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

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(Received June / 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

Zwanzig frei abgeblühte Familien von *Pinus pungens* LAMB. wurden im Gewächshaus auf zwei verschiedenen Bodentypen angezogen: einem feinen sandigen Lehm der Muskingum-Serie und einem tonigen Lehm der Groseclose-Serie. Das Überleben und Wachstum der Sämlinge auf beiden Bodentypen waren signifikant verschieden, ebenso wurden signifikante Familieneffekte auf das Überleben und das Wachstum beobachtet. Die Genotyp x Umwelt-Interaktion zwischen Familien und Bodentypen war auch signifikant. Die Bedeutung dieser Ergebnisse wurde diskutiert.

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 580—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 droughty. 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 *P. 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
P_2O_5	6	90
K_2O	79	202
Nitrates (ppm)	5	25
Organic Matter (%)	1.5	1.9

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Table 2. — Linear Model for GLM analysis of dry matter accumulation in *P. pungens* families grown in two soils.

Linear Model: $Y_{ijkl} = \mu + A_i + B_j(A_i) + C_k + D + C_k * D + E_{ijk}$

Where: Y_{ijkl} = an observation and

A = Block; i = 1, 2, 3....5
B = Replication; j = 1, 2, 3
C = Soil; k = 1, 2
D = Family; = 1, 2, 3....20
E = Error

and: A, B, and D are random; C is fixed

ANOVA

Source	df	Sum of Squares	EMS
A	a-1	R(A/μ , C, D, C*D)	$\delta E^2 + \delta B^2 + \delta A^2$
B(A)	ab-a	R(B/μ , A, C, D, C*D)	$\delta E^2 + \delta B^2$
C	c-1	R(C/μ , A, B, D, C*D)	$\delta E^2 + \delta CD^2 + Q_{(c)}$
D	d-1	R(C/μ , A, B, C, C*D)	$\delta E^2 + \delta D^2$
C*D	(c-1)(d-1)	R(C*D/μ , A, B, C, D)	$\delta E^2 + \delta CD^2$
E			δE^2

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 χ^2 of 234.7, significant at $\alpha = 0.01$ for 19 df.

An evaluation of family survival rates using chi square analysis yielded significant ($\alpha = 0.01$) χ^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 χ^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

Table 3. — Survival by family for Soil 1, 2 & combined data with χ^2 values (calculated from numerical survival counts, not percentage figures given here).

	% Survival		
Family	Combined	Soil 1	Soil 2
1	86.7	75.6	97.8
2	75.6	60.0	91.1
3	72.2	53.3	91.1
4	85.6	71.1	100.0
5	76.7	62.2	91.1
6	95.6	91.1	100.0
7	75.6	60.0	91.1
8	78.9	62.2	95.6
9	78.9	64.4	93.3
10	77.9	68.9	86.7
11	78.9	57.8	100.0
12	72.2	55.6	88.9
13	66.7	37.8	95.6
14	84.4	71.1	97.8
15	84.4	75.6	93.3
16	87.8	77.8	97.8
17	91.1	94.4	97.8
18	84.4	71.1	97.8
19	84.4	71.1	97.8
20	82.2	64.4	100.0
	$\lambda^2 = 53.98$	53.38	31.53
	P = <.01*	<.01*	0.04 NS
	df = 19	19	19
	X = 81.0	66.8	95.2

Table 4. — Total weight and plant part weights, coefficients of variation, variances for all plants growing in Soil 1 (n = 601) and Soil 2 (n = 857).

	WT. (gms. ± 1 std. dev.)		Coeff. of Var (%)		Variance	
	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
Root Wt.	2.48 ± 0.84	2.68 ± 0.33	34	12	0.71	0.11
Top Wt.	2.50 ± 1.06	2.68 ± 0.37	42	14	1.12	0.14
Stem Wt.	1.90 ± 0.26	1.95 ± 0.09	14	5	0.07	<0.01
Needle Wt.	0.60 ± 0.80	0.73 ± 0.29	135	39	0.65	0.08
Total Wt.	4.98 ± 1.88	5.36 ± 0.64	38	12	3.53	0.41
Root/Shoot	1.01 ± 0.09	1.00 ± 0.10	9	10	<0.01	<0.01

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 × 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 negati-

Table 5. — Results of significance tests for effect of soil and family on mean dry weight values and soil X family interaction.

Variable	P>F Soil	P>F Family	P>F Soil X Family
Root Weight	0.0001*	0.0008*	0.0034*
Top Weight	0.0025*	0.0046*	0.0011*
Stem Weight	0.0015*	0.0161NS	0.0035*
Needle Weight	0.0035*	0.0025*	0.0008*
Total Weight	0.0006*	0.0024*	0.0015*
Root/Shoot	0.1301NS	0.0001*	0.1139NS

*indicates significant at α <0.01.

NS = not significant

ve 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).

Listed 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 × family inter-

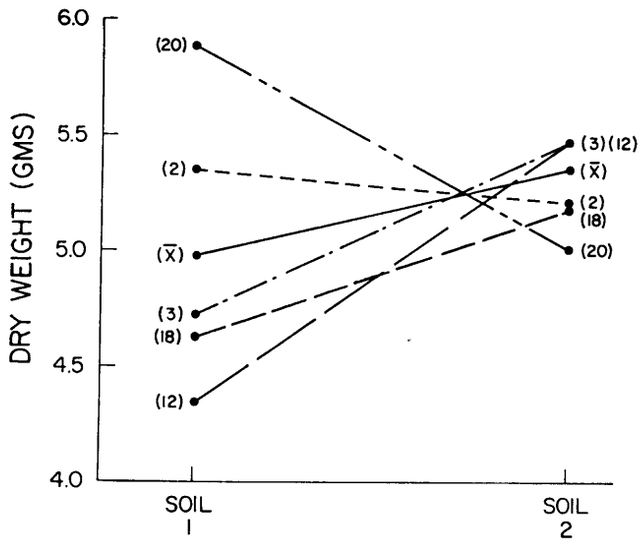

Figure 1. — Illustration of family performance in the two soils used (Soil 1 and Soil 2), showing families interacting relatively strongly [families (20) (— — —) and (12) (— — —), moderately (3) (— — —) and (2) (— — —) and relatively little (18) (— — —) to soil type. Mean performance of all families is represented by (X̄) (————)].

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 20). Although these responses are not without parallel in forestry literature (see SHELBOURNE, 1972), the results do illustrate that relatively small geographic areas contain trees divergent in their genetic constitution and adaptibility 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 (FERET, 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 6.* Using Kendall's rank correlation (GRIFFIN, 1958) it may be shown that the rankings are independent sets ($\alpha = 0.05$). Thus there is probably

Table 6. — Summary of family total dry weight means, Duncan test and rankings in Soil 1 and Soil 2.

Family	Total Dry Wt. (gms)					
	Soil 1			Soil 2		
	(1)*	(2)	(3)	(1)	(2)	(3)
1	5.26	abcd	6	5.51	abc	3
2	5.35	abcd	5	5.21	cdefg	16
3	4.72	abcd	13	5.47	abcde	5
4	4.86	abcd	11	5.40	abcde	9
5	5.39	abcd	4	5.45	abcde	7
6	5.06	abcd	8	5.66	a	1
7	4.63	bcd	16	5.08	fg	19
8	4.42	cd	18	5.34	bcdefg	13
9	5.01	abcd	9	5.44	abcde	8
10	5.00	abcd	10	5.38	abcdef	11
11	5.69	ab	2	5.49	abcd	4
12	4.34	cd	20	5.47	abcde	6
13	4.46	bcd	17	5.19	defg	17
14	5.19	abcd	7	5.25	cdefg	14
15	4.67	bcd	14	5.38	abcdef	10
16	4.36	d	19	5.35	bcdefg	12
17	5.51	abc	3	5.64	ab	2
18	4.63	bcd	15	5.17	efg	18
19	4.79	abcd	12	5.25	cdefg	15
20	5.87	a	1	5.06	g	20

*(1)=dry wt.(gms) (2)=Duncans Test (3)=Rank

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.

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