SEED ORCHARD MANAGEMENT: SOMETHING OLD AND SOMETHING NEW

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Abstract.--Today, seed orchard management in the southeastern United States stands at a crossroad. Thirty-four years of research and experience have brought regional seed orchard production to the point that large surpluses of genetically improved seeds are available for sale. Despite this progress, unanswered questions remain regarding management techniques for advanced generation seed orchards. Older orchards producing surplus seed present one set of problems. Young second generation seed orchards and the third generation seed orchards planned for the turn of the century will require cost-effective management to promote rapid orchard development and early seed production which is a different set of challenges.

Continuing research on irrigation, subsoiling, fertilization, supplemental mass pollination and roguing practices is needed to provide improved understanding of these management practices. Additional research is required if we are to understand the role of seed orchard ground covers, provide better fertilization prescriptions, improve pollen handling procedures, understand the influence of selected rootstock, and understand intensive levels of orchard roguing.

INTRODUCTION

To sustain and increase forest productivity in the southeastern United States, great emphasis was placed on the genetic improvement of forest trees approximately thirty years ago. Seed production areas and seed orchards were hurriedly established to supply genetically improved seed for the vast regeneration needs. Approaches to orchard design and techniques for establishing and managing the seed producing units were widely debated and were almost as diverse as the various organizations initiating the work.

Research and experience over the past thirty years has brought seed orchard production in the southeastern United States to the point of wide scale surplus production of first generation seed. Yet, despite the seed surpluses of slash, loblolly, and Virginia pine (*Pinus elliotti*, *P. taeda*, and

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Paper No. 11094 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, North Carolina 27695. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named, nor criticism of similar ones not mentioned.

P. *virginiana),* there is, more than ever, an acute need for seed orchard management research. Three factors drive this continuing need for seed orchard management research: (1) Seed production from second generation seed orchards is not sufficient to meet regeneration requirements; (2) third generation seed orchards will be a reality by the mid-1990's; and, (3) the forest industry is under the grip of management driven by the need for short term economic gain. All of these factors contribute to the pressure to produce more seed sooner and more economically.

Today, seed orchard management is at a crossroad between generations. Very mature orchards and very young orchards exist side by side requiring different approaches. Mature orchards require inputs to maintain seed quality and strategies designed to deal with surplus seed. New orchards require focusing on factors to promote growth and initiate seed production.

It is the purpose of this paper to take a brief look at some areas of seed orchard management that are being researched, provide some new, as yet unpublished, research results and to pose questions for future research. However, it is impossible to address all aspects of seed orchard operations. As an example, seed orchard insect control practices and strategies continue to require a great deal of research. The whole area of rootstocks and rootstock/scion interactions and how they affect graft vigor and fecundity offers an exciting area of research. However, these topics and others were deliberately omitted from this discussion because either research results are not currently available or the author believes the topics could be better addressed in separate papers.

SEED ORCHARD MANAGEMENT TECHNIQUES

Seed Orchard Site Selection

Economists have determined that forest tree seed orchards are sound investments only when they are fully productive (Talbert et al. 1985). Perhaps the single most important factor in promoting a fully productive seed orchard is seed orchard site selection. Orchard productivity is dependent upon climatic, edaphic, management and genetic factors. Three of these factors are site related and underscore the need to carefully choose seed orchard sites.

While it is not necessary to locate an orchard in the native provenance of the seed source, an excellent rule of thumb is under no circumstances should an orchard be placed in a more harsh environment than that from which the octets were selected. Moving loblolly pine seed orchards south has been conducive to seed production (Schmidtling 1978, 1983; Richmond and McKinley 1986). Within the North Carolina State University-Industry Cooperative, a trend is to move northern orchard operations to south-central Georgia. Experience has shown that orchards in this region produce more seed per year and reach commercial production sooner than in northern locations.

Despite the positive influence on seed production, important questions are being raised about how this type of movement might influence cold hardiness of orchard progenies through possible local nonorchard pollen contamination. Other questions concern parental environment after-effects on progenies that extend beyond the immediate questions of seed size and vigor.

Irrigation

Irrigation of seed orchards has received much interest over the years from both researchers and orchard managers. Neither published reports nor experience provide a clear understanding of the impact of irrigation on cone production. Some proponents of orchard irrigation believe that irrigation of young seed orchards is worthwhile because of enhanced tree growth. The larger trees should ultimately result in larger cone crops via enhanced crown size. An irrigation-nitrogen fertilization study in a young second generation loblolly pine orchard documented the impact of irrigation on tree crown size. Crown volume of irrigated trees was found to be 32 percent greater than nonirrigated trees (Jett 1983). Importantly, irrigated trees averaged two more potential flowering sites per primary branch than did nonirrigated trees. Although full growing season irrigation was stopped in this orchard at the end of the 1983 growing season, measurements taken following the 1986 growing season (age seven) revealed that the early size superiority of d.b.h. and crown volume for the irrigated trees was being maintained (table 1). While the differences are not statistically significant, irrigated trees averaged 19 more cones per tree than nonirrigated trees during the 1986 cone harvest (table 1).

A continuing irrigation timing study installed in 1978-79 in a four year-old 1.5 generation loblolly pine seed orchard located in the northern piedmont of South Carolina is yielding erratic information. After one year of treatment, trees irrigated mid-June through July produced a significantly greater flower crop than did other treatments (Harcharik 1983). Subsequent analyses indicate that both male and female strobilus production is erratic by treatment and year (table 2). Subsequent analyses of cones/tree harvested in 1985 and 1986 failed to reveal any significant treatment differences.

Irrigation studies need to be long term in order to truly gauge treatment effects over highly variable year effects. A real need is to learn how to account for natural precipitation effects which can obscure irrigation effects. Understanding how irrigation can influence seed production depends on a better understanding of how irrigation effects basic tree physiology and nutrition. Other, more applied questions, need to focus on the potential cone and seed quality effects.

Subsoiling

Although subsoiling has been used by American agriculture for over 50 years to alleviate soil compaction (Cassel 1979), it was first used in a loblolly pine seed orchard in 1964 to alleviate what was considered to be adverse soil compaction (Gregory 1975). The positive response of this early subsoiling effort resulted in increasingly wide use of this cultural practice.

At present, we do not clearly understand the reasons behind the positive response to subsoiling. Flowering responses might be due to stresses induced by root pruning as suggested by Gregory and Davey (1977), or subsoiling could result in improved tree vigor and higher seed production through amelioration of soil conditions. Root pruning may represent an immediate short-term response to subsoiling which soon disappears as the roots quickly recover and expand beyond the subsoil trench. Experience has shown that the roots branch prolifically at the point where they were severed by the subsoiler. On the

Table 1.--Main treatment effect means for total height, d.b.h. and crown volume 1/ following the 1986 growing season and for cones per tree from the 1986 harvest for an irrigation-fertilization study in a seven-year-old second generation loblolly seed orchard

Variable	Irrigation	No Irrigation	
Total Height (m)	8.5	8.3	NS 2/
D.b.h. (cm)	21.9	19.5	LSD.05 = .96
Crown Volume (m^3)	75.6	55.2	LSD.05 = 9.7
Cones/Tree	159	140	NS

1/ Crown volume calculated on the basis of a cone using mean crown diameter and live crown length
2/ NS = statistically nonsignificant at P < .05

Table 2.--Male and female strobili production in loblolly pine as affected by irrigation timing, 1982-1984

	Male Strobili				Female Strobili			
Treatment 1/	1982	1983	1984	Mean	1982	1983	1984	Mean
	------ Clusters/tree 2/ -------				------Strobili/tree 2/ ----------			
DD	2.7 a	8.7 a	24.7 b	12.0	17.7 a	40.3 a	50.7 a	36.2
DW	1.7 a	10.4 a	44.2 ab	18.7	12.5 a	40.1 a	41.6 a	31.4
WD	1.8 a	10.9 a	41.8 ab	18.2	12.3 a	50.5 a	42.0 a	35.1
WW	3.7 a	16.8 a	84.4 a	34.9	12.7 a	46.1 a	37.9 a	32.2

1/ DD= no irrigation
WW = irrigation throughout the growing season
DW = no irrigation 16 June – 31 July (with irrigation rest of the season), and
WD = no irrigation 1 August – 15 September
2/Means with a common letter are not significantly different at the .05 level

other hand, alterations to the soil structure represent a long term influence benefiting the tree through improved health and vigor. Both long- and short-term benefits to subsoiling were noted by Schmidtling (1986) in Virginia pine.

Accumulating evidence from a North Carolina State University Cooperative study to evaluate the frequency and intensity of subsoiling lends support to the idea that the positive response to subsoiling consists of more than stress responses. Fifth year study results in a 11 year-old orchard following the 1985 growing season indicate that none of the treatments significantly influenced (neither positively nor negatively) total tree height, rate of growth, d.b.h. or crown size. In contrast to the lack of response in tree growth variables, there was a significant response to treatments on the 1984 cone crop (table 3). Despite the lack of statistically significant treatment effects in 1985 and 1986, there was a trend for the four subsoiling treatments to promote the number of cones per tree compared to the control.

Some very recent and still preliminary results from this subsoiling study indicate that the subsoiling treatments increased the number of seeds per cone in comparison to the nonsubsoiled control. There were no significant differences between treatments in the number of large, medium or small sized seed.

Table 3.--Mean number of cones per tree by year following five subsoiling frequency and intensity treatments in a loblolly pine seed orchard

Treatment 1/	1984 3/	1985 4/	1986
	Cones/Tree		
Multiple rip - 3 year cycle	144a	117a	73a
Multiple rip - 2 year cycle	140a	174a	93a
Single rip - 3 year cycle 2/	117ab	139a	74a
Single rip - 2 year cycle	108 b	152a	73a
Control - no subsoiling	97 b	128a	58a

1/ Multiple ripping involves 3 parallel cuts on opposite sides of a tree. A three year cycle entails ripping every other year as opposed to every year as in the 2 year cycle
2/ Equivalent to operational subsoiling
3/Means followed by the same letter are not significantly different at the 5 percent level
4/ This harvest follows an operational orchard roguing which involved removing 33 percent of study trees

To date, research on subsoiling has largely focused on gross cone production and tree growth parameters. A necessary step in fine tuning this practice will be to understand how subsoiling alters plant nutrition, moisture relationships and hormonal balances. How transient or, conversely, longlasting the affects might be needs much more research effort.

Orchard Fertilization

The most widely accepted cultural practice to enhance cone production in southern pine orchards is fertilization. While the mechanism through which nitrogen enhances flowering in conifers remains unclear (Ross and Pharis 1985), its use in conifers has been very effective (Owens and Blake 1984; Schmidtling 1975).

The most pressing need to refine seed orchard fertilization as a management tool is a better means of detecting nutritional needs. While much remains to be learned about foliar nutrient levels and how they relate to flower production, foliar analyses offer a sensitive diagnostic and predictive tool to supplement soil analyses for making seed orchard fertilization recommendations. Recent research by the North Carolina State Cooperative Tree Improvement Program and the North Carolina State University Forest Nutrition Cooperative has been directed at developing guidelines for the use of foliar nutrient analyses to prescribe seed orchard fertilization. Preliminary results involving bimonthly collection of foliage samples from numerous clones for 12 months in one piedmont and one coastal plain loblolly pine seed orchard provide some basic understanding of sampling requirements. As anticipated, there were significant clonal differences for essentially all elements evaluated (N, P, K, Ca, and Mg). There was a significant clone x sample date interaction, and the sampling date was a significant source of variation for foliar nitrogen at both locations. Both sites displayed a similar nitrogen concentration x date response, but the two sites have markedly different nitrogen concentrations at almost every point in time. Foliar levels peaked at the coastal plain and piedmont locations at the May sampling date and dropped rapidly as the female flower initiation for loblolly pine period of mid-July to August approached. If elevated levels of foliar nitrogen are conducive to flower stimulation, these results suggest June is the best time to guide summer nitrogenous fertilizer applications.

A potentially useful approach to interpreting foliar nutrient analyses data is through use of the Diagnosis and Recommendation Intergrated System (DRIS) (Beaufils 1973). This technique has been successfully employed in several agricultural crops to overcome problems of foliar diagnosis and interpretation. The DRIS approach considers all nutrients together and can indicate both the limiting nutrients, and also which ones are likely to become limiting (Davee et al. 1986). Currently, the North Carolina State University Cooperative is initiating work to apply the DRIS procedure to seed orchard management.

Pollen Management

Seed orchard pollen management has experienced renewed interest in the last few years. Early concern about pollen management centered on attempts to minimize pollen contamination from sources outside the orchard and to increase both the quantity and genetic quality of the seed. Many studies (e.g. Wright 1953; McElwee 1960, 1970; and Silen 1962) evaluated pollen dispersion and developed strategies to minimize pollen contamination in seed orchards such as the pollen dilution zone, size and arrangement of orchards and orchard site selection.

The movement of northern seed orchards south raised hopes that it might be possible to obtain pollen isolation by having the flowering of the orchard clones out-of-phase with the local populations. Experience to date has been mixed with some orchard managers reporting asynchronous flowering and others unable to detect any differences. Some orchards with minimal internal pollen production have still produced many viable seeds. As orchards mature, the significance of any partially out-of-phase local pollen may be reduced. Data from an experimental loblolly pine orchard in south Texas, well out of the loblolly pine range, seem to indicate the presence of little, if any, contaminating foreign pollen (Richmond and McKinley 1986).

Published reports indicate that pollen contamination in seed orchards varies widely: Greenwood and Rucker (1985) reported in a study of four orchards that contamination varied from 31 to 88%. Friedman and Adams (1981), using electrophoretic techniques, estimated contamination of 28%. Economic analyses of the consequences of pollen contamination indicate that appropriate corrective measures depend upon the number of acres an organization will be planting, the amount of pollen contamination and the gene frequency diffential for desired characteristics between the orchards and the source of pollen contamination (Sniezko 1981). As tree improvement programs develop advanced generation seed orchards, the economic value associated with reducing pollen contamination increases significantly. As previously noted, selecting seed orchard sites for the next cycle of seed orchards may require re-evaluation of the trend toward moving northern seed orchards south. Obviously, important questions remain to be answered about the significance of pollen contamination over a variety of locations and how to minimize the impact of contamination.

Supplemental mass pollination (SMP) procedures have received attention as a means to reduce the impact of self pollination in first generation production orchards and to increase the supply of desirable pollen in young seed orchards where pollen is often lacking. In recent years, SMP has been evaluated as a method to improve genetic gains through full-sib crosses and, to some extent, to produce interspecific hybrids. Supplemental mass pollination procedures have proven to be quite effective in improving seed yields of *Pinus* spp. in South Africa (van der Sijde 1969, and Denison 1973). Although the feasibility of SMP has been demonstrated on an experimental basis, much developmental work under operational conditions remains to be done (Bridgwater and Williams 1983). To date, relatively few organizations have attempted to use SMP on an operational basis. However, SMP is likely to become an important tool for many seed orchard managers.

Orchard Roguing

Currently, the profitability and realization of genetic gain pivots on the production of seed for use in regeneration programs. With the exception of supplemental mass pollination, orchard roguing is the only orchard managewent technique which can increase the genetic quality of the seed produced and, at the same time, frequently increase seed production per tree.

Cone production is definitely affected by the amount of light the tree crown receives. Full crown release in a loblolly pine plantation resulted in a four-fold increase in cone production during the fourth year following crown release (Bilan 1960). Similar increases have been observed in thinned and rogued seed orchards across the southeastern United States. In fact, orchard thinning and roguing based on genetic test information have become established practices throughout the life of first generation seed orchards and is now being routinely applied to second generation orchards.

Seed production by many organizations across the south has been so successful in recent years that an over supply of genetically improved loblolly pine seed has resulted. For example, during the 1986 cone harvest season, an estimated 8,182 kilograms of loblolly pine seed were deliberately not harvested by members of the North Carolina State University Cooperative Program. However, there has never been an over supply of the very best genetically improved seed. To expand production of very high genetic quality seed, more and more organizations are turning to very intensive seed orchard roguing. This type of roguing leaves only the best nine to 12 parents. The genetic quality can be increased four to five percent, and operating costs are substantially reduced.

Two concerns with roguing to these low stocking levels are the potential increase in the amount of self-pollination and the potential for greater contamination levels by nonorchard pollen. Preliminary research findings from orchard blocks rogued to four and 12 clones (17 and 54 ramets/hectare, respectively) have indicated equal outcrossing rates. If the remaining clones are good pollen producers or, if supplemental mass pollination was employed, selfing and background pollen contamination might be of reduced concern. Very intensive roguing should be viewed as experimental, pending further studies.

Orchard Ground Cover Management

Maintenance of a well-established ground cover in southern pine seed orchards has been a standard practice providing erosion control, enhancing trafficability, and reducing compaction due to vehicular traffic. However, little attention has been given to the choice of ground cover, how various ground covers might interact with the orchard trees, and how they might affect orchard management costs.

In horticultural crops, there are numerous cases where the grass cover crop competed directly with the trees, influencing both growth and fruit production (Haynes 1980, Skroch and Shribbs 1986). Various cover crop species compete directly for moisture and nutrients, particularly nitrogen (Proebsting 1958, Fales and Wakefield 1981, and Jordon 1982). How serious grass competition for N might be is unknown, especially in view of the high levels (80 kg/ha/yr) of N commonly applied to seed orchards. In the case of a cool season grass, like tall fescue *(Festuca arundinacea)*, N competition may be mild during the summer but intense during the cooler portions of the year.

Grasses also have an influence on the use of soil systemic insecticides such as Furadan®. Sod effectively competes with trees for soil systemics, necessitating application of larger amounts of insecticides. However, sod helps to prevent runoff of insecticides, thus protecting water resources.

Horticultural literature contains numerous references dealing with allelopathic relationships between various ground covers and weeds and tree crops (see Putnam 1983 and 1986). However, the presence or absence of allelopathic relationships and their possible importance in southern pine seed orchards are unknowns.

Periodic mowing continues to be the most commonly employed method of controlling orchard turf. Recent estimates of costs per hectare per cut range from $27 to $37 (Jett and Weir 1984). With three to six mowings per year, mowing is expensive. Additionally, the costs of mowing are not limited to the obvious direct costs of personnel and equipment but extend to the indirect costs associated with soil compaction, especially when operating equipment during periods of high soil moisture. Careless mowing also results in damage to the trees.

Strip spraying of Roundup®, Oust®, and even Velpar® along the tree rows in older orchards has become commonplace. This practice essentially eliminates the need to cross-mow in the orchard and results in at least three advantages: 1) Equipment traffic in the orchard is significantly reduced; 2) mower and tractor damage to the trees is essentially eliminated; and 3) strip spraying results in substantial savings on mowing costs. Various orchard managers have calculated savings of approximately 12.5 to 25 percent, more than enough to offset herbicide spraying costs.

Increasingly, orchard managers are asking questions about reducing costs beyond those achieved through strip spraying herbicides. What are the possibilities of using grass species requiring fewer cultural inputs, or using chemical growth retardants and sub-lethal rates of herbicides to reduce turf management costs and expedite operations like cone harvest? Understanding how various species of ground covers or orchard floor management schemes might affect moisture availability, nutrient status, tree growth and flowering in southern pine seed orchards awaits research.

CONCLUSIONS

Opportunities abound for research into virtually every facet of seed orchard management. At this point in time, the research needs focus on a more basic understanding of how various cultural practices impact tree development and flowering. This more basic understanding should allow refinement of management procedures, while at the same time offering a cost savings to orchard programs.

Probably some of the most pressing research should address the movement of northern source seed orchards to southern locations. If this type of movement can be done without jeopardizing cold hardiness, the benefits to northern tree improvement programs are important. Additionally, understanding pollen contamination and how to effectively deal with it are of real importance to tree improvement programs.

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