Comparative Physiology of Contrasting Genotypes of Loblolly Pine Under Dry Field Conditions

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INTRODUCTION

In this field study, effects of root and shoot genotypes on leaf physiology of loblolly pine (*Pinus taeda* L.) seedlings were evaluated and related to biomass production. A primary objective was to show whether physiological performance of different genotypes could be associated with productivity differences, when grown in a droughty environment. Productivity differences of these contrasting genotypes have been previously described and were related to biomass allocation among tree parts, especially to roots (Grissom and McKeand 1999). Differences in biomass allocation and production can be important, so understanding physiological origins and influences of root:shoot allocation within the tree may be informative. Such physiological properties may be particularly valuable if they can be used to detect genotypic differences in stemwood production, which may persist over time.

METHODS

Twelve-week-old seedlings from contrasting provenances were grafted reciprocally to facilitate distinction of rootstock and scion effects. Five open-pollinated families each from a mesic region (Atlantic Coastal Plain) and from a xeric region (Lost Pines Texas) were used. In January 1998, seedlings were planted in a split-plot design on a nutrient-poor site in the Sandhills region of central North Carolina. A total of 1800 seedlings were used, including ungrafted trees as controls. Half of the plots were fertilized annually, and after one and two growing seasons, seedlings were harvested for component biomass determinations. Stem growth efficiency was calculated on a family mean basis as stem mass increment divided by foliage mass at the final harvest.

Effects of root system genotype on leaf physiology of selected families were evaluated and related to whole-plant growth of genotypes. In four families (two from each provenance), midday light-saturated net photosynthesis (A_n) and stomatal conductance to water vapor (g_s) were measured monthly during the summer of 1999. Leaf carbon isotope discrimination (Δ) was analyzed for estimation of long-term water use efficiency (WUE) of genotypes (Farquhar et al. 1982).

RESULTS

During the summer months of 1999 at the field site, weather conditions were characterized by below-average rainfall and above-average air temperatures. Rainfall from May through August 1999 was 40% below normal (20.1 cm actual/ 33.3 cm average) for central North Carolina. Water vapor pressure deficits (VPD) measured on sample trees exceeded 3.0 kPa during late July and August.

Table 1. Means of leaf gas exchange parameters, using the non-grafted and self-grafted seedlings measured over five sample dates from July through September 1999. Means in bold print and followed by lowercase letters denote significant difference between provenances at α=0.05 level. Numbers in parentheses are standard errors of the mean.

Prov.	N	A_n	g_s	A/g	C_i/C_a
Mesic	66	5.73 (0.23)	**47.2** b (2.57)	**0.130** a (0.004)	**0.548** b (0.034)
Xeric	67	5.81 (0.19)	**50.0** a (2.28)	**0.123** b (0.004)	**0.601** a (0.034)

***A_n*- net photosynthesis, *A/g*- intrinsic WUE, *Ci/C_a*- intercellular CO_2 to ambient CO_2, *g_s*- stomatal conductance to water vapor.

Combining data over all sample dates, the two provenances differed in stomatal conductance rates (g_s) but not in net photosynthetic rates (A_n) (Table 1). The mesic families had lower g_s and higher intrinsic WUE (WUE_i; A_n/g_s). The mesic sources also exhibited lower intercellular CO_2 concentrations (C_i), when averaged over all months. Stomatal limitation to photosynthesis accounted for a large percentage, ranging from 40% to 70% among family means on sampling dates.

In the grafting portion of the experiment, rootstock effect was significant on g_s but not A_n, averaged over all sample dates. Xeric rootstocks were associated with reduced g_s of mesic scion (Table 2). Rootstock effect on WUE_i (A_n/g_s) was not significant. Rootstocks had a large effect on C_i, where the lowest C_i was found when the xeric rootstock was combined with mesic scion. It was evident that stomatal behavior was pre-conditioned by factors inherent with root genotype.

Table 2. Means of leaf gas exchange parameters of grafted seedlings measured over five sample dates, July through September 1999. Means in bold print denote significant difference between rootstocks for a given scion type at α=0.05 level.

Scion	Rootstock	N	A_n	g_s	A/g_s	C_i/C_a
Mesic	Mesic	59	5.47	**39.8** a	0.143	**0.42** a
Mesic	Xeric	41	4.99	**33.6** b	0.151	**0.33** b
Xeric	Mesic	50	5.22	**39.6** b	0.141	**0.41** b
Xeric	Xeric	65	5.50	**43.7** a	0.136	**0.46** a

Xeric rootstocks were also associated with lower leaf ^{13}C discrimination (Δ) (P<0.01). The stronger rootstock effect on Δ than on WUE_i concurs with that reported by Sylvertsen et al. (1997) in a grafting study comparing effects of *Citrus* rootstocks. The lower Δ and the lower C_i both suggest a higher long-term WUE associated with the xeric rootstocks. In terms of scion effect, the mesic scions were associated with lower Δ (P<0.01). Rootstock by scion interaction was not significant for Δ (P>0.10).

Degree of correlation between leaf Δ and WUE_i depended on the degree of relatedness between genotypes grafted as scion and rootstock. Within-provenance grafts showed the expected negative correlation between Δ and WUE_i (R=-0.67, P<0.01), but between-provenance grafts showed no such trend (R=0.10). This finding bolstered the claim that root genotype can substantially influence physiological performance in leaves.

Leaf tissue Δ was related to stem growth efficiency (GE) and to root mass among families. Linear correlation between Δ and stem/foliage mass ratio was –0.46, and correlation between Δ and root biomass was +0.51, among families (Table 3). The opposite-signed correlations suggest a trade-off between allocation to stem and roots, the balance of which depends heavily on root genotype.

Table 3. Linear correlation coefficients between leaf Δ, gas exchange variables, and biomass component traits for grafted families (N=16 observations for each R value). Values in bold print are significant at the α=0.10 level.

Trait[1]	Δ (^{13}C)	A_n/g_s	g_s	A_n
Mass	+0.32	+0.02	-0.18	**-0.48**
SMR	**-0.46**	n.s	n.s.	n.s.
RMR	n.s.	n.s.	**+0.59**	**+0.70**
RtMass	**+0.51**	n.s.	n.s.	n.s.

[1] Mass- Total biomass, SMR- stem/foliage mass ratio (~growth efficiency), RMR- root mass ratio (root/total mass), RtMass – root biomass.

In this study, low leaf Δ was associated with high GE and low root mass allocation, though not strongly related to total biomass production. The results show that root system genotype can substantially affect certain aspects of leaf physiology, which can have large impacts on tree growth. The findings may have utility in genotype selection and breeding for environments where water intermittently or chronically limits tree growth.

REFERENCES

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