POLLEN MANAGEMENT IN SOUTHERN SEED ORCHARDS

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Many of our southern seed orchards have been plagued in recent years by poor cone crops and disappointingly low yields of viable seeds. Greatly increased emphasis on pollen management in the orchards may offer solutions to seed yield and quality problems, and also provide increased genetic gains through increased selection differentials on the paternal side of the pedigree. The degree of sophistication in pollen management can vary from complete control with artificial pollination, to nothing more than an unimproved isolation zone around the orchard. While the latter may be sufficient in some orchards, additional efforts should prove to be economically sound in many cases. Therefore, a review of problems such as pollen contamination, non-synchronous flowering, and natural selfing, and a realistic appraisal of benefits to be gained from improved pollen management is needed.

DEFINING THE PROBLEMS

One of the first problems that deserves consideration is that we have very sketchy data as a basis for comparison of yields among orchards. A standardized monitoring system could supply the necessary yield information to indicate which orchards are consistently having problems. Low yields in terms of bushels of cones per acre of orchard, percentage of filled seed, and percentage of germinable filled seed have all been observed. The nature of the problem for a specific orchard can often be recognized by identifying the point where yields fall off most drastically.

For example, it has been shown for most pine species that selfing will not reduce cone yields but will drastically reduce percentage of filled seed, and substantially reduce germination percentage (Franklin, 1970). The low yields of seedlings per acre of orchard, characteristic of many orchards in recent years, has been the result of not one but many causal factors. Age and geographic origin of ortets or seedlings, lack of insect control, lack of fertilization, lack of irrigation or improper irrigation, poor cone collection and seed extraction practices, and lastly, the subject of this discussion, lack of pollen management.

The idea of pollen management in our orchards is not new. Virtually all orchards have pollen dilution (isolation) zones, and most orchards are designed to have maximum distance between ramets of the **same** clone, or between siblings. These practices are necessary and helpful but they are in many cases not sufficient to prevent contamination by foreign pollen or high-levels of self-pollination. The reasons are these. Whereas only 5 percent of the pollen from a point source will travel as far as 400 feet, many point

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sources, each contributing a small percentage of its pollen to the total pollen load, will yield a high background count of pollen almost anywhere in the vicinity of the species range. This is why "dilution zone" is a more appropriate term than "isolation zone". If the orchard produced no pollen at all, the background load would give adequate pollination in most cases for normal seed yields (Squillace 1967). Genetic gain for such a seed crop would be about half of that obtained if orchard pollen were totally effective. Non-synchronous flowering of different clones in the orchard would have a similar effect, but to a lesser extent. With non-synchronous flowering, the background contribution to the average pollen load in the orchard at any particular time would be proportionally more than if flowering were perfectly synchronous.

Maximum distance between ramets of the same clone or among siblings will minimize inbreeding between orchard trees, but will have no effect on frequency of selfing within the crown of each tree. The important factor within the crown seems to be the proximity of conelets and catkins. Thus in a young tree, where conelets are borne near the top and catkins near the bottom of the crown, selfing will be minimal. The typical result of crown development in orchard trees is that the mid-crown becomes an area of intimate association of conelets and catkins. The typical result is a tremendous increase in self-pollination in the lower and mid-crown areas, and a corresponding drop in percentage of filled seed as indicated by results from a single, large-crowned slash pine in Alachua County, Florida (figure 1). Corresponding increases in

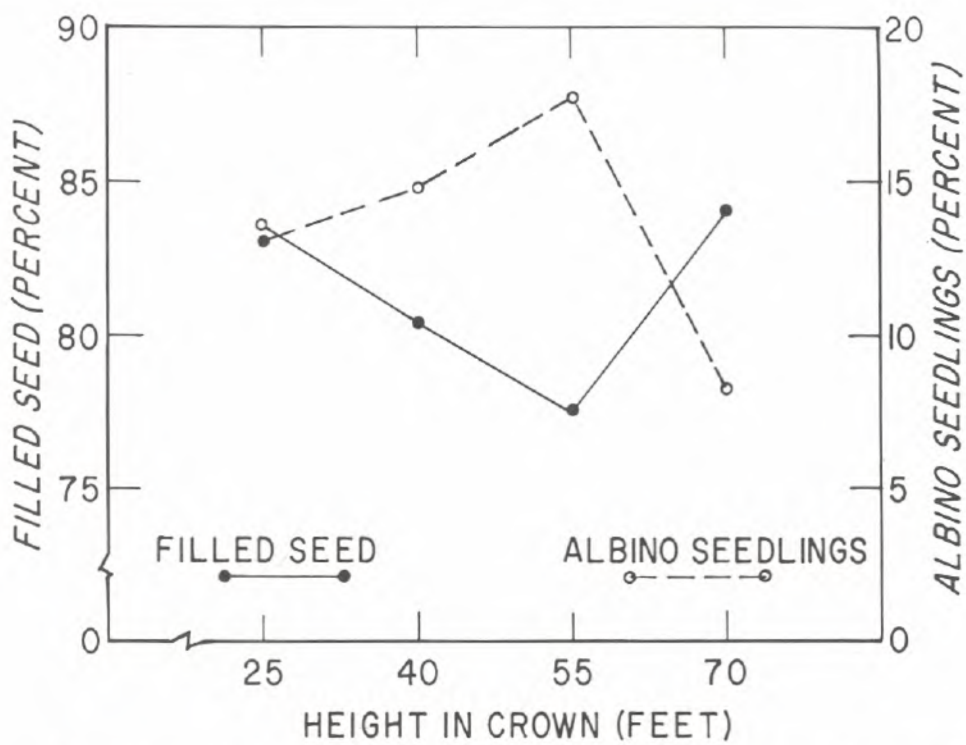

Figure 1.--Percentages of filled seed and albino seedlings by seedlots from various heights in the crown of a slash pine tree in Alachua County, Florida.

frequency of albino seedlings confirm that this is indeed the result of natural selfing. Similar results for frequency of natural self-fertilization within the crown have been found for loblolly pine (Franklin, in press). This illustration may explain in part the observation that seed yields in many orchards start out at satisfactory levels for the age of the orchard but then show a relative decrease with increasing age of the orchard.

A demonstration of the amount of self-fertilization in seed orchards is provided by an experiment recently conducted by our laboratory with the assistance of Dr. John Kraus 2/. Three ramets of each of 5 clones in the Arrowhead Seed Orchard 3/ were control-pollinated using self-pollen and a 20-tree-mix from the vicinity of Olustee, Florida. Orchard open-pollinated cones were also collected. In each clone, the percentage of filled seed was less for orchard open-pollination than for controlled crossing (figure 2). Percentages of self-fertilization were estimated by the following relationship:

$\frac{c-w}{c-s} \times 100$, where c, w, and s are proportions of filled seed after controlled cross-, orchard open-, and controlled self-pollination. Estimated percentages

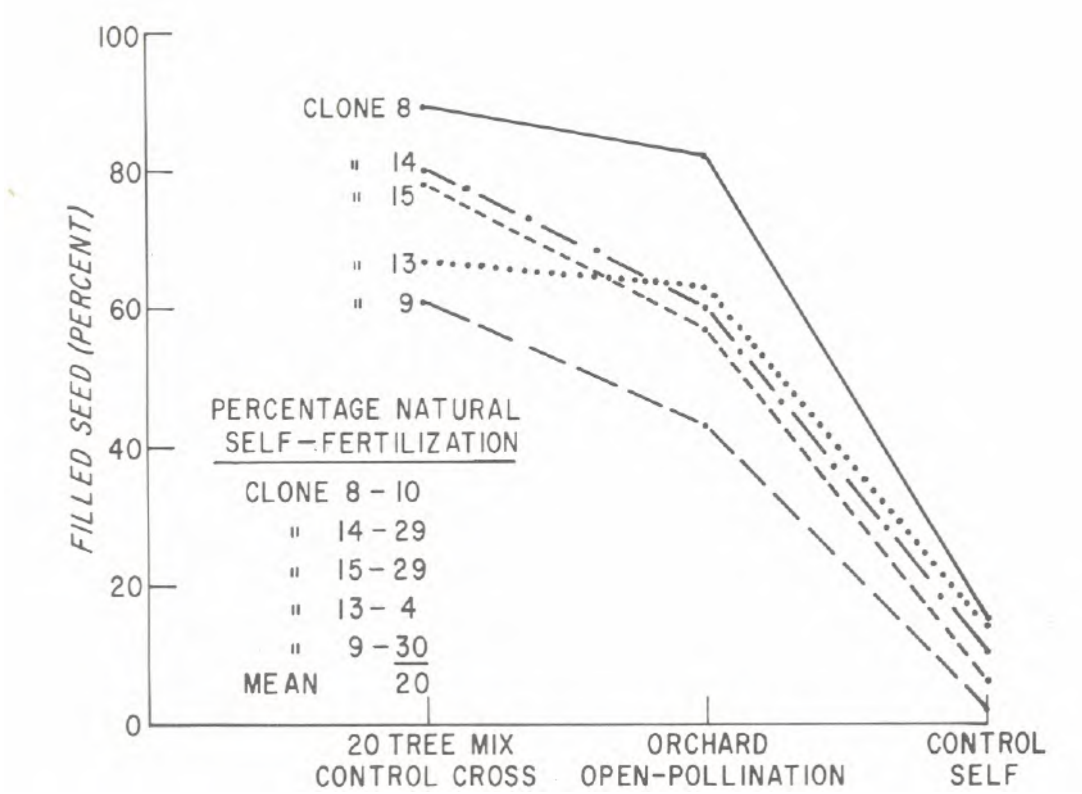

Figure 2. --.P of filled seed obtained from controlled selfing and crossing and orchard open-pollination from 5 clones in the Arrowhead Seed Orchard, Wheeler County, Georgia.

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of natural self-fertilization ranged from 4 to 30 percent and averaged 20 percent.

To summarize the problems, inadequate amounts of orchard pollen will reduce the genetic quality of the seed crop, and an abundance of orchard pollen will result in much self-fertilization within ramets with well developed crowns. Thus the problems involve both amount and distribution of orchard pollen in time and over areas.

SEEKING SOLUTIONS

Supplemental pollination of southern seed orchards may prove to be a profitable step toward more seed of better quality and greater genetic improvement in commercial stands. In the tree improvement program in the Republic of South Africa, hand pollination of unisolated conelets has been done for several years (Sijde, van der 1970). It has been conclusively demonstrated that hand pollination more than doubled the yield of filled seeds compared to orchard open-pollination, even with abundant pollen production in the orchard (Denison, 1971). The impact of this can be seen in yields of seed from loblolly and slash orchards in South Africa 4/.

In the 1970 seed year, unbent, hand-pollinated Pinus elliottii clones were 10-years-old and yielded about 40 pounds of seed per acre. Similarly, on the basis of conelets counts, unbent, hand-pollinated P. taeda clones in the tenth seed year are expected to yield about 150 pounds of seed per acre. Spacing for both species is 27' x 27', and germination averages 80 percent of 80 seeds per cone.

Of course, hand-pollination would not be feasible for southern seed orchards because of high labor costs. But pollen delivery systems involving agricultural dusting equipment, mist blowers, etc., could be perfected. Other technological problems involving collection, extraction and storage must be considered. Pollen produced in the seed orchard could be used advantageously for several reasons: (1) it would be easy to collect, (2) its removal would reduce natural self-pollination, (3) it is of improved genetic quality.

With a supplemental pollination system, pollen becomes an expensive and scarce commodity. Therefore, quality, principally percentage germination, becomes very important with respect to efficient use of pollen. If pollen has higher viability then necessary for effective seed set, it should be diluted with pollen of insufficient germinability, or with suitable foreign substances.

4/ Special thanks are expressed to Mr. N. P. Denison, South African Forest Investments Limited, and to Mr. S. F. Hagedorn, D. R. de Wet Forest Research Station, both of Sabie, Transvaal, Republic of South Africa, for graciously supplying the latest information on their seed orchard yields.

Application of the pollen in the orchard must be timely; i.e. supplemental pollen, if it is to be maximally effective, must reach the conelet in advance of ambient pollen. This was illustrated in a recent experiment involving a slash pine tree which is heterozygous for albinism, and gives very high yields of filled seed after selfing. Fifty isolation bags were selfed and fifty others were crossed. At the same time, 10 of the previously selfed bags received cross pollen and 10 of the previously crossed bags received self pollen. One day later, 10 more selfed bags received cross pollen and 10 more crossed bags received self pollen. A similar pattern was followed after 2, 3, and 5 days. Results averaged for all time intervals showed that 73 percent of the fertilizations were effected by the pollen first introduced into the bag. This illustrates the hypothesized "first come, first served" principle with respect to pollination and fertilization. It also indicates that non-isolated flowers could be effectively pollinated if the supplemental pollen were supplied in advance of ambient pollen. The effect of time interval between the first and second pollen received was not conclusively apparent; therefore, the experiment is being repeated.

A second question which must be answered experimentally is "what is the earliest stage of development at which a conelet can be effectively pollinated?". This cannot be determined with the use of isolation bags and will therefore require the use of genetic markers. We hope to be able to attempt to answer this question in the near future.

BENEFITS TO BE DERIVED

Benefits to be derived by supplemental pollination have already been enumerated (Sijde, van der 1970). As indicatd above, supplemental pollination assures adequate cross-pollination with pollen of improved genetic quality. Therefore, seed yields and seed quality are enhanced as evidenced by the results in the Republic of South Africa. Furthermore, increased selection pressure could be applied by using only the best parents as pollen sources. This principle is very effectively applied in many agronomic breeding programs, and can be applied in forest tree breeding as well. Another advantage related to the last mentioned one, is that genetically tailored seed crops could be produced. This would mean that male parents with high combining ability for fusiform rust resistance, high specific gravity, high salt tolerance, etc. could be used exclusively on the entire orchard or on specified clones. Genetic gains resulting from this procedure could be appreciable in many cases.

It is clear that more research is needed before supplemental pollination could become a routine operational reality. Nevertheless, some orchardists have already made trial applications. I will predict that in the near future many more orchardists will be seriously considering this technique.

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