CHARACTERIZING REPRODUCTIVE PHENOLOGY OF SEED ORCHARD CLONES

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Abstract.--Phenological observations were made on fifteen clones in two first-generation loblolly pine seed orchards. A Coastal seed orchard was observed in 1986; a Virginia Piedmont seed orchard was observed in 1988. A method for illustrating clonal patterns of female and male reproductive phenology is presented. Within-clone variation in reproductive phenology was generally low. Within-tree variation was greater among crown levels (upper, middle, lower) than it was by crown aspect (north, south). These data are discussed from a seed orchard management perspective.

Keywords: Pinus taeda L., seed orchard, flowering, phenology.

INTRODUCTION

As Southern seed orchards mature, seed production has increased so that seed orchard managers can now be more concerned with the genetic quality of the seed orchard crop. A seed orchard with clones of high breeding values has the potential to produce high quality wind-pollinated seed. This potential is realized when conditions essential for achieving genetic efficiency are met (El-Kassaby et al. 1984): (a) minimal outside pollen contamination, (b) equal female/male strobili production, (c) equal cross-compatibility, (d) flowering synchronization, (e) random mating, and (f) minimal self-fertilization. Flowering synchronization is a condition of major consequence. Female/male reproductive phenology is an important determinant of random mating and can influence the degree of self-fertilization (Griffin 1984, El-Kassaby et al. 1988). Characterizing reproductive phenology of clones in established seed orchards can provide the manager with information useful for a variety of management activities. Breeding activities can be efficiently scheduled. Clonal patterns of reproductive phenology can be useful additional information when making thinning, roguing, and cone collecting decisions. Bridgwater et al. (1987) have found supplemental mass pollination to be more effective when done on clones receptive before peak seed orchard pollen flight. It may also be possible to modify genetic gain estimates based on a clone's mating relationships with its cohorts. Information on phenological patterns of seed orchard clones is thus of increasing value as we attempt to improve the genetic quality of seed orchard seed.

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MATERIALS AND METHODS

Study Material and Sampling Strategy

In 1986, fifteen clones comprising a first-generation Coastal loblolly pine (*Pinus taeda* L.) seed orchard were observed. In 1988, fifteen clones of managerial interest in a 24-clone first-generation Virginia Piedmont loblolly pine seed orchard were observed. Two ramets of each clone were selected from interior orchard positions. Selection was done to facilitate repeated observations from a mobile aerial lift. Both seed orchards are located near Charleston, South Carolina.

On each study tree, 20 female- and 30 male-bearing observation branches were selected and tagged for repeated observations. With two study trees, a total of 40 female and 60 male observation branches was selected per clone. One-half of the observation branches on a tree were located on the south side of the crown, one-half on the north side. On each crown side (north and south), observation branches were distributed among the upper, middle, and lower crown levels in proportion to the amount of strobili located in that region of the crown. For the fifteen clones observed in 1986 and 1988, a total of 1500 observation branches was selected. Of this total, 600 were female and 900 were male. More observation branches were allocated to males than to females because male strobili clusters appear to be more variable in their phenological patterns than females.

Phenological Observations

Observations were made in a systematic order on all observation branches during a day's census. A census was taken at two- to four-day intervals until all clones ceased to be receptive or shed pollen. Receptivity of female observation branches was scored using the 1 to 6 rating system of Bramlett and O'Gwynn (1980). Strobili clusters on male-bearing observation branches were scored 1 if shedding pollen or 0 if not shedding pollen when the branch was lightly tapped. Due to the somewhat subjective nature of determining female receptivity, one person conducted all censuses during an observation year. From the phenological observations of female and male observation branches of a clone, the proportions of receptive female observation branches (stages 4L to 5L) and of shedding male observation branches were calculated for each census date. These proportions were then used to construct "phenograms" for each clone in which the duration of female receptivity and pollen shed are represented by bands on a time line. The width of the band represents the proportion of strobili receptive or shedding pollen on a particular census date (Figure 1).

RESULTS AND DISCUSSION

Patterns of Reproductive Phenology

Figure 1 illustrates the periods and intensity of female receptivity and pollen shed respectively for fifteen first-generation Virginia Piedmont seed orchard clones observed in 1988. The upper half of each phenogram represents the proportion of receptive females or shedding males observed on ramet 1, the

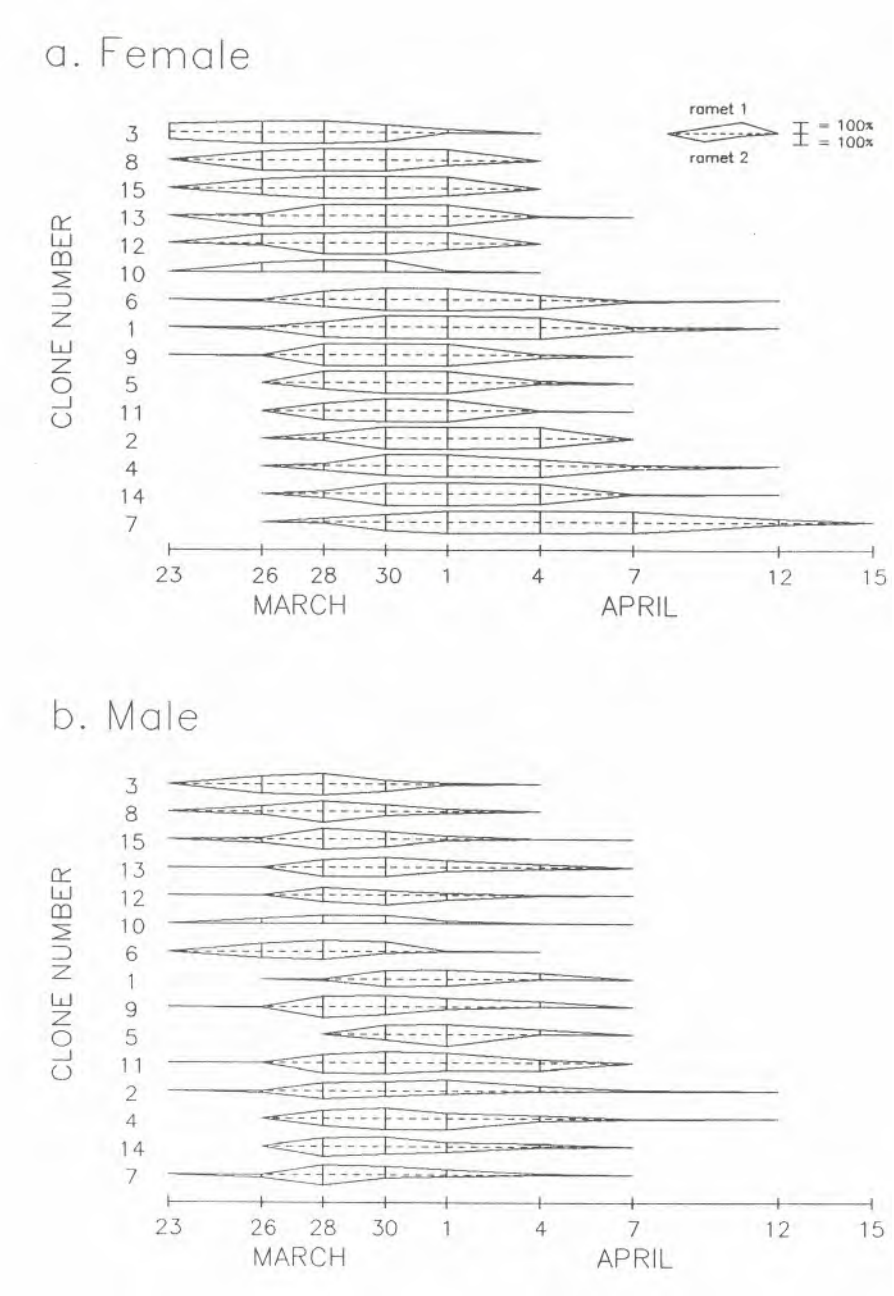

Figure 1. Female (a) and male (b) reproductive phenology of fifteen Virginia Piedmont loblolly pine seed orchard clones in 1988. The width of a horizontal band represents the percentage of strobili receptive on the indicated census day for each of two ramets. Observation branches were located on north and south crown aspects and stratified amongst lower, middle, and upper crown levels. Clones arranged in order of their female receptivity period, earliest to latest. Ramet two of clone 10 was eliminated from the study due to ambiguous clonal identification.

lower half represents ramet 2. These observations have proven quite useful for seed orchard management activities. It is important to verify that clones managed as an intermating reproductive population are, indeed, well synchronized with one another. This is especially important when seed orchard clones are relocated to regions far from the ortets' native range as is the case for some of the clones depicted in Figures 1 and 2. Relocation may result in reproductive anomalies (Schmidtling 1987). Our study clones were generally well synchronized. Clone 3 is classified as an "early" clone, while female receptivity of clone 7 is "late" and of extended duration. The remainder of the clones are classified as "middle". *We* have found these data useful for scheduling breeding activities, devising pollen management strategies, and as an adjunct to thinning and roguing decisions.

Figure 2 plots the percent of all female observation branches receptive and all male observation branches shedding pollen during 1986 in a first-generation Coastal loblolly pine seed orchard. On March 26, female receptivity peaked with 80% of the observation branches receptive and pollen shed peaked with 65% of observation branches shedding pollen. During peak reproductive activity we have documented a greater proportion of receptive female observation branches than there were shedding male observation branches. This pattern reflects the tendency in loblolly pine for individual female strobili clusters to remain receptive over a longer time span than that over which pollen shed occurs in male strobili clusters.

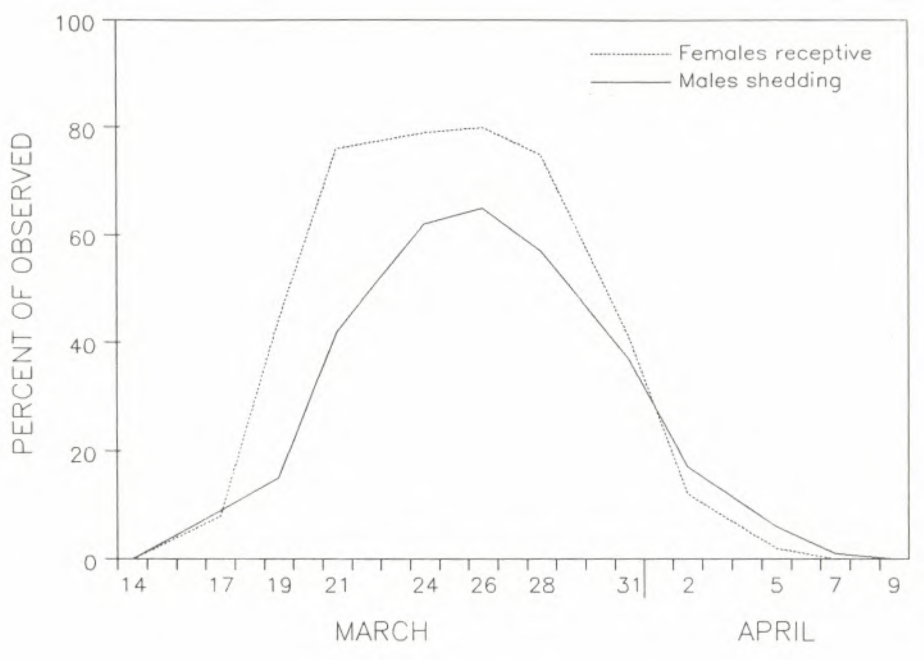

Figure 2. Percent of all female observation branches receptive and all male observation branches shedding pollen. Observations made on indicated census date during the 1986 reproductive period in a fifteen clone first-generation Coastal loblolly pine seed orchard.

Influence of Crown Aspect and Crown Level on Reproductive Phenology

Differences in phenological patterns between north and south crown spects were usually not pronounced. Figure 3 illustrates this for 1988 bservations of female strobili on Virginia Piedmont seed orchard clones. hale strobili in 1988 tended to be more variable, with a trend for north-side strobili to shed pollen over a longer time span than south-side strobili. In 1986 this trend was not apparent, however.

Differences in phenological patterns by crown level were more pronounced and consistent. Figure 4 presents observations taken in 1988 of female strobili (Figure 4a) and 1986 observations of male strobili (Figure 4b). The proportions of receptive female strobili located in the upper and middle crown levels were higher than those in the lower crown level at early census dates. A similar pattern was observed in 1986 observations. Male observation branches showed no differences at the beginning of pollen shed, but there was a trend for males in the upper crown to complete pollen shed before those at mid-crown level, and mid-crown males, in turn, shed pollen before lower crown males (Figure 4b). Similar trends were also seen in Virginia Piedmont clones in 1988. These trends in pollen shed are a reflection of the number and size of male strobili clusters by crown level. Male strobili clusters in the lower crown tended to be larger than those in the upper crown, and thus shed pollen for a longer time period due to their larger size (i.e. more and larger strobili per cluster).

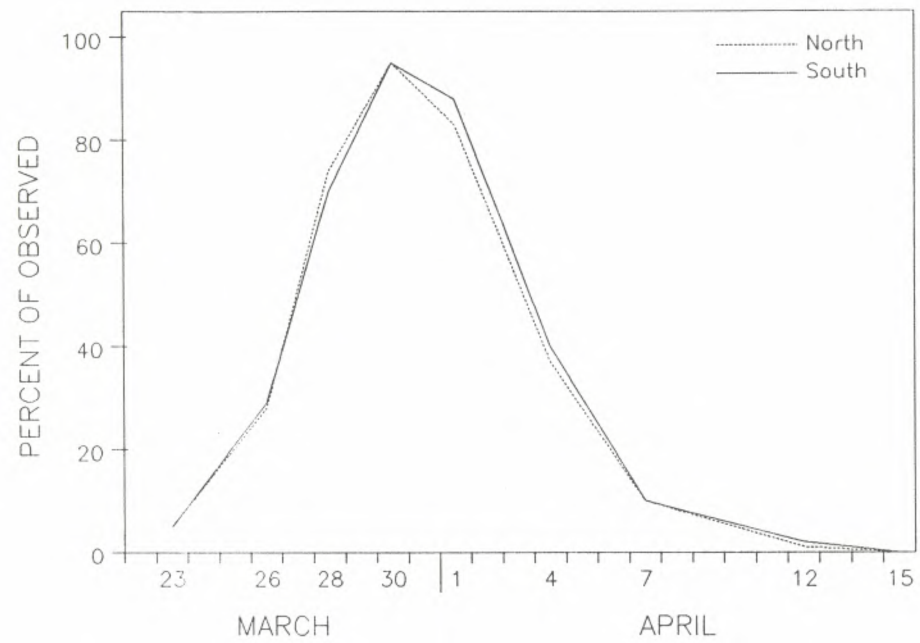

Figure 3. Comparison of female receptivity between crown aspects. Observations made on indicated census date during the 1988 reproductive period on fifteen clones in a first-generation Virginia Piedmont loblolly pine seed orchard. Percent of all receptive female observation branches on north and south crown aspects is shown.

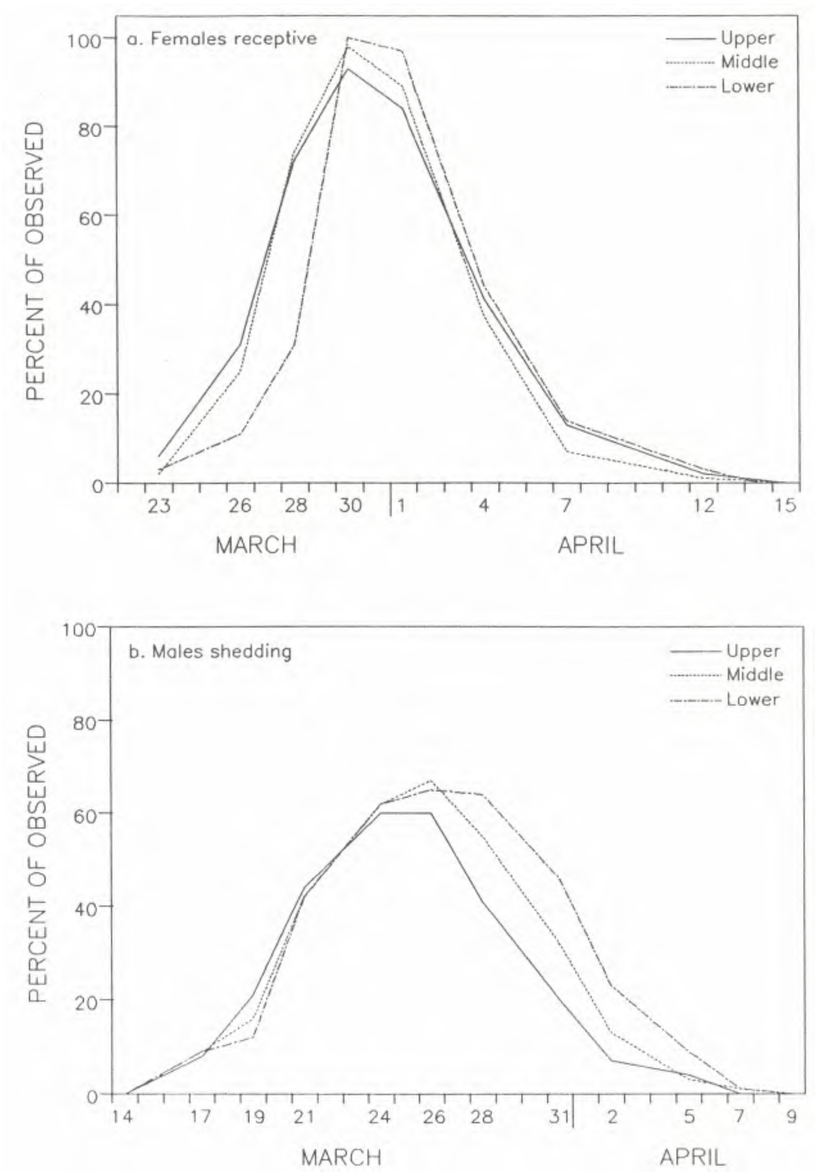

Figure 4. Comparison of female receptivity and male pollen shed between crown levels. (a) Percent of all receptive female observation branches in upper, middle, and lower crown levels on indicated census date during the 1988 reproductive period in a first-generation Virginia Piedmont loblolly pine seed orchard. (b) Percent of all shedding male observation branches in upper, middle, and lower crown levels on indicated census date during the 1986 reproductive period in a first-generation Coastal loblolly pine seed orchard.

These observations suggest that within-crown patterns of female reproductive phenology may be determined more by branch hierarchy than by the microclimate experienced in different crown regions. I know of no literature on within-crown influences on reproductive phenology. In the absence of experimental data, some speculations can be made based on patterns of physiological function within tree crowns. The position of a reproductive branch in the crown determines its nutritional and water stress status, and these factors probably influence the timing and pattern of receptivity. Female strobili on rapidly elongating upper-crown branches become receptive sooner than those on subordinate lower-crown branches (Figure 4a). Rapidly elongating upper-crown branches are a strong nutrient sink and have favorable water relations. This should benefit accompanying female strobili by shortening their time to ripen under permissive environmental conditions. Due to their variability and the confounding of cluster size with crown level, it is difficult to interpret within-crown patterns of pollen shed in male strobili from the observations of these studies. The influence that branch hierarchy and related physiolcgical differences have on patterns of reproductive phenology is not well understood. This would be an interesting area in which to do further research.

CONCLUSIONS

The results o these and other studies have shown the value of characterizing patterns of reproductive phenology in conifer seed orchards. Phenograms are a convenient way to characterize the intensity and duration of female receptivity and pollen shed for a collection of clones, and they facilitate comparison among clones. Clones not synchronized with the rest of the seed orchard can be readily identified. For the seed orchard as a whole, female strobili clusters appear to remain receptive over a longer time span than male strobili clusters. Within-crown variation in female reproductive phenology appears to be greatest by crown level, with little differences by crown aspect. The timing of pollen shed within the crown is highly variable. More intensive sampling is needed to determine within-crown patterns (if any) of pollen shed.

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