Dry Matter Accumulation in Twenty Wind-Pollinated Pinus pungens Families from Southwest Virginia

By P. P. Feret, D. Wm. Smith and H. M. Rauscher

(Received June 1, November 1979)

Summary
Twenty wind-pollinated families of Pinus pungens Lamb. were greenhouse grown under two soil types, a Muskingum fine sandy loam and a Groseclose silt loam. Seedling survival and growth were significantly different between soils and significant family effects on survival and growth were also observed. Genotype × environment interaction between families and soil type was also significant. The implications of these results were discussed.

Key words: Genotype-environment interaction, seedling survival, Muskingum, Groseclose.

Zusammenfassung

Introduction
Table-Mountain pine (Pinus pungens Lamb.) is an Appalachian endemic (Little, 1971) usually found on extremely droughty sites of southwesterly exposure. It often occurs in relatively small and scattered populations; the genetic relationship among these populations is ambiguous (Feret, 1974).

In an attempt to understand more of the genetics of P. pungens a greenhouse experiment was established to test genotype-environment interaction of wind-pollinated families grown on different soil materials. It was envisioned the study results might provide insight into the adaptive genetic mechanisms that permit the species to regenerate and grow on extremely poor sites in the Appalachian mountains of Virginia.

Material and Methods
Twenty wind-pollinated families were grown from seed collected and kept separate by mother-tree, from 20 trees growing on Brush Mountain in Montgomery and Craig Counties, Virginia. The elevational range exhibited at parent tree sites was 590—915 meters. All parent trees were growing within a 3 km radius.

Seed was extracted from cones and germinated in replicate petri dishes on filter paper. When cotyledons were developed and primary needles just visible, seedlings were transplanted into plastic 13 cm pots.

Two soil materials were used as a growing medium. Soil one (1) was the A horizon from a P. pungens site on Brush Mountain, VA. The soil is representative of the Muskingum Soil Series and is classified as a fine-loamy, mixed, mesic, Typic Dystrochrept. It is derived from fine sandstone and siltstone and because of the steep slope position it is shallow and quite dry. The natural fertility is low (Table 1) and the mixed pine-hardwood stands that dominate the area are of very poor quality. The second soil material was the surface horizon from a cultivated field in Blacksburg, Va. The soil is representative of the Groseclose series and is classified as a clayey, mixed, mesic, Typic Hapludult. It is a deep, well-drained soil derived from residuum of dolomitic limestone and shale breccia. The soil is common on broad ridges and uplands. It is high in natural fertility (Table 1) and has been modified by agricultural activity. Where the soil has not been disturbed good forest stands of predominantly white oak are prevalent. These two series closely represent the extremes of soils that dominate in the natural range of P. pungens in Southwest Virginia. Both soils were inoculated 8 weeks after seedling transplanting with 8 gm of ground litter root mat from the P. pungens mother tree site.

Plants were grown for 8 months in a replicated design consisting of five blocks, each with three complete replications. Each replication contained forty pots; each pot

| Table 1. Soil analysis data for soil materials used to grow seedlings of Pinus pungens. Characteristics for soil 1 (Muskingum) and soil 2 (Groseclose). |
|-----------------|-----------------|
|                | Soil 1          | Soil 2          |
| ph              | 5.5             | 6.4             |
| Soluble Salts (ppm) | 256             | 269             |
| Elemental Avail (kg/ha) |  |                |
| CaO             | 740             | 2100            |
| MgO             | 151             | 336             |
| P2O5            | 6               | 90              |
| K2O             | 45              | 202             |
| Nitrate (ppm)   | 5               | 25              |
| Organic Matter (%) | 1.5             | 1.9             |
three seedlings. Thus each wind-pollinated family-soil combination was replicated 15 times. Individual seedling values were used for analysis providing 1800 observations, 900 per soil type and 45 per family-soil combination.

Analysis of variance for all data was executed using the SAS, GLM procedure (BARR et al. 1976) and the linear model presented in Table 2.

**Results**

**Survival**. Plant survival was significantly better in Soil 2 than Soil 1. A total of 601 of 900 plants survived in Soil 1, 857 in Soil 2. Chi square analysis of survival by Soil yielded a \( \chi^2 \) of 234.7, significant at \( \alpha = 0.01 \) for 19 df.

An evaluation of family survival rates using chi square analysis yielded significant \( (\alpha = 0.05) \) \( \chi^2 \) values for survival over both soils as well as within Soil 1. For Soil 1 \( \chi^2 = 53.4 \) (19 df); for Soil 2 \( \chi^2 = 31.5 \), a non significant value at \( \alpha = 0.01 \) for 19 df. Survival data and \( \chi^2 \) analyses are listed in Table 3.

**Dry Weights**. Dry weight accumulation was significantly affected by soil and family. Table 4 lists dry weights and the root/shoot ratio for plants in Soil 1 and Soil 2, along with standard deviations, coefficients of variation and variance statistics. Of particular note are the variance statistics, demonstrating that variability among plants in dry weight accumulation was considerably greater in Soil 1 than in Soil 2. For all parameters measured, plants in Soil 1 accumulated less dry matter than those in Soil 2, the “better” soil.

Analysis of variance results are presented in Table 5. The results show that for all measured variables soil type had a significant effect; family effects were also significant except for stem weight estimates. Soil \( \times \) family interactions were significant for all measured variables. However, only family effects were significant for root/ shoot ratios.

**Family-Soil Interactions**. Wind-pollinated families interacted significantly with soil type (Table 5) for all measured variables but not for root/shoot ratio. There were several families which interacted little (e.g. Fig. 1, Family 18), several interacted mildly with a positive or negative response relative to mean plant performance (e.g. Fig. 1, Families 2 and 3) and several exhibited strong interactions (e.g. Fig. 1, Families 20 and 12).

In Table 6 are estimated total dry weights of families in Soil 1 and Soil 2; the results of a Duncans range test (BARR et al. 1976) for each set of means; and rankings for total dry weight accumulation. Of particular note is the fact that Family 20 ranked 1 in total dry weight growing in Soil 1, but ranked 20 in Soil 2. Of the 5 top-ranked families in Soil 1, Families 17 and 11 ranked similarly in Soil 2. Of the 5 lowest-ranked families in Soil 1, 13 and 7 were also among the 5 lowest ranked in Soil 2.

**Discussion**

Survival rates were uniformly high in Soil 2 indicating that experimental techniques were acceptable. Because Soil 2 was a “good” soil relatively little stress was experienced by the plants in that soil. Thus, in the absence of stress and selection pressures, family differences in survival were non-significant. In the native soil, Soil 1, family differences in survival were significant indicating genetic variability in natural populations for this parameter. However, there was no significant rank correlation (GRIFFIN, 1958) between survival and dry matter accumulation indicating that survival and growth are genetically independent.

The significant differences among families in dry matter accumulation coupled with significant soil \( \times \) family inter-
actions provide strong evidence that *P. pungens* local populations contain significant genetic variance to exploit site variability. Although some families were stable in their response to soil type (e.g. families 11, 10, 9, 4, 13, 17) others exhibited marked instability (e.g. families 2, 12, and 29). Although these responses are not without parallel in forestry literature (see Shielburne, 1972), the results do illustrate that relatively small geographic areas contain trees divergent in their genetic constitution and adaptability to particular soils.

The results of this study showing genetic differences among wind-pollinated families in survival on a native soil and showing significant growth variance and site interactions, lends support to a hypothesis that *P. pungens* seedling populations respond genetically to microsite characteristics (Feket, 1974).

The strength of the ability of *P. pungens* to respond genetically to different environments may be further supported by an examination of the ranking of total weight accumulation listed in Table 4. Using Kendall's rank correlation (Griffin, 1958) it may be shown that the rankings are independent sets (α = 0.05). Thus there is probably little "genetic correlation" (Falconer, 1952) among the families on Soil 2 and Soil 1. This suggests that genes important to the species for growth on native soils are different from those important for growth on the non-native soil used here.

**Conclusions**

The results of this study clearly illustrate that for *P. pungens*, genetic variability is large within a relatively local area for survival and growth. Genetic studies of a parallel nature in other *Pinus* species would be desirable to determine if phenomena observed are characteristic of the genus.

**Literature**