouldn't it be 3-0 stock? Is it the growth plan in your nursery to produce 2-0 stock, and if this is the case would 3-0 be as adequate?

CALLAHAM - We know that height growth in the first year is very severely influenced by seed size, germination time and geographic source. If you can account for these influences, you could use first year growth. In the second year many of

these early environmental invluences are minimized. If we take just second-year height growth, we know we have a better estimate of the genetic height growth potential. Really, we would like to outplant 1-0 seedlings because they survive best. but with proper care the bigger 2-0 seedlings can be transplanted into the orchard and into the progeny test sites.

ROLLINS - Would a selection of 3-0 stock be as satisfactory?

CALLAHAM - I suppose it would. Our results on height of one parent progenies of ponderosa pine at one, two, five, twelve and twenty years shows that the correlation with twenty years goes up for each succeeding measurement. I think the coefficient of determination between twelve-year and twenty-year heights was about eighty percent. The longer you can wait, the better.

SCHREINER - Bob, do you think selection for height growth of one-year seedlings would be fairly safe if seed-weight classes were taken into consideration; if selection of one-year seedling progenies were made on the basis of their seed weights. For our black cherry seedling seed orchards we want to select one-year seedlings for the outplanting; two-year seedlings get too big. We plan to determine seed-weight and to evaluate the progenies on the basis of seed-weight classes, It is my recollection that the work that's been done on nursery height differences does indicate that seed weight is a critical factor.

CALLAHAM This is true and it's a good approach. You can either do it by sowing by seed weight classes or by using a regression technique. In the latter you take deviations from the regression of height growth on seed weight. Progenies then are selected if they deviate by say, two standard deviations from their predicted value.

GENYS - In addition to the statistical methods mentioned by Dr. Callaham, the influence of seed-weight on the performance of juvenile seedlings can be calculated by the analysis of covariance.

ALLISON - I'd like to ask Dr. Callaham one question since he mentions zone-wide testing. How has he counteracted this difference in growing-site indexes based on exposure and slope. In West Virginia we have somewhat the same, plus benches that may be in the middle of the slope. We are also thinking of zone-wide seed collection zones, and I am wondering how you might handle this type of problem in your state.

CALLAHAM - This is a tough one. Let me say that I'm not happy with the seed collection zones as established in California, but I have neither the knowledge nor the ability to improve upon them. We're going to have to start with what well call approximations of appropriate zones I'm sure that geneticists fifty years from now will scoff at you and me and everyone else for what we do today. The handwriting is on the wall that at least in our West, elevation is going to be very important. For example, on the west side of the Sierra Nevada mountains, our silviculturists have set up a low two-thousand-foot elevational zone and a high two-thousand-foot elevational zone. We may have to put in a third elevational zone. Yet, we know that there are significant differences even by five-hundred-foot zones. These five-hundred-foot zones may be economically important fifty to a hundred years from now. We don't know enough yet to say whether they are. Second, as to site, we have tremendous site variations. Let me give you an example. In a very closely controlled experiment site varied from Class I on the top of a hill where the soils were deep to a low Class II about four hundred feet to the south on the shallow soils on the side hill.

There must be inherent adaptation to those kinds of changes be probably should be selecting from trees on the hill top and from trees four hundred feet away as separate populations for tree improvement. But the magnitude of the tree improvement effort soon becomes infinitesimally large. If you have to figure on genetic improve-ment for every site, within every elevational zone, within each climatic zone, for each species, for each soil type, for each character--Wow!!

GERHOLD - A lot of the discussion so far has been concerned with improvement within a species. I wonder if we could have a few comments on hybridization? I recall that Dr. Stairs mentioned a seed orchard for producing hybrid larch. Could you enlarge on some of the details?

STAIRS - The larch hybrid orchards we have field planted at this time are "single clone orchards". That is, a single clone of each parent species is used with the expectation that selfed seedlings will be recognized and discarded in the seed beds. We have also completed the grafting for a white pine (P. strobus x P. monticola) hybrid orchard containing ten clones of each parent species. I anticipate using controlled pollination in this orchard as it begins to flower.

HUNT - To answer your question about the basic arrangement of the hybrid larch, as Dr. Stairs explained, there are just two clones present, one of each species, planted in a checkerboard design. The seed produced is either hybrid or selfed. The inbred material should become apparent in the seedbed as small, runty seedlings with depressed vigor.

GERHOLD - Do you know anything about their selfing or crossability?

HUNT - No, the selfing and the crossability are still to be determined. The only characteristic determined was the ability of both of these clones during one year to flower simultaneously. They were planted out in a somewhat different climate, so the bud-break and blooming in Saratoga has not always coincided as it did back in Syracuse.

CALLAHAM - I'd like to comment on hybrid seed orchards that I heard about in Germany, and then our own in California. Langner, at Schmalenbeck, described to me their procedure for producing Picea omorika x jezoensis crosses. He plants a single clone of omorika known to produce hybrids in a small plot in the midst of a planta- tion of the other species. Then all seeds set on the clone would either be hybrids or selfs. These are readily distinguished in the nursery. You just rogue all the runts to remove the selfs, This sounded like a very simple and very efficient procedure to me.

In California, Region Five of the Forest Service is producing hybrids en masse. In their Badger Hill breeding orchard they have twenty-seven different geographic sources of knobcone pine planted. On these each year they produce knobcone-Monterey hybrids by controlled pollination. The results are pleasant in one respect; these trees have flowered abundantly in their fifth and sixth years. Region 5 uses about two thousand pollination bags each year. So far the seed sets are very low. This puzzles us. It looks as if young trees in seed orchards may not produce the quality of seed produced by large trees. Dr. Krugman is following this now to see how long it is going to take before we begin to get abundant seed from controlled pollinations on young trees.

HUNT - Langner was quite fortunate to have worked with individuals that were compatible and produced progeny of such marked heterosis as shown by his P. sitchensis x P. jezoensis cross. Even after a large number of screenings, there is a degree of seren-dipity in choosing two exotic individuals for parents from all the possibilities which will result in hybrid growth such as Langner demonstrated. I would anticipate a long series of trials to locate and match the best pair for each interspecific crossing.