A TREE IMPROVEMENT PROGRAM TO DEVELOP CLONES OF LOBLOLLY PINE FOR REFORESTATION

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Abstract.--The program emphasizes resistance to fusiform rust (Cronartium quercuum) (Berk.) Miyabe ex Shirai F. sp. fusiforme) as well as volume production of loblolly pine (Pinus taeda L). Parent trees are selected from a tested first generation population and crossed. A controlled-environment screening technique serves as an early selection for disease-free individuals and provides family information for later selection. Rust-free seedlings enter a vegetative propagation system using rooted cuttings. Clonal progeny tests, planted at multiple sites, provide data for later selection. Clonal selections are made using information derived from controlled-environment rust testing as well as field tests. The selections produce two populations: a clonal production population and a breeding population. The two populations may contain different subsets of selections since the one is selected mainly for general combining ability while the other is selected for total genetic value.

Clonally derived production plantings have become an intergal part of tree improvement programs where species are amenable to vegetative propagation. As a vehicle for reforestation, populations of clonal selections express genetic gains that are unattainable by traditional seedling propagation methods. Clonal selection and vegetative propagation utilize total genetic variation; therefore clonal programs can be opportunistic in capturing non-additive genetic variation as well as carefully planned to utilize additive genetic variation comparable to traditional programs. Examples of the results of selection and clonal propagation for reforestation include Norway spruce (Picea abies Karst.) (Roulund 1981), radiata pine (Pinus radiata D. Don) (Fielding 970), and eastern cottonwood (Populus deltoides Bartr.) (McKnight 1970).

Techniques that are currently utilized by International Forest Seed Company enable large scale production of rooted cuttings of loblolly pine (Pinus taeda L.). Such vegetative propagation technology is being applied in combination with a recurrent selection program to develop clonal selections superior for both fusiform rust resistance and production traits.

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BASE POPULATION AND MATING DESIGN

One hundred and twenty-seven parent trees are selected from a pool of tested, first-generation selections from a combination of two sources: North Carolina State University-Industry Cooperative Tree Improvement Program, and the Cooperative Program between the U.S.D.A. Forest Service and the Georgia Forestry Commission. Traits for parental selection include superior resistance to fusiform rust and superior height growth as evidenced in progeny tests. The select trees are then mated at random using small disconnected factorials (generally 4 x 4).

EARLY SCREENING FOR RUST RESISTANCE

Seedlings from the resultant seed are then screened in the U.S.D.A. Forest Service Bent Creek Resistance Screening Center using standard techniques (Anderson et al. 1983). Data include percent of seedlings from each cross with a rust gall as well as other traits which are combined into a resistance score (C.H. Walkinshaw; U.S.D.A. For. Ser.; Principle Plant Pathologist; personal communication; gall traits defined by Walkinshaw et al. 1980). Seedlings which emerge from the screening with no rust symptoms then became the population for field testing.

The rust free survivors are planted in a cutting orchard at an approximate age of six months from seed. Henceforth, the trees are hedged at a height of about 1.5 ft. The hedging serves two purposes: 1. to maintain juvenility (Libby et al. 1972) and 2. to increase the number of potential cuttings (Foster et al. 1981).

FIELD TESTING

The field tests are designed to achieve a compromise between the total number of trees that can be planted and efficiencies of genetic value estimation for families and clones in families (Shaw and Hood 1983). Each tested clone is planted at three locations with two ramets per clone at each location, providing a total of six ramets per clone (3 locations x 2 ramets per location). At each location one ramet per clone is placed in each of two complete blocks with clones from a single family distributed among six blocks per location. This design achieves balance at the family level across replications and locations but is only partially balanced at the clone within family level. The testing program contains a maximum of 25 clones per family. The model utilizes factorials as sets of families (Hallauer and Miranda 1980). Clones from single families are distributed randomly within blocks and treated statistically as a single, non-contiguous family plot (Lambeth et al. 1980). Three check lots (N.C. State Cooperative) are included in each block as both seedlings and rooted cuttings.

In order to further screen the greenhouse-test survivors for fusiform rust resistance, each test is located in a high rust hazard area (over 50 percent infection) (Anderson 1986). Additionally the tests are geographically separate; such a distribution is intended to maximize sampling of divergent rust strains and promote selection for generally resistant clones.

Tests are measured annually for the first five years and again at 10 years. Traits measured include survival, presence of rust galls, height, d.b.h., and volume.

SELECTION AND PRODUCTION OF PROPAGULES

Initial selection of clones is based on the early screening data for rust incidence at the family level and third year field data for both rust incidence and height. Clones are selected for two populations (Foster 1986): 1. a breeding population and 2. a production population.

The initial breeding population contains approximately 300 clones selected for breeding value, using an index of multiple traits and a combination of family and individual information. This relatively early schedule for initial selection allows the clones to enter an accelerated breeding program (Greenwood 1983), while later culling can remove inferior clones. A further reduction of the select population (100 clones eliminated at age four and an additional 40 at age 5) depends on later measurements. Therefore the actual breeding of select trees entails only 160 selections (approximately the size of the initial population). The early selection procedure described expends effort in maintaining some clones that are never included in subsequent generations but shortens by two years the time required before crossing can be completed.

Two hundred selections are chosen for the production population based on third-year test data. These clonal selections depend only on genotypic value, rather than breeding value, derived from a multiple trait index. Hence simple, mass genotypic selection is employed (Foster 1986). Gain from genotypic selection utilizes total genetic variance, and therefore the selections for the breeding population may contain a subset of trees that overlaps only partially with the production population.

As with the breeding population, early selection in the production population provides necessary advanced warning to allow multiplication of the chosen clones with additional hedged ramets prior to final selection. A process of progressive elimination based on age 4 and 5 data is used to reach a final population of 50 clones. Early selection results in expended effort for increasing clones that eventually will be discarded. However, such an investment saves two years between selection and commercial scale propagation for the 50 clones eventually selected. Rapid deployment of advanced planting stock for reforestation is a very real advantage of clonal propagation (Matheson and Lindgren 1985).

ADVANCING THE BREEDING POPULATION

The same mating design as in the first generation is used for the second generation selections, with the exception of the matching of mates in which a a positive assortative mating arrangement is used (Foster 1986). The ranking of selections is based on their breeding values, and then the list is subdivided into progressively descending groups of eight selections. These eight selections then constitute a 4 x 4 factorial, and selections are designated as male or female parents in alternating fashion down the list. This arrangement of mates helps to maximize the correlation of breeding values which is an important consideration in positive assortative mating (Crow and Felsenstein 1968). If related selections occur within a factorial, they are all assigned as the same sex to avoid potential crossing.

As with the mating design, the testing and selection schemes are duplicated from the previous generation.

CONCLUSIONS

The described program provides a system to greatly increase genetic gain in fusiform rust resistance and height growth in loblolly pine by using a recurrent selection scheme for the breeding population while using clonal propagation for the production population. Separation of the two populations and allocation of effort to different goals of selection result in steady, yet somewhat slower, gains from improving additive genetic effects in the breeding population; while the production population delivers maximum gain from the breeding population each generation. Selection of preliminary populations for both breeding and production purposes at age three, with subsequent culling based on later results, increases the flow of advanced cycle material into reforestation programs and shortens the generation interval.

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