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Rubber tree (*Hevea brasiliensis*) behaviour in marginal climatic zones of Cote d'Ivoire: assessment of ten years of observations

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Abstract

Fifteen experimental plots were established throughout Côte d'Ivoire in 1984 - 85 in order to test rubber tree performance in different locations in order to extend the boundaries and to meet the demand of new areas for rubber tree cultivation. The sites were chosen on the basis of their rainfall isobar, ie 1500mm which is known as the lowest tolerable level for tree growth on soils with good water holding capacity.

Ten years after setting up the experiment, the following main results have been obtained with respect to the growth and production of the rubber trees:

- a long-duration dry season and a water-balance deficit appeared to be the major limiting factors for growth and the tapping age of the rubber trees.
- immature girth represented 20% - 90% of the levels established in southern Côte d'Ivoire. Clones PB 235 and AVROS 2037 showed the highest growth and clones GT1 and PR 107 the lowest.
- ten plots have been tapped according to normal opening standards. After 3 years of tapping, the average yield represented about 50% of that obtained in large scale trials in Côte d'Ivoire. There were no significant differences between the sites; these are comparable. The yield of clone PB 235 was significantly higher than the yield of clones RRIM 600, AVROS 2037 and PB 217.
- *Rigidoporus lignosus*, the causal agent of white root disease, caused considerable damage in six fields established directly after manual forest clearing.

Introduction

Located between latitudes 5° and 10° North and longitudes 3° and 8° West, Côte d'Ivoire has regions with a tropical climate favourable to the cultivation of *Hevea brasiliensis*. In particular, if the rainfall isobar of 1500mm is taken as a reference (Figure 1) and subject to the dry season not exceeding 5 consecutive months, then 20% of the surface of the country can be considered as favourable to *Hevea* cultivation from the rainfall standpoint[1]. For this reason, a study has been undertaken since 1984, by the "Société Africaine des Plantations d'Hévéas" and the Institute of Research on natural rubber, as part of the *Hevea* development plan to meet area and regional development requirements and also to support the development of *Hevea* in various regions of Côte d'Ivoire.

Studies were conducted by the "Bureau pour le Développement des Productions Agricoles" in 1979 on the agroclimatology of Côte d'Ivoire[2]. This data was taken into account in selecting the sites concerned with respect to, on the one hand, rainfall (amount and distribution) and the water deficit (dry season length) and, on the other hand, the soil characteristics (essentially their physical properties). Ten years after the setting up of this network, this report sets out to bring together the growth and production results comparing them to statistics established in Lower Côte d'Ivoire, the traditional *Hevea* cultivation areas.

Material and methods - experimental design

Sites - The country's annual rainfall has been estimated as being from 1800 to 2500mm and therefore satisfactory for rubber tree cultivation since one should avoid[3] going below 1500mm. This isobar has served as the reference level to assess favourable and unfavourable areas in Côte d'Ivoire[1,4]. Tolerable annual distribution limits of 4 or 5 consecutive dry months (monthly rain below 100mm) and 3 consecutive very dry months (monthly rain below 50mm) have been set since it is accepted that *Hevea* can tolerate such dryness conditions due to its rooting-system (taproot and creeping roots) on deep well-drained and aerated soils.

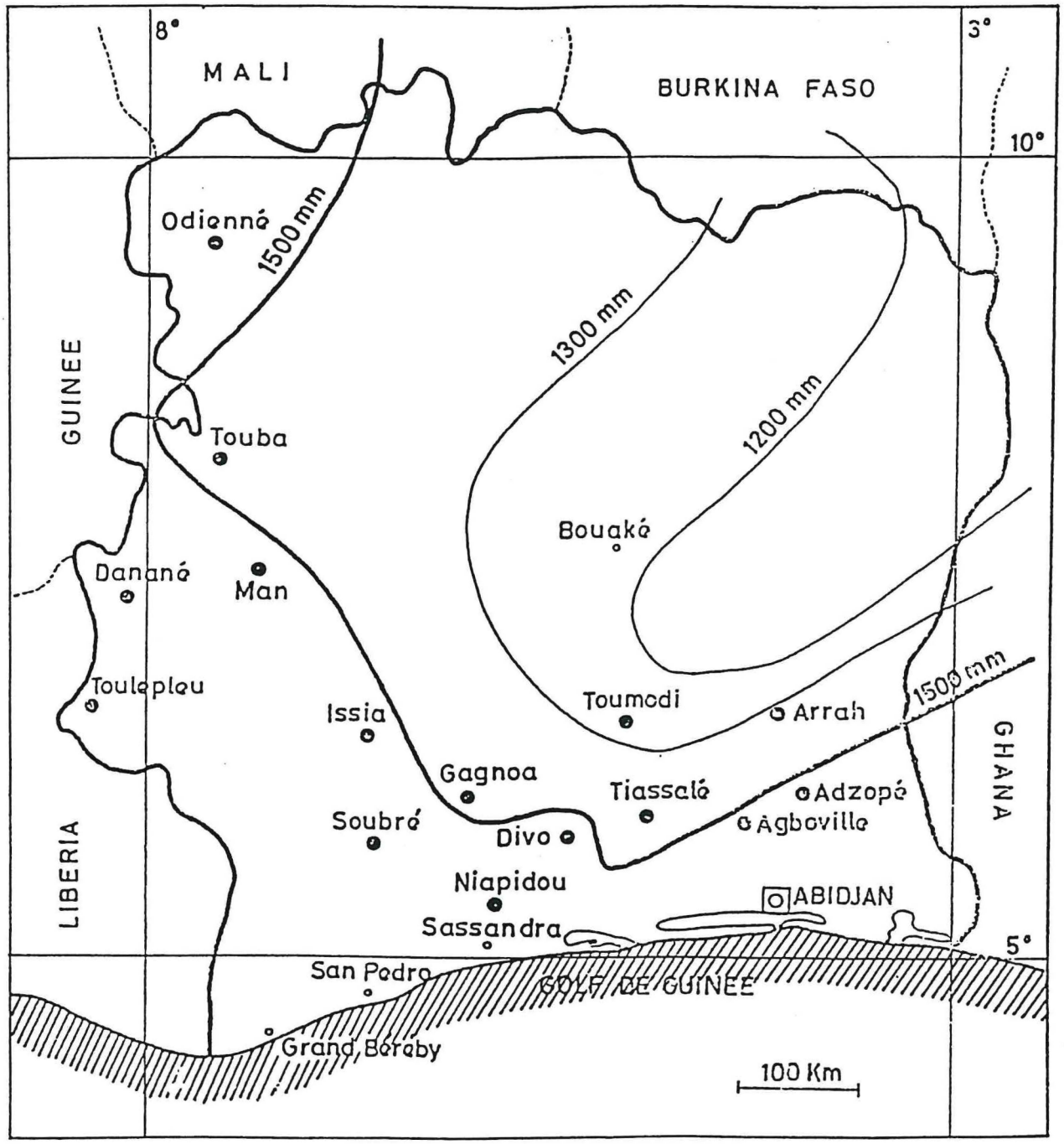


Figure 1 ***Rubber tree geographical distribution: Behaviour field trials in Côte d Ivoire.***

Thus fifteen plots have been selected throughout the country:

- zones *considered a priori* very favourable to the cultivation of *Hevea* owing to the suitability of soil and climate: Soubré, Agboville, Adzopé and Niapidou.
- zones *supposed to be marginal* because of a long dry season and/or poor soils and/or altitude: Danané, Man, Divo, Toulépleu, Arrah, Tiassalé and Toumodi.
- zones *considered probably* unfavourable because of soil and climate which would serve to estimate the limits of rubber tree cultivation: Gagnoa, Issia, Touba and Odienné.
- a control *zone* located in the traditional rubber tree area: The plantation of the "Institut des Forêts/Département des Plantes à Latex", located at Anguedédou (Abidjan area).

Planting material - Seven clones were selected, namely GT1, PR 107, PB 217, PB 235, IR 22, AVROS 2037 and RRIM 600, to obtain greatest variability relative to growth, production, disease resistance,wind damage resistance and leaf characteristics criteria (Figure 2).

Statistical design - An identical Fischer' block design was adopted for each plot (Figure 2). For each clone, there are 4 repetitions of 70 trees planted at a density of 510 trees/hectare (a spacing of 7 × 2.8m). Thus, each plot has over 2000 trees (4.2 hectares) and hence the whole network represents over 60 hectares.

6 RRIM 600	2 PR 107 .	1 GT 1	4 PB 235	7 AV. 2037	3 PB 217	5 IR 22
3	7	2	4	5	6	1
5	4	7	2	6	1	3
1	5	3	7	2	6	4

Clones:
1 -GT1
2 - PR 107
3 - PB 217
4 - PB 235
5 - IR 22
6 - RRIM 600
7 - AVROS 2037

Figure 2 ***Planting material and statistical design***

Major cultural techniques - Land clearing and holing were manual. Planting was with 20-month-old budded stumps at the beginning of the rainy season in May/June of 1984 and 1985. A basic fertiliser was applied in a complete N.P.K. fertiliser form during setting up at doses of 50, 100, 1000 grams/site. Weeding was done manually and the cover plant was *Puereria phaseloides*.

Control measures

1. A physico-chemical analysis was carried out in the laboratory on soil samples from each plot taken to a depth of 1m (Table 1).

Soils were clayish with a significant presence of coarse elements (20% to 80% of gravel and stones with a diameter above 2mm) and the pH varied from 4.4 to 6.5. From the cultivation point of view, these are favourable soils for *Hevea*.

2. Each plot was equipped with a rain gauge which was checked daily. Supervision was regular from 1985 to 1991. The mean annual rainfall varied from 1109mm (Odienné) to 2150mm (Danané). With respect to monthly distribution, the following can be distinguished:

- Odienné: 7 consecutive dry months/year,
- Touba: 6 months,
- Adzopé, Gagnoa, Issia and Toumodi: 5 months,
- Agboville, Danané, Divo, Man, Soubré, Tiassalé, Toulépleu: 4 months,
- Arrah, Niapidou: 3 months.
- In Bimbresso located at the control site, the mean annual rainfall for the same period (1984 to 1994) was 1600mm and the length of dry season was 4 months.

3. Each year, between May and June, the girth of trees was measured at 1m above the union in the immature period and at 1.7m after tapping.

4. When at least 50% of the trees had reached a girth of 50cm, they were tapped for three years on the ½ S d/4 6d/7 ET. 2.5 % Pa 1(1) 4/Y.

Table 1 *Physical and chemical characteristics of soils*

	Clay	f. Silt	c. Silt	f. Sand	c. Sand	O.M.	C	C/N	pH
Adzope:									
0 - 30cm	18.0	5.1	14.3	44.8	17.7	2.5	1.5	10	5.1
30 - 50cm	40.7	6.6	10.1	26.6	16.0	1.7	1.0	11	5.1
50 - 100cm	50.4	9.8	9.7	17.2	12.9	1.1	0.7	11	5.0
Agboville:									
0 - 30cm	26.3	7.9	7.3	13.9	44.6	2.2	1.3	10	5.5
30 - 50cm	43.9	7.3	5.0	8.4	35.5	1.4	0.8	8	5.3
50 - 100cm	48.4	5.4	6.7	8.4	31.1	0.9	0.5	8	5.2
Arrah:									
0 - 30cm	22.9	12.3	17.5	28.1	19.2	3.3	1.9	11	6.5
30 - 50cm	45.5	9.0	11.5	14.7	19.2	1.6	1.0	11	6.2
50 - 100cm	32.6	15.6	14.5	16.3	21.0	0.7	0.4	12	5.2
Danane:									
0 - 30cm	16.5	5.4	3.6	19.9	54.7	2.7	1.6	10	5.8
30 - 50cm	31.6	5.6	4.1	18.3	40.4	1.3	0.8	10	4.7
50 - 100cm	38.4	5.6	4.2	20.1	31.8	1.0	0.6	11	4.9
Divo:									
0 - 30cm	28.6	5.6	6.6	23.7	35.4	2.3	1.3	8	6.4
30 - 50cm	36.6	4.9	4.9	18.1	33.8	1.1	0.6	9	5.9
50 - 100cm	46.3	6.0	6.0	12.9	28.0	0.8	0.5	8	5.5
Gagnoa:									
0 - 30cm	45.0	4.7	8.4	8.9	33.1	1.8	1.0	11	4.9
30 - 50cm	49.0	4.0	3.0	9.7	33.7	1.3	0.7	9	5.0
50 - 100cm	33.2	6.3	5.3	10.5	44.6	0.9	0.5	9	5.1
Issia:									
0 - 30cm	36.6	6.0	21.8	19.9	15.7	1.5	0.9	9	4.8
30 - 50cm	42.0	5.2	13.5	15.5	23.8	1.3	0.8	10	4.9
50 - 100cm	42.6	9.3	17.4	12.8	17.8	1.1	0.6	9	4.7
Man:									
0 - 30cm	29.4	4.9	3.5	30.0	32.2	4.3	2.5	11	5.7
30 - 50cm	43.6	4.9	2.5	22.9	26.1	1.8	1.1	11	5.1
50 - 100cm	44.2	4.4	2.4	21.1	28.0	1.4	0.8	10	5.2
Niapidou:									
0 - 30cm	15.5	3.7	3.0	19.5	58.3	2.7	1.5	10	5.9
30 - 50cm	48.2	4.9	2.1	8.5	36.2	1.6	0.9	11	4.5
50 - 100cm	51.3	6.7	4.2	11.7	26.1	1.2	0.6	11	4.7
Odienne:									
0 - 30cm	27.2	7.3	17.9	24.3	23.3	2.1	1.2	11	6.3
30 - 50cm	39.9	6.5	14.0	17.2	22.3	1.1	0.7	11	5.7
50 - 100cm	26.1	7.1	11.1	18.0	37.7	0.6	0.4	12	5.8
Soubre:									
0 - 30cm	28.9	4.4	3.2	13.7	49.8	1.5	0.9	12	4.5
30 - 50cm	38.3	6.2	4.7	11.1	39.7	1.1	0.7	10	4.4
50 - 100cm	41.9	9.9	6.7	12.9	29.3	0.9	0.5	11	4.6
Tiassale:									
0 - 30cm	27.8	10.5	12.6	21.1	22.0	1.7	1.0	10	5.4
30 - 50cm	38.2	6.2	13.2	14.9	27.5	1.1	0.7	8	5.0
50 - 100cm	42.2	5.4	10.8	10.5	31.1	1.1	0.5	11	5.2
Touba:									
0 - 30cm	33.5	4.7	4.4	17.0	40.4	2.1	1.2	11	6.1
30 - 50cm	48.1	2.2	3.0	17.2	29.4	1.5	0.9	10	5.8
50 - 100cm	53.3	2.8	4.4	12.7	26.8	1.0	0.6	11	6.0
Toulepleu:									
0 - 30cm	40.5	6.8	5.3	27.8	19.5	1.2	0.7	10	5.0
30 - 50cm	6.2	4.4	5.8	28.8	54.8	1.5	0.9	11	6.5
50 - 100cm	3.7	2.1	3.6	22.7	67.9	0.7	0.4	12	6.4
Toumodi:									
30 - 50cm	17.5	3.2	6.7	49.9	22.6	2.7	1.5	10	4.5
50 - 100cm	27.5	4.1	6.7	38.9	22.9	1.2	0.7	12	5.2

Analysis of soil fractions (diameter < 2mm): Clay, Fine (f) and Coarse © Silt, Fine and Coarse Sand, Organic matter (O.M.), Carbon (C), Nitrogen (N) in percent (%).

Results

Preliminary remarks

1. Problems of the availability of budwood and lack of success in budding IR 22 have caused many substitutions of this clone by PB 260 and thus this clone has been removed from the analysis.
2. Ten fields have been opened in accordance with the norms mentioned above at five years and ten months of age, namely Agboville, Divo, Issia, Gagnoa, Niapidou, Danané, Toulépleu, Tiassalé, Soubré and Man.
3. Ten years after planting, only 45% of the *Hevea* trees at Touba and Odienné have reached the opening norm and thus these have not been taken into account in this partial yield analysis.
4. The plot at Toumodi has been the victim of several fires, and moreover a dam laid out in the surrounding area has flooded half of the plantation.
5. The fields at Adzopé and Arrah have been abandoned by their owner for over three years which has brought about many delays before tapping.

Growth

At five years, (before tapping), the mean growth of the network (37.1cm) was inferior by nearly 20% to that in the control area (Figure 3a and b).

Clones PB 235 and AVROS 2037 had significantly superior girth to the other clones followed by PB 217 and RRIM 600 and lastly PR 107 and GT1.

Three categories were noticed within the sites:

- 8 fields (Danané, Toulépleu, Gagnoa, Man, Soubré, Agboville, Tiassalé and Niapidou) have a girth slightly inferior to that of the control site: 40cm < girth < 44cm
- 4 fields (Arrah, Divo, Issia and Adzopé) have a girth inferior to 40cm: 37.9cm < girth < 40cm
- 3 fields (Touba, Odienné and Toumodi) have a girth inferior to 25cm (less than 50% of that measured in Lower Côte d'Ivoire).

There are no significant annual girth increment differences between sites. The girth measured after tapping shows the same tendencies as noted at 5 years and the annual girth increment is comparable with the sites and with the clones (6.7cm betwenn the 6th and 7th years).

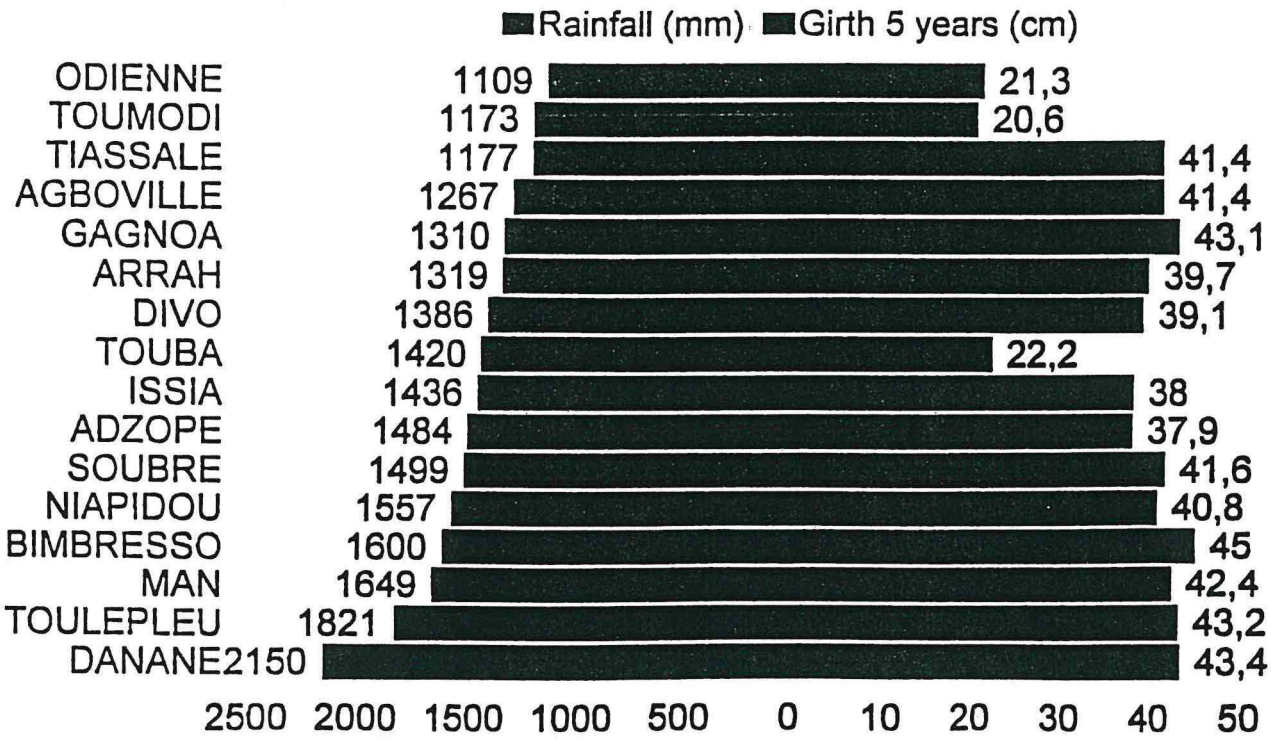
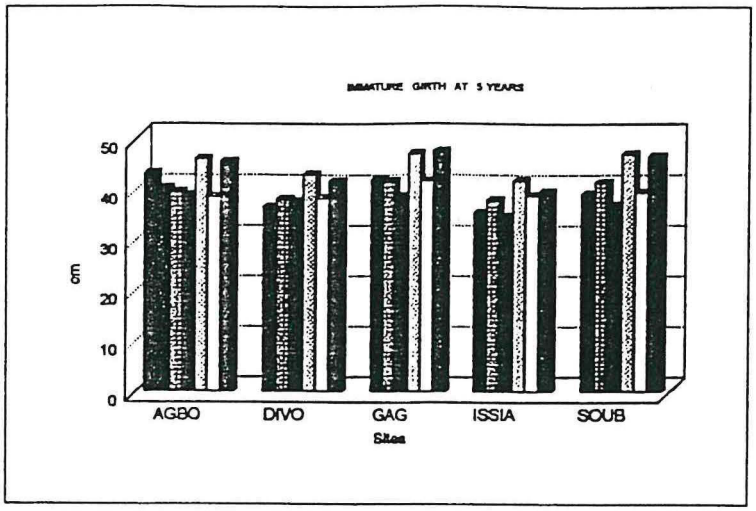
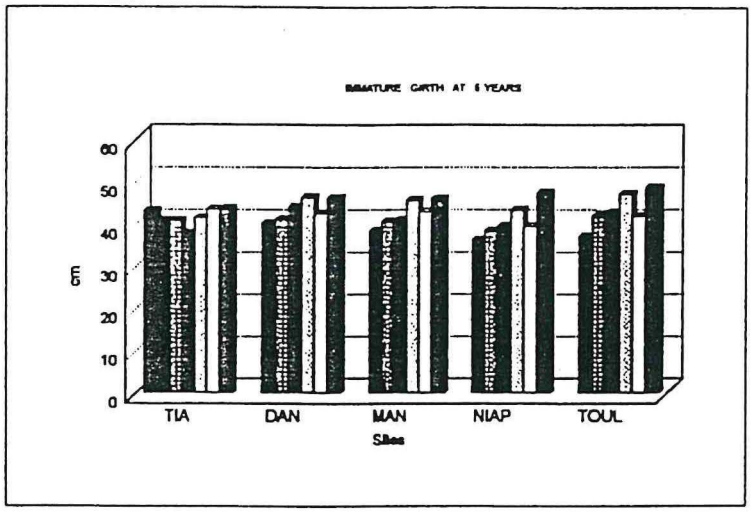


Figure 3a ***Rubber-tree adaptability field trials in Côte d'Ivoire - Growth/pluviometry relationship (1984 - 1991)***





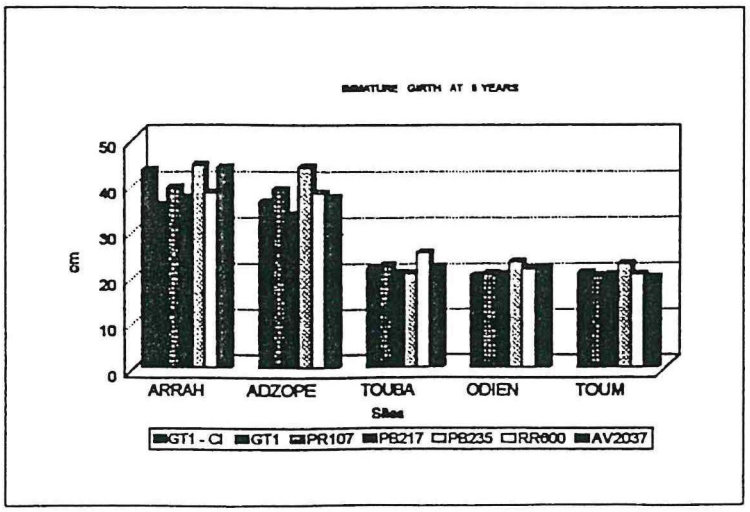


Figure 3b *Immature growth.*

Yield

First year yield - The mean production in the first year was 364 kg/ha and 20.8 g/t/t (Tables 2a and b), that is to say 42% (in kg/ha) and 60% (g/t/t) of the large scale production trial in Côte d'Ivoire[5].

The ten fields are statistically comparable in kg/ha as well as in g/t/t. Two groups of clones are distinguishable in terms of kg/ha: PB 235 is significantly higher than clones of the second group, ie RRIM 600, AVROS 2037, PB 217, GT1 and PR 107. Three groups of clones emerge in terms of g/t/t: i) PB 235 is significantly higher than the others followed by ii) PB 217 and RRIM 600 and finally iii) GT1, PR 107 and AVROS 2037.

Second year yield - The yield was 741 kg/ha and 29.9 g/t/t which represents 52% and 67% of the large scale production trial in Côte d'Ivoire (Table 1).

The ten plots are statistically comparable in kg/ha as well as in g/t/t. Clone PB 235 gave a production statistically higher than the other clones.

Third year yield - The production in the third year was 864 kg/ha and 46.5 g/t/t, which is 44% and 83% of the comparable large scale trials in Côte d'Ivoire.

Statistical analysis indicates that all the fields are comparable in kg/ha, whereas Divo has the best production with respect to g/t/t.

In terms of kg/ha, there are three groups of clones: PB 235 (1324 kg/ha) is higher than RRIM 600 (900 kg/ha) followed by the group consisting of AVROS 2037, GT1, PB 217 and PR 107.

In terms of g/t/t, PB 235 (64.6 g/t/t) gave a statistically higher production than all other clones.

Production in the third year is significantly higher to that in the second and first years. This confirms what has already been indicated, ie that the activation of the metabolism of production of *Hevea* is more important in the second year than in the first year.

Table 2a ***Production of the ten fields and the six clones (in kg/ha)***

Year 1 (kg/ha)	Year 2 (kg/ha)	Year 3 (kg/ha)	Cumulative Y1/Y2 in kg/ha	Cumulative Y1/Y3 in kg/ha
Toulepleu 465 Gagnoa 433 Tiassale 394 Soubre 385 Man 385 Agboville 374 Divo 357 Niapidou 319 Danane 298 Issia 226	Toulepleu 977a Niapidou 899ab Divo 856ab Man 793abc Danane 760abcd Agboville 732abcd Gagnoa 723bcd Tiassale 644cd Issia 552de Soubre 474e	Divo 1188a Gagnoa 1017ab Soubre 1014ab Tiassale 958bc Agboville 830cd Issia 820cd Toulepleu 722d Danane 713d Niapidou 698d Man 676d	Toulepleu 1442a Niapidou 1218ab Man 1178ab Divo 1172ab Gagnoa 1142ab Agboville 1080ab Danane 1058ab Tiassale 1012ab Soubre 842b Issia 771b	Divo 2040a Gagnoa 1739b Toulepleu 1699bc Tiassale 1602bcd Niapidou 1597bcd Agboville 1562bcd Danane 1491bcd Soubre 1488bcd Man 1469cd Issia 1372d
PB 235 762a RRIM 600 338b AVROS 2037 319bc PB 217 302bcd GT1 240cd PR 107 220d	PB 235 1140a RRIM 600 775b AVROS 2037 706bc PB 217 660bc GT1 587c PR 107 577c	PB 235 1324a RRIM 600 900b AVROS 2037 776c GT1 776c PB 217 753c PR 107 663c	PB 235 1867a RRIM 600 1104b AVROS 2037 1020bc PB 217 952bc GT1 818c PR 107 789c	PB 235 2464a RRIM 600 1675b AVROS 2037 1483c PB 217 1413c GT1 1363cd PR 107 1240d
Mean 364	Mean 741	Mean 864	Mean 1090	Mean 1606

a, b, c, d, e: the sites and clones with the same letter are not significantly different according to the NEWMAN-KEULS test at 5%.

Table 2b ***Production of the ten fields and the six clones (in g/t/t)***

Year 1 (g/t/t)	Year 2 (g/t/t)	Year 3 (g/t/t)	Cumulative Y1/Y2 (g/t/t)	Cumulative Y1/Y3 (g/t/t)
Toulepleu 26.7a Divo 22.9ab Tiassale 22.5ab Agboville21.7ab Gagnoa 21.2ab Niapidou19.8ab Soubre 19.4ab Issia 19.1ab Man 18.9ab Danane 15.2b	Toulepleu 39.4a Niapidou 37.4a Man 34.2ab Danane 33.3ab Divo 32.5ab Agboville 28.4b Gagnoa 25.3bc Issia 25.0bc Tiassale 24.7bc Soubre 17.2c	Divo 70.8a Toulepleu 59.4b Danane 57.4b Man 45.3c Niapidou 45.0c Tiassale 41.4cd Gagnoa 38.4cd Issia 37.4cd Soubre 35.7d Agboville 33.8d	Toulepleu 33.8a Niapidou 29.0ab Divo 27.4abc Man 26.6abc Agboville 25.1abc Danane 24.4abc Tiassale 23.7bc Gagnoa 23.6bc Issia 22.3bc Soubre 18.5c	Divo 52.5a Toulepleu 49.5ab Danane 45.4bc Man 40.1c Tiassale 33.6d Agboville 32.1d Niapidou 32.0d Gagnoa 31.9de Issia 31.2de Soubre 26.5de
PB 235 34.4a PB 217 22.4b RRIM 600 21.2b GT1 17.5c PR 107 16.0cd AVROS 2037 13.0d	PB 235 42.6a RRIM 600 33.2b PB 217 28.5bc GT1 25.6c PR 107 24.6c AVROS 2037 24.0c	PB 235 64.6a RRIM 600 49.0b GT1 46.1bc PB 217 42.0cd AVROS 2037 39.8d PR 107 37.4	PB 235 38.7a RRIM 600 27.5b PB 217 25.6bc GT1 21.7c PR 107 20.1c AVROS 2037 19.0	PB 235 52.1a RRIM 600 39.7b GT1 34.9c PB 217 34.2c AVROS 2037 33.3cd PR 107 30.7d
Mean 20.74	Mean 29.74	Mean 46.48	Mean 25.4	Mean 37.5

a, b, c, d, e: the sites and clones with the same letter are not significantly different according to the NEWMAN-KEULS test at 5%.

Phytopathological situation

Many *Hevea* parasites[6] have been observed on these fifteen plots:

- on the roots: *Rigidoporus lignosus, Phellinus noxius, Sphaerostilbe repens, Thoningia;*
- on the trunks and branches: *Phytophthora palmivora, Botriodiplodia theobromae;*
- on the leaves: *Colletotrichum gloeosporioides, Helminthosporium heveae, Phytophthora palmivora, Oïdium heveae.*

Among these parasites, only *Rigidoporus lignosus* (Fomes) caused very serious damage in six fields planted directly after manual forest clearing and holing. The rate of attack was of 19.8% at Danané, 15.5% at Toulépleu, 5.1% at Issia and 2.5% at Niapidou. Other fields have been slightly attacked by Fomes (less than 1%). Only the field at Agboville was unscathed as it was without root stumps (preceding cultivation was banana).

Treatments were applied twice a year over three years (in May and November of 1993, 1994, 1995) using fungicide pellets around the taproot followed by gentle hoeing to spread the product in the soil. These treatments helped to save more than 36% of infected trees and protect more than 95% of the trees in direct contact with the focus point.

Discussion

Climatic factors, such as hygrometry, exposure to sun, temperature, wind etc, which seem less determining for *Hevea* in the conditions of Côte d'Ivoire, have not been retained as selection criteria in this macroscopic and regional approach to the study of marginality. Rainfall is considered as the dominating factor in terms of the water balance and the study of the availability of water for *Hevea* has been combined with a study of precipitation.

Climate and soils

Rainfall - Rainfall has declined regularly except in the Western semi-mountainous regions of the country (mainly at Danané, Toulépleu and Touba).

The fields at Adzopé, Agboville, Divo, Gagnoa, Issia, Soubré and Tiassalé are below the minimum of 1500mm. The 1600mm mean annual rainfall at the Bimbresso control area during the period of study is to be compared to 1800mm in 1980 and 2000mm in 1966. This tendancy to a reduced rainfall has been accentuated in Côte d'Ivoire over the last fifteen years.

Rainfall reduction and, moreover, dry season length and water deficit appear to be the most restrictive growth factors in the all of the fields studied.

The correlation between "total rainfall and girth" is significant for extreme values; that is the case when comparing Danané and Odienné. Elsewhere this relation is less obvious: when comparing Danané and Gagnoa at equal girth (43cm), the rainfall in Gagnoa is 60% of that in Danané. The correlations are quite weak in both cases.

The correlations between "cumulative water deficit and girth" are significant. The period in which the trees were more sensitive to humidity conditions was between the 3rd and 4th years. AVROS 2037 appears to be the clone in which girth could best be linked to the water deficit whereas it is a less sensitive factor for GT1. Thus, growth seems much more influenced by water deficit than by total rainfall[4] and soils in marginal areas. For this reason, clones with a high growth potential (PB 235 and AVROS 2037) do not have the opportunity to express themselves fully to reach the growth values in the South: a levelling of all of the clones is noticed and hence PR 107 can have girths identical to those of PB 235 (Tiassalé) or those of the AVROS 2037 (Toumodi, Touba).

Soils - The control area is located on ferrallitic (sandy) soils derived from tertiary sands developed on the Ivorian sedimentary basin (Latitude 5°- 5°30′ North and Longitude 3°- 6° West).

The clayish soils of the network and of the rest of the Ivorian territory is characterized by the presence of coarse elements. These can constitute a restrictive factor to root development if they exceed 50%. Tillage was manual in the present case. According to the position of the coarse elements in the profile, the growth of *Hevea* can be reduced to 20 - 30%[7]. Though no correlation has been found between "soil nature and rubber tree growth", the weak growth at Niapidou, in spite of a favourable rainfall and a short dry season, could be explained by the presence of gravelled elements.

It is not known if this texture, *a priori* favourable, permits both good restitution of soil water during dry seasons and good aeration and good drainage in the rainy season because of the lack of detailed studies. For example, there is the case of the Xishuangbanna region in China where the growth and production of *Hevea* is noteworthy[8] despite a very poor rainfall (1200 - 1500mm) because of, among other conditions, a deep, rich and very humid soil (18 - 23% humidity). Considering that on these soils the length of the dry season and the water deficit must not exceed 3 months, the sites of Odienné, Touba and Toumodi (4 - 5 very dry months) are marginal. Touba and Odienné, tapped much later (at 10 years), are interesting for the study of the influence of the length of the dry season and the water deficit on growth and the importance of production. Currently, it is generally acknowledged that water balance is among the most important aspects[8] of the environmental factors affecting rubber production in marginal zones.

Clone growth and yield

The six clones tested can be classified into three groups according to their growth:

- quick-growing: PB 235, AVROS 2037,
- intermediate-growing: PB 217, RRIM 600,
- slow-growing: GT1, PR 107.

In addition, clonal typology of production can be defined as follow :

- high yielding clones: PB 235, RRIM 600.
- low/average yielding clones: PB 217, PR 107, GT1, AVROS 2037.

Clone PB 235, with an high yield potential, is sensitive, to both wind damage (breaking and uprooting due to winds) and to dry panel disease; this clone is not recommended for smallholders in Côte d'Ivoire. The same applies to clone RRIM 600 which is also sensitive to wind.

Clone PR 107, the main limitations of which are slow growth before opening and a slow production start,

cannot be suited to a long period of dryness such as occurs in Touba and Odienné.

Clone GT1 is the best known and most planted clone in Côte d'Ivoire and no crippling drawback has been detected up to the present. Clones GT1 and PB 217 have been recommended in all *Hevea* areas though their slow growth is an handicap in zones with a long dry season as at Touba and Odienné.

Conclusions

After over ten years of observations, it is certain that the main objective of this study has been achieved, ie the expansion of the areas for the cultivation of *Hevea.*

Some marginal zones of Côte d'Ivoire can allow the cultivation of *Hevea* by the adaptation of clones and cultural techniques. The zones of Agboville, Gagnoa, Issia, Niapidou and Soubré have become areas of intensive development for the cultivation of *Hevea.* The regions of Toulépleu, Danané and Man, though having growth and production values below the average of the traditional *Hevea* areas, are zones where smallholder cultivation is possible. This depends on control techniques for white root disease being mastered and profitability being confirmed by socio-economic studies.

Nevertheless, growth and production in these experimental fields continues to be inferior to that of the traditional cultivation zones in Côte d'Ivoire due to the influence of the length of the dry season. The rapid growth clones of the traditional areas remain at the head of the list though their annual girth increment is affected by ecological stresses such as water deficit.

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