RECOVERY OF MEDICINAL TREES AFTER DEBARKING IN THE MONTS KOUFFÉ WOODLAND OF BENIN

[1]C. Delvaux, [2]B. Sinsin and [1]P. van Damme
[1]Department of Plant Production, University of Ghent, Gent, Belgium
[2]Faculté des Sciences Agronomiques, University of Abomey–Calavi, Cotonou, Bénin

Abstract

The wound in the debarked zone on a tree does not re-grow with the same reaction according to species, season, stem diameter and intensity of the debarking. Firstly, we analysed separately the impact of each factor after 12 months. It was very obvious that 1) each species showed its own ability to re-grow its bark: the worst species are *Afzelia africana* and *Maranthes polyandra* and the best ones are *Khaya senegalensis* and *Lannea kerstingii*; 2) the re-growth is clearly better after debarking at the end of the dry season than at the end of the rainy season; 3) the re-growth is slightly better for the 10-20 cm diameter class than for the 21-30 cm and >30 cm diameter classes; 4) the best intensities of debarking are 50% E-W (two sides of tree) and 20% E-W (two sides of tree) and the worst are 100% and 20% square debarking. Secondly, we analysed each species according to the three other factors after 12 months. 1) three species were not influenced by the season: eight species showed a better re-growth after harvesting towards the end of the dry season and only *Pterocarpus erinaceus* had a better re-growth after harvesting towards the end of the rainy season; 2) six species did not show an influence of the diameter and the other six species showed a significant better re-growth with the 10-20 cm stem diameters; 3) four species did not show any difference in re-growth between the different debarking intensities, five species showed the worst re-growth (significantly different from other intensities) with the 20% square AND the 100% debarking, and six species showed the same good re-growth with four debarking intensities (no significant difference between the intensities): 20% E (one side of tree), 20% E-W (two sides of tree), 50% E (one side of tree) and 50% E-W (two sides of tree).

1. Introduction

In Benin as for most countries in Africa, the medicinal plants are used by 80% of rural people. These plants are used for their different parts: leaves, fruits, root, bark, bulbs, rhizomes, tubers and the whole plant. Depending on the plant part selected, the impact on the resource will be variable. Harvesting of the bark or the root is more damaging for the survival of the tree than the harvesting of the leaves or fruits (Cunningham, 1991). But harvesting leaves and fruits has an important impact on the regeneration of the species/ the population (Hall & Bawa, 1993). Bark has a protective role and its harvesting may have a negative impact on the survival of the tree. Firstly, removing a ring of bark around the stem leaves the tree with no natural protection and makes it more sensitive to external attacks. Secondly, the physiological functioning of the tree is disrupted and if the bark is removed to too much depth, the vascular vessels will be completely cut. In a short time, this disturbance may lead to the death of the tree.

The demand for bark varies between countries. In South-West Nigeria bark constitutes 35% of medicinal products (Aboaba, 2002 in Fasola & Egunyomi, 2005). In South Africa (Durban) the demand for bark is as high as 60% against 12% in Malawi and Zambia and 17% in Mozambique (Williams, 2005). In Benin a national enquiry (Adjanohoun *et al*., 1989) showed that bark represents 10.5% of the medicinal plant products (herbs and trees together), but if only the trees are counted, 31.5% of species are selected for their bark, i.e. 53 of 168 species.

Species vary in their ability to regenerate their bark. Cunningham and Mbekum (1993) mentioned that *Prunus africana* and *Warburgia salutaris* have a complete re-growth of the bark after ring barking. Similar studies in Nigeria (Fasola & Egunyomi, 2005) indicated that *Alstonia boonei*, *Entandophragma angolense*, *Khaya grandifolia*, *Khaya senegalensis* and *Spondias mombin* belong to the fast re-growth group while bark of *Adansonia digitata*, *Gliricidia sepium*, *Newbouldia laevis* and *Theobroma cacao* has relatively slow re-growth. In South Africa, *Prunus africana* and *Ocotea bullata* show good re-growth and by contrast the bark of *R. melanophloeos* shows no re-growth (Vermeulen, 2005).

How would medicinal trees in Benin react to debarking? The research aim of this study is to determine the factors which influence the re-growth of the bark after harvesting.

2. Study area

Our study area is the Forêt Classée des Monts Kouffé located between 8°30' and 8°52' North latitude and between 1°40' and 2°27'East longitude in the centre of Benin. It is a woodland of 180.000 ha and it belongs to the Sudano-Guinean phytogeographic region. The mean monthly temperature vary from 21°C to 33.2°C and the mean annual precipitation is 1190.7 mm. Our sites are located in woodland (*Isoberlinia doka*, *Anogeissus leiocarpus*, *Daniellia oliveri*, *Lannea kerstingii*) and in wooded savanna (*Pericopsis laxiflora*, *Pterocarpus erinaceus*, *Pseudocedrela kotschyi*, *Parinari curatelifolia*, *Maranthes polyandra*, *Uapaca togoensis*, *Detarium microcarpum, Monotes kerstingii* and *Lophira lanceolata*).

3. Material and methods

3.1 Factors

We chose 4 main factors: (1) species, (2) season of harvesting, (3) stem diameter of the tree and (4) debarking intensity.

SPECIES
Following enquiries with traditional healers and the population (Bockx, 2004), we selected 12 species: *Afzelia africana*, *Burkea africana*, *Detarium microcarpum*, *Khaya senegalensis*, *Lannea kerstingii*, *Lophira lanceolata*, *Mangifera indica*, *Maranthes polyandra*, *Parkia biglobosa*, *Pseudocedrela kotschyi*, *Pterocarpus erinaceus* and *Uapaca togoensis*.

SEASON
We have harvested trees at the end of the dry season (March-April 2004) and other trees at the end of the rainy season (September-October 2004).

DIAMETER (DBH)
Three diameter classes were selected: 1) 10 – 20 cm (D1); 2) 21 – 30 cm (D2) and 3) > 30 cm (D3).

DEBARKING INTENSITY
The debarking intensity meant the percentage of the circumference of the tree that we have harvested.
The shape of the debarking is a rectangle or square. For a rectangle the length was fixed at 60 cm high and the width varied between 5 to 61.8 cm, as a function of the DBH and the intensity of the debarking. For a square, the length of the sides was a function of the stem diameter, but it was always the same intensity: 20%. For the intensity of 20% and 50%, we decided to remove this percentage once (on east side) or twice (on east and west side).

We chose 7 different intensities: 1) 20% on east side; 2) 20% on east and west side; 3) 50% on east side; 4) 50% on east and west side; 5) 20% square; 6) 75%; and 7) 100% (ring barking).

3.2 Samples

For each species (depending on the availability in the forest and the characteristic of the species) we applied the three other factors with 3 repetitions and obtained:

- Season : 457 trees harvested in dry season and 468 trees harvested in rainy season ;
- DBH: 1) 10 to 20 cm: 309 trees; 2) 21 to 30 cm: 395 trees; 3) >30 cm: 216 trees.
- Debarking intensity: 1) 20% east side: 201 trees; 2) 20% east-west side: 163 trees; 3) 50% east side: 167 trees; 4) 50% east-west side: 141; 5) 20% square: 157 trees; 6) 75%: 39 trees; 7) 100%: 57 trees.
- Species: *Afzelia africana*: 68 trees; *Burkea africana*: 78 trees; *Detarium microcarpum*: 82 trees; *Khaya senegalensis*: 73 trees; *Lannea kerstingii*: 48 trees; *Lophira lanceolata*: 102 trees; *Mangifera indica*: 86 trees; *Maranthes polyandra*: 53 trees; *Parkia biglobosa*: 44 trees; *Pseudocedrela kotschyi*: 93 trees; *Pterocarpus erinaceus*: 96 trees; *Uapaca togoensis*: 102 trees.

3.3 Measurements and Data analysis

VARIABLE: P
We have measured the length (p') of the re-growth of the perimeter of each harvested portion. Consequently we obtained the percentage of the re-growth, P:

$$P = \frac{p'}{p} x100$$

where p' = measurement of re-growth of perimeter ; p = harvested perimeter.

For statistical analyses we transformed the variable *P*:

$$p'' = 2\arcsin\sqrt{P}$$

For explanation of the results and discussion, we will use the percentage of re-growth of the perimeter (P) and not the transformed variable p''.

PERIODICITY OF THE MEASUREMENT
This variable was measured one month after debarking, and thereafter every two months for a period of one year. Consequently for each tree we have 7 measurements. For this paper we will use only data of the first and twelfth month to study the impact of each factor.

DATA ANALYSIS
The rate of re-growth (Rg) is the ratio between the rate of monthly mean re-growth on twelve months and the rate of re-growth during the first month:

$$Rg = \frac{P12/12}{P1}$$

Where P1 = percentage of re-growth of the perimeter after 1 month; P12 = percentage of re-growth after 12 months; P12/12 = rate of mean monthly re-growth over twelve months.
If Rg = 1, then the re-growth is constant throughout the year.
If Rg >1, then the re-growth increases during the year.
If Rg <1, then the re-growth decreases during the year.

Univariate analysis of variance in SPSS version 11 was used.

4. Results

In the comparisons below of the re-growth of the wound perimeter for each factor (species, season, stem diameter or debarking intensity), the data were combined for all the other factors. For example, in the comparison between species, the data were combined across season, stem diameter and debarking intensity. As some trees died during the year, the number of trees (N) for the first month and the twelve month differed.

4.1 Effect of species

AFTER 1 MONTH
Perimeter re-growth showed a significant difference between the 12 species (p=0.00). We obtained 7 homogenous groups (Table 1). The species with the worst re-growth is *Lophira lanceolata* (0.32 %) and the best one is *Khaya senegalensis* with a re-growth of 58.89 %.

AFTER 12 MONTHS
Perimeter re-growth showed a significant difference between the 12 species (p=0.05). We obtained 8 homogenous groups (Table 2). The species with the worst re-growth is *Afzelia africana* (22.2 %) and the best one is *Khaya senegalensis* with a re-growth of 94.81 %.

Table 1. After 1 month, the seven homogenous groups of species based on the percentage perimeter re-growth in terms of p'' (transformed value of P) depending on a Student Newman-Keuls statistic

Species	N	Means of p'' for groups in homogeneous subset						
		1	2	3	4	5	6	7
Lophira lanceolata (Lo)	139	0.0091						
Afzelia africana (Af)	85	0.0505						
Mangifera indica (Mg)	118	0.0624						
Uapaca togoensis (Ua)	137	0.0909	0.0909					
Detarium microcarpum (De)	106	0.1214	0.1214	0.1214				
Burkea africana (Bu)	102	0.1625	0.1625	0.1625				
Maranthes polyandra (Ma)	70		0.2653	0.2653				
Parkia biglobosa (Pa)	54			0.2911				
Pterocarpus erinaceus (Pe)	128				0.5659			
Lannea kerstingii (La)	63					1.0127		
Pseudocedrela kotschyi (Ps)	127						1.5768	
Khaya senegalensis (Kh)	96							1.7336
Significance of differences within Group*		0.237	0.060	0.071	1.000	1.000	1.000	1.000

* The mean difference is significant at the 0.05 level.

Table 2. After 12 month, the eight homogenous groups of species based on the percentage perimeter re-growth in terms of p'' (transformed value of P) depending on a Student Newman-Keuls statistic

Species	N	Means of p'' for groups in homogeneous subset							
		1	2	3	4	5	6	7	8
Afzelia africana (Af)	82	0.7493							
Maranthes polyandra (Ma)	68	0.8593							
Burkea africana (Bu)	95		1.1834						
Uapaca togoensis (Ua)	129			1.3878					
Lophira lanceolata (Lo)	134			1.4240					
Detarium microcarpum (De)	103				1.7169				
Pseudocedrela kotschyi (Ps)	120					1.9697			
Parkia biglobosa (Pa)	52					2.0787			
Pterocarpus erinaceus (Pe)	123						2.2570		
Mangifera indica (Mg)	118						2.3941		
Lannea kerstingii (La)	53							2.6658	
Khaya senegalensis (Kh)	95								2.9041
Significance of differences within Group*		0.209	1.000	0.680	1.000	0.213	0.117	1.000	1.000

* The mean difference is significant at the 0.05 level.

If we compare the re-growth after 1 month and after 12 months (Figure 1), we found that species showed five different reactions after debarking (Table 3):

1) a general low re-growth: the re-growth remained low: after 1 month <10.80%; after 12 months <35.29%. Examples are *Afzelia africana*, *Maranthes polyandra* and *Burkea africana*.
2) a latent period: a very bad re-growth after one month (<15%) followed by a very good re-growth after 12 months (>60%). Examples are *Detarium microcarpum*, *Parkia biglobosa* and *Mangifera indica*.

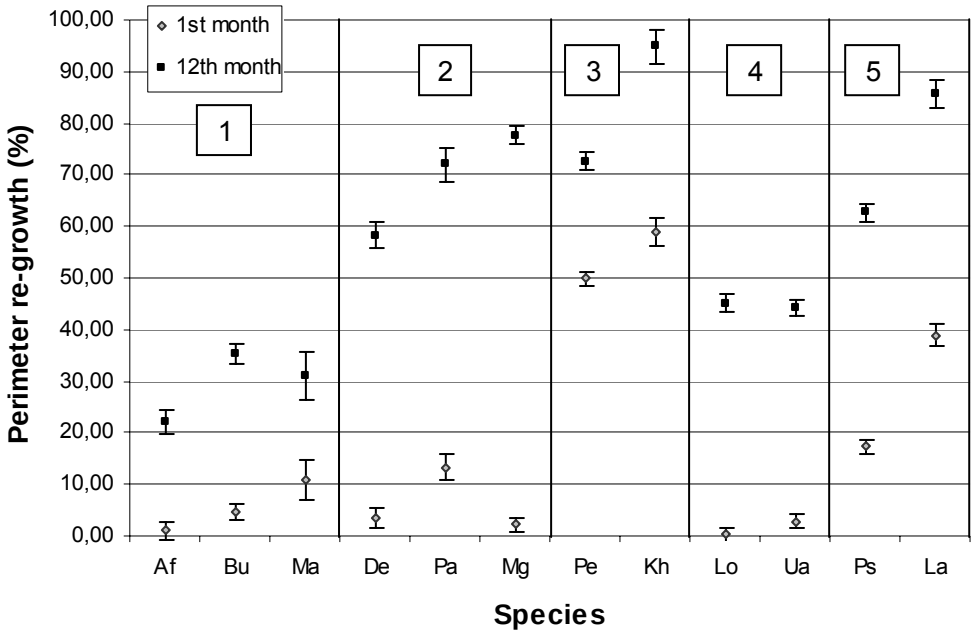

Figure 1. **Mean wound perimeter re-growth (%) of each species 1 month and 12 months after harvesting, showing the five different reactions: 1: a general low re-growth, 2: a latent period, 3: a higher re-growth during the first month, 4: Intermediate low re-growth, 5: Intermediate high re-growth.**

Table 3. **For the twelve species, the ratio between the rate of monthly mean re-growth over twelve months (P12/12) and the rate of re-growth during the first month (P1). If the rate of regrowth Rg = 1, then the re-growth is constant throughout the year. If Rg >1, then the re-growth increases during the year. If Rg <1, then the re-growth decreases during the year. P12 = percentage of re-growth after 12 months**

Species	P1 (%)	P12 (%)	P12/12	Rg
Lophira lanceolata	0.32	45.13	3.76	11.81
Afzelia africana	1.02	22.20	1.85	1.82
Mangifera indica	2.13	77.58	6.46	3.03
Uapaca togoensis	2.90	44.17	3.68	1.27
Detarium microcarpum	3.63	58.31	4.86	1.34
Burkea africana	4.59	35.29	2.94	0.64
Maranthes polyandra	10.80	31.11	2.59	0.24
Parkia biglobosa	13.34	71.91	5.99	0.45
Pseudocedrela kotschyi	17.32	62.61	5.22	0.30
Lannea kerstingii	38.95	85.70	7.14	0.18
Pterocarpus erinaceus	49.87	72.61	6.05	0.12
Khaya senegalensis	58.89	94.81	7.90	0.13

3) a higher re-growth during the first month: the re-growth starts very quickly: more than 50% after 1 month and growing slower for the 11 next months. Examples are *Pterocarpus erinaceus* and *Khaya senegalensis*. That is shown by the ratio of re-growth of <1 (respectively 0.12 and 0.13) and consequently the re-growth decreases after the first month.
4) Intermediate low re-growth: the re-growth is very low after 1 month (<2.90%) and became good after 12 months (≈ 45%). Examples are *Lophira lanceolata* and *Uapaca togoensis*. Effectively, as the Rg is >1 (respectively 11.81 and 1.27) the rate of re-growth continued to increase after the first month.

5) Intermediate high re-growth: the re-growth is already good after 1 month (17.32% and 38.95%) and continues to increase but at a slower monthly rate after 12 months (62.61% and 85.70%). Examples are *Pseudocedrela kotschyi* and *Lannea kerstingii*. Effectively, the ratio of re-growth was <1 (respectively 0.30 and 0.18) with the rate of re-growth decreasing during the year.

4.2 Effect of season

Perimeter re-growth showed a significant difference between seasons, after 1 month (p=0.002) and after 12 months (p=0.000). The re-growth was better when the harvesting was done at the end of the dry season (20.5% after 1 month; 65.9% after 12 months) than at the end of the rainy season (13.4% after 1 month; 47.1% after 12 months) (Figure 2).

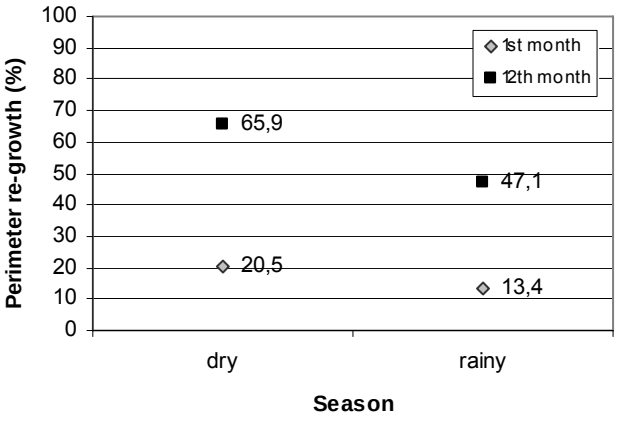

Figure 2. Mean wound perimeter re-growth (%) after 1 month or 12 months, with harvesting at end of dry season or end of rainy season.

After 1 month or 12 months, the re-growth remained better after harvesting in the dry season than rainy season (Figure 2). For both dry and rainy seasons, the rate of re-growth was higher during the first month than for the last 11 months, with the ratio of re-growth respectively 0.27 and 0.29 (Table 4).

Table 4. For both dry and rainy seasons, Rg <1, then the re-growth decreases during the year: the rate of re-growth is higher during the first month than for the last 11 months

Season	P1 (%)	P12 (%)	P12/12	Rg
Dry season	20.5	65.9	5.49	0.27
Rainy season	13.4	47.1	3.93	0.29

4.3 Effect of diameter

AFTER 1 MONTH
Perimeter re-growth was significantly different (p<0.005) between the three diameter classes. We obtained three homogenous groups (Table 5). The re-growth was better for the 10-20 cm diameter class (D1) with 18.6% than for the >30 cm diameter class (D3) with 16.5% than for the 21-30 cm diameter class (D2) with 15.8% (Figure 3).

AFTER 12 MONTHS
Perimeter re-growth was significantly different (p<0.005) between the three diameter classes. We obtained only two homogenous groups (Table 5). The re-growth of the perimeter was better for D1 (62.2%) than for D2 (56.1%) and D3 (57%) (Figure 3).

Table 5. After 1 month, three homogenous groups of diameter classes and after 12 months, two homogenous groups of diameter classes based on the percentage perimeter re-growth in terms of p'' (transformed value of P) using the Student Newman-Keuls statistic

Diameter classes	N 1st month	Means of p'' for groups in homogeneous subset		
		1	2	3
> 30 cm	289	0.3497		
21-30 cm	505		0.4854	
10-20 cm	431			0.5703
Significance*		1.000	1.000	1.000

Diameter classes	N 12th month	Means of p'' for groups in homogeneous subset	
		1	2
> 30 cm	278	1.7341	
21-30 cm	472	1.7591	
10-20 cm	422		1.8681
Significance*		0.559	1.000

* The mean difference is significant at the 0.05 level.

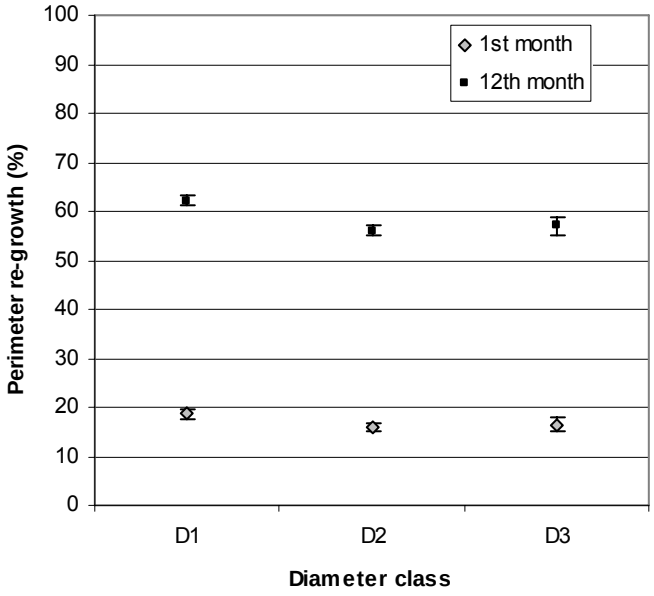

Figure 3. Mean wound perimeter re-growth (%) after 1 month or 12 months, in three stem diameter classes: D1 (10-20 cm); D2 (21-30 cm); and D3 (>30 cm).

After 1 month or 12 months, the re-growth stayed better for diameter class D1 than for the classes D2 and D3 (Figure 3). For the three diameter classes, the rate of re-growth was higher during the first month than for the last 11 months. Effectively the ratio of re-growth was respectively 0.28, 0.30 and 0.29 (Table 6).

Table 6. Re-growth rate (Rg) for the three diameter classes across all species

Diameter	P1 (%)	P12 (%)	P12/12	Rg
D1	18.6	62.2	5.18	0.28
D2	15.8	56.1	4.68	0.30
D3	16.5	57.0	4.75	0.29

4.4 Effect of intensity of debarking

AFTER 1 MONTH

Perimeter re-growth showed a significant difference ($p<0.005$) between all seven intensities of debarking. We obtained two homogenous groups (Table 7) with four species in common for the two groups. The two worst intensities of debarking were 50% East and 100% and the best one was 75% (Figure 4).

AFTER 12 MONTHS

The differences between the seven intensities of debarking were still significant ($p<0.005$). We obtained two homogenous groups (Table 7) but no species were in common for the two groups. The two worst intensities of debarking were the 20% square and 100% and the best one was 50% East-West and 20% East-West (Figure 4).

Table 7. Perimeter re-growth after 1 and 12 months in response to different intensities debarking, based on the percentage perimeter re-growth in term of p'' (transformed value of P) depending on a Student Newman-Keuls statistic, showing two homogenous groups of intensities

Intensity debarking	N 1st month	Means of p'' for groups in homogeneous subset	
		1	2
50 % E	143	0.3629	
100 %	49	0.3720	
50 % E-W	247	0.4335	0.4335
20% square	125	0.4446	0.4446
20 % E	161	0.5291	0.5291
20 % E -W	274	0.5539	0.5539
75 %	39		0.6208
Significance*		0.105	0.086

Intensity debarking	N 12th month	Means of p'' for groups in homogeneous subset	
		1	2
20% square	125	1.3088	
100 %	34	1.4606	
50 % E	138		1.7172
75 %	39		1.8179
20 % E	160		1.8397
50 % E-W	235		1.9255
20 % E -W	268		1.9586
Significance*		0.123	0.102

* The mean difference is significant at the 0.05 level.

After 1 month or 12 months, the re-growth stayed worst for ring-barking (100%) and best for 20% East-West (Figure 4). For the seven intensities of debarking, the rate of re-growth is higher during the first month than for the last 11 months. Effectively the ratio of re-growth was between 0.23 and 0.33 (Table 8).

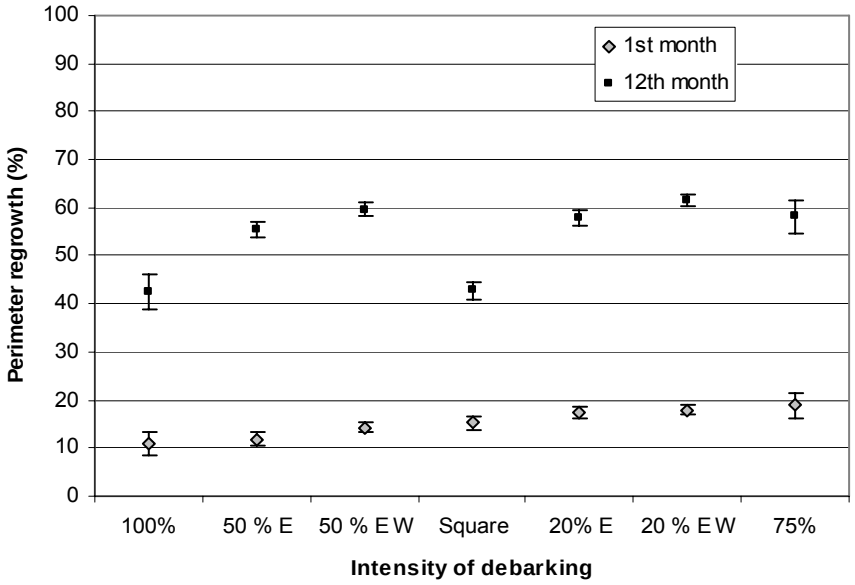

Figure 4. Mean wound perimeter re-growth (%) after 1 month or 12 months, with different intensities of de-barking.

Table 8. Re-growth rate (Rg) for the seven intensities of debarking across all species

Intensities of debarking	P1	P12	P12/12	Rg
100%	10.80	42.39	3.53	0.33
50 % E	11.91	55.51	4.63	0.39
50 % E W	14.24	59.62	4.97	0.35
Square	15.25	42.83	3.57	0.23
20% E	17.48	58.03	4.84	0.28
20 % E W	17.87	61.50	5.12	0.29
75%	18.92	58.22	4.85	0.26

4.5 Effect of season on each species

AFTER 1 MONTH (Table 9)
Six species (50%) did not present a significant difference in perimeter re-growth after debarking in the dry or rainy season: *Afzelia africana*, *Burkea africana*, *Lophira lanceolata*, *Mangifera indica*, *Uapaca togoensis* and *Pterocarpus erinaceus*. For the first five species, the re-growth was less than 10%, but for *Pterocarpus erinaceus* the re-growth was about 50%.

The other six species showed a significant difference in perimeter re-growth between the seasons: *Detarium microcarpum*, *Lannea kerstingii*, *Maranthes polyandra*, *Parkia biglobosa*, *Pseudocedrela kotschyi* and *Khaya senegalensis*. Only *Khaya senegalensis* showed a better re-growth after debarking in the rainy season (63.36%) than the dry season (51.71%). For the other species the re-growth was better in the dry season than rainy season, but they did not show the same re-growth ability:

- *Lannea kerstingii* showed the better re-growth: 21.35% for the rainy season and 43.31% for the dry season;
- *Detarium microcarpum*, *Maranthes polyandra*, *Parkia biglobosa* and *Pseudocedrela kotschyi* had a low re-growth for the rainy season (less than 4%), but the re-growth varied between species for the dry season, respectively 7.14%, 16.59%, 18.62% and 32.47%.

AFTER 12 MONTHS (Table 9)
Three species (25%) did not show a significant difference in perimeter re-growth after debarking between the dry or rainy season: *Khaya senegalensis*, *Lannea kerstingii*, *Mangifera indica.* Their re-growth was high: 72.12% to 89.99%.

The other nine species showed a significant difference in re-growth between the seasons: *Afzelia africana*, *Burkea africana*, *Detarium microcarpum*, *Lophira lanceolata*, *Maranthes polyandra*, *Pseudocedrela kotschyi*, *Pterocarpus erinaceus* and *Uapaca togoensis*. Only *Pterocarpus erinaceus* showed a better re-growth after debarking in the rainy season (74.87%) than the dry season (66.01%). For the other eight species, the re-growth was better in the dry season than the rainy season. In the rainy season, only *Parkia biglobosa* had a re-growth higher than 50%. For the other seven species, the re-growth was between 12.85% and 46.52%. But in the dry season five of the species had a re-growth between 53.47% and 73.37%, with the lowest re-growth of 30.56% in *Afzelia africana*.

Generally, the impact of the season was more important after 12 months than after 1 month, although in *Mangifera indica* the season had no influence neither after 1 month or 12 months. All others species showed a significant difference between seasons for the re-growth of the perimeter after 1 month and/or 12 months.

- *Detarium microcarpum*, *Maranthes polyandra*, *Parkia biglobosa* and *Pseudocedrela kotschyi* showed a significant difference between seasons after 1 month AND after 12 months.
- *Khaya senegalensis* and *Lannea kerstingii* showed a significant difference only after 1 month. After 12 months the re-growth was very high in both seasons (85.07% to 89.99%).
- *Afzelia africana*, *Burkea africana*, *Lophira lanceolata*, *Pterocarpus erinaceus* and *Uapaca togoensis* showed a significant difference only after 12 months. After 1 month the re-growth was very low in both seasons (except for *Pterocarpus erinaceus*).

Table 9. Wound perimeter re-growth (%) for each species during the end of the dry and rainy seasons

Species	Month	Dry season		Rainy season		P+
		Mean (%)	std. Error	Mean (%)	std. Error	
Afzelia africana	1 month	2.53	8.65	0.00	0.00	n.s.
	12 months	30.56	3.45	16.88	4.94	**
Burkea africana	1 month	6.24	11.00	4.23	8.44	n.s.
	12 months	39.21	4.06	25.91	3.61	**
Detarium microcarpum	1 month	7.14	1.69	1.81	1.66	**
	12 months	61.57	4.20	46.52	3.88	**
Khaya senegalensis	1 month	51.71	6.76	63.36	6.00	**
	12 months	89.31	1.67	89.99	1.47	n.s.
Lannea kerstingii	1 month	43.31	5.06	21.35	3.04	**
	12 months	85.07	2.35	86.08	1.57	n.s.
Lophira lanceolata	1 month	0.57	0.40	0.19	0.39	n.s.
	12 months	68.42	2.47	23.86	2.72	**
Maranthes polyandra	1 month	16.59	4.42	3.26	4.77	**
	12 months	40.25	5.25	12.85	6.08	**
Mangifera indica	1 month	2.60	1.41	0.83	1.80	n.s.
	12 months	72.12	1.25	69.96	1.60	n.s.
Parkia biglobosa	1 month	18.62	4.66	2.60	2.56	**
	12 months	73.37	5.72	54.23	3.28	**
Pterocarpus erinaceus	1 month	45.02	3.32	49.98	3.61	n.s.
	12 months	66.01	1.83	74.87	1.98	**
Pseudocedrela erinaceus	1 month	32.47	2.66	0.95	2.61	**
	12 months	72,80	2.75	38.35	2.66	**
Uapaca togoensis	1 month	3.28	0.95	3.68	0.95	n.s.
	12 months	53.47	2.77	37.10	2.78	**

+n.s. : non significant, ** : significant difference ($p<0.05$)

4.6 Effect of diameter on each species

AFTER 1 MONTH (Table 10)
Eight species (66%) did not show a significant difference in bark re-growth between the three diameter classes: *Afzelia africana*, *Detarium microcarpum*, *Lophira lanceolata*, *Mangifera indica* and *Uapaca togoensis* with a maximum re-growth of 5%, *Maranthes polyandra* and *Parkia biglobosa* with a maximum re-growth of 13% and *Khaya senegalensis* with a re-growth between 56 – 63%.
Four species (33%) showed a significant difference in re-growth between the three diameter classes: *Burkea africana*, *Lannea kerstingii*, *Pterocarpus erinaceus* and *Pseudocedrela kotschyi*. For *Burkea africana* and *Pterocarpus erinaceus*, the trees of the D1 diameter class has a better re-growth (8.70 % and 60.61%) than the D2 (2.97% and 46.30%) and D3 (2.09 % and 35.60%) diameter classes. *Lannea kerstingii* has a better re-growth for the D3 diameter class (41.53%) >D1 (33.27%) = D2 (22.20%). *Pseudocedrela kotschyi* showed a significant difference between the three diameter classes: D1 (26.11%) > D2 (17.27%) > D3 (6.77%).

AFTER 12 MONTHS (Table 10)
Six species (50%) did not show a significant difference in bark re-growth between the three diameter classes: *Afzelia africana* and *Maranthes polyandra* with a maximum re-growth of 30%, *Detarium microcarpum* and *Uapaca togoensis* with a maximum re-growth of 65%, and *Lannea kerstingii* and *Khaya senegalensis* with a maximum re-growth of 92%. The other six species (50%) showed a significantly different re-growth between the three diameter classes: *Burkea africana*, *Lophira lanceolata*, *Mangifera indica*, *Parkia biglobosa*, *Pterocarpus erinaceus* and *Pseudocedrela kotschyi*. *Mangifera indica, Pterocarpus erinaceus* and *Pseudocedrela kotschyi* showed a better re-growth in the D1 diameter class (79.59%, 80.04% and 62.29%) than in the D2 (69.10%, 64.65% and 56.51%) and D3 (64.43%, 66.62% and 47.93%) diameter classes. But for *Parkia biglobosa* D1 (71.22%) and D2 (68.42%) are similar and superior to D3 (51.76%). *Burkea africana*

and *Lophira lanceolata* present a significant difference respectively between D1 (39.71%, ≈ D2 with 35.24%) and D3 (22.73%), and D1 (53.81%, ≈ D3 with 46.26%) and D2 (38.34%).

Generally, the contribution of the diameter is slightly more important after 12 months than after 1 month. In *Afzelia africana*, *Detarium microcarpum*, *Khaya senegalensis*, *Maranthes polyandra* and *Uapaca togoensis* the diameter had no influence after 1 month or after 12 months. All other species showed a significant difference in wound perimeter re-growth between diameter classes after 1 month and/or 12 months.

- *Burkea africana*, *Pterocarpus erinaceus* and *Pseudocedrela kotschyi* showed a significant difference between the diameter classes after 1 month AND after 12 months.
- *Lannea kerstingii* showed a significant difference only after 1 month (D1=D2<D3). After 12 months the re-growth is almost the same for the three diameter classes (D1=86.55%, D2=82.87% and D3=87.31%).
- *Lophira lanceolata*, *Mangifera indica* and *Parkia biglobosa* showed a significant difference only after 12 months.

Table 10. Wound perimeter re-growth (%) for each species over the three diameter classes

Species	Month	Diameter class D1 10-20 cm		Diameter class D2 21-30 cm		Diameter class D3 >30 cm		P+
		Mean (%)	Std. Error	Mean (%)	Std. Error	Mean (%)	Std. Error	
Afzelia africana	1 month	0.00	1.28	3.34	1.17	0.94	1.51	n.s.
	12 months	26.53	4.60	23.58	3.73	21.05	5.84	n.s.
Burkea africana	1 month	8.70	1.44	2.97	1.44	2.09	2.21	**
	12 months	39.71	4.21	35.24	3.72	22.73	5.51	**
Detarium microcarpum	1 month	3.47	1.64	5.29	1.37	4.66	3.22	n.s.
	12 months	52.71	3.84	47.03	3.29	62.40	7.76	n.s.
Khaya senegalensis	1 month	56.28	5.10	52.56	4.01	63.77	15.13	n.s.
	12 months	88.20	1.26	89.63	0.99	91.11	3.70	n.s.
Lannea kerstingii	1 month	33.27	4.74	22.20	4.38	41.53	4.81	**
	12 months	86.55	2.20	82.87	2.29	87.31	2.24	n.s.
Lophira lanceolata	1 month	1.02	0.51	0.06	0.40	0.06	0.50	n.s.
	12 months	53.81	3.22	38.34	2.55	46.26	3.24	**
Maranthes polyandra	1 month	8.39	2.89	8.95	3.07	12.44	11.56	n.s.
	12 months	26.62	3.03	22.90	4.09	30.14	14.47	n.s.
Mangifera indica	1 month	4.72	2.15	0.52	1.47	0.00	1.89	n.s.
	12 months	79.59	1.91	69.10	1.31	64.43	1.68	**
Parkia biglobosa	1 month	9.59	6.05	13.57	4.17	8.67	3.16	n.s.
	12 months	71.22	7.40	68.42	5.14	51.76	4.02	**
Pterocarpus erinaceus	1 month	60.61	4.27	46.30	3.28	35.60	4.82	**
	12 months	80.04	2.31	64.65	1.80	66.62	2.66	**
Pseudocedrela kotschyi	1 month	26.11	3.20	17.27	2.47	6.77	3.75	**
	12 months	62.29	3.23	56.51	2.51	47.93	3.73	**
Uapaca togoensis	1 month	2.90	1.22	3.37	0.94	4.16	1.23	n.s.
	12 months	50.12	3.51	44.09	2.76	41.65	3.55	n.s.

+n.s. : non significant, ** : significant difference (p<0.05)

4.7 Effect of intensity of debarking on each species

AFTER 1 MONTH (Table 11)
Nine species (75%) did not show a significant difference in bark re-growth between the intensities of debarking: *Lophira lanceolata* with a maximum re-growth of 2%; *Burkea africana*, *Mangifera indica* and *Uapaca togoensis* with a maximum re-growth of 8%; *Detarium microcarpum* with a maximum re-growth of

11%; *Maranthes polyandra* and *Parkia biglobosa* with a maximum re-growth of 23%; and *Pterocarpus erinaceus* and *Khaya senegalensis* with respectively a maximum re-growth of 58% and 73%.

Three species (25%) showed a significant difference in bark re-growth between the seven intensities of debarking. For *Afzelia africana* only the 20% square was significantly different. For *Lannea kerstingii* and *Pseudocedrela kotschyi* three intensities showed a significant difference from the others, respectively intensities 20% E, 20% E-W and 20% square (I1-I2-I5) and intensities 20% E, 20% E-W and 75% (I1-I2-I6).

AFTER 12 MONTHS (Table 11)

Four species (33%) did not show a significant difference in bark re-growth between the intensities of debarking: *Afzelia africana* with a maximum re-growth of 35%; *Burkea africana* with a maximum re-growth of 44%; and *Lophira lanceolata* and *Uapaca togoensis* with a maximum re-growth of 55%.

Eight species (66%) showed a significant difference between the seven intensities of debarking: *Detarium microcarpum*, *Khaya senegalensis*, *Lannea kerstingii*, *Maranthes polyandra*, *Mangifera indica*, *Parkia biglobosa*, *Pterocarpus erinaceus* and *Pseudocedrela kotschyi*. Harvesting a 20% square (I5) and ring-barking (I7) showed significant difference in re-growth over the other five debarking intensities, for all the species (except *Pseudocedrela kotschyi* for the 20% square). The best re-growth for the square is shown by *Khaya senegalensis*, *Lannea kerstingii* and *Mangifera indica,* respectively 58.94%, 56.81% and 53.53%. The worst re-growth for the square was shown by *Maranthes polyandra* (26.54%). The best re-growth after ring-barking (100%-I7) was shown by *Khaya senegalensis* with a re-growth of 86.44% and the worst re-growth by *Parkia biglobosa* and *Detarium microcarpum,* respectively 17.68% and 19.71%. *Detarium microcarpum*, *Khaya senegalensis*, *Mangifera indica*, *Parkia biglobosa*, *Pterocarpus erinaceus* and *Pseudocedrela kotschyi* did not show significant differences in re-growth between the harvesting intensities of 20% E (I1), 20% E-W (I2), 50% E (I3) and 50% E-W (I4). The best re-growth for these four intensities is shown by *Khaya senegalensis* (97.75% to 100%) and the worst was shown by *Detarium microcarpum* and *Pseudocedrela kotschyi* with respectively 54.56% to 68.60% and 50.00% to 71.01%. For *Lannea kerstingii* the harvesting of 50% E-W (I4) was significantly different from the other intensities. For *Maranthes polyandra* both 50% E (I3) and 50% E-W (I4) showed significantly different re-growth of the bark. When we harvested 75% (I6) of the circumference of the trunk, only *Khaya senegalensis* and *Mangifera indica* showed significantly different regrowth from the other intensities.

Table 11. Wound perimeter re-growth (%) per species and intensity of debarking after 1 and 12 months

Species	M	Intensity 1		Intensity 2		Intensity 3		Intensity 4		Intensity 5		Intensity 6		Intensity 7		P+
		20% E		20% E-W		50% E		50% E-W		20% square		75%		100%		
		Mean %	SE %	Mean %	SE %	Mean %	SE %	Mean %	SE %	Mean %	SE %	Mean %	SE %	Mean %	SE %	
Afzelia africana	1	0.00	1.6	0.00	1.3	0.00	1.7	0.00	1.5	11.35	1.8	0.00	3.5	2.36	2.7	*
	12	16.84	5.3	15.88	4.5	26.19	5.3	22.24	5.0	28.99	5.8	21.53	11.7	34.37	10.0	ns
Burkea africana	1	6.16	2.3	4.07	1.8	3.01	2.4	7.98	2.3	7.37	2.6	0.00	5.6	0.00	5.6	ns
	12	36.91	4.6	37.75	3.8	36.59	4.9	41.46	5.8	22.97	5.3	43.36	11.8	8.90	14.3	ns
Detarium microcarpum	1	2.49	2.1	3.27	2.1	1.48	2.5	4.01	2.0	10.25	2.7	10.32	5.4	-0.51	3.9	ns
	12	54.56	4.9	68.48	5.0	57.13	5.7	63.80	4.5	46.04	6.1	68.60	12.5	19.71	10.8	*
Khaya senegalensis	1	61.64	6.7	72.58	7.4	48.47	9.1	49.43	7,4	46.42	9.4	68.79	16.5	55.45	12.1	ns
	12	98.37	1.6	100.1	1.8	97.49	2.2	97.75	1.8	58.94	2.3	88.42	4.0	86.44	3.2	*
Lannea kerstingii	1	44.35	4.1	48.30	4.2	27.10	7.3	13.97	7.8	32.90	4.7	-	-	27.38	10.4	*
	12	93,55	1.9	98.54	2.0	95.03	4.6	83.95	4.2	56.81	2.2	-	-	-	-	*
Lophira lanceolata	1	-0.02	0.7	0.21	0.5	0.03	0.7	-0.03	0.5	1.82	0.7	0.32	1.2	0.34	1.1	ns
	12	38.77	3.9	49.25	2.8	49.20	4.1	45.50	2.9	36.38	3.9	54.03	7.2	49.85	10.1	ns
Maranthes polyandra	1	13.44	4.6	8.14	5.2	10.86	6.1	1.03	5.8	18.45	6.5	-	-	7.64	9.8	ns
	12	36.53	5.8	39.26	6.5	23.75	7.7	6.68	7.3	26.54	8.1	-	-	-	-	*
Mangifera indica	1	0.84	2.1	0.66	1.6	1.73	2.5	5.29	1.7	2.43	2.6	0.31	5.6	0.75	4.9	ns
	12	83.49	1.9	84.81	1.4	75.07	2.2	78.57	1.5	53.53	2.3	70.81	5.0	51.00	4.3	*
Parkia biglobosa	1	22.78	3.7	6.92	4.4	11.38	4.8	9.95	7.1	7.59	5.9	-	-	5,04	9.2	ns
	12	88.30	4.5	76.28	5.4	66.22	5.9	84.50	8.6	49.82	7.1	-	-	17.68	13.0	*
Pterocarpus erinaceus	1	57.78	5.5	55.81	3.9	42.35	5.5	49.72	4.5	37.12	6.1	55.72	10.1	34.01	10.1	ns
	12	77.25	3.0	82.19	2.2	68.34	3.0	72.61	2.4	48.38	3.3	77.92	5.4	66.36	5.8	*
Pseudocedrela erinaceus	1	23.93	4.2	24.14	3.0	8.06	4.1	13.29	3.1	14.23	5.5	28.11	7.6	5.23	7.6	*
	12	71.01	3.9	70.76	2.8	50.00	3.8	62.47	3.0	55.10	5.4	56.39	7.1	23.28	9.8	*
Uapaca togoensis	1	1.45	1.5	1.83	1.2	4.21	1.6	2.47	1.1	4.85	1.6	3.71	2.9	5.84	2.9	ns
	12	42.28	4.3	40.49	3.3	44.17	4.7	51.67	3.2	34.84	4.4	54.12	8.0	49.45	9.6	ns

+n.s. : non significant, *: significant difference (p<0.05)

Generally, the impact of the intensities of debarking is more important after 12 months than after 1 month, except for *Burkea africana*, *Lophira lanceolata* and *Uapaca togoensis* for which the intensities of debarking have no influence neither after 1 month nor after 12 months. All other species showed a significant difference between intensities of debarking for the re-growth of the perimeter after 1 month and/or 12 months.

- *Lannea kerstingii and Pseudocedrela kotschyi* showed a significant difference between the intensities of debarking after 1 month AND after 12 months.
- *Afzelia africana* showed a significant difference only after 1 month. After 12 months the re-growth was almost similar for every intensity (15.88% to 34.37%).
- *Detarium microcarpum, Khaya senegalensis, Maranthes polyandra, Mangifera indica, Parkia biglobosa and Pterocarpus erinaceus* showed a significant difference only after 12 months.

5. Conclusion

Following all these results we may separate species into two groups: species with a general re-growth less than 50% and species with a general re-growth higher than 50%.

The species which require a better attention are those with the worst recovery after 12 months: *Afzelia africana*, *Maranthes polyandra*, *Burkea africana*, *Uapaca togoensis* and *Lophira lanceolata*. That means that for these species the season, stem diameter class and intensity of debarking are very important considerations during bark harvesting. Indeed the most important factor for these species is the season, with the stem diameter and intensity of debarking of lesser importance. For the season, the 5 species showed a significant difference between the two seasons: the re-growth is almost double after harvesting towards the end of the dry season than after the rainy season.

For the other seven species, these factors (may) influence the re-growth of the bark but re-growth remains higher than 50%.

In the light of this study, it is clear that other factors (intrinsic or environmental) may influence the ability of the bark to re-grow. We may have to work at both the microscopic and macroscopic levels to gain a better understanding of this mechanism of re-growth.

References

ADJANOHOUN, E., ADJAKIDJÈ, V., AHYI, M.R.A., AKÉ ASSI, L., AKOÈGNINOU, A., D'ALMEIDA, J., APOVO, F., BOUKEF, K., CHADARÉ, F., CUSSET, G., DRAMANE, K., EYME, J., GASSITA, J.-N., GBAGUIDI, N., GOUDOTÉ, E., GUINKO, S., HOUGNON, P., ISSA, L., KEITA, A., KINIFFO, H.V., KONE BAMBA, D., MUSAMPA NSEYYA, A., SAADOU, N., SODOGANDJI, T.H., DE SOUZA, S., TCHABI, A., ZINSOU DOSSA, C. & ZOHOUN, T.H. (1989). *Contribution aux études ethnobotaniques et floristiques en République Populaire du Bénin,* ACCT, Paris.

BOCKX, B. (2004). *Etnobotanische studie van geneeskrachtige planten in Manigri en Igbèbè, Bénin.* Unpublished thesis, Universiteit van Ghent, Gent. 209pp.

CUNNINGHAM, A.B. (1991). Development of a conservation policy on commercially exploited medicinal plants: a case study from Southern Africa. *In*: AKERELE, O., HEYWOOD, V. & SYNGE, H. (eds). *Conservation of Medicinal Plants*. Cambridge University Press, Cambridge. pp. 337-358.

CUNNINGHAM, A.B. & MBEKUM, F.T. (1993). Sustainability of harvesting *Prunus africana* bark in Cameroon. A medicinal plant in international trade. People and Plant working paper 2, UNESCO. 28 pp.

FASOLA, T.R. & EGUNYOMI, A. (2005). Nigerian usage of bark in phytomedicine. *Ethnobotany Research and Applications* 3: 73-77.

HALL, P. & BAWA, K. (1993). Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. *Economic Botany* 47(3): 234-247.

VERMEULEN, W. (2005). Choice of harvesting system: Matching prescriptions to species. Oral presentation for Trees for Health – Forever: Implementing sustainable medicinal bark use in Southern Africa Regional Workshop,1 – 3 November 2005, Johannesburg.

WILLIAMS, V. (2005). Market networks for medicinal bark in southern Africa. Oral presentation for Trees for Health – Forever: Implementing sustainable medicinal bark use in Southern Africa Regional Workshop, 1 – 3 November 2005, Johannesburg.