GENOTYPE X ENVIRONMENT INTERACTION OF THE UROGRANDIS HYBRID OF EUCALYPTS IN WESTERN VENEZUELA

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Abstract:-- In Western Venezuela Smurfit Carton de Venezuela is developing clonal plantations with the urograndis hybrid of eucalyptus *(Eucalyptus grandis* x *Eucalyptus urophylla)* to supply wood for pulp and paper. These plantations provide a good opportunity for evaluating whether genotype performance varies by site type. Four trials were established in 1996 to evaluate the performance of 16 different clones of urograndis in three physiographic zones. Evaluations of volume per hectare were done at 16, 23 and 28 months of age. Results showed large genotype x site interaction, with most of the interaction attributable to specific clones at the different ages. Few clones were stable and they were average performing clones across sites. At 28-months of age the best three clones in each site outperformed the check-lots from 71% to 152% in volume. These results suggest that greater research effort needs to be done in order to find the cause of the interaction and find the best clone-site match. If the advantage of genotype-environment interaction is to be used, the clonal program must reflect it producing the genotypes needed for each type of environment. The use of stable clones in this trial series would have resulted in less growth and reduced genetic gain.

Keywords: Urograndis, yield, clonal forest, genotype-environment interaction.

INTRODUCTION

Since 1982, forest plantations have been developed in western Venezuela to supply wood for pulp and paper. Several species of eucalypts and some eucalypt hybrids have been tested in different soil conditions to assess their adaptability and productivity. The urograndis hybrid of eucalyptus *(Eucalyptus grandis* x *Eucalyptus urophylla)* along with the pure species of *Eucalyptus urophylla* S.T. Blake have shown the most satisfactory results in Venezuela (Rosales, 1997) and other countries (Wright and Osorio, 1996; Wright 1997a,b). Smurfit Carton de Venezuela (SCV) has the major area planted with eucalypts in western Venezuela with 8868 hectares as of 1998. A major clonal program with the urograndis hybrid and *E. urophylla* has been developed by SCV in order to increase the productivity and homogeneity of its paper products. After several years of selection and clonal screening, in 1996 SCV made the decision to use clonal material on 50% of the total annual plantation of eucalypts. Along with this change, considerable effort has been devoted to understanding soils in the area for site matching and commercial deployment of the different clones included in the clonal program.

A site classification system is being developed in order to better understand the soil and climatic limitations for eucalypt plantations. Four physiographic zones; piedmont, mesas, high llanos and low llanos, have been identified in the area where SCV is planting.

Piedmont has been classified as that area with hills and slope greater than 15%. The soils of this area have been classified as belonging to the entisols, inceptisols, and to some extent ultisols. The majority of this area has been severely eroded and the previous use has been mostly for cattle grazing. **Mesas** are defined as that area with flat-topped hill with cliff-like sides. The soils in this area belong mostly to the ultisols and inceptisols orders. The previous use was grazing and secondary woody plant vegetation (Chaparrals). **High nano** is that area with less than 15% of slope and soils derived mostly from alluvial deposits. The soils are well-drained ultisols, alfisols and inceptisols. Most of the high llanos had been

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used for grazing and to a lesser extent agriculture. The low **llanos zone** is represented by areas with poor drainage. Vertisols, alfisols and to some extent, ultisols are found in this area. Floods are common in the low ilanos so drainage and bedding are require obtaining acceptable tree growth. This area had been mainly used for grazing and crop production such as sugarcane. The distribution and mean temperatures and precipitation are similar across sites.

The site types diversity, due mainly to soil conditions, have tremendous impact on productivity of eucalypt plantations. This is why SCV has decided to test a group from the high yielding clones on those four physiographic zones and thus select those clones better adapted to each area for deployment.

Selection of genotype is the primary objective of conducting multi-environment tests and must guide the selection of analytical methods. As simply stated by Matheson and Cotterill, 1990, genotype-environment interaction (GxE) occurs when genotypes perform differently in different environments. That is, the differences between genotypes are not the same in different environments. Much of the work on GxE has been directed at establishing whether the interaction is significant or not, but these statistical statements do not specify whether any of the significant interaction has biological importance (Robertson. 1959) or will have financial impact. Because of the relative importance of GxE in forest tree breeding programs, it has been reviewed by many authors such as Baker, 1988; Cooper and DeLacy, 1994; Shukla, 1972; Howard, 1997; Matheson and Cotterill, 1990, among others. The objective of this paper is to present the results of the four GxE trials established in 1996 in Western Venezuela with clones of the urograndis hybrid of eucalypts.

MATERIALS AND METHODS

In 1996 the first set of four genotype vs environment interaction (GxE) trials were established in three physiographic zones were SCV has plantations. Sixteen different clones from the high yielding group were planted on each site. Seedlings of *E. urophylla* from two seed sources in Brazil, Aracruz (UA) and Ripasa (UR) were used as check lots. These seed sources were used by SCV for commercial plantations. Additional seedlots of the hybrid (HIB) and a clone of *E grandis* Hill. ex Maiden (4610) were also put in the trials as check lots.

A total of 20 treatments (16 clones and four check lots) were established in a complete randomized block design with three replications, each using square plots of 25 trees. One trial was established in each of the mesas and high llanos while two trials were established in two different locations within the low llano zone (Table 1). Measurements of diameter and height in the 3x3 central trees of each plot were

Table 1. Summary of location and soil characteristics of the different trials

Test code	Farm name (Physiographic zone)	Latitude N Longitude W	Elevation M	Percentage of particle Size			Soil pH
				Sand	Silt	Clay	
031801	El Toco (Mesa)	9°17' 69°30'	300	50	23	27	3.98
031802	La Cabaña (High llanos)	9°20' 69°21'	180	40	36	24	3.58
031803	Garachico (Low llanos)	9°34' 69°45'	160	39	44	17	4.54
031804	Garachico (Low llanos)	9°34' 69°45'	160	17	62	21	4.48

done at 16, 23 and 28 months of age. Volume without bark per hectare was calculated on a plot mean basis as the trait of greatest importance for the statistical analysis.

The linear model used for the statistical analysis was:

$$Y_{ijk} = u + S_i + B(S)_{ik} + G_j + GS_{ij} + E_{ijk} \quad (1)$$

Where:

Y_{ijk} : the plot mean observation
u : the overall mean
S_i : the random effect of the i^{th} site
$B(S)_{ik}$: the effect of the k^{th} block within i^{th} site
G_j : the effect of the j^{th} genotype (Clone)
SG_{ij} : the effect of the interaction of the j^{th} genotype in the i^{th} site
E_{ijk} : the residual variation contributed by the k^{th} block of the j^{th} genotype within i^{th} site.

The derived volume per hectare at each of the three ages was analyzed individually to determine how the trait of interest changes with time (Figure 1); however, the last inventory was used to draw final conclusions. Duncan's range tests were performed to determine mean differences among clones and sites.

The GxE interaction when significant was further analyzed using the methodology proposed by Shukla (1972). This method estimates a component of the GxE interaction corresponding to each genotype, thus giving a better measure of the genotype stability. Shukla (1972) calculated the genotype stability as the sum of two components, the within environment variance (error term) and between environment variance of the j^{th} genotype, after correcting for the additive common effect of the environment S. This is called stability variance of the i^{th} genotype. Shukla defines a genotype as stable if its stability variance is equal to within environment variance (error term), which means that the between environment variance of the j^{th} genotype is zero. Relatively large values of stability variance will indicate more instability of genotype.

RESULTS AND DISCUSSION

Yield curves for the overall genotypes mean within site is shown in Figure 1. Yield over time varied dramatically by site with mesa and high llanos sites showing similar high yields and the two low llanos sites having low yields. However, low llanos I and low llanos II are diverging, after the 23th month of age, performing better in low llanos I. The Duncan multiple range tests done for volume also show the differentiation of the two locations within the low llanos sites (Table 2).

When the data from each site were analyzed together, the analysis of variance for yield showed no statistical significance among clones for all three ages (Table 3). This is due to the large GxE interaction of these clones which indicates that the clones used in this analysis are performing differently on each site. Rank changes were evident from site to site, although there were some clones that appeared to be stable across sites (Figure 2). Abrupt changes in ranking are represented by solid lines, which give an idea of the,interaction of these clones with the site. Dotted lines represent those clones with the lowest stability variance (more stable clones across sites).

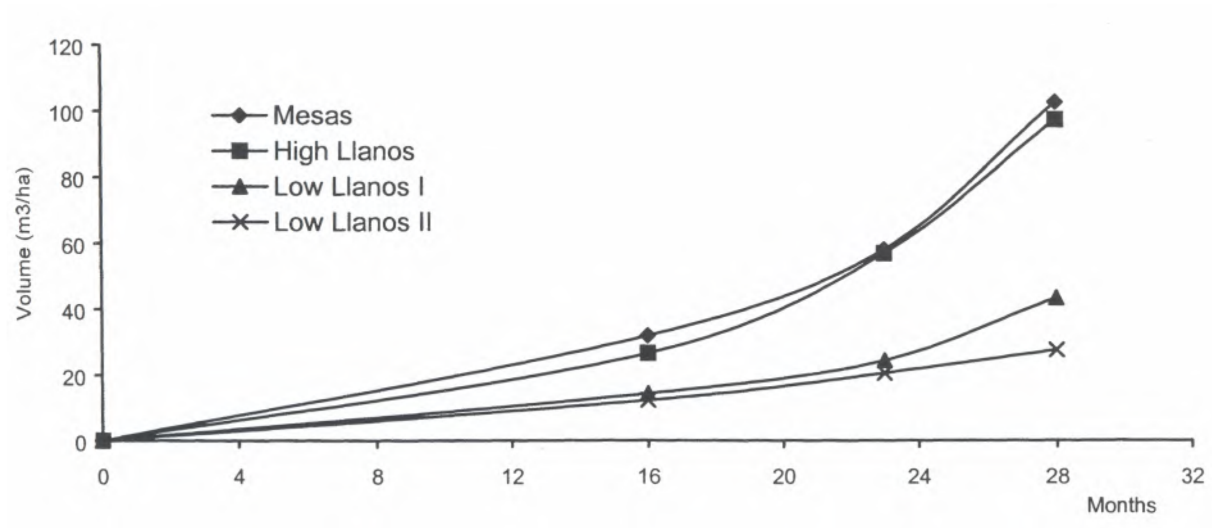

Figure 1. Yield curve for the overall mean of 16 different clones of urograndis growing in four differen sites in western Venezuela.

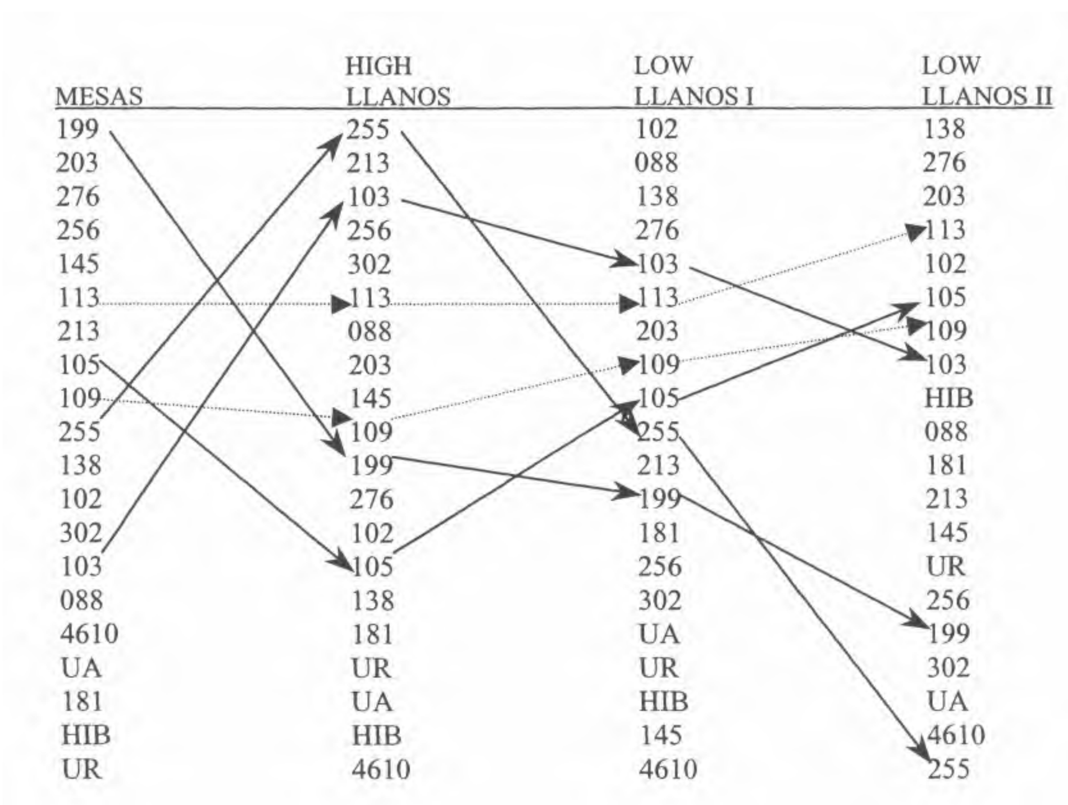

Figure 2. Rank changes of the 16 clones of urograndis and the four check lots growing in four differen sites. Arrows with the dotted line indicate stable clones, and solid indicate non-stable clones.

Table 2. Duncan multiple range tests for volume per hectare without bark of urograndis clones at different ages in Western Venezuela.

	AGE (months)		
	16	23	28
Sites	Volume without bark per hectare (m^3 / ha)		
Mesas	31.95 a	58.11 a	102.52 a
High Llanos	26.64 b	56.92 a	97.31 a
Low Llanos I	14.38 c	24.46 b	43.41 b
Low Llanos II	12.32 c	20.64 b	27.67 c

a,b,c Duncan groups

Table 3. Analyses of variance and stability variance for volume per hectare without bark of 16 clones of urograndis at 16, 23 and 28 months of age. * Statistical significant $p< 0.05$ ns: not significant

Source of variation	Ages					
	16		23		28	
	Mean Squares					
Site	4231.08	*	19427.96	*	66934.77	*
Block (Site)	66.90	*	322.93	*	994.74	*
Clones	41.11	ns	117.70	ns	400.08	ns
Site*clones	48.25	*	174.25	*	579.12	*
Heterogeneity	73.42		229.82		863.48	
Balance	35.67		146.46		436.95	
088	16.18		108.00		614.21	
102	7.80		59.25		132.28	
103	39.74		265.68	*	918.99	*
105	38.53		351.50	*	713.06	
109	8.44		9.88		1.98	
113	0		0.00		15.84	
138	33.04		35.76		279.50	
145	23.26		178.91		642.66	
181	23.40		28.46		13.70	
199	15.35		152.39		676.65	
203	0		25.16		232.52	
213	1.54		26.84		187.16	
255	278.81	*	983.21	*	2130.99	*
256	1.76		0.73		1.86	
276	85.47	*	121.03		720.05	
302	0		61.23		406.33	
Error	22.617		75.48		241.51	

The stability variance calculated for each clone indicated that 2 out of the 16 clones were contributing to the significance of GxE at 16 months of age (Table 3). However, for the 23-month data three clones were unstable. For the 28-month data, the number of clones contributing to the significance of the GxE increased to five clones though only clone 255 contributed to GxE at all three ages. These results suggest that the number of clones contributing to the GxE increase as the stand develops; however further analysis with data at older ages must be used to confirm this trend. A second indication is that older trials are required to determine which clones are contributing to GXE in order to utilize this information in operational deployment.

From those clones with low stability variance, such as 109, 113, 181, and 256, only clone 113 performed well enough across sites to be considered a "plastic clone" for deployment. All of the other clones vary in their performance or simply do not grow well when planted in different sites. This indicates that selection and deployment of stable clones will result in lower growth rates for these hybrid clones and species on these sites.

The high GxE present suggests a major change in the SCV clonal program. As can be seen from Figure 2, the clones that can be deployed in each physiographic zone are different. This implies that the selection of the clones for the clonal program must be based on a thorough screening of all of them across sites. If a group of "plastic clones" can not be found, that is a group of clones that perform well across sites (stable clones), then the clonal program must be partitioned so that it can provide clones for each physiographic zone. Another approach would be to find the cause of the GxE and ameliorate it as an attempt to increase the stability of those clones.

As mentioned by Zobel and Talbert (1984) when the GxE is ignored, large production losses in operational forestry can result. Table 4 presents the average volume per hectare of the best three clones in each site and the average of the two check-lots (UA and UR) used by SCV for commercial plantation. By using the best performing clones in each site, the increment at 28 months of age reached 71, 72, 137 and 152% in volume per hectare above the mean of the two check-lots. Clonal gains in volume were larger on the sites with lower productivity and it is important to remember that the seedling checklots were from seed orchards in Brazil. If the GxE is properly managed, there is, then, a tremendous opportunity for SCV to increase productivity.

The deployment of different clones in different sites as suggested by Table 4 carries, however, large cost due to the greater number of tests that are needed in order to find the best clone for each site. The management of the clonal gardens also must be taken in to consideration according to the number of clones that can be deployed and the fraction of the area from each site to be planted anually (Weright, 1997a,b; 1995).

Table 4. Volume per hectare without bark and outperform made for the best three clones of urograndis as compared to the seedling check-lots at 28 month of age in four physiographic zones in Western Venezuela.

	Yield[1] (m^3/ha)			
	Mesas	High Llano	Low Llano I	Low Llano II
Best 3 Clones	119.2	123.3	54.3	40.6
Avg. of stable clones	106.1	98.2	46.8	33.1
Check-Lots	69.7	71.8	22.9	16.1
Performance above stable	12%	25%	16%	23%
Performance above check-lots'	71 %	72 %	137 %	152 %

[1]Yield (m^3/ha)
[2]Average of the two check-lots (UR and UA) used for SCV in commercial plantation.
'Percent gain of the average when the best three clones are planted as compared to the check-lots

CONCLUSIONS

1. Large GxE interaction was found for the 16 clones of the urograndis hybrid tested in the four physiographic zones where SCV has plantations.
2. The GXE interaction was attributable to different numbers of clones at different ages. The number of clones contributing to the significant GxE increased from two to five at 16 and 28-months of age, respectively. The clone 255 was unstable at all ages.
3. The lack of stable (plastic) clones that perform well in each physiographic zone suggests more testing in order to find the best match of clone to site. For the Company to use the advantages of the GxE the clonal program must move toward producing separate groups of clones for each zone.
4. Characterization of each site is imperative in order to find the environmental cause of the interaction.

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