EXPERIMENTAL PROTOCOLS AND LESSONS LEARNT FROM STRIP HARVESTING OF BARK FOR MEDICINAL USE IN THE SOUTHERN CAPE FORESTS

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BACKGROUND

The harvesting of non-timber forest products is an important aspect of the sustainable management of natural forests. The harvesting of medicinal plants is of particular importance, with the most valued traditional medicines coming from natural forests (Lawes *et al* 2000). Bark harvested from selected species is a commonly used traditional medicine but, due to increasing urbanisation, has become highly commercialised. This has resulted in the overexploitation of some target species, posing a major challenge to resource managers to develop mechanisms for sustainable resource use and forest protection. The National Forests Act (Act No. 84 of 1998) makes provision for access by local communities to forest resources for domestic use, subject to sustainable management principles, as well as for community development through Community Forestry Agreements.

The need for a strategy and to explore different options for the sustainable harvesting of bark for medicinal use from the southern Cape forests, was identified by Lübbe *et al* (1991). In 2001 an experimental bark harvesting project (initially part of the Innovative Fund Project: Commercial Products from the Wild) (*vide* Geldenhuys 2000, 2002) was initiated at two study sites in the Southern Cape to develop yield regulation systems for selected species, and to formulate management prescriptions and best practices for bark harvesting. *Ocotea bullata*, *Curtisia dentata* and *Rapanea melanophloeos* were selected for the study as they are highly in demand and well represented in the southern Cape forests. The objective with the umbrella project (Innovative Fund Project) was to develop ecologically realistic and socially acceptable SMMEs based on the sustainable utilization of species and products traditionally harvested from forests and woodlands in South Africa (Geldenhuys 2000).

The purpose with this paper is to evaluate the experimental layout and assessment protocols used, based on preliminary results and lessons learnt with the assessment of bark stripped trees in the southern Cape.

STUDY AREA

The study was conducted at two study sites in the natural forests in the southern Cape, South Africa (Figure 1). It is the largest forest complex in Southern Africa, covering a total area of ca 60500 ha between 22°00' and 24°30'E at approximately 33°45'S latitude. It forms the southern end of the chain of Afromontane forests along the eastern escarpment and the Indian Ocean Coastal Belt forests along the east coast of South Africa (White 1978). It has been classified as Southern Cape Afrotemperate Forests (CSIR 2003), consisting of mountain forests, coastal platform forests and scarp forests. The canopy consists of a mixture of canopy tree species, with *Cunonia capensis*, *Ocotea bullata*, *Olea capensis* subsp. *macrocarpa*, *Podocarpus latifolius*, *Cassine peragua* and *Pterocelastrus tricuspidatus* dominating, depending on the type and specific locality. The area receives orographic rain throughout the year, but with peaks during autumn and early summer, and has a moist, warm temperate climate. Rainfall varies between 500 mm at the coast and 1200 mm in the mountains in the heart of the forest complex. Mean daily maximum temperature ranges from 23.8° C in February to 18.2° C in August, with the mean daily minimum between 19.7° C and 8.9° C. (CSIR 2003).

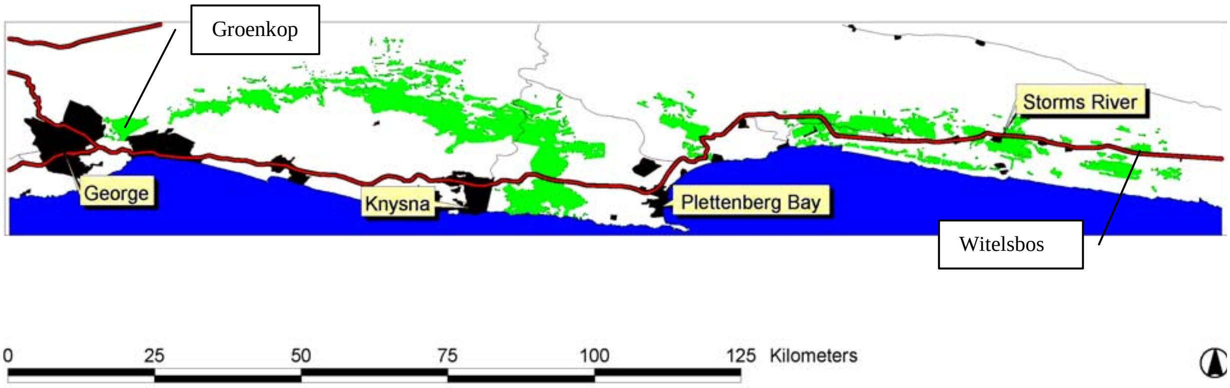


Figure 1. Distribution of natural forests in the southern Cape and study sites for experimental bark stripping.

The state-owned forests are managed in accordance with a multiple-use management system, with conservation, resource use (timber and non-timber) and eco-tourism important land-use types. A policy of participatory forest management (PFM) is followed to ensure local participation in decision-making and the sharing of economic, social and environmental benefits from the forests (Durrheim & Vermeulen, in prep). Although the management focus has for many years been timber harvesting for furniture making (*vide* Seydack & Vermeulen, in press), the harvesting of non-timber forest products, especially for medicinal use, is becoming increasingly important. The species selected are well represented in the southern Cape forests, with limited illegal harvesting that could interfere with controlled, experimental bark stripping.

Two sites were selected for the study both, within platform forest, i.e. Groenkop, a drier site near George, and Witelsbos, a moister site near Stormsriver, in the west and east of the distribution range of the Southern Cape forest respectively (Figure 1). The Groenkop site is located about 260 m a.s.l. with a rainfall of 850 mm per annum (Geldenhuys 1998a). The moister Witelsbos site receives ca 1200 mm of rain per annum, at an altitude of 200 m a.s.l. (Geldenhuys 1998b). Both the sites have been allocated to the Research Management Class (Durrheim & Vermeulen, in prep) and many forest ecological studies had been conducted in the areas. Long-term studies on recruitment, growth and mortality still continue (Geldenhuys 1998a,b).

METHODOLOGY

Three species were selected for the study as part of the Commercial Products from the Wild Innovative Fund Project (*vide* Geldenhuys 2000), *viz. Ocotea bullata*, *Curtisia dentata* and

Rapanea melanophloeos, primarily because of their importance in commercial bark harvesting and impact on the resource in KwaZulu-Natal (*vide* Geldenhuys 2002). The experimental layout and assessment protocols were first described by Geldenhuys & Rau (2001) and Geldenhuys *et al*. (2002).

Tree selection

Trees were categorized in three tree size classes, taking into consideration the diameter class distribution of the species, as follows:

Species	Small	Medium	Large
Ocotea bullata	10 – 19 cm DBH	20 – 39 cm DBH	40 + cm DBH
Curtisia dentata	10 – 19 cm DBH	20 – 29 cm DBH	30 + cm DBH
Rapanea melanophloeos	10 – 19 cm DBH	20 – 39 cm DBH	40 + cm DBH

Only relatively healthy trees that met the following crown health categories of percentage foliage, were selected for treatment:

- 81 – 100% healthy crown (crown densely covered with foliage with no apparent die-back)
- 61 – 80% (tips of terminal shoots without leaves while the rest of the tree appears healthy.

Trees with major structural damage (e.g. large branches broken off) or serious stem rot, also did not qualify for selection.

Treatment procedures

Depth of bark removal

Two bark removal methods were used, namely total and partial bark removal. For total bark removal, an axe was used to cut two vertical lines through the bark onto the wood. This enabled the bark to separate totally from the wood, as is usually the practice with bark harvesting. For partial bark removal, the bark had to be peeled from the stem with a sharp axe, as the vertical lines could not be cut, with a thin layer of inner bark not removed. Both methods were applied to each selected tree, allocated randomly to the eastern and western side of the tree.

Strip width

Three strip widths were used:

- 5 cm
- 10 cm
- 15 or 20 cm (15 cm wide for trees <20 cm DBH)

Strips were 1m in length and removed in a vertical direction, upward from a starting point at 50 cm above ground level, or if on a stump or swollen base, from 50 cm above the stump or swollen base.

Use of tree sealer

Commercial tree sealer was used on the lower part of each wound (total and partial removal) to test their effect on wound recovery or the process of decay. (Applying the sealer at random to the upper or lower part was not considered because of the possible flow of the substance onto the lower part during wet weather).

Season of treatment

The treatments were applied during two seasons:

- Mid-winter (July – August), the driest period in the southern Cape but with relatively low temperatures. The trees were selected and treated during the period 23 to 28 July 2001 at Groenkop and 30 July to 3 August 2001 at Witelsbos.
- Mid-summer (November – December), a period with good rains but high temperatures, which cause moisture stress. The trees were treated during the period 26 to 30 November 2001 at Groenkop and 3 to 6 December 2001 at Witelsbos.

Treatment application procedures

All trees were selected during the July – August period following a paired sample procedure. This also ensured that enough trees were present for both seasons. If two trees of a species of similar size were found, they were randomly allocated to the winter and summer treatment. Each tree was assigned a number, and the number was painted on the tree. The experimental layout made provision for the following minimum number of trees to be selected per species per site:

Tree size	Number of trees per species per season per site			
	Strip width (cm)			Total
	5	10	15/20	
Small	5	5	5	15
Medium	5	5	5	15
Large	5	5	5	15

The following information was recorded for each tree after treatment:

- Date of treatment
- Tree number
- Species
- DBH (cm)
- Estimated tree height (m)
- Estimated stem length (up to major branches) (m)
- Crown health category
- Strip width (cm)
- Mass of bark removed (g)

The location of trees were indicated on 1: 10 000 management maps to ease relocation during assessment.

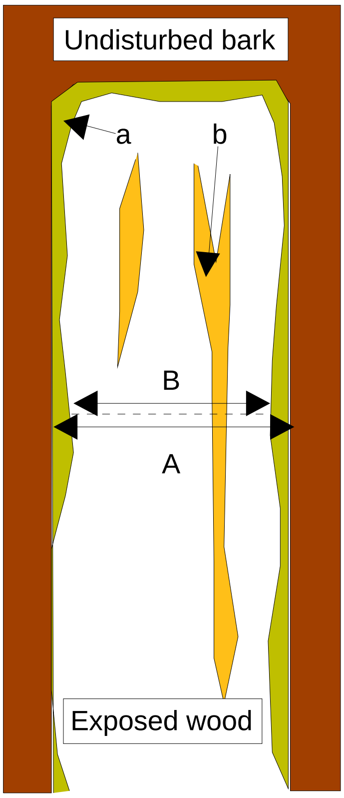
Assessment protocols

Assessments are done six monthly, with the first done six months after treatment. A separate evaluation is made of the four treatments applied to each tree, i.e. total versus partial bark removal, and application of tree seal or not. Data and information recorded during each assessment include crown condition, recovery through phellogen edge growth (only for total bark removal), recovery through phellogen sheet growth, insect damage, fungal growth and the presence of agony shoots.

Tree condition
A visual assessment of crown condition is made, and trees are allocated to one of six crown health crown categories of percentage foliage (after Lübbe & Geldenhuys 1990):
0 = Tree dead (no foliage in crown, but live vegetative shoots may be present at base of stem below breast height)
1 = 1 – 20% healthy crown (few leaves, only present near bole of tree)
2 = 21 – 40% healthy crown (leaves present only near branches closest to the main stem)
3 = 41 – 60% healthy crown (leaves present on branches)
4 = 61 – 80% healthy crown (tips of some terminal shoots without leaves, rest appears healthy)
5 = 81 – 100% healthy crown (crown densely covered with foliage, no apparent die-back)

Only trees meeting the criteria for crown condition classes 4 and 5 were initially selected for treatment (see Tree Selection).

Edge development
This is recorded as the percentage of the edge of the wound showing phellogen growth, i.e. tissue showing wound recovery from underneath the bark ('a' in Figure 2). The following edge development percentage classes were used:



0 = no edge recovery
1 = 1 – 10%
2 = 11 – 20%
3 = 21 – 30%
4 = 31 – 40%
5 = 41 – 50%
6 = 51 – 60%
7 = 61 – 70%
8 = 71 – 80%
9 = 81 – 100%

Rate of edge growth
A horizontal line was marked with lumber crayon in the middle of the strip, for both the sections with and without tree sealer (total bark removal only). On this line two distances were measured ('A' & 'B' in Figure 2):

- The distance between the outer edges of the wound, i.e. edge of the bark surface;
- The distance between the boundaries of the phellogen edge growth (where it exists) or the inner edge of the wound, on the wood.

The latter is remeasured during assessments to determine the rate of wound closure through phellogen edge growth.

Figure 2. Schematic view of measurements of response after bark removal. 'a' shows phellogen edge growth, and 'b' shows phellogen sheet growth.

Sheet growth
This is recorded as the percentage of the wound surface (exposed wood) showing phellogen sheet growth, i.e. live tissue development on the wound surface ('b' in Figure 2). Regarding partial bark removal, it refers to the amount of living bark below the outer hardened surface of the remaining inner bark. The same percentage classes were used as for edge development.

Insect damage
The number of pinholes, irrespective of size, on the wound surface is recorded to assess insect damage. The following classes are used:
1 = 1 – 2 pinholes present
2 = 3 – 5 pinholes present
3 = 6 – 10 pinholes present
4 = 11 – 20 pinholes present
5 = more than 20 pinholes present

Fungal growth
The presence of surface fungal growth (white, green, grey discoloration) is recorded as the percentage cover on the exposed wound surface, using the same percentage classes as for edge development.

Agony shoot development
The presence of vegetative shoots, developing on the stem around the wound, is recorded.

General observations
Observations, especially on or around the wound area, that may be relevant to the interpretation of the results, or anything that could be a reaction to the treatment, are recorded.

RESULTS

A total of 360 trees were treated, 181 at Groenkop (91 *C. dentata*, 90 *R. melanophloeos*) and 179 at Witelsbos (88 *C. dentata*, 91 *O. bullata*), with 182 in winter and 178 in summer (Table 1). Due to the limited number of *Ocotea bullata* and *Rapanea melanophloeos* trees present at the Groenkop and Witelsbos study sites respectively, only *Curtisia dentata* was treated at both sites.

Assessments are done six monthly, with the first done six months after treatment. The results after three assessments, i.e. 24 months after treatment, are summarized in Table 2. For the purpose of this paper, the results are presented for trees of different size classes and strip widths combined, for winter and summer treatments and sealer versus no sealer.

Tree condition

All trees selected for treatment had a crown condition of 4 or 5. In none of the species or sites is there a clear decline in crown condition two years after treatment (3rd assessment), with an average of still above four. The lowest crown condition average (all strip widths and diameter classes) is for *O. bullata* (4.4 and 4.5; winter and summer treatments respectively). This is the result of the crown condition of seven trees (all < 30 cm DBH; strip width 10cm or wider) deteriorating to Class 3 or lower, including one mortality.

Table1. Actual number of trees treated by site, species, tree size, strip width and season

Site	Species	Tree size	Winter				Summer				Total
			Strip width (cm)				Strip width (cm)				
			5	10	15/20	Total	5	10	15/20	Total	
Groenkop	*Curtisia dentata*	Small	5	5	5	15	4	4	3	11	
		Medium	5	5	5	15	5	6	7	18	
		Large	5	5	6	16	6	5	5	16	
		Totals				46				45	91
	Rapanea melanophloeos	Small	8	5	5	18	4	5	3	12	
		Medium	3	4	5	12	6	6	6	18	
		Large	6	6	4	14	5	4	5	14	
		Totals				46				44	90
Witelsbos	*Curtisia dentata*	Small	6	6	5	17	5	4	5	14	
		Medium	6	3	5	14	5	5	5	15	
		Large	4	6	4	14	4	5	5	14	
		Totals				45				43	88
	Ocotea bullata	Small	4	4	5	13	5	5	5	15	
		Medium	6	6	5	17	6	5	5	16	
		Large	5	5	5	15	5	5	5	15	
		Totals				45				46	91

Table 2. Summary of results of third assessment (24 months after treatment) for *O. bullata*, *R. melanophloeos* and *C. dentata*, combined for tree size classes and strip widths

Season	Treatment		Crown condition	Edge growth % (class aver.)	Edge growth rate (mm)	Sheet growth % (class aver.)	Presence of pinholes (class aver.)	Fungal growth (class aver.)	Presence of agony shoots (% of trees)
Ocotea bullata (Witelsbos)									
Winter	Total	No sealer	4.4	8.77	22.6	0.00	0.39	0.73	0.00
		Sealer		8.58	25.3	0.12	0.37	1.65	9.30
	Partial	No sealer				8.20	0.09	0.09	4.00
		Sealer				8.36	0.09	0.20	0.00
Summer	Total	No sealer	4.55	8.23	11.7	0.05	0.37	0.93	0.00
		Sealer		8.70	18.2	0.21	0.19	1.56	4.65
	Partial	No sealer				8.09	0.02	0.16	0.00
		Sealer				7.86	0.00	0.33	5.00
Rapanea melanophloeos (Groenkop)									
Winter	Total	No sealer	4.96	0.04	-0.3	0.02	1.76	1.48	0.00
		Sealer		0.13	0.7	0.24	1.28	2.41	30.43
	Partial	No sealer				6.89	1.57	0.57	0.00
		Sealer				8.22	0.65	0.48	4.35
Summer	Total	No sealer	4.71	0.00	-3.1	0.00	1.26	2.14	0.00
		Sealer		0.05	-4.0	0.00	1.33	3.17	26.19
	Partial	No sealer				6.07	0.69	0.79	2.38
		Sealer				6.62	0.50	0.90	0.17
Curtisia dentata (Witelsbos)									
Winter	Total	No sealer	4.66	3.68	2.9	0.49	0.23	0.74	2.00
		Sealer		4.35	5.4	0.95	0.05	0.95	21.00
	Partial	No sealer				8.37	0.14	0.05	0.00
		Sealer				8.79	0.00	0.05	5.00
Summer	Total	No sealer	4.68	3.33	-5.3	1.09	0.07	0.28	0.00
		Sealer		2.86	-4.9	2.93	0.05	0.70	14.00
	Partial	No sealer				7.49	0.05	0.33	0.00
		Sealer				8.30	0.05	0.16	0.07

Curtisia dentata (Groenkop)									
Winter	Total	No sealer	4.87	4.27	1.8	1.36	1.13	0.80	0.00
		Sealer		4.11	3.2	3.38	0.02	0.71	22.22
	Partial	No sealer				8.91	0.00	0.00	0.00
		Sealer				8.91	0.02	0.02	6.67
Summer	Total	No sealer	4.80	3.00	-3.5	3.38	0.11	0.62	0.00
		Sealer		3.24	-1.3	3.24	0.16	1.02	8.89
	Partial	No sealer				7.93	0.04	0.25	0.00
		Sealer				8.78	0.00	0.16	4.44

Total bark removal

The results show a significant difference between species in terms of phellogen edge growth, both in terms of edge growth percentage and rate of growth, as well as sheet growth. Clear differences also exist in terms of susceptibility to insect and fungal attack.

Edge growth percentage
The class average per treatment for *O. bullata* varies between 8.23 and 8.77 (more than 70% of wound edge covered by phellogen growth, compared to between 2.86 and 4.35 for *Curtisia dentata* and almost no growth, 0.0 to 0.13, for *R. melanophloeos*, depending on sealer treatment and season. For all species there seem to be little difference in edge growth between sites and sealer versus no sealer. For *C. dentata* recovery through edge growth are significantly better for trees treated during winter, for all strip widths and diameter classes.

Rate of edge growth
Also in terms of the rate of edge growth, *O. bullata* performs significantly better. For this species wound closure took place at a rate of between 11.7 and 18.2 mm for the summer treatment and significantly faster at 22.6 and 25.3 mm for trees treated during the winter, for the 18 months period after the first assessment. Trees treated with sealer also show a better edge growth rate for all strip widths compared to untreated trees.

For *C. dentata* rate of wound closure took place at a rate of between 1.8 and 5.4 mm for the winter treatments, with the best recovery rate at Witelsbos and for the trees treated with sealer. For the summer treatment a negative recovery rate was recorded for most treatments at both study sites. This can primarily be attributed to erratic edge growth and the tendency of the bark to lift from the wood, widening the wound. For *R. melanophloeos* a negative recovery rate was recorded, with the summer treatments showing slightly higher negative values. This was to be expected as little phellogen edge growth was recorded (see *Edge growth percentage*), and the bark drying out around the wound. The latter is evident through insect damage and woodpecker pecking marks appearing around the strips of many trees.

Sheet growth
As is the case with edge growth, the response is species specific. *Ocotea bullata* and *R. melanophloeos* show little sheet growth, with a class average of 0.00-0.21 and 0.00-0.24 respectively. The best response is from *C. dentata* with a class average of 0.49-3.38 for the two study sites. For *C. dentata* and *R. melanophloeos* trees treated during summer show slightly better sheet growth, unlike edge growth that had better growth from winter treatments. This could be attributed to the dry and hot conditions in summer, resulting in less easy bark removal with some of the cambium cells remaining on the wound. Also, for *C. dentata*, better sheet growth was recorded at the Groenkop site with better response at both

sites from wounds treated with sealer. For all species, no clear difference could be detected between tree diameter classes.

Presence of pinholes
Rapanea melanophloeos is most susceptible to insect attack with a class average of 1.26-1.76, followed by *O. bullata* (0.19-0.39) and *C. dentata* (0.02-0.23). No clear differences exist between season of treatment at this stage, although wounds treated with tree sealer seem to be less vulnerable to insect attack.

Fungal growth
As with insect damage, *R. melanophloeos* is most susceptible to fungal growth, of the tree species treated, with a class average of between 1.48 and 3.17, followed by *C. dentata* (0.28 – 1.02) and *O. bullata* (0.73-1.65). At this stage this seems to be largely surface growth, causing little damage to the inner wood. Fungal growth on wounds treated with sealer seems to be slightly higher, but this could partly be attributed to fungal growth being more visible on the darker surface. No clear differences between season of treatment and site are evident.

Presence of agony shoots
Of all species, *R. melanophloeos* has the highest incidence of agony shoot development, mostly at the lower part of the vertical strip (which is also the part treated with sealer), followed by *C. dentata*, and with little reaction from *O. bullata*. For *R. melanophloeos,* ca 30% and 26% of the trees developed agony shoots for the winter and summer treatments respectively, compared to 9 and 5% for *O. bullata*. For *C. dentata* about 22% of the trees treated during the winter developed agony shoots, compared to about 9 and 14% respectively for Groenkop and Witelsbos for the summer treatment.

Should the development of agony shoots be an indicator of trees being under stress, the results support the findings of *O. bullata* recovering best after bark stripping, followed by *C. dentata*, with little recovery from *R. melanophloeos*. The higher incidence of fungal and insect attack with *R. melanophloeos* is also of significance.

Partial bark removal

Sheet growth
Consistent with the results of sheet growth for total bark removal, *C. dentata* and *O. bullata* had the highest percentage of living tissue at the 3rd assessment. For *C. dentata* the class average varies between 8.37 and 8.91 for the winter treatment and slightly lower at between 7.49 and 8.78 for the summer treatment. For the summer treatment, wounds with no tree sealer had the lowest cover at both study sites. For *O. bullata* the class average varies between 7.86 and 8.36, and slightly lower at between 6.07 and 8.22 for *R. melanophloeos*. For *R. melanophloeos,* trees treated during the winter and wounds treated with tree sealer represent the best sheet growth.

Presence of pinholes
As with total bark removal, the presence of pinholes was most prevalent with *R. melanophloeos*, with a class average of between 0.50 and 1.57, with wounds treated with tree sealer the least susceptible. No clear differences between sites and sealer verses no sealer exists. Incidences of insect attack for *O. bullata* and *C. dentata* are negligible.

Fungal growth
As for total bark removal, the highest cover of fungal growth occurs with *R. melanophloeos* with a relatively low class average of between 0.48 and 0.90. As with insect attack, the occurrence of fungal growth with *O. bullata* and *C. dentata* is negligible.

Presence of agony shoots
Incidences of agony shoot development are much less common than with total bark removal, and are largely limited to the lower part of the strip, also treated with tree sealer. *Curtisia dentata* most often develops agony shoots (ca 4% of all trees) followed by *R. melanophloeos* (3%) and *O. bullata* (2%).

DISCUSSION AND RECOMMENDATIONS

The results show a differential response of species to bark stripping, with good recovery from *O. bullata* through phellogen edge growth, fair recovery from *C. dentata* through edge and sheet growth, and little response from *R. melanophloeos*. The poor recovery from *R. melanophloeos* is also reflected in the species being more susceptible to insect damage and fungal attack, and showing more agony shoot development.

Although a detailed analysis of data has not been conducted, it appears that there is a slightly better response of wounds treated with commercial tree sealer, at least in terms of sheet growth after partial bark removal. This could be attributed to sealer preventing or delaying the drying out of the inner bark after outer bark removal. Phellogen edge development seems to be substantially better for trees treated during the winter months, while trees treated during summer showed best sheet growth. The latter could be attributed to the hot conditions, resulting in some of the cambium cells remaining on the wound during stripping. Although the occurrence of edge or sheet growth is not affected by strip width as such, strip width is an important consideration when formulating prescriptions and best practices for bark harvesting. No clear evidence exits at this stage that there is a differential response within species between sites, but this needs further investigation.

In view of the above, experimental bark harvesting could be adapted or simplified as follows:

- Total bark removal is normally the practice with bark harvesting for medicinal use, but destructive. Partial removal, leaving a thin layer of inner bark, is less practical but could ease bark recovery. This was a difficult method to apply, and it was difficult to control the thickness of the inner layer to remain on the wood. It is also unlikely that this method of bark harvesting would be acceptable to especially commercial bark harvesters. Partial bark removal is therefore not considered as a viable option for bark harvesting, except for species that are harvested this way, traditionally. Furthermore, total and partial bark removal on the same tree complicates data analyses and interpretation of results. Where it is applied, it should be on different trees.
- As the occurrence or not of edge and sheet growth is not determined by strip width, experimentation with strip width could be restricted to one, or two at the most, depending on tree diameter. The ideal strip width seems to be 5 or 10 cm as a strip width of more than 10 cm is unlikely to be recommended as a management option for most species.
- To experiment with different strip widths and tree diameters, results in a large number of treatments. As a minimum number of replications are also required, this could result in a large number of trees needed for experimentation. This is often not practical, or due to the destructive nature of the research, undesirable. At least for *O. bullata*, the preliminary

results show crown dieback for trees smaller than 20 cm DBH, for a strip width of 10 cm or more. Combined with partial removal on the same tree, this could prove detrimental. Also taking into consideration bark thickness, a minimum DBH of 20 cm seems to be the most appropriate.

- It appears that the biggest advantage of tree sealer is for partial bark removal, with sealer delaying the drying out of the inner bark. With any future experimentation with sealer, it should be applied at random to the top or bottom part of the wound, taking appropriate steps to prevent the substance form flowing onto the bottom part when applied to the top half. Alternatively, whole strips could be treated with sealer, but on separate trees selected for this purpose.
- The current experimental layout with tree sealer applied to the bottom part of the strip, automatically results in assessments being done separately for the top and bottom part of the wound. Where this is not the case, the experimental layout should make provision for the separate assessment of the top and bottom part of the wound.
- Diameter growth of treated trees should be monitored as part of the long-term monitoring of treated trees, as variation within species may be attributed to the growth rate of the individual tree. The point of measurement could by fixed with a painted line above the strip area.

In terms of assessment protocols, the following is recommended:

Tree condition

The crown condition classes used are useful and sound to define crown condition during the establishment of the project and to ensure that only relatively healthy trees are selected for treatment. However, for monitoring decline in crown condition of evergreen trees the classes should be finer to follow gradual crown die-back, and provision should be made for other signs of deterioration such as structural damage and sparseness of foliage (*vide* Durrheim 2001). Ideally untreated trees should also be assessed for control purposes.

The following crown condition classes, based on percentage foliage die-back, could be considered (narrower classes for initial die-back, and wider classes for advanced die-back):
< 5% crown die-back
6 – 12% crown die-back
13 – 24% crown die-back
25 – 49% crown die-back
50 – 74% crown die-back
> 75% crown die-back

Crown sparseness, the presence of structural damage, such as major branches or main shoot broken off, and the presence of stem rot, could also be recorded.

Edge development

Currently provision is made for ten edge development percentage classes, including one for zero growth, over 10% intervals (e.g. 10-20, 20-30, etc.). The last class, however, has a 20% range (80-100%). It is suggested that this be split up into two classes, 80-90 and 90-100%, which would not only be consistent with the other classes, but also allow for following growth after 80% cover. Although fair edge growth does occur with *C. dentata*, the rate of growth is not recorded effectively through current measurements, due to erratic growth and bark lifting from the wood. It is suggested that a second point of measurement be fixed to cover the wound area better.

Sheet growth

As is the case with the edge development percentage classes, it is suggested that the last class be split up into two, 80-90 and 90-100% to allow for monitoring growth after 80% sheet growth cover.

Regards partial bark removal, it is difficult to assess sheet growth in this way, as it is not possible to see what happened below the hardened outer surface of the wound. A sharp knife was used to cut the bark to assess the condition of the bark and search for moisture below the surface, so as to determine the possible area with live tissue. This becomes increasingly difficult as the bark dries out and the living tissue occurs deeper under the surface. Therefore, although the sheet cover could still be high with no change since the treatment, the cambium is gradually dying off. This should also be recorded during the assessment. As with edge and sheet growth for total bark removal, the last class of 80-100% should be split into two classes with a range of 10% (*viz*. 80-90 and 90-100%).

Insect damage

Although the classes as currently defined, make effectively provision for determining differences in susceptibility to insect attack between species, sites and season of treatment, this can only be done within the same treatment (strip width). To also assess the effect of different strip width, a sliding scale, making provision for the wound area, could be developed.

During the first 24 months after treatment, insect damage is reflected by small pinholes of largely similar size appearing in the exposed wood. With time, as the wood dries out, larger pinholes caused by woodborers appear. In addition to number of pinholes, the classes should also make provision for at least two different types (sizes) of pinholes, e.g. small and large as to allow for long-term monitoring. The same applies to partial bark removal.

Fungal growth

As with edge and sheet growth, the last class of 80-100% should be split into two classes with a range of 10%, as is the case with the other classes (80-90 and 90-100%). This is an effective way of quantifying surface fungal growth during the first two or three assessments. Provision should, however, also be made for recording fungal growth of a more destructive nature appearing as the wood dries out, e.g. shelf fungi. The same applies to partial bark removal.

Cutting down sample trees to assess harmful internal fungal growth, should only be considered towards the end of the experimental monitoring period. For the interim a borer could be used to collect wood samples from selected trees, preferably by identifying trees for this during the establishment phase of the project.

Agony shoot development

With this experimental layout with tree sealer only put onto the lower part of the strip, the position of agony shoots are defined as assessments are done for sealer and no sealer separately. With an experimental layout where this is not the case, the position of agony shoots should be recorded. Observations are that some agony shoots die off with time. This should be recorded during assessments, even if new shoots develop. In the case of some species e.g. *C. dentata*, some agony shoots develop into stronger leader shoots. In such cases shoot growth could be monitored by measuring shoot length.

CONCLUDING REMARKS

Through experimental bark stripping, species-specific results on tree response to bark stripping are obtained in a relatively short period. This allows for the development of interim measures and prescriptions for sustainable bark harvesting in areas were uncontrolled bark harvesting demand the immediate implementation of control measures. The appropriate strip width and harvest rotation would depend on the rate of wound closure and tree diameter, but should also consider the intensity of fungal and insect attack. Through a process of adaptive management, interim measures can be refined as quantitative data on tree response to bark stripping is acquired through long-term monitoring.

Based on the experience with experimental strip harvesting in the southern Cape and pre-assessments of woodland species treated as part of an extended experimental bark harvesting programme (*vide* FRP-DFID 2003), protocols for the assessment of experimental bark stripped trees were revised to accommodate a wider range of reactions to bark stripping (attached as Appendix 1). This should contribute towards ensuring consistency with the approach to experimental bark harvesting, and ease and validate comparison of results from different experiments in southern Africa.

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Appendix 1:

PROTOCOLS FOR EVALUATION OF TREE RESPONSE IN BARK HARVESTING EXPERIMENT

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January 2004

The evaluation procedure followed in the CPW bark study in Groenkop forest was adapted for use in the FRP-DFID Bark study. The protocols below should be read in conjunction with the diagram in Figure 1 and the attached field form.

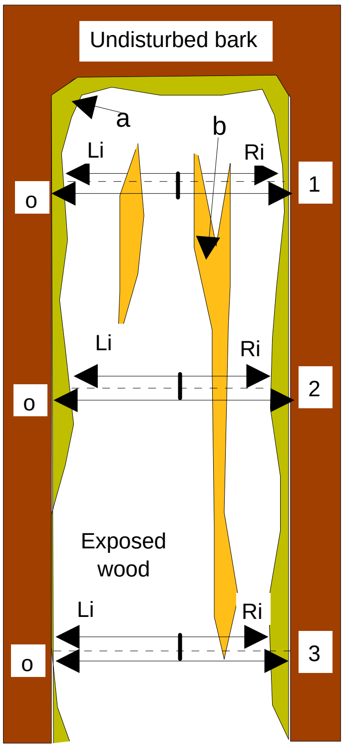

Figure 1. Schematic view of measurements of response after bark removal:

'a' is edge growth, i.e. tissue showing wound recovery from underneath the bark. With bark lift on the edge, this tissue starts to develop underneath the lifted bark.

'b' is sheet growth, i.e. live tissue developing on the wood of the wound surface.

'1, 2, 3' represents three horizontal lines (shown as dotted lines) across the wound, marked with a soft pencil at the time of bark removal, to indicate the points for bark growth measurements. The midpoint of each line should be indicated with a short vertical line.

'i' represents the distance between the midpoint of the line and boundaries of the edge growth (where it exists), or the inner edge of the wound (on the wood), to the left (L) and the right (R) of the midpoint.

'o' represents the distance between the outer edges of the wound (edge of the bark surface).

1. *General Information*: Provide the information for each tree as recorded on the initial field form when the trees were harvested: Forest, Species, Tree no and Season of treatment (Dry [D] or Rainy [R]).

2. *Date*: For each section of the assessment, four lines are provided for the date. The first line (Date 1) is the date of treatment. The relevant measurements and assessments during that day should be written to compare the later measurements and assessments. Dates 2 to 4 are for the second, third and fourth assessments for the particular tree.

3. *Bark growth measurements:* On each wound there should be three horizontal lines, marked with a soft pencil (B1). The midpoint of each horizontal line should also be marked with a short vertical line. On each marked line (1 = top; 2 = middle; 3 = bottom), measure the following (see Figure 1):

Bark lift: Use a ruler with the zero point on the edge of the ruler, to measure the vertical lift from the wood surface to the inner edge of the lifted bark, in mm, both on the left (Llift) and the right (Rlift) end of the horizontal line.
Edge growth: Measure the distances from the marked mid-point to the left (Li) and to the right (Ri) to the boundary of the edge growth tissue (where it exists and is visible outside of the bark edge of the wound), or the inner edge of the wound (on the wood, if there is no visible edge growth). Remeasurement of Li and Ri will indicate the rate of recovery of the wound by edge growth, if there is no sheet growth. The measurements should be done with tape, in mm, not with the vernier caliper.
Bark drying (o): Measure the distance from the outer edges of the wound (edge of the bark surface). This will indicate the amount of bark movements away from the original wound edge.
If termite activity occurs at the point of measurement, remove this only at this point to see the regrowth tissue.

4. *Diameter at line 2:* This measurement should be done after bark removal, or if it was not done at the time of bark removal, it should be done during the first assessment, and every subsequent assessment. This will indicate the swelling of the stem around the wound through new bark tissue development.

5. *Crown condition (*Percentage healthy crown as measure of crown die-back): This is the most reliable indicator of senility, but also the most difficult to assess. It is vital to standardize individual perceptions of the percentage of healthy crown (or severity of crown die-back). A tree should be assessed only on what is visually evident at the time of assessment, i.e. parts of the crown that were already broken off (structural damage) should not be included in the assessment of crown condition. A note should be made with reference to trees displaying sparsely foliated crowns as opposed to actual loss of crown foliage resulting from die-back. The approach used in the assessment of crown condition during the implementation of the bark harvesting experiment was to assess crown condition according to the following criteria:
   5 = 81 – 100% healthy crown (crown densely covered with foliage, no apparent die-back);
   4 = 61 – 80% healthy crown (tips of some terminal shoots without leaves, rest appears healthy);
   3 = 41 – 60% healthy crown (leaves present on branches);
   2 = 21 – 40% healthy crown (leaves present only on branches closest to the main stem);
   1 = 1 – 20% healthy crown (few leaves, only near bole of tree);
   0 = dead (no foliage in tree crown, but live vegetative shoots may be present near tree base).

   Check condition of untreated trees of the same species in vicinity as a control over the condition of a tree at the time of assessment, particularly in case of deciduous trees. Record the general condition of untreated trees of the species in the particular forest on separate form.

6. *Assessments*: The wound should be divided in an upper and a lower half (note that line 2 may not be at the middle of the wound). Assessments of edge and sheet development, and presence of insects and fungi are done separately for the two halves (called 't' for top, and 'b' for bottom, on the field form).

   a. *Edge development*:
   Three assessments of edge development are done: Assess the percentage of the wound edge that shows i) **Bark lift** (defined as 1 mm or more lift of the bark away from the wood); ii) **Visible edge growth**; and iii) **Total edge growth**, including those visible underneath the lifting bark; according to the following categories: 0 =

no development; 1 = 1 – 10% development; 2 = 11 – 20% development; .. 8 = 71 – 80%; 9 = 81 – 90%, 10 = 91 - 100% (see field form).

b. *Sheet development*:
Assess the percentage of the wound surface (exposed wood) that shows sheet growth, according to the following categories: 0 = no sheet recovery; 1 = 1 – 10% recovery; 2 = 11 – 20% recovery; .. 8 = 71 – 80%; 9 = 81 – 90%, 10 = 91 - 100% (see field form).

c. *Insects*:
Record the presence of insects for the upper and lower part of the wound separately, according to the following categories: For Pinholes: Indicate with a P with one of the following codes for number of pinholes: 1 = for 1-2 pinholes; 2 = 3-5 pinholes; 3 = 6-10 pinholes; 4 = 11-20 pinholes; and 5 = 21+ pinholes. For Termites: Indicate with a T with one of the following codes for percentage cover of the wound: 0 = no termite activity; 1 = 1 – 10% termite activity; 2 = 11 – 20% termite activity; .. 8 = 71 – 80%; 9 = 81 – 90%, 10 = 91 - 100% (see field form).

d. *Fungi*:
Record the presence of fungi (white, green, grey discoloration with fruiting bodies), as a percentage as for sheet growth: 0 = no fungal development; 1 = 1 – 10% fungal development; 2 = 11 – 20% fungal development; …. 8 = 71 – 80%; 9 = 81 – 90%, 10 = 91 - 100% (see field form).

7. *Agony shoots*: These are vegetative shoots developing on the stem around the wound or at the base of the stem. Record the position of the agony shoots ('a' for above wound, 's' for to the either side of the wound, 'b' for below the wound) plus the number of agony shoots (if several shoots in a cluster, with several clusters, record the number of clusters and record this under 'Notes'), for a particular position. For example, a2, s1, means 2 agony shoots above the wound plus 1 agony shoot on the side of the wound. Also record coppice (c) shoot development (at base of stem) and root suckering (r) where this occur.

8. *Notes*: Record general notes, where/when relevant, of observations on or around the wound, that may be relevant for interpretation of results, such as the following:
   a. Exudates on wound edge, even more than two months after wounding (provide rating as for sheet growth cover %);
   b. Cracks and sunken areas near wound;
   c. Woodpecker activity on bark adjacent to wound;
   d. Damage/scorch of wound/surrounding bark by veld fires (rate severity of damage).

FRP-DFID EXPERIMENTAL BARK HARVESTING: EVALUATION FORM

Forest:			Species:			Tree no:			DBH:		Treatment season:				
Date	Bark edge measurements														
	1					2					3				
	Llift	Li	Rlift	Ri	o	Llift	Li	Rlift	Ri	o	Llift	Li	Rlift	Ri	o
1															
2															
3															
4															
Date	DBH	Cc	Edge development						Sheet growth		Insects		Fungi		Agony
			Bark lift		Edge visible		Edge total								
			t	b	t	b	t	b	t	b	t	b	t	b	
1															
2															
3															
4															
Date															
1															
2															
3															
4															

Forest:			Species:			Tree no:			DBH:		Treatment season:				
Date	Bark edge measurements														
	1					2					3				
	Llift	Li	Rlift	Ri	o	Llift	Li	Rlift	Ri	o	Llift	Li	Rlift	Ri	o
1															
2															
3															
4															
Date	DBH	Cc	Edge development						Sheet growth		Insects		Fungi		Agony
			Bark lift		Edge visible		Edge total								
			t	b	t	b	t	b	t	b	t	b	t	b	
1															
2															
3															
4															
Date															
1															
2															
3															
4															

FRP-DFID EXPERIMENTAL BARK HARVESTING EVALUATION FORM EXPLANATION SHEET

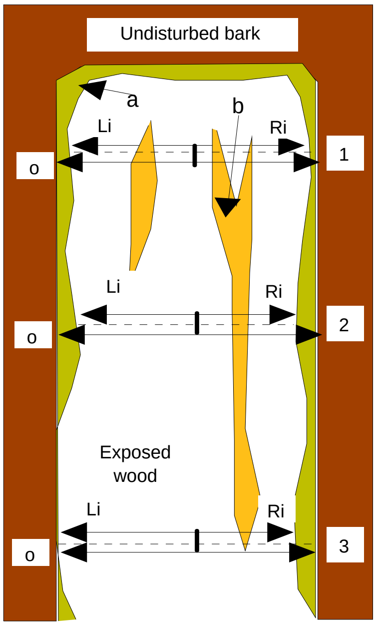

Figure 1. Schematic view of measurements of response after bark removal:

'a' is edge growth, i.e. tissue showing wound recovery from underneath the bark. With bark lift on the edge, this tissue starts to develop underneath the lifted bark.

'b' is sheet growth, i.e. live tissue developing on the wood of the wound surface.

'1, 2, 3' represents three horizontal lines (shown as dotted lines) across the wound, marked with a soft pencil at the time of bark removal, to indicate the points for bark growth measurements. The midpoint of each line should be indicated with a short vertical line.

'i' represents the distance between the midpoint of the line and boundaries of the edge growth (where it exists), or the inner edge of the wound (on the wood), to the left (L) and the right (R) of the midpoint.

'o' represents the distance between the outer edges of the wound (edge of the bark surface).

Dates: 1 (treated): …… 2 (1st evaluation): ……. 3 (2nd evaluation): ……… 4 (4th evaluation): ……….

Measurements: Bark lift, mm (Llift on left; Rlift on right); i = Measurement between inside edges, mm (Li left of midpoint; Ri right of midpoint); o = Measurement between outside edges, mm

DBH, cm (diameter at line 2, to measure swelling);

Crown condition (Cc): 5 = 81 – 100% healthy crown; 4 = 61 – 80% healthy crown; 3 = 41 – 60%; 2 = 21 – 40%; 1 = 1 – 20%; 0 = dead

Edge development: bark lift, visible & total edge growth (assess top half = 't', and bottom half = 'b' separately): 0=Zero; 1 = 1-10%; 2 = 11-20%; 3 = 21-30%; 4 = 31-40%; 5 = 41-50%; 6 = 51-60%; 7 = 61-70%; 8 = 71-80%; 9 = 81-90%; 10 = 91-100%.
Sheet development: (assess top half = 't', and bottom half = 'b' separately): 0=Zero; 1 = 1-10%; 2 = 11-20%; 3 = 21-30%; 4 = 31-40%; 5 = 41-50%; 6 = 51-60%; 7 = 61-70%; 8 = 71-80%; 9 = 81-90%; 10 = 91-100%.

Insects (top & bottom separately): **Pinholes**: 1 = 1-2 pinholes; 2 = 3-5 pinholes; 3 = 6-10 pinholes; 4 = 11-20 pinholes; 5 = 21+ pinholes (indicated as P1, .. P5); **Termites**: Cover as 0=Zero; 1 = 1-10%; 2 = 11-20%; 3 = 21-30%; 4 = 31-40%; 5 = 41-50%; 6 = 51-60%; 7 = 61-70%; 8 = 71-80%; 9 = 81-90%; 10 = 91-100% (indicated as T1, .. T10).
Fungi (top & bottom separately) = Cover as 0=Zero; 1 = 1-10%; 2 = 11-20%; 3 = 21-30%; 4 = 31-40%; 5 = 41-50%; 6 = 51-60%; 7 = 61-70%; 8 = 71-80%; 9 = 81-90%; 10 = 91-100%.
Agony shoots = number present & position (a = above; s = on side; b = below wound; c = coppice shoots at base of stem; r = root suckers).

General notes: For each date, record general observations.

a. Exudates on wound edge, even more than two months after wounding (provide rating as for sheet growth cover %);
b. Cracks and sunken areas near wound;
c. Woodpecker activity on bark adjacent to wound;
d. Note if wound was damaged by veld fires (rate severity of damage).

FRP-DFID EXPERIMENTAL BARK HARVESTING EVALUATION: ASSESSMENT OF GENERAL STAND CONDITONS AS A CONTROL

Assess the general conditions in the stand and the condition of the bark-harvested species to help with the interpretation of the condition of the harvested trees. Do the assessment before the evaluation of the bark harvesting response.

Assess the stand/species (note specific species) in terms of **Canopy Condition** as follows:
Foliage density: D for dense, S for sparse, 0 for no foliage (deciduousness)
Foliage color: G for green, Y for yellow. If any other color, note the color
Insect defoliation: H for heavy, M for minor, 0 for no insect defoliation

Understorey condition:
Vegetation type: G for mainly grass, W for mainly woody, M for mixed grass/woody
Vegetation density: D for dense, S for sparse
Vegetation color: G for green, Y for yellow (dry)
Fire since last time: Y for yes, N for no

Forest		Date		
Canopy condition	Foliage density		Foliage color	Insect defoliation
Stand				
Sp 1				
Sp 2				
Sp 3				
Sp 4				
Sp 5				
Sp 6				
Understorey	Rating	Notes		
Type				
Density				
Color				
Fire since last time				
General				