Genotype x environment interactions for growth and wood traits for eucalyptus hybrids

Gilles Chaix[1], M. Denis[2], J. Polidori[3], P. Vigneron[4], G. Makouanzi[5], Abdoulaye Diombokho[6], Sophie Nourissier[7], Jean Marc Bouvet[8]

Background

Forest trees are long-lived organisms and the expression of genes in relation to age and competitive environment is likely one of the most important features to consider in tree genetics and tree breeding. If genetic of growth traits is well known in eucalyptus, the understanding of genetic control for wood traits needs some additional experimental data. In this work, based on one experiment including full-sib families of two eucalyptus hybrids planted at two contrasted densities, two specific questions are asked:

(1) Genotype x environment interactions are lower for wood traits than for growth traits.

(2) Heritability of growth and wood traits are affected by the environment effects as tree density

Methods

Data were obtained from one field trial established in the Republic of the Congo in the experimental area of the "Centre de Recherche et de Developpement des Plantations Industrielles". The climate is tropical humid with a mean annual temperature of 24°C, a mean annual rainfall of 1,200 mm and a dry season from May to October.

The R90-13 experiment used a set of 6 hybrid families created by controlled pollination of different unrelated parent trees : 6 families of *Eucalyptus urophylla* x *E. pellita* and 6 families of *E. urophylla* x *E. grandis* planted in 1991 at two spacing 2 m x 2 m (2,500 trees/ha) and 4 m x 4 m (625 trees/ha).

Within each density, the experiment was a complete block design with a 36-tree square plot in three replicates. To minimise the impact of competition between

[1] gilles.chaix@cirad.fr, Cirad, UMR AGAP, F-34398 Montpellier, France
[2] marie.denis@ciard.fr, Cirad, UMR AGAP, F-34398 Montpellier, France
[3] joelpolidori@yahoo.fr, Cirad, UMR AGAP, F-34398 Montpellier, France
[4] philippe.vigneron@cirad.fr, CRDPI, Republic of the Congo
[5] garelmak@yahoo.fr, CRDPI, Republic of the Congo
[6] diombokho@yahoo.fr, Cirad, UMR AGAP, France
[7] sophie.nourissier-mountou@cirad.fr, Cirad, UMR AGAP, France
[8] jean-marc.bouvet@cirad.fr, Cirad, UMR AGAP, France

plots, only the 16 inner trees were measured.

Data of circumference at breast height and total height were extracted from data base for growth traits each two years, starting at 12 months to 86 months. Chemistry related traits: Klason lignin, cellulose, S on G ratio, and extractive values were assessed by Near Infrared Spectroscopy (NIRS) predictions based our own calibrations.

Analyses of family by spacing interaction were performed at the individual level, using the following mixed model with ASREML package on R statistical programming language (R Development Core Team 2010):

$$y_{ijklm} = \mu + h_i + d_j + h*d_{ij} + b(d)_{kj} + f(h)_{li} + f(h)*d_{lij} + f(h)*d*b_{ijkl} + r_{ijklm}$$

where y_{ijklm} is the m^{th} tree in the l^{th} family in the k^{th} block in the i^{th} hybrid in the j^{th} density

μ is the overall mean,

h_i is the fixed effect of the i^{th} hybrid,

d_j is the fixed effect of the j^{th} density

$h*d_{ij}$ is the fixed effect of the interaction between the i^{th} hybrid and the j^{th} density,

$b(d)_{kj}$ is the random effect of k^{th} block in the j^{th} density with variance σ^2

b(d) and mean 0,

$f(h)_{li}$ is the random effect of the l^{th} family in the i^{th} hybrid with variance σ^2

f(h) and mean 0,

$f(h)*d_{lij}$ is the random effect of the interaction between the l^{th} family in the i^{th} hybrid and the j^{th}

density with variance of σ^2

f(h)*d and mean 0,

$f(h)*d*b_{ijkl}$ is the random effect of the interaction between the l^{th} family in the i^{th} hybrid and the j^{th}

density and the k^{th} block with variance of σ^2

f(h)*d*b and mean 0,

r_{ijklm} is the residual random effect, with variance of σ^2

r and mean 0.

Broad-sense family heritabilities were estimated by variance component using the following model:

$y_{ijkl} = \mu + h_i + b_j + f(h)_{ik} + r_{ijkl}$

where y_{ijkl} is the mth tree in the k^{th} family in the j^{th} block in the i^{th} hybrid

μ is the overall mean,

h_i is the fixed effect of the i^{th} hybrid,

b_j is the fixed effect of j^{th} block,

$f(h)_{ik}$ is the random effect of the k^{th} family in the i^{th} hybrid with variance σ^2 f(h) and mean 0,

r_{ijkl} is the residual random effect, with variance of σ^2 r and mean 0.

Results discussions

The family*density interactions were significant for growth traits after 12 and 35 months,respectively for height and circumference (Table1). However for wood traits, there was no family*density interactions. Wood traits seemed not affected by competition. The variation level for wood traits (generally the coefficients of variation were less than 20-25%) was lower than for growth ones.

Hybrid *E. urophylla* x *E. pellita* showed higher family variances (10 times) for wood traits than for *E. urophylla* x *E. grandis* (Table 1). However this trend was not observed for growth traits. In terms of wood traits E. urophylla was closer to E. grandis than to *E. pellita*. Recombination between *E. urophylla* x *E. pellita* could be one source of higher variability.

The Figure 1 showed the trend of heritability of growth from 12 to 86 months and the heritability of wood traits at 222 months. Heritability of height decreased

Table 1. Results of analyses of variances for each hybrid (Hybrid1: *E. urophylla* x *E. pellita*, Hybrid 2: *E. urophylla* x *E. grandis*) for circumference and height at different ages and for wood traits (in gray significant family x density interactions)

Traits	Age (months)	Family		Family*density interaction		Plot	Residual
		Hybrid 1	Hybrid 2	Hybrid 1	Hybrid 2		
Height	12	0.251	0.383	0.000	0.016	0.154	0.630
	35	1.039	1.335	0.000	0.431	0.131	3.474
	58	0.569	1.327	0.474	0.972	0.160	7.476
	86	0.016	1.578	1.169	1.441	0.000	10.830
Circ.	12	0.316	0.432	0.000	0.000	1.871	7.142
	35	0.920	1.687	0.629	1.767	0.683	31.120
	58	0.000	1.435	4.599	4.808	0.000	66.660
	86	0.000	2.295	8.780	5.919	0.000	98.944
Lignin		0.161	0.016	0.000	0.000	0.029	0.264
SG ratio		1.144	0.104	0.000	0.000	0.656	2.838
Cellulose		1.230	0.090	0.069	0.015	0.000	2.929
Extractives		2.533	0.867	0.046	0.000	0.067	2.619

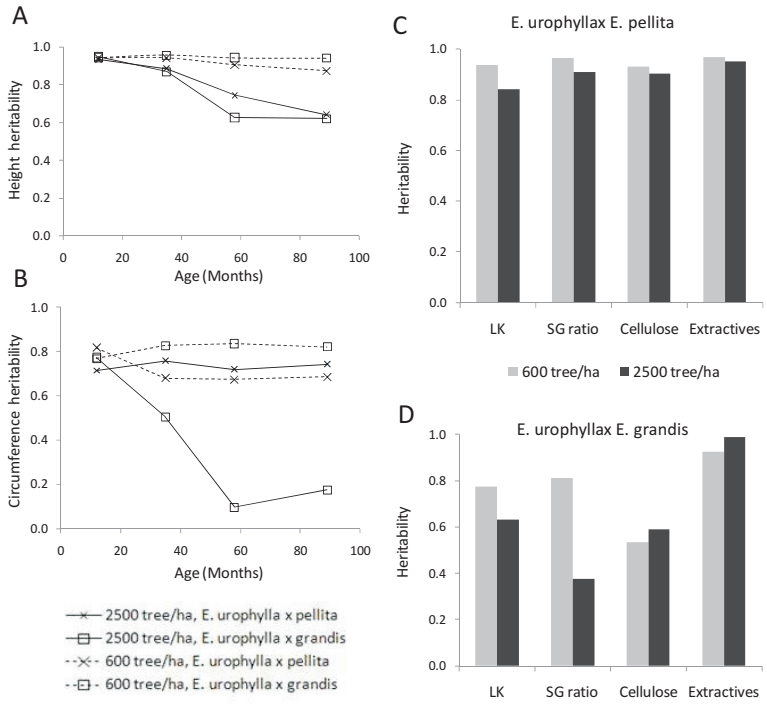

Figure 1. Trend of growth trait heritabilities and heritabilities of wood traits - A and B variation of heritability with age for growth traits (A : Height, B : Circumference), C and D heritabilities of wood traits (C: *E. urophylla* x *E. pellita*, D: *E. urophylla* x *E. grandis*)

with age for the high density, whereas low density heritability was stable up to 86 months (Figure 1A). The trend of circumference heritability for high density depended of the hybrid (Figure 1B). For *E. urophylla* x *E. pellita* there was no effect. However for hybrid *E. urophylla* x *E. grandis* heritability decreased dramatically. Heritability of wood traits depended of the hybrid and the density (Figure 1C and 1D). Independently of traits, the values were lower for *E. urophylla* x *E. grandis* than *E. urophylla* x *E. pellita*. The effect of density was higher for this hybrid.

The sensibility to the competition for *E. urophylla* x *E. grandis* hybrid seemed to be higher than the other one. But this sensibility did not appear for height. This was linked to the different functioning under competition of apical meristem and the cambium.

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