GENETIC VARIATION IN LOBLOLLY PINE ROOT GROWTH POTENTIAL

L.E. DeWald, P.P. Feret, and R.E. Kreh[1]

Abstract.--Half-sib families of 1-0 loblolly pine seedlings were evaluated for genetic variation in their ability to regenerate new roots (root growth potential (RGP)) when outplanted. Half-sib family variation was significant with heritabilities ranging 0.34-0.37 for two independent samples of seedlots lifted in March 1983 and 1984. Variation patterns of root growth potential were different for half-sib families lifted at different times during the nursery growing season, and RGP of March lifted half-sib families was related to both first- and second-year field performance.

Additional keywords: RGP, field performance, height growth, nursery management, lifting season, Pinus taeda.

INTRODUCTION

Loblolly pine (Pinus taeda L.) is typically regenerated in the southern U.S. by planting bare-root 1-0 seedlings. Although nearly one billion loblolly pine seedlings are planted annually, (Johnson et al. 1983), highly variable transplanting success has resulted in decreased survival rates since 1960 (Weaver et al. 1981).

Analysis of the ability of bare-root **seedlings** to regenerate new roots (root growth potential) has improved the understanding of plantation establishment failures of western North American conifers (Ritchie and Dunlap 1980, Jenkinson and Nelson 1978). A direct relationship between root growth potential (RGP), and field survival and height growth has been established for many western conifer species. Among the factors found to affect western conifer RGP are genetic origin, nursery practices, and handling procedures (Ritchie and Dunlap 1980). Jenkinson (1980) determined that one of the keys to successful plantation establishment of western yellow pines is knowing when to lift seedlings from the nursery. Similar results have been obtained for Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) (Jenkinson 1984, Jenkinson and Nelson 1983) and for other western species (Stone and Norberg 1979). Subsequently, optimum lifting periods or "windows" have been established for different species which are based on genetic background and climatic data.

Stimulated by the success of RGP research in the west, and the studies in the southeast which indicate a relation between loblolly pine RGP and field performance (Feret and Kreh 1985, Feret et. al 1985) a project was undertaken to examine the role of genetic variation in RGP among half-sib families of loblolly pine seedlings. The specific objectives were to determine if root growth potential is affected by genetic orgin; to describe the relationship between root growth potential, genetic origin, and field performance; and to

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determine if there is a lift date by genetic origin interaction.

MATERIALS AND METHODS

Two separate studies were established to examine genetic variation in loblolly pine RGP. The first study, conducted in 1982-1983, measured the genetic variation in RGP among 15 half-sib families and determined the relationship between RGP, genetic origin, and field performance. The second study, which measured genetic variation in RGP over the nursery lifting season, was conducted in 1983-1984 using 14 half-sib families completely independent of those used in the 1982-1983 study.

The 1982-1983 study used seedlings grown from seed donated by the N.C. State Cooperative Tree Improvement Program, and a Virginia Division of Forestry (VDF) nursery mix. The seedlings were grown in four replicate nursery beds at the VDF nursery in Providence Forge, Va. using standard nursery practices, except they were not undercut or top pruned.

On March 15, 1983, 90 seedlings per half-sib family (seedlot) were hand-lifted; 30 seedlings per seedlot were evaluated for RGP and 60 outplanted on the Virginia Piedmont Plateau, in Patrick County, Va. The outplanted seedlings were randomly assigned to 4 five-tree plots per seedlot within each of three blocks using a 0.5 by 1.0 m spacing. The outplanting site was a southwest facing slope originally containing a mixed pine-hardwood stand that was clearcut, followed by a chop and burn site preparation. The soil was a Hayesville fine sandy loam (SCS 1973). Seedling height and survival were measured at the start of the growing season and again in December of 1983 and 1984 when growth had ceased.

Root growth potential was measured by root pruning the seedlings to 12 cm below their root collars and then planting 15 seedlings per seedlot into two acrylic trays (46 x 10 x 40 cm) containing Promix Bx® ' a commercial growth media containing peatmoss, pearlite and nutrient additives. The trays were watered to field capacity, sealed and placed in a waterbath at 20 C for 24 days under a 16 hour photoperiod in a greenhouse maintained above 15 C at night and below 24 C during the day.

After 24 days, seedlings were excavated from the trays and the number of new roots greater 0.5 cm (easily distinguished from old roots by their white color) were removed and counted. Root growth potential was expressed as the number of new roots produced by each seedling. Each seedling was also characterized at harvest by measuring root collar diameter, and shoot and root dry weights (dried at 70 C to constant weight).

The 1983-1984 study used 14 half-sib families donated by the VDF plus a VDF nursery mix. The seedlings were grown operationally from seed at the same VDF nursery as the previous study in 8 replicate nursery blocks. They were top pruned but not undercut. Severe 1983 spring storms caused poor survival in the nursery and, consequently, only four lift dates were possible. On October 25, November 22, 1983 and on February 2 and March 13, 1984 two randomly selected nursery field replicates were handlifted, common seedlots from both replicates were combined, and the RGP of 28 seedlings per seedlot measured.

A simpler less expensive RGP testing system, which gives similar relative results to the soil system used in the 1982-1983 study (DeWald et al. 1985), was used in the 1983-1984 study. In this system, 4-seedling plots per seedlot were grown hydroponically in a greenhouse under a 16-hour photoperiod in 7 replicate 37.8 liter fish aquariums for 15 days. The seedlings were suspended in aerated tap-water by inserting them at their root collars in floating sytrofoam blocks. The water temperature was maintained at ambient air temperature (minimum of 16 C nights and up to 27 C days) and 0.5 g of 20-20-20 (nitrogen-phosphorus-potassium) was added to the water (approximately 13 ppm final concentration). After the 15 days of hydroponic growth the RGP of the seedlings was quantified in the same manner as the 1982-1983 study.

Root growth potential and field performance (expressed as total height, height increment and survival) were analyzed using analyses of variance. Seedlot means were separated with Duncan's multiple range tests. Heritability of root growth potential was calculated (Falconer 1983) using data from the half-sib families (excluding the VDF nursery mix). Regression analysis was used to elucidate the relationship between RGP and field performance of the different seedlots. Since the 1982-1983 seedlings were not top pruned regression analyses were conducted using annual height increments (obtained by subtraction).

RESULTS

1982-1983 Study

The number of new roots averaged over all seedlots ranged from 14.6 to 23.5 with a mean of 17.9 (standard deviation = 3.4), and seedlot variation was significant (a=0.01). The heritability estimate for RGP was 0.34 (+0.12). First-year height increment averaged over seedlots ranged from 14.9 to 22.2 cm with an overall mean of 17.1 cm (standard deviation = 3.38). Second-year height increment averaged over seedlots ranged from 43.4 to 60.7 cm with a mean of 50.4 (standard deviation = 5.1). Survival after the first growing season was 95.9 percent and remained unchanged after two years. The regression of field performance on number of new roots was significant for both first- and second-year height increment (a=0.01), with R^2 values of 0.59 (standard error = 1.86 cm) and 0.28 (standard error = 4.46 cm), respectively. The relationships of RGP and height increment are illustrated in Figures 1 and 2.

Regression analyses of mean seedlot shoot dry weight, root dry weight, root-shoot ratio (based on dry weights), and root collar diamter versus mean number of new roots revealed that only root-shoot ratio was significantly (a=0.05), although weakly, related (r=0.25).

1983-1984 Study

Root growth potential varied significantly (a=0.01) among seedlots and among lift dates. In general, RGP and heritability were lowest for October and highest for the February lift. There was little RGP variation among seedlots for these two lifts, with only one seedlot differing significantly (a=0.05) from the rest. RGP variation among seedlots for the November and March lift dates was similar and greater than in October and February. The heritability estimates for the March and November lift dates were also

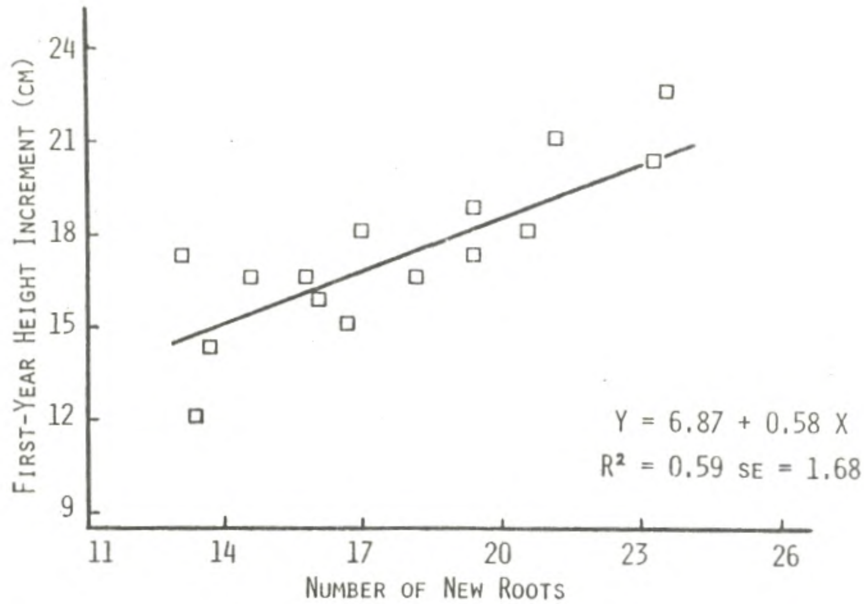

Figure 1. Relationship of first-year field performance and root growth potential of loblolly pine half-sib families lifted and outplanted on the Virginia Piedmont Plateau, Patrick County, Va., in March 1983.

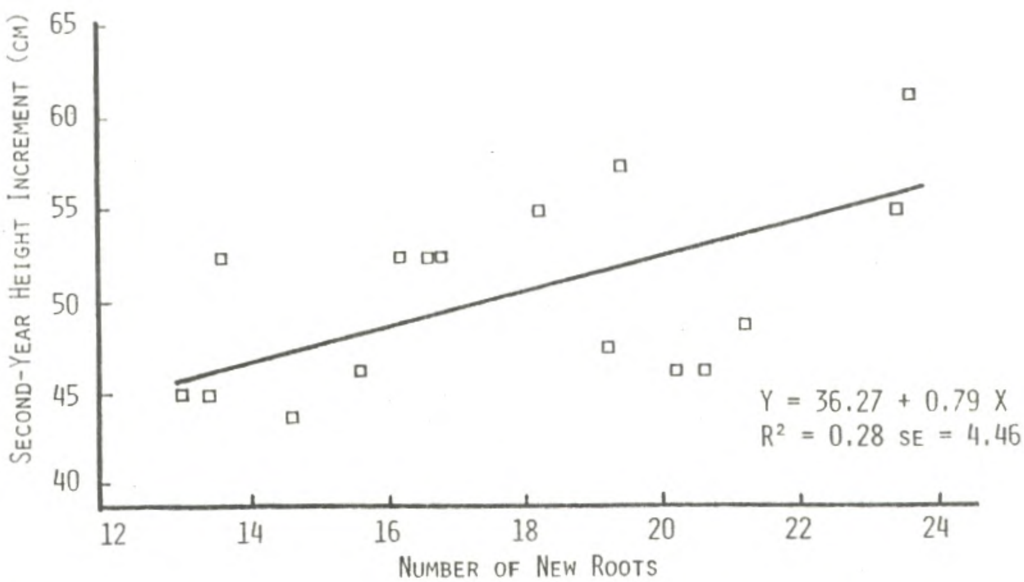

Figure 2. Relationship of second-year field performance and root growth potential of loblolly pine half-sib families lifted and outplanted on the Virginia Piedmont Plateau, Patrick County, Va., in March 1983.

similar. The RGP results and heritabilities for each lift are summarized in Table 1.

The seedlot by lift date interaction was also significant (1=0.01). This interaction was both a relational (rate) as well as a complete reversal type of interaction. In general, the October RGP was always the lowest and either the February or March lift dates had the highest RGP. The specific direction of change in RGP from date to date varied depending on the seedlot. This relationship is illustrated in Figure 3.

Table 1. Summary of half-sib loblolly pine seedling root growth potential performance over the 1983-1984 nursery lifting season.

Time of Lift	Seedlot Variation Significance	Number of New Roots (Seedlot Means)		Heritability	
		Mean	Range	h^2	SE
October	$\alpha = 0.05$	0.44	0.14-1.14	0.15	±0.03
November	$\alpha = 0.01$	6.17	2.71-9.29	0.30	±0.04
February	$\alpha = 0.01$	8.97	6.54-18.36	0.50	±0.05
March	$\alpha = 0.01$	8.32	4.39-13.42	0.37	±0.05

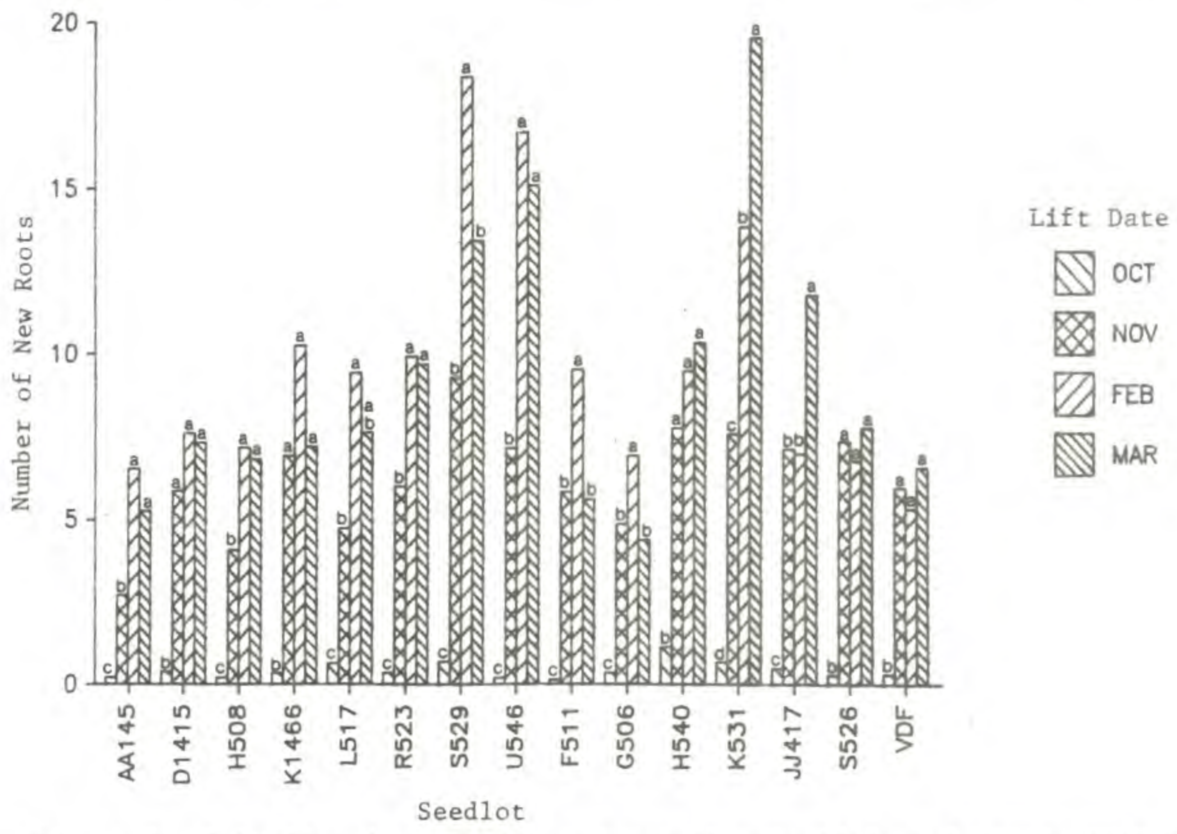

Figure 3. Loblolly pine seedlot root growth potential performance over the 1983-1984 lifting season. Means followed by the same letter within each seedlot do not differ significantly (α=0.05).

DISCUSSION

Results from both years indicate strong genetic control for loblolly pine RGP and selection would probably be successful for-improving this trait. The heritabilities for March lifted seedlings are similar for both years even though two completely independent groups of half-sib families were used. The different heritabilities for the four lift dates indicate that different degrees of environmental control exist over the growing season, but this difference is in part due to the lift date by seedlot interaction.

The interaction between time of lift and genetic origin suggests that different optimum lifting and planting dates exist for different loblolly pine seedlots. It appears that lifting "windows", such as those described for western species (Jenkinson (1980, 1984), also exist for loblolly pine.

Field performance, genetic origin, and RGP appear to be closely linked and the results indicate that seedlots with superior RGP will have greater height increment the first growing season, with this effect lasting at least two years. The relationship between field performance and RGP is consistent with other loblolly pine studies where treatments with low RGP had poor field performance (Feret and Kreh 1985, Feret et al. 1985). When interpreting the field performance data of individual seedlots, it must be kept in mind that some of the RGP and subsequent height differences may have been due to March not being an optimum time for lifting some seedlots.

The differences in RGP responses over the lifting season suggest that family-block plantings in the nursery have an advantage over composite seedlot plantings since time of lift could be scheduled to maximize RGP for groups of families that respond similarly. In the western U.S. nurseries that utilize family-block plantings can use lifting windows ensuring appropriate lifting schedules for each seedlot, thereby increasing the probability of plantation success (Jenkinson 1984).

In addition to lifting schedules, seedlot blocks in the nursery also allow cultural practices to be tailored to maximize RGP. For example, certain cultural treatments such as fertilization might result in increased RGP of some seedlots at a time when their RGP would otherwise be low. These seedlots could then be lifted at what would have been a non-optimal time.

The genetic control of RGP permits screening of seedlots for an indication of potential relative field performance. This can be particularly useful for the selection of seedlots for difficult sites or difficult years. In addition, the lift date by seedlot RGP interaction may be a partial cause of obscure genotype by environment interaction in progeny tests.

The differential RGP response among seedlots over the lifting season should be considered in the establishment of progeny tests. Since all seedlots are not at their optimal RGP for lifting simultaneously, progeny tests should perhaps be established over a period of weeks to minimize seedlot differences caused by non-optimal lifting dates. This procedure would allow more precise estimates of the actual field performance rankings of improved families by minimizing error variance due to non-optimal lifting from the nursery.

CONCLUSIONS

Results of this research show RGP is a genetically controlled trait, and suggests that RGP should be considered in improvement programs as well as in nursery management of loblolly pine seedlings. Genetic selection for improved RGP should be successful and yield seedlings better able to withstand transplanting. If the relationship between RGP and height growth continues beyond the first two years, RGP may be a screening tool for the early selection of superior genetic stock.

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