PHENOLOGICAL VARIATION IN HEIGHT AND DIAMETER GROWTH *IN* PROVENANCES AND FAMILIES OF LOBLOLLY PINE

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Abstract. We present results on the phenology of eight open-pollinated families from each of four different provenances in a trial (on two locations) in southwest Georgia. The provenances are: Atlantic Coastal Plain, Gulf Hammock (FL), Lower Gulf Coast and Upper Gulf Coast. The trees were measured from summer to fall in 1993 and 1994 when the trees were in their fifth and sixth growing seasons.

There was little difference between provenances as to when height growth started in spring, but there were very significant differences for the date of cessation of growth in fall. The fast growing Gulf Hammock provenance grew the longest (till the end of August) while the slowest growing Upper Gulf source was first to stop growing (early August). Provenances were also different for the date of cessation of diameter growth, and the order of cessation was the same as for height. Families within provenances were different for date of cessation of both height and diameter growth.

Keywords: Pinus taeda L., height growth phenology, diameter growth phenology.

INTRODUCTION

There is evidence that phenology of height growth in conifers is under strong genetic control (Hanover 1963, Li and Adams 1993, Mergen et. al. 1964). Diameter growth phenology of Douglas-fir is also moderately heritable (Li and Adams 1994). With regards to loblolly pine, southern sources appeared to have a longer growing season than northern sources (Perry et al. 1966). Height and diameter growth phenology appear to affect cold-hardiness, growth rate (Bridgwater 1990) and possibly wood properties. This paper presents phenology data from a study established to determine how wood properties are affected by the timing of the initiation and cessation of height and diameter growth of juvenile loblolly pine.

MATERIALS AND METHODS

Study Trees

The Early Selection Verification Study of the NCSU-Industry Cooperative Tree Improvement Program, planted in 1989, was used for this research. Details of the study are given in McKeand and Bridgwater (1993) and McKeand and Jett (1993). In the spring of 1991 and the summer of 1992, the two plantings in southwest Georgia (at Cedar Springs, by Georgia Pacific

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Corporation or G-P; and Bainbridge, by International Paper Company or IPCo) were thinned as follows:

- From each of the four provenances (Atlantic Coastal - ACP, Gulf Hammock - GH, Lower Gulf - LG, and Upper Gulf - UG), the tallest 4 families and the shortest 4 families were left, giving 32 families in all.
- About 10 trees were left per family per location as evenly spaced as possible.
- This left about 320 trees per location, 640 total.

Growth Phenology

Total height was measured in February 1993 (the beginning of the growing season). In 1993, total height was measured every two weeks from mid-June till growth stopped in late October. In the spring of 1994, flushing of the trees was observed. Following budbreak, height was measured in May, June and then every three weeks from late July to early October. To accurately measure height, a height pole was placed near each tree and the tip observed from a bucket truck with the aid of 15- to 20-X binoculars. The height pole was placed on a stake driven in the ground next to each tree, minimizing variation in placing the pole.

Dendrometer bands were installed on each tree, in the middle of the first flush originating in the trees' second growing season. In 1993, diameter growth was measured at the same time as height, and also once in November and once in December. In 1994, in addition to occasions when height was measured, weekly measurements were taken from July to the end of September, and also once in October, November and December.

Cessation of growth for a given tree (for both height and diameter) was defined as the Julian day when the tree completed 95% of growth for the season. Analysis of variance was conducted using the GLM procedure in SAS (SAS Institute Inc. 1990). Approximate F-tests were constructed for certain terms (Satterthwaite 1946).

RESULTS AND DISCUSSION

Budbreak and flushing for all the trees took place within a very short period (about a week) in the spring of 1994. Thus it was not possible to observe differences between provenances and families for the date of initiation of height growth. This contrasts with results for Douglas-fir where there were significant differences in date of bud-break (Li and Adams 1993). Our results may perhaps be attributable to the mild climatic conditions prevalent at the two sites.

Provenances were significantly different for all three traits analyzed (Table 1). Averaged over both years, the Gulf Hammock (north Florida) provenance finished 95% of the season's height growth 20 days later than the Upper Gulf Coast provenance. The difference was about the same for diameter growth in 1994. Total height is plotted for provenance means, by site, for 1994 (Figure 1) showing GH to continue growing longer in the fall and UG slowing down relatively early. Tests planted by the NCSU-ICTIP have shown the GH source to be consistently fast in growth. Provenance variation in height growth phenology has been reported previously (Hanover 1963, Perry et al. 1966).

Families within provenances were significantly different for the length of growing season. For height growth averaged over both years, the range was from 247.9 days (family 22-29, GH) to 211.8 (8-503, UG) (Table 2). The longest season for diameter growth also was from GH (22-27, 302.6 days) and the shortest from UG (8-526, 276 days). Annual height increment was

significant at the 10 % level (p=0.0516).

Thus provenances and families which continued height growth longer tended to continue diameter growth longer as well. Diameter growth continued about two months longer than height growth, which implies that if latewood begins to be formed after cessation of height growth (eg. Larson 1969), all four provenances have about the same period for latewood formation. Families which grew most in height tended to have longer growing seasons, and the family which grew least in height was the first to reach 95e of the season's diameter growth.

With respect to differences between **years**, height growth seemed to slow down earlier in 1994 than in 1993 (about 10 days) although on average the trees grew about 40 cm. more in 1994. 1994 was a very wet summer while there was a pronounced dry spell in July-August 1993. The fact that the trees were one year older may have contributed to the earlier transition although it was probably not the only factor. Most of the second and third order interactions were not significant.

CONCLUSIONS

Differences in the length of the growing season explained part of the difference in growth rate among provenances of loblolly pine, with faster-growing provenances tending to grow longer in the fall. Cessation of diameter growth took place in the same order as for height growth, and occurred about two months later. In continuation we are evaluating wood samples from this study to see how variation in height and diameter growth phenology affect wood formation, especially the proportion of latewood.

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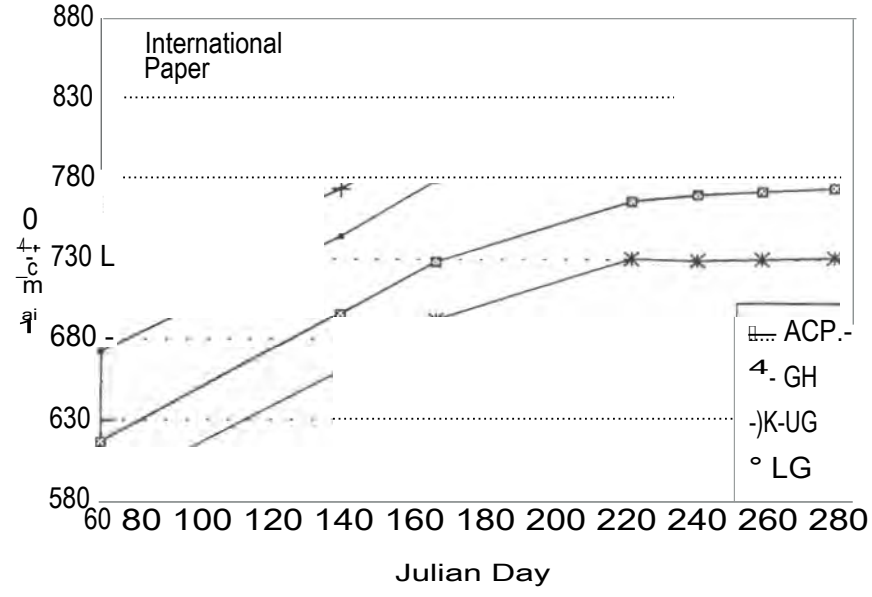
Table 1. Analysis of variance for three traits: Height increment and Julian days to complete 95% of season's height growth (for 1993 and 1994) and Julian days to complete 95% of season's diameter growth (for 1994)

		Annual Height increment (cm)	Julian Days to complete 95% of season's height growth
Source	DF	Prob>F	
Location	1	0.3632	0.2884
Block(location)	32	0.0001	0.0571
Year	1	0.1729	0.0126
Provenance	3	0.0137	<0.0001
Family(Provenance)	28	0.0516	0.0005
Year*Provenance	3	0.2797	0.8071
Year*Location	1	0.0018	0.4665
Year*Family(provenance)	28	0.2552	0.6456
Location*Provenance	3	0.2902	0.4546
Location*Family(Prov.)	28	0.5407	0.4682
Location*Year*Prov.	3	0.6856	0.5332
Location*Year* Family(Provenance)	28	**0.0174**	0.7370
Error	1144		

		Julian days to complete 95% of season's diameter growth
Source	DF	Prob>F
Location	1	.1238
Block(location)	32	.0001
Provenance	3	.0072
Family(Provenance)	28	.0003
Location*Provenance	3	.0001
Location*Family(Prov.)	28	.6248
Error	626	

Table 2. Least squares means for 1. Annual height increment in cm. 2. Number of Julian days to complete 95% of season's height growth and 3. No. of Julian days to complete 95% of season's diameter growth. Means for year, location, provenance and family(provenance). Traits 1 and 2 for 1993 and 1994, trait 3 for 1994 only

		Height Increment	Days (Height)	Days (Diameter)
Location				
GS		125.01	228.18	291.33
IP		143.22	229.9	286.88
Year				
93		113.34	234.21	
94		154.89	223.87	
Provenance				
ACP		142.84	233.07	290.89
GH		138.52	240.1	299.42
IC		126.34	218.68	279.14
LG		128.76	224.32	286.98
Family	**Proven.**			
5063	ACP	148.01	226.98	289.13
5065	ACP	135.63	232.51	288.04
7002	ACP	152.19	236.58	292.71
7004	ACP	138.27	226.78	293.49
7034	ACP	143.04	229.38	292.55
7056	ACP	149.8	236.04	297.25
7058	ACP	142.22	236.25	286.35
11009	ACP	133.57	240.04	287.56
22001	GH	135.19	241.59	302.15
22004	GH	134.81	240	299
22027	GH	137.96	241.83	302.57
22029	GH	149.4	247.87	299.42
22030	GH	140.27	244.56	300.7
22031	GH	137.09	232.23	295.91
22032	GH	135.87	237.99	296.24
22034	GH	137.55	234.74	299.36
8503	UG	131.11	211.79	277.79
8509	UG	124.8	221.94	281.56
8526	UG	123.87	212.01	276.02
12008	UG	141.53	227.99	283.19
17016	UG	126.94	215.38	283.92
17044	UG	134.12	229.89	283.53
19002	UG	111.66	214.83	270.6
19016	UG	116.71	215.58	276.47
17004	LG	123.35	218.2	277.95
17019	LG	114.56	229.58	286.27
23026	LG	129.22	219.9	284.08
23028	LG	133.41	221.4	287.2
24001	LG	137.54	223.69	291.85
24002	LG	135.08	228.67	291.05
24004	LG	127.04	220.06	289.49
24009	LG	129.89	233.08	287.98



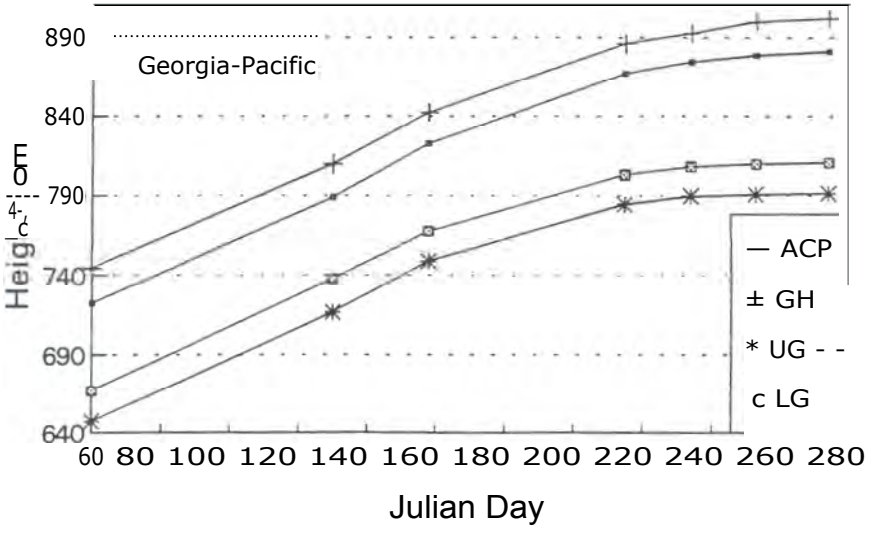


Figure 1. Total height by provenance, by site, during the 1994 growth season. (ACP = Atlantic Coastal, GH = Gulf Hammock, UG = Upper Gulf, LG = Lower Gulf).