INFLUENCE OF SOIL PREPARATION AND WEEDING ON THE ROOT DEVELOPMENT OF AN HYBRID *Eucalyptus* IN THE CONGO

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SUMMARY

Until 1990 the *Eucalyptus* plantations in the Kouilou area (43,000 ha) were established in soil which was ploughed and subsequently weeded mechanically. The initial silvicultural regime (IS) was replaced by another (NS) which had a minimum soil preparation and chemical weed control. A study was undertaken to find out the impact of this change on the development of the root system (RS) of the trees.

The RS of 19 trees under the IS regime and 15 trees under the NS regime was categorised up to 40 cm depth and 100 cm from the centre of the tree. Individual root characteristics of each tree were noted in the row and inter-row directions. Kernel discriminant analyses were performed on 18 variables.They show that: 1) The RS are statistically different; IS was characterised by more vertical roots, whereas NS had more horizontal roots 2) There are less roots in the inter-row direction especially for the IS regime.

NS causes a more even and better development of RS. This result should however be confirmed by complementary studies which take more depth into account.

Key-words: root system, site preparation, weeding, non parametric discriminant analysis, *Eucalyptus*, Congo.

I - INTRODUCTION

Since 1978, 43,000 ha *Eucalyptus* hybrids have been planted in the Kouilou savannah for pulp production. Two hybrids were planted mainly: *E.PF1* and *E.12 ABL* saligna* (BOUVET, 1995).

The initial silviculture regime (IS) was as follows. The whole area was ploughed with a disc- harrow, followed by a ripping of the soil along each row of planting. Weeding was carried out mechanically with a disc harrow between the rows and manually in the rows. Five to six passes were necessary on average during the first three years.

Since 1990, radical changes were made. The original savannah is burned, and then 2-3 months later, the regrowth is treated with glyphosate. Ripping of the soil is performed in the line of planting. This is the only soil preparation which is made. Weeding is carried out chemically: 1 to 3 treatments of glyphosate are applied in the first two years after planting. This new silvicultural regime (NS) was made possible by the reduction in price of this herbicide, following its emergence into the public domain. It enables one to control weeds effectively, but at a lower cost, while also limiting the risks of erosion, which are very real with these sensitive soils.

Under the NS regime, the growth of *Eucalyptus* seems to be better, as the results obtained in two adjoining trials of the same clone showed. In the one trial, ploughing and ripping were used, and in the other, chemical preparation and ripping were used. Different weeding regimes were applied to both. The growth is consistently more productive with the chemical preparation and ripping. After 42 months, the mean gain was 1 m in height (19.6 m *vs* 18.6 m) and 1.8 m^2/ha in basal area (15.1 m^2/ha *vs* 13.3 m^2/ha) (BOUILLET *et al.*, 1996).

It is important to determine whether the different manners of soil preparation and weeding cause a particular root development, which would explain (at least partially) these differences. More generally, it is important to understand the impact the NS regime has on the root development, and its practical implications: the placement of fertilizer or the production potential of the coppices in the 2nd

rotation, *etc*...

This is why a preliminary study was performed by HAMEL (1992). He observed the root systems of plants 6 and 12 months old. The main results were that: 1) 60% of the roots were in the row direction; 2) On average, NS was characterised by a slightly larger number of roots (20.8 *vs* 18.8) and also a slightly larger number of ramifications of horizontal roots from the vertical ones (2.3 *vs* 1.4); 3) Weeding with a disc-harrow caused on average 3 horizontal roots to be cut under the IS regime.

This last study will be built upon, by considering older trees which have developed most of their root systems.

II - MATERIALS AND METHODS

Location

The trial is located in the commercial plantations of ECO SA (Eucalyptus du Congo Société Anonyme) near the village of Kondi, 25 km north from Pointe-Noire (4°45' S, 11°54' E). The climate is tropical; mean annual temperature is 24°C and mean annual rainfall is 1200 mm, with a dry season from May to October. The winds are weak or moderate. The soils are very deep (depth >30m). They are ferralitic, yellow, very desaturated, 90% sand and 5% clay. The exchangeable cations rate and the cation exchange capacity are very low (NZILA, 1996). Vegetation before planting was a savannah with *Imperata diplandra* and *Anona arenaria*.

Experimental design

The clone studied is *E.PF1* 1-41. This clone has been planted the most (≈ 7,000 ha). The trees are 4 years old. The normal felling age should have been 7 years.

The characteristics of the two treatments are as follows.

IS. 1991 September: the savannah was burned. 1992 January: the whole area was ploughed and then a ripping of the soil was performed in the ligne of planting. 1992-1994: weeding was carried out mechanically in the inter-row and manually in the row (4 times in 1992, 2 times in 1993 and 1 time in 1994). No more weeding was carried out afterwards.

NS: 1991 September: the savannah was burned. 1992 January: the regrowth was treated with glyphosate and then a ripping of the soil was performed in the ligne of planting. 1992-1993: one manual chemical weeding was carried out in 1992 and in 1993. No more weeding was carried out afterwards.

For both treatments, the cuttings were planted in 20 cm x 20 cm x 20 cm pits, the spacing was 4.2 m by 4.7 m and a starter fertilizer (150 g of N-P-K 13-13-21) was applied after planting at the bottom of each tree.

Sample

Each treatment is established on a flat area. The two stands are 100 m far from each other and have the same soil characteristics. They are the continuation of the two adjoining trials previously mentionned in §-I. The samples were composed of trees not surrounded by empty places and which did not exhibit basal shoots. The samples were girth stratified. Thirty four trees were felled (19 for the IS regime and 15 for the NS regime). Then the soil was very carrefully taken off by hand, at least up to 40 cm depth and 100 cm from the centre of the tree.

Root types and measurements

Different types of horizontal roots (codified H..) and vertical roots (codified V...) were observed (Figure 1). Some precisions can be given:

- V1 are vertical but were initially horizontal, due to the root cutting development during the juvenile stage. The change of direction can be noticed, up to 30 cm from the centre of the stem.
- The root pith patterns show that the vertical roots V2H are formed from the horizontal H1, even their dimensions are often bigger.
- The roots taken into account had a diameter greater than 0.5 cm at the point where they were formed.

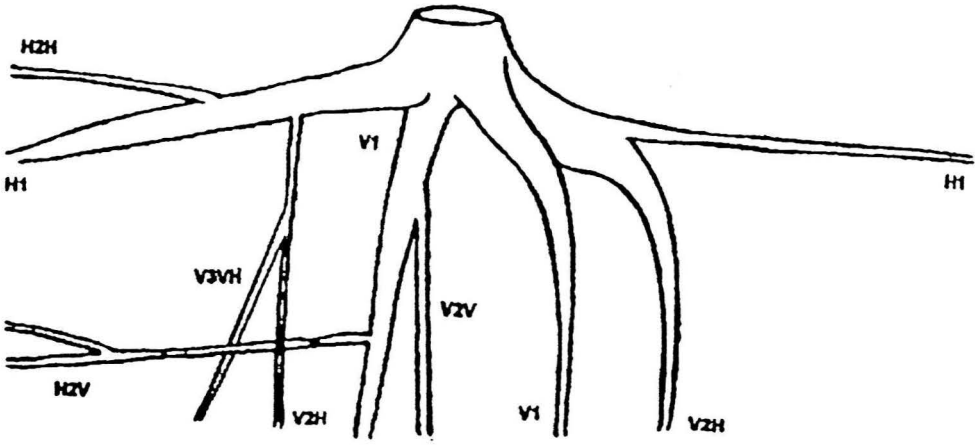

FIGURE 1. Roots types identified

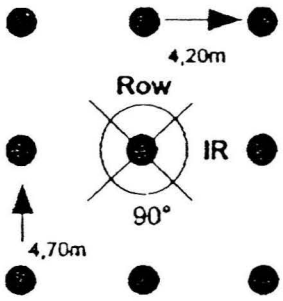

FIGURE 2. Demarcation of row and inter-row (IR) sectors

Two sectors were delimited (Figure 2). For each of them we located the point where the roots were formed according to:
- two depths; 1) 0-20 cm, maximum depth of the tillage 2) 20-40 cm, maximum depth of the ripping.
- two distances from the centre of the tree; 1) 0-40 cm, minimum distance of the disc harrow passage 2) 40-100 cm.

For each root, two perpendicular diameters were measured with a calliper rule (to the nearest 1/10 mm) at 40 cm depth for the vertical roots and at 100 cm from the centre of the tree for the horizontal roots. To calculate the value of the basal area it was considered that the root perimeter was a circle, a rectangle or an ellipse, according to the cases. This variable was calculated because it is often highly positevely correlated with the growth of the above ground parts of the tree (CHAUVIERE, 1996 ; FAYLE, 1968 ; STOKES *et al.*, 1996). Thus, for each sector, each depth and each distance, the number of roots was known by root type and the corresponding basal area was calculated.

Data analysés

Non Parametric Discriminant Analyses (NPDA) were performed, with SAS Proc Discrim (SAS Institute, 1988).The density was estimated by gaussian kernels. The selection of the discriminant variables was performed with Proc Stepdisc. The observations were classified by the "Leaving one out" method (*jackknife*).

III - RESULTS

In order to limit the number of outcomes

for which there was no data for the two treatments, it was decided:
- to merge the depths 0-20 cm and 20-40 cm;
- to differentiate between 0-40 cm and 40-100 cm only in the case of the two variables V2H ($V2H_{0-40}$, $V2H_{40-100}$) and H2H ($H2H_{0-40}$, $H2H_{40-100}$).

Eighteen variables describing the roots were thus retained (Table 1).

Comparison between IS and NS

Each tree was represented by its two sectors; initially, the IS group consisted of 38 individuals, while the NS group consisted of 30. The NPDA performed with the 18 root variables shows that all the individuals are classified correctly. In the order of contribution to the discriminant axis, the discriminant variables are V2Vn, $V2Hg_{40-100}$, H1n, $V2Hg_{0-40}$, $H2Hn_{0-40}$, $V2Hn_{40-100}$. The projection of the individuals onto the discriminant axis illustrates the differences that exist between the two populations (Figure 3). The NPDA on the only discriminant variables indicates once again that the individuals were classified correctly, except for one from IS.

The discriminant variables and the information in Table 2 show that the two silvicultural regimes differ by the number of roots, as well as the basal area of vertical/ horizontal roots.

IS: both the number of vertical roots, and their basal area are larger, except for V1.

NS: both the number of superficial horizontal roots (H1 and H2H), and their basal area are larger.

Comparison between row and inter-row

In order to complete the previous results, the development of the roots, depending on their location (row or inter-row) was compared. Initially, the groups consisted of 34 individuals each.

The NPDA with the 18 root variables

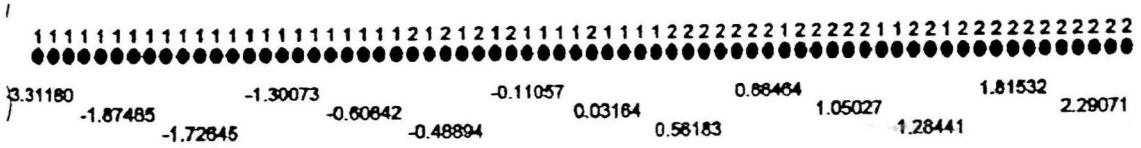

FIGURE 3. Tree coordonnates on discriminant axis (analysis done with all the variables). 1=Initial Silviculture ; 2= New Silviculture.

TABLE 1. Mean value of the roots variables for IS regime (19 trees) and NS regime (15 trees). For each root type, index g is used for total basal area and index n is used for the number of roots.

	VERTICAL ROOTS									
	Basal area (cm^2)					Number of roots				
	V1g	V2Vg	$V2Hg_{0-40}$	$V2Hg_{40-100}$	V3V Hg	V1n	V2 Vn	$V2Hn_{0-40}$	$V2Hn_{40-100}$	V3V Hn
IS	126.89	9.88	64.01	6.70	1.53	7.84	5.89	19.63	7.21	3.42
NS	174.00	6.09	40.37	2.72	1.52	9.20	2.60	19.07	5.80	2.87
	HORIZONTAL ROOTS									
	Basal area (cm^2)					Number of roots				
	H1g	$H2Hg_{0-40}$	$H2Hg_{40-100}$	H2Vg		H1 n	$H2Hn_{0-40}$	$H2Hn_{40-100}$	H2Vn	
IS	9.05	0.33	1.52	1.30		10.79	2.42	4.58	5.95	
NS	9.49	0.60	1.64	0.76		13.20	3.53	6.07	5.27	

shows that all the individuals are correctly classified. The discriminant variables are $V2Hg_{0-40}$, V1g, V3VHg, $H2Hg_{0-40}$, $V2Hg_{40-100}$, H2Vg, $H2Hn_{40-100}$. The NPDA indicates once again that the individuals are classified correctly.

As shown by the discriminant variables, the row and inter-row sectors differ by the number and basal area of the roots (Table 2). The values are larger in the row sector for all the variables, except for V2Vg et V2Vn. Ripping breaks up the soil, and consequently favours the prospecting of the roots in the row, both for the horizontal and vertical roots.

It is interesting to note that the sectors do not contribute in the same way to the differences observed between the two treatments. Indeed, the larger number of horizontal roots and corresponding basal areas observed in NS are due mainly to the inter-row sector (Table 3).

IV - CONCLUSION

This study confirms that the two types of silviculture cause marked differences in root development.

TABLE 2. Mean value of roots variables for row (R) and inter-row (IR) sectors. Means calculated with 34 trees by sectors. For each root type, index g is used for total basal area and index n is used for the number of roots.

	VERTICAL ROOTS									
	Basal area (cm^2)					Number of roots				
	V1g	V2Vg	$V2Hg_{0-40}$	$V2Hg_{40-100}$	V3VHg	V1n	V2Vn	$V2Hn_{0-40}$	$V2Hn_{40-100}$	V3VHn
R	87.55	3.63	33.95	3.56	1.05	4.44	1.91	10.79	4.32	1.76
IR	60.13	4.58	19.63	1.38	0.48	4.00	2.53	8.59	2.26	1.41

	HORIZONTAL ROOTS							
	Basal area (cm^2)				Number of roots			
	H1g	$H2Hg_{0-40}$	$H2Hg_{40-100}$	H2Vg	H1n	$H2Hn_{0-40}$	$H2Hn_{40-100}$	H2Vn
R	5.30	0.28	0.97	0.69	6.59	1.71	3.03	3.06
IR	3.94	0.17	0.60	0.37	5.26	1.21	2.21	2.59

TABLE 3. Mean value of horizontal roots variables for row and inter-row according to AS regime (19 trees) and NS regime (15 trees).

	ROW							
	Basal area (cm^2)				Number of roots			
	H1g	$H2Hg_{0-40}$	$H2Hg_{40-100}$	H2Vg	H1n	$H2Hn_{0-40}$	$H2Hn_{40-100}$	H2Vn
AS	5.84	0.21	1.04	0.95	6.42	1.47	2.95	3.37
NS	4.61	0.37	0.88	0.37	6.80	2.00	3.13	2.67

	INTER - ROW							
	Basal area (cm^2)				Number of roots			
	H1g	$H2Hg_{0-40}$	$H2Hg_{40-100}$	H2Vg	H1n	$H2Hn_{0-40}$	$H2Hn_{40-100}$	H2Vn
AS	3.21	0.12	0.48	0.35	4.37	0.95	1.63	2.58
NS	4.88	0.23	0.76	0.40	6.40	1.53	2.93	2.60

1) IS is characterised by a larger vertical ramification which is noticed mostly close to the stem and in the row. This could be explained by the better depth of soil preparation due to ripping already ploughed soil. On 17 of the 19 trees, one can also see horizontal roots which were cut in the inter-row sector: on average 2 H1, 1.7 H2H et 1.5 H2V. At the wound, not many roots were formed, as with root pruning. On average, a single root is observed. It is very small and never has ramification.
2) NS is characterised by more superficial horizontal roots and a better overall prospecting of the soil, especially in the inter-row sector. This is explained firstly by the fact that there are not any cut roots. Secondly, the development of the horizontal roots is probably reduced in the IS case by the compaction caused on the moist soil by the tractor which pulls the ripping tine; a marked compaction occurs under the wheels' tracks.

These results show that the new silvicultural regime causes a much more even root system development with better prospecting of the superficial layers. They are supported not only by an economic point of view and protection of the soil, but also agronomically. In order to be able to relate the root development with the growth of the stem, it is proposed that this study be followed by studies of other trees and deeper root investigations (at least to a depth of 5 metres).

More generally, the above investigation should include estimating the influence vegetative material, the age and the silvicultural regime on the development and functioning of the root system. These observations should be connected to the development of the above ground parts of the tree.

V- REFÉRENCES

BOUILLET JP, NZILA JD, OGNOUABI N, SAFOU R, 1997. Principaux résultats sylvicoles obtenus en 1996. Note interne UR2PI, 20p.

BOUVET JM, 1995. Evolution de la variabilité avec l'âge et corrélation juvénile-adulte dans des populations d'*Eucalyptus*. Thèse de doctorat de l'INAPG, 227p.

CHAUVIERE M, 1996. Une méthode de description et d'analyse des systèmes racinaires d'arbres adultes. Application au chêne sessile (*Quercus petrae* Liebl.). Université H.POINCARE Nancy/INRA/ENGREF, DEA de Biologie Forestière, 26p.

FAYLE DCF, 1968. Radial growth in tree roots. Distribution, timing, anatomy. University of Toronto, Faculty of Forestry, technical report N°9, 174p.

HAMEL O, 1992. Etude racinaire. Note interne UAIC/DRD, 10p.

NZILA JDD, 1996. Principales caractéristiques des sols des reboisements dans la région de Pointe-Noire - revue bibliographique. Pointe-Noire, UR2PI, Note interne, 15p.

SAS Institute, 1988. SAS/STAT user's guide. Release 6.03 edition. SAS Institute Inc., Cary, NC, 1028p.

STOKES A, NICOLL B, COUTTS MP, FITTER AH, 1996. Responses of young Sitka spruce clones to mechanical perturbation and nutrition: effects on biomass allocation, root development and resistance to bending. Paper submitted to the Canadian Journal of Forestry Research.