LONGLEAF PINE FLOWERING IN RESPONSE TO NITROGEN FERTILIZATION, BRANCH GIRDLING, GROWTH SUBSTANCES, AND CULTIVATION

R. C. Hare, E. B. Snyder, and R. C. Schmidtling[1]

ABSTRACT.--Biweekly applications of 400 µg $GA_{4/7}$ plus 25 µg NAA per bud from June 1 to August 10 promoted male and female flowering in longleaf pine (*Pinus palustris* Mill.), especially when combined with partial branch girdling and NH_4NO_3 fertilization. Fertilization was the most effective single factor, and girdling was second. Cultivation had no significant effect on flowering. Vegetative bud growth was doubled by GA-NAA, independent of fertilizer stimulation.

Poor pollen production has seriously hindered improvement breeding in longleaf pine. Certain cultural treatments (nitrogen fertilization, cultivation, subsoiling) and branch treatments (partial girdling, gibberellins) increase flowering in conifers. Varnell (1970) found that partial branch girdling increased eightfold the number of longleaf pine branch tips bearing male flowers, but did not increase female flowering. With loblolly pine (*P. taeda* L.) nitrogen fertilization promotes female flowering (Schmidtling 1974, van Buijtenen 1966). However, van Buijtenen reported that this was accompanied by a decrease in male flowering, and he also found that cultivation increased both male and female flowering.

Gibberellins (GAs) have enhanced flowering in many conifers (Pharis 1974, 1975, 1976). GA_3 is effective except in Pinaceae species, which require a less polar gibberellin like $GA_{4/7}$. Biweekly bud applications of 400 µg $GA_{4/7}$ combined with partial branch girdling promoted flowering in loblolly pine. Low levels of naphthaleneacetic acid (NAA) combined with $GA_{4/7}$ further improved flowering.

Our experiment tested effects of partial branch girdling, GA-NAA bud application, NH_4NO_3 fertilization, and shallow cultivation on the percentage of buds with male and female flowers. An attempt was also made to evaluate the effects of these treatments on the number of flowers per flowering bud.

---

1 Plant Physiologist, Principal Plant Geneticist, and Plant Geneticist, Southern Forest Experiment Station, Forest Service, USDA, Gulfport, MS.

MATERIALS AND METHODS

Twenty 13-year-old longleaf pines with poor flowering histories were selected from a thinned south Mississippi plantation which was beginning to flower. Average diameter at breast height was 18 cm.

Four cultural treatments (control, fertilized, disked, and fertilized plus disked) were randomly assigned in each of five blocks containing four trees each. In late May, 900 g NH_4NO_3 were distributed evenly among six 30 cm deep holes around the drip lines of the designated trees. Trees selected for soil treatments were far enough apart to avoid cross-over effects. Light disking beneath the crown was done in late May.

Eight branches were selected on each tree--four in the lower crown and four in the mid- to upper crown (hereafter called upper). Four branch treatments (control, partial girdle, GA-NAA, and partial girdle plus GA-NAA) were randomly assigned at each crown level. Branches were girdled in late May 1976 by removing two staggered strips of bark and cambium. Strips were 1 cm apart, 1 cm wide, and covered 3/4 of the branch circumference. From June 1 to August 10 growth substances were applied biweekly to each bud in dosages of 400 μg $GA_{4/7}$ and 25 μg NAA in 0.1 ml 50% ethanol.

In February 1977, each bud was measured for length, and male and female flowers were counted. Data were then calculated on a branch basis for average bud length, percentage of buds with male flowers, percentage with female flowers, and average number of male and female flowers per flowering bud.

The statistical design was a split-split plot with five replicates: whole plots were soil treatments, first order subplots were crown levels, second order subplots were branch treatments. Analysis of variance was used to test for significance at the 0.05 level of probability.

RESULTS AND DISCUSSION

Bud length increased with nitrogen fertilization and doubled with GA-NAA treatments (fig. 1). Disking had no effect and girdling reduced bud growth. Girdling plus GA-NAA increased bud length less than did GA-NAA alone. For bud growth, there were no significant soil/branch or soil/crown level interactions. Upper crown buds averaged more growth than lower crown buds.

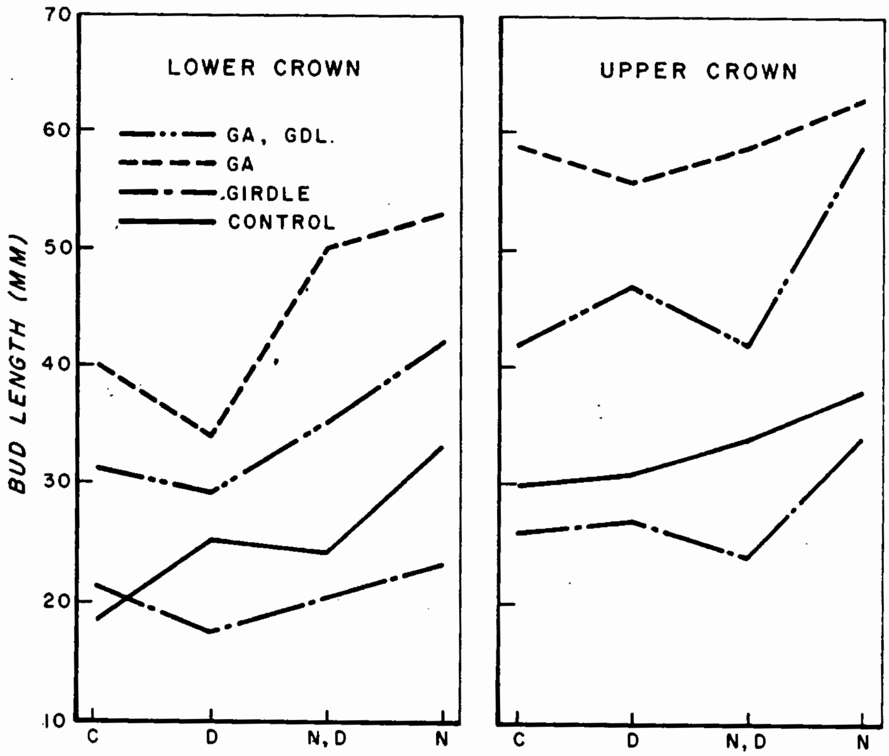

Figure 1.--Effect of soil and branch treatments on average bud length. Soil treatments were control (C), disking (D), NH_4NO_3 fertilization plus disking (N,D), and NH_4NO_3 fertilization alone (N). Branch treatments were control, girdle, $GA_{4/7}$ - NAA (GA), and girdle plus $GA_{4/7}$-NAA (GA,GDL).

Nitrogen generally promoted both male and female flowering, but there was no significant effect from disking nor nitrogen plus disking (figs. 2 and 3). In fact, the combination of disking and nitrogen usually produced fewer flowers than either treatment alone.

All three branch treatments promoted flowering. At both crown levels female flowering was promoted best by GA-NAA plus girdle (fig. 2). Combined with nitrogen fertilization this treatment gave 50% female flowering in the upper crown, compared with no flowering on the control. For male flowering in the upper crown the combined branch treatment was less effective than girdling alone (fig. 3), which produced 60% flowering on fertilized trees. In the lower crown the three branch treatments were about equally effective for male flowering.

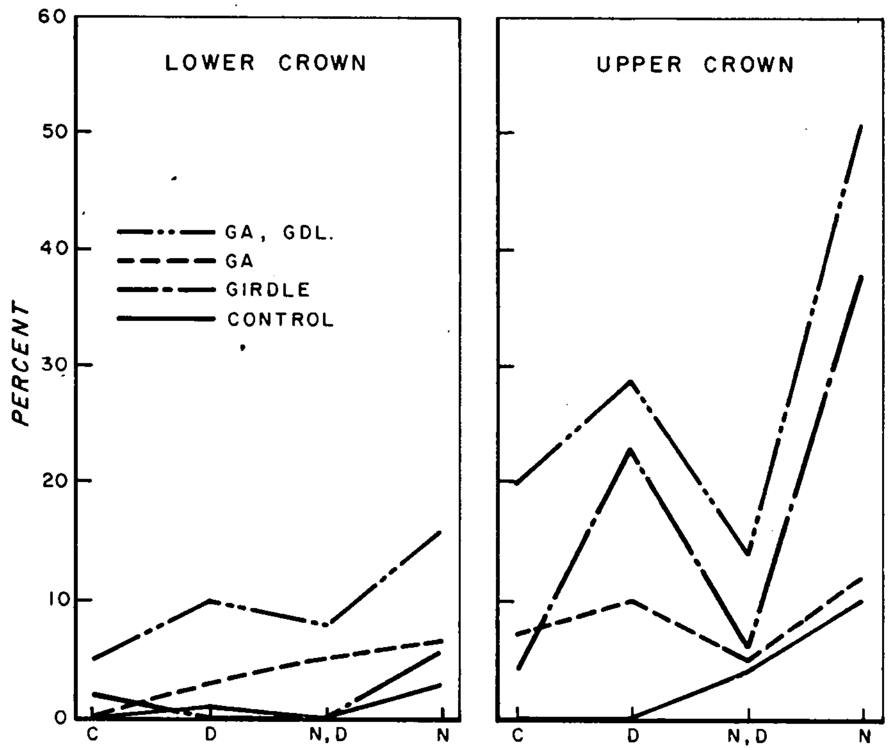

Figure 2.--Effect of soil and branch treatments on percentage of buds with female flowers. Soil treatments were control (C), disking (D), NH_4NO_3 fertilization plus disking (N,D), and NH_4NO_3 fertilization alone (N). Branch treatments were control, girdle, $GA_{4/7}$-NAA (GA), and girdle plus $GA_{4/7}$-NAA (GA, GDL).

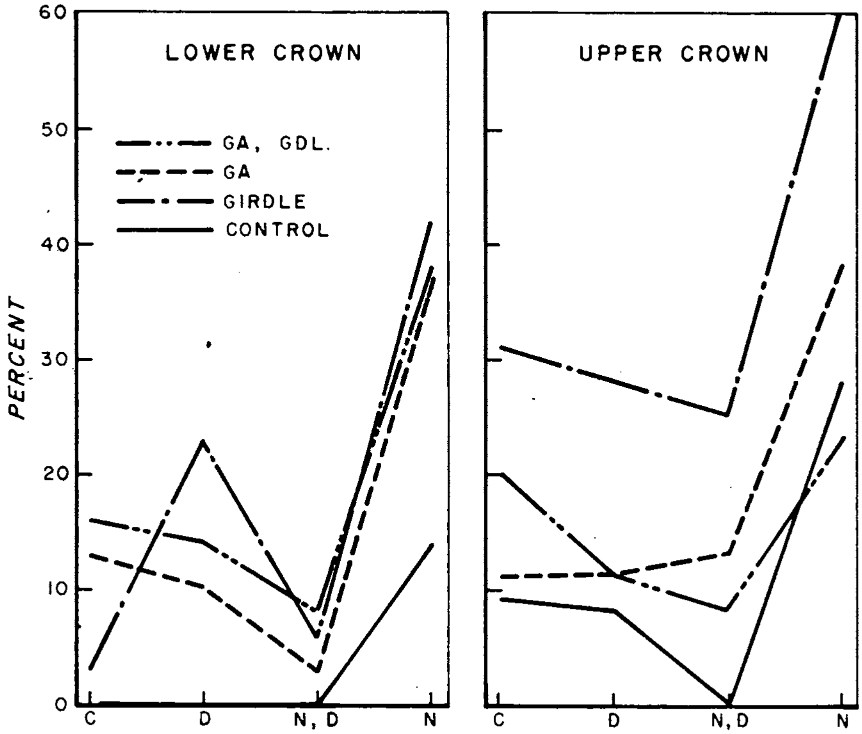

Figure 3.--Effect of soil and branch treatments on percentage of buds with male flowers. Soil treatments were control (C), disking (D), NH_4NO_3 fertilization plus disking (N,D), and NH_4NO_3 fertilization alone (N). Branch treatments were control, girdle, $GA_{4/7}$-NAA (GA), and girdle plus $GA_{4/7}$-NAA (GA,GDL).

Most of the literature on promoting pine flowering deals only with the percentage of branch tips having male or female flowers. More important is the total flower production, which depends not only on percentage of flowering buds but also on number of flowers per flowering bud. Unfortunately, treatment effects on flowers per flowering bud in this study could not be compared statistically because some branches had no flowers. It appeared, however, that branch treatments increased flowering percentage but decreased the average number of flowers per flowering bud, whereas nitrogen fertilization markedly increased both male and female flowering percentage and number of flowers per flowering bud. These observations might be explained if nitrogen is a limiting factor in flower initiation and development. Induction of more flowering buds by branch treatments may channel nitrogen for amino acid synthesis into these new sinks, thus limiting substrate per bud and allowing fewer flowers to form. Girdling may induce more buds to flower by keeping organic nitrogen compounds and carbohydrates from moving out of the branch via the phloem, but without nitrogen fertilization the number of flowers produced will be limited.

From this experiment we conclude that a combination of NH_4NO_3 fertilization, partial branch girdling, and bud treatment with $GA_{4/7}$ plus NAA most effectively promotes longleaf pine flowering. Cultivation is ineffective or even detrimental with fertilization. At present only fertilization appears to lend itself to an operational program in seed orchards. Girdling takes too much time and occasionally kills the branch. If GA-NAA could be applied by foliar spray the treatment would be practical, but GA appears to require tedious application to individual buds (Pharis et al.1975)

ACKNOWLEDGMENT

The authors wish to thank Dr. R. M. Couture of Imperial Chemical Industries for his very generous gift of Gibberellin $A_{4/7}$.

LITERATURE CITED

Pharis, R. P. 1974. Precocious flowering in conifers: The role of plant hormones. Yale Univ. Sch. of For. Bull. 85:51-80.

Pharis, R. P. 1975. Promotion of flowering in conifers by gibberellins. For. Chron. 51:244-248.

Pharis, R. P. 1976. Manipulation of flowering in conifers through the use of plant hormones. In Modern Methods in Forest Genetics, J. P. Miksche (Ed.), p.265-282. Proc. in Life Sci.

Pharis, R. P., R. L. Wample, and A. Kamienska. 1975. Growth, development, and sexual differentiation in *Pinus*, with emphasis on the role of the plant hormone, gibberellin. Proc. Manage.Lodgepole Pine Ecosystems Symp. p. 106-134.

Schmidtling, R. C. 1974. Fruitfulness in conifers: Nitrogen, carbohydrate and genetic control. Proc.3rd N.Amer.For.Biol.Wkshop.p.148-164.

van Buijtenen, J. P. 1966. The effect of spacing, fertilization, and cultivation on flowering and seed production in loblolly pine. Proc. 8th South. Conf. For. Tree Improv. Savannah, GA. p.141-146.

Varnell, R. J. 1970. Effects of branch girdling on the production of male and female strobili in longleaf pine. For. Sci. 16:195-196.