Height, branch-free bole length and bark thickness for six tree species used medicinally in South Africa

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Information on tree stem characteristics and dimensions is sparse, especially information that would enhance conservation and trade monitoring efforts for species where bark is harvested for medicinal use. Several tree stem characteristics were investigated during a study on the relationship between bark thickness and stem diameter, and this paper presents the mean height, branch-free bole length and wet and oven-dry bark thickness per stem diameter-class for six species. Additionally, prediction tables are constructed that allow bark thickness to be determined from diameter at breast height.

Key words: *Acacia xanthophloea*, *Albizia adianthifolia*, *Balanites maughamii*, bark, diameter at breast height, *Elaeodendron transvaalense*, medicinal plants, *Rhus chirindensis*, *Warburgia salutaris*.

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Introduction

Woodland and forest species account for at least 73 % of the income of traders in Johannesburg's traditional medicine street market (Williams 2004). Bark products account for the largest proportion (52 %) of the volume sold (Williams 2004). Despite the importance of bark in traditional medicine in South Africa, ethnobotanical literature about it is scant or inaccessible (Grace *et al.* 2002). Additionally, there is a lack of detailed information to empower conservation and trade monitoring efforts (Grace *et al.* 2002).

Uncontrolled bark harvesting for traditional medicine seriously impacts on forest ecosystems and species (Geldenhuys 2004), and harvesting is often highly selective for families, genera, species or tree size-classes based on particular bark qualities and secondary plant chemicals (Cunningham 2001). In an effort to monitor the availability of bark thickness size-classes in medicinal plant markets, as well as the impact of bark harvesting on tree populations, the authors explored the relationship between bark thickness and tree size for six species. In the absence of practical techniques to determine the age of trees, size can be used as a surrogate (van Wyk *et al.* 1996). Tree stems generally increase in girth as they get older, and diameters are therefore the most appropriate measure for grouping plants into size-classes. Bark thickness generally increases with diameter and stem age (Borger 1973). In some species, a straight-line relationship exists between bark thickness and stem diameter, owing to the persistence of the rhytidome (outer bark) and the resistance of bark to weathering (Borger 1973). In other species, however, the relationship is weak or curvilinear owing to the shedding of the bark to a greater or lesser extent (Borger 1973).

The authors have already described the strength of the linear relationship between bark thickness and stem diameter (at 1.3 m, diameter at breast height (dbh)) for six species, and constructed "tariff tables" to predict the dbh of the trees targeted by harvesters from the thickness and age of the bark found for sale in medicinal plant markets (Williams *et al. in prep.*). This paper presents the results of the mean wet and oven-dried bark thickness per size class of trees sampled, as well as the regressions and estimates of bark thickness at 1.3 m for trees of a specified diameter at breast height. Additionally, the mean height and branch-free bole length of individuals sampled from the six species are listed. The bark of the six tree species investigated are all used for traditional medicine and sold in the markets of KwaZulu-Natal, Gauteng and Mpumalanga (Cunningham 1988; Williams *et al.* 2000; Botha 2001; Williams 2003). The information presented in this paper will serve as base-line autecological data for the species concerned, and is expected to be of value to researchers in the field of ethnobotany as well as to forest and resource managers/ecologists investigating population dynamics and the change in resource availability over time.

Study sites and species

Six species were sampled at fifteen woodland sites in three South African provinces between March and May 1998 (Table 1). Seven of the sites were on privately-owned

Table 1
Description of sample sites and the number of individuals sampled per species at each site

Province	Site code	Area in province	Ownership and management regime	Species sampled (No.)
Limpopo	L1	Western Soutpansberg	Private game farm	*R. chirindensis* (11) *W. salutaris* (27)
	L2	Western Soutpansberg	Private farm	*B. maughamii* (17) *E. transvaalense* (1) *R. chirindensis* (9)
	L3	Western Soutpansberg	Private farm	*E. transvaalense* (5)
	L4	Western Soutpansberg	Private farm	*B. maughamii* (13)
	L5	Nylstroom	Protected area	*E. transvaalense* (13)
	L6	Eastern Soutpansberg	State-owned forestry land	*A. adianthifolia* (29)
	L7	Eastern Soutpansberg	State-owned forestry land	*A. adianthifolia* (13)
	L8	Eastern Soutpansberg	State-owned forestry land	*R. chirindensis* (4)
Mpumalanga	M1	Nelspruit	Protected area	*A. xanthophloea* (1) *B. maughamii* (2)
	M2	South of Malalane	Private farm	*R. chirindensis* (5)
	M3	South of Malalane	Private mine	*R. chirindensis* (5)
KwaZulu-Natal	K1	Maputaland	Protected area	*A. xanthophloea* (12)
	K2	Maputaland	Communal land	*A. xanthophloea* (1) *B. maughamii* (3) *E. transvaalense* (6)
	K3	Zululand	Protected area	*A. xanthophloea* (1) *A. adianthifolia* (4) *B. maughamii* (1)
	K4	Zululand	Private company protected area	*A. xanthophloea* (19) *A. adianthifolia* (1) *B. maughamii* (3) *E. transvaalense* (6)

Table 2
Descriptive data for the six tree species investigated

Species and family	Size (Height)	Bark type[a] and description	Other tree & habitat characteristics
Acacia xanthophloea Benth. MIMOSACEAE	Medium to large; average 10-15 m, up to 30 m	Smooth/scaly/powdery bark: smooth, exfoliating, greenish-yellow becoming powdery yellow; as tree gets bigger, bark peels off in huge, thick pieces	Semi-deciduous; fast growing 1-1.5 m in height per year; woodland
Albizia adianthifolia (Schumach.) W.F.Wight MIMOSACEAE	Large to very large; 10-20 m, up to +25 m	Fissured bark: smooth and grey when young, becoming rougher and forming fine yellowish-brown blocks with age	Deciduous; intermediate growing 0.6 m in height per year; forest
Balanites maughamii Sprague BALANITACEAE	Medium to large; 8-20 m, up to 25 m	Tessellated bark. smooth and grey when young, becoming rougher with age	Deciduous, older trunks strongly fluted and buttressed; slow growing; woodland
Elaeodendron transvaalense (Burtt Davy) R.H.Archer CELASTRACEAE	Shrub or small to medium multi-branched tree, 4-6 m, up to 10-15 m	Patchy bark: fairly smooth and pale grey when young, becoming darker, 'blocky' and deeply fissured with age; rhytidome exfoliates in thin scales	Semi-deciduous; slow growing 0.5 m in height per year; woodland
Rhus chirindensis Baker f. ANACARDIACEAE	Shrub or small to large tree; 3-4 m, occasionally 6-10 m; exceptional specimens up to 20 m	Tessellated bark: smooth and dark grey or brown when young, becoming dark and cracked with age	Semi-deciduous; fast growing up to 1 m in height per year; forest and woodland
Warburgia salutaris (Bertol.f.) Chiov. CANELLACEAE	Shrub or medium-sized to large; usually 5-10 m, up to 20 m	Fissured bark: slightly rough, mottled dark brown and grey when young, becoming courser and more fissured with age, lenticellate	Evergreen aromatic; fairly slow-growing, but can be as much as 0.9 m in height per year in warm, frost-free areas; forest and woodland

Sources: Archer & van Wyk (1998); Carr (1994); Grant & Thomas (1997, 1998, 2000); Hankey & Stern (2002); Immelman *et al* (1973); Mander *et al* (1995); Palgrave (1977); Pooley (1993); Schmidt *et al* (2002); Scott-Shaw (1999); Turner (2003); Van Wyk (1974); Van Wyk & Van Wyk (1997); Van Wyk *et al* (1997); Venter & Venter (1996).

[a] Bark classified according to macroscopic bark terminology given in Borger (1973) and Junikka (1994).

land, four were in protected areas, three on state-owned forestry land and one on communal land. The species were previously selected to represent various risk categories for over-exploitation by the medicinal plant trade (V.L. Williams unpubl. data). In high demand and at high risk are *Warburgia salutaris* (Bertol.f.) Chiov. and *Elaeodendron transvaalense* (Burtt Davy) R.H. Archer [formerly known as *Cassine transvaalensis* (Burtt Davy) Codd]. Also widely used but at a lower risk due to lower levels of exploitation are *Albizia adianthifolia* (Schumach.) W.F.Wight, *Balanites maughamii* Sprague and *Acacia xanthophloea* Benth. *Rhus chirindensis* Baker f. tends not to be as widely utilised as the other species, but in some areas significant damage to populations has been reported (Geldenhuys 2004). The species range in size, growth rate, bark type and habitat (Table 2).

Field methods and data analysis

At each sample site, individuals were selected from various representative size-classes based on the stem diameter at breast height (dbh, 1.3 m above ground). A minimum of five and maximum of ten trees was sampled per diameter-class per species, although specimens in the ≥40 cm size-classes were sometimes more difficult to find, and hence 2–4 trees were often sampled in this class (except for *Albizia*, where trees larger than 60 cm dbh could have been sampled). Stem diameter-classes for *Acacia*, *Albizia*, *Balanites* and *Elaeodendron* were in increments of 10 cm, starting at 10 cm and ending at 50 cm, 60 cm, 60 cm and 50 cm respectively. Diameter-classes for *Rhus* and *Warburgia* were in increments of 5 cm, starting at 5 cm and ending at 35 cm and 30 cm respectively due to the prevalence of individuals in this size range.

Various aspects of the tree stem profile were measured: 1) diameter of the stem at five height intervals (0.5 m, 1.0 m, 1.3 m, 1.5 m and 2.0 m); 2) approximate tree height; and 3) branch-free bole length. A diameter tape was used to measure the diameter of the stem directly from the circumference measurement. Vertical height and branch-free bole length were directly estimated using a two-metre-high pole that was marked in 0.5 m intervals. The number of pole lengths was then counted by eye to estimate height and length. Bark samples were removed from the stem using a 50 mm diameter hole-saw attached to a hand drill brace. Bark thickness of the samples was measured on site using a digital Vernier calliper (accuracy: 0.01 mm), and mass was measured using a portable digital scale (accuracy: 5 g). The bark samples were placed into a phytotron chamber at the University of the Witwatersrand to dry out, and thickness and mass measurements (this time with an electronic balance accurate to 0.001 g) were recorded weekly for each sample. The temperature and relative humidity (RH) in the chamber were set to mimic mean day and night summer conditions (September–March) in Johannesburg, namely: day T° = 20 °C; night T° = 16 °C; day RH = 59 %; night RH = 66 %. Twelve weeks after the samples were harvested, they were oven-dried at 80 °C for four days. Regressions between dbh, bark thickness and mass were calculated using STATISTICA 6 and Excel 2000. Refer to Williams *et al* (*in prep.*) for detailed information on the methods and regression analysis between bark thickness and stem diameter, as well as the estimation of tree dbh from bark thickness and age (time after harvesting) records.

Results and discussion

Between the six species, 1026 bark samples were removed from 207 individual stems. The largest tree encountered was a mature *W. salutaris* located on a private farm in the Limpopo Province which had a dbh >68 cm (also the level that branching occurred, which could have rendered the dbh reading inaccurate) (Table 3). In terms of the availability of individuals within the various size-classes that could be sampled, most prevalent were stems between 10-39 cm dbh for *A. xanthophloea*, *A. adianthifolia*, *B. maughamii* and *E. transvaalense* (Table 4). Stems with dbh <10 cm were not measured for these four species. Mature trees with stems of dbh >40 cm were not as common (except

Table 3
Tree dimensions for the six study species

Species	N	Tree height (m)		Branch-free bole length (m)		LD
		Mean ± SD	Min; Max	Mean ± SD	Min; Max	
Acacia xanthophloea	33	10.2 ± 2.1	6.0; 15.0	4.3 ± 2.5	1.5; 10.0	47.4 cm (K4)
Albizia adianthifolia	46	9.9 ± 2.1	6.0; 14.0	4.6 ± 2.5	0.5; 11.0	59.9 cm (L6)
Balanites maughamii	38	7.9 ± 2.2	4.0; 12.0	2.9 ± 1.4	0.9; 7.0	59.2 cm (K4)
Elaeodendron transvaalense	30	5.1 ± 1.4	3.5; 8.0	2.1 ± 0.8	1.0; 4.5	48.3 cm (L5)
Rhus chirindensis	33	7.7 ± 2.6	4.0; 14.0	3.5 ± 1.8	1.7; 8.0	31.2 cm (L8)
Warburgia salutaris	27	8.1 ± 2.9	3.5; 14.0	2.8 ± 1.3	1.2; 6.0	>68 cm (L1)

LD = Largest diameter recorded at 1.3m (dbh) (site abbreviation, see Table 1) for *Albizia*, where individuals between 50-59 cm were abundant). For *R. chirindensis* and *W. salutaris*, however, the most prevalent size-classes were between 5-24 cm and 5-19 cm dbh respectively. Individuals larger than 25 cm were infrequently encountered (Table 4), although a revisit to two of the sites in 2004 located populations with individuals in the 30-39 cm class that had previously not been observed. The data for *A. xanthophloea* and *W. salutaris* correspond with population structure data obtained by Botha *et al.* (2002, 2004) for these species in the Lowveld, South Africa.

The minimum and maximum heights of the trees are consistent with the size range of the species in the wild (Tables 2 & 3). The mean heights of *A. xanthophloea*, *A. adianthifolia* and *B. maughamii* indicated that the individuals sampled tended to be at the lower end of the size range, whereas *E. transvaalense*, *R. chirindensis* and *W. salutaris* were at the larger end of the range. In the Umzimkulu forests of the Eastern Cape, the stem diameters of *R. chirindensis* are much larger than recorded in this study (C.J. Geldenhuys *pers. comm.*). The mean branch-free bole length indicated that on average, branching commences above 2 m—the level to which bark is assumed to be within reach for harvesting from a standing tree.

The mean wet bark thicknesses of the individuals sampled are shown in Table 4, as well as the minimum and maximum thickness measured. Wet-bark thickness was measured on the day the samples were removed from the trees. The results show a positive increase in bark thickness with stem diameter, except for *A. xanthophloea*. There is a weak relationship between bark thickness and dbh in this species (Table 5) because of the tendency for the bark to be shed in large strips and hence no age-related accumulation of the outer bark (Williams *et al. in prep.*).

The oven-dry bark thickness is also presented (Table 4) because the moisture content of the bark generally varies seasonally and between sites (Cunningham 2001), hence

Table 4

Mean wet and oven-dry bark thickness of the samples per size-class per species

Size-class (dbh) (cm)	Mean (mm)	SD	Min (mm)	Max (mm)	N[1]
Acacia xanthophloea					
a) Wet bark thickness					
10 - 19	8.22	1 27	6 65	10 56	10
20 - 29	8 62	3 09	3 96	13 05	10
30 - 39	8 83	2 74	5 99	13 18	10
40 - 49	7.02	1.6	5.89	8 15	2
b) Oven-dry bark thickness [mean decrease in thickness 50 5% ± 4.2% (SD)]					
10 - 19	3 87	0.60	3.07	4.68	10
20 - 29	4 34	1 71	1.83	7.11	10
30 - 39	4 60	1.58	3.05	7.50	10
40 - 49	6.24	5 34	2.54	12.36	3
Albizia adianthifolia					
a) Wet bark thickness					
10 - 19	5 83	1 99	2 07	9.77	10
20 - 29	8.75	2.54	6.55	15 66	11
30 - 39	10 92	1.01	8.99	12.05	10
40 - 49	12.25	2 65	7 69	15.06	7
50 - 59	13 55	1.27	11 73	15 18	8
b) Oven-dry bark thickness [mean decrease in thickness 52 3% ± 10.5% (SD)]					
10 - 19	2.63	0 84	1 05	4 16	10
20 - 29	3.84	0.86	2 73	5.70	10
30 - 39	5.40	1 10	3.45	6.68	10
40 - 49	6.20	1.18	4.08	7.67	7
50 - 59	7 08	1 33	5 20	8.90	9
Balanites maughamii					
a) Wet bark thickness					
10 - 19	5.73	2.08	1 76	10.38	13
20 - 29	8 04	2.57	4.37	12.42	10
30 - 39	8.80	2.80	3 78	12.52	8
40 - 49	9.69	1 87	7.26	11.67	4
50 - 59	9 91	3.33	4.95	12.1	4
b) Oven-dry bark thickness [mean decrease in thickness 24.0% ± 8 3% (SD)]					
10 - 19	5.31	1 62	4.05	8.74	7
20 - 29	6.26	2.41	3.33	9 89	10
30 - 39	6.88	2.27	2.32	9 32	8
40 - 49	6.18	1.09	5.24	7.37	3
50 - 59	7.87	2.77	4.07	10.59	4

[1] The discrepancies between N (wet bark thickness) and N (oven-dry bark thickness) result from some of the bark samples breaking and not being measurable after 13 weeks. Additionally, the discrepancy in N for wet and oven-dry thickness for the 40-49 cm and 50-59 size-classes of *A xanthophloea* and *A adianthifolia* respectively are the result of one bark sample not being measured on-site for wet bark thickness, but being measured every week thereafter until oven-dried.

Table 4 (*continued*)

Size-class (dbh) (cm)	Mean (mm)	SD	Min (mm)	Max (mm)	N[1]
Elaeodendron transvaalense					
a) Wet bark thickness					
10 - 19	6.90	2.23	4.05	10.36	10
20 - 29	9.21	2.87	5.53	15.11	10
30 - 39	10.81	1.59	8.54	13.20	8
40 - 49	13.46	1.48	12.41	14.51	2
b) Oven-dry bark thickness [mean decrease in thickness 30.4% ± 8.5% (SD)]					
10 - 19	4.86	1.86	2.64	8.40	10
20 - 29	6.45	2.24	3.31	10.79	10
30 - 39	7.84	1.33	6.00	9.70	9
40 - 49	8.74	0.37	8.48	9.00	2
Rhus chirindensis					
a) Wet bark thickness					
5 - 9	3.19	0.46	2.56	3.98	10
10 - 14	5.24	1.82	2.73	7.38	7
15 - 19	5.65	1.31	4.81	7.87	5
20 - 24	7.31	1.59	4.56	10.06	8
25 - 29	10.79	1.18	9.95	11.62	2
(31.2)	(7.36)[a]				1

[a] Only one bark sample for the size class hence figure is the actual, not mean, value

Size-class (dbh) (cm)	Mean (mm)	SD	Min (mm)	Max (mm)	N[1]
b) Oven-dry bark thickness [mean decrease in thickness 50.7% ± 9.7% (SD)]					
5 - 9	1.59	0.25	1.14	1.99	9
10 - 14	2.24	0.90	1.22	3.89	7
15 - 19	3.12	1.06	2.32	4.94	5
20 - 24	3.72	1.33	2.30	5.87	7
25 - 29	5.23	0.55	4.84	5.62	2
30 - 34	(-)[b]				-

[b] Bark sample broke up and could not be oven dried

Size-class (dbh) (cm)	Mean (mm)	SD	Min (mm)	Max (mm)	N[1]
Warburgia salutaris					
a) Wet bark thickness					
5 - 9	4.64	0.99	3.44	6.38	11
10 - 14	5.41	0.45	4.66	5.86	7
15 - 19	6.81	2.01	5.36	11.26	6
20 - 24	9.91	0.01	9.90	9.92	2
25 - 29	(12.68)[c]				1
(60 - 69)	(≈ 15.0)[d]				

[c] Only one bark sample for the size class hence figure is the actual, not mean, value

[d] Sample not taken at dbh because of branching. Estimate based on bark thicknesses at 1.0 and 1.5m

Size-class (dbh) (cm)	Mean (mm)	SD	Min (mm)	Max (mm)	N[1]
b) Oven-dry bark thickness [mean decrease in thickness 49.3% ± 7.6% (SD)]					
5 - 9	2.39	0.79	1.39	3.56	10
10 - 14	3.01	0.35	2.47	3.52	7
15 - 19	3.70	1.55	1.99	6.22	5
20 - 24	4.76	0.45	4.44	5.07	2
25 - 29	(4.48)				1
(60 - 69)	(≈ 9.0)				

[1] The discrepancies between N (wet bark thickness) and N (oven-dry bark thickness) result from some of the bark samples breaking and not being measurable after 13 weeks. Additionally, the discrepancy in N for wet and oven-dry thickness for the 30-39 size-class of *E transvaalense* is the result of one bark sample not being measured on site for wet bark thickness, but being measured every week thereafter until oven-dried.

the measurement provides a standard for comparison with other samples. The increase in mean bark thickness with increased dbh size-class is still evident. The mean percentage decrease in wet- and oven-dried bark thickness is indicative of the amount of moisture stored and the density of the bark. In general, bark of the targeted species lose 50 % of their original thickness after oven drying, except for *B. maughamii* and *E. transvaalense*, which lose a quarter and a third of their original thickness respectively (Table 4).

The equations and strength of the linear relationship between wet bark thickness and dbh are shown in Table 5. These relationships are described in more detail in Williams *et al.* (*in prep.*), especially in relation to bark type and shedding. Here, however, we present tables derived from the regressions that predict the wet bark thickness and prediction limits at the specified dbh for each tree species (Table 5). These results represent bark thicknesses that would likely be encountered at 1.3 m trunk height during field measurements of tree populations. For species such as *A. adianthifolia* and *W. salutaris*, there is a strong positive correlation between bark thickness and tree size owing to the persistent nature of the bark on the stem (Williams *et al.in prep.*). The relationship is weaker in

Table 5

Predicted bark thickness (x ± 95% prediction range) from dbh. Predictions are for bark thickness on the day of sampling. No prediction table was constructed for Acacia xanthophloea *because there was no significant linear relationship between bark thickness and dbh. The regression equations, r^2 and p for the species are as follows, where y = bark thickness (mm) and x = dbh (cm).* Acacia xanthophloea: $y = 7.9869 + 0.0065x$, $r^2 = 0.005$, $p = 0.91$. Albizia adianthifolia: $y = 2.1853 + 0.2146x$, $r^2 = 0.802$, $p < 0.0001$. Balanites maughamii: $y = 3.1844 + 0.1601x$, $r^2 = 0.61$; $p < 0.0001$. Elaeodendron transvaalense: $y = 3.6746 + 0.202x$, $r^2 = 0.503$, $p = 0.00002$. Rhus chirindensis: $y = 1.1473 + 0.301x$, $r^2 = 0.677$, $p < 0.0001$. Warburgia salutaris: $y = 1.5087 + 0.3791x$, $r^2 = 0.882$, $p < 0.0001$

Spp.	*Albizia adianthifolia*		*Balanites maughamii*		*Elaeodendron transvaalense*		*Rhus chirindensis*		*Warburgia salutaris*	
DBH (cm)	Predicted bark thickness (mm)	±95% prediction range (mm)	Predicted bark thickness (mm)	±95% prediction range (mm)	Predicted bark thickness (mm)	±95% prediction range (mm)	Predicted bark thickness (mm)	±95% prediction range (mm)	Predicted bark thickness (mm)	±95% prediction range (mm)
3	3.4	<1; 6.7	3.7	2.4; 4.9	4.3	<1; 8.6	2.1	<1; 5.1	2.6	0.9; 4.4
4	3.7	<1; 6.9	3.8	2.6; 5.1	4.5	<1; 8.7	2.4	<1; 5.4	3.0	1.3; 4.7
5	3.9	<1; 7.1	4.0	2.8; 5.2	4.7	<1; 8.9	2.7	<1; 5.7	3.4	1.7; 5.1
6	4.1	<1; 7.3	4.1	3.0; 5.3	4.9	<1; 9.1	3.0	<1; 6.0	3.8	2.1; 4.6
7	4.3	1.1; 7.5	4.3	3.2; 5.4	5.1	<1; 9.2	3.3	<1; 6.2	4.2	2.5; 5.9
8	4.5	1.3; 7.7	4.5	3.4; 5.6	5.3	1.2; 9.4	3.6	<1; 6.5	4.5	2.9; 6.2
9	4.7	1.6; 7.9	4.6	3.6; 5.7	5.5	1.4; 9.6	3.9	<1; 6.8	4.9	3.3; 6.6
10	5.0	1.8; 8.1	4.8	3.8; 5.8	5.7	1.6; 9.8	4.2	1.2; 7.1	5.3	3.6; 7.0
11	5.2	2.0; 8.3	4.9	4.0, 5.9	5.9	1.9; 9.9	4.5	1.5; 7.4	5.7	4.0; 7.3
12	5.4	2.2; 8.5	5.1	4.2; 6.1	6.1	2.1; 10.1	4.8	1.8; 7.7	6.1	4.4; 7.7
13	5.6	2.5; 8.7	5.3	4.4; 6.2	6.3	2.3; 10.3	5.1	2.1; 8.0	6.4	4.8; 8.1
14	5.8	2.7; 8.9	5.4	4.5; 6.3	6.5	2.5; 10.5	5.4	2.4; 8.3	6.8	5.2; 8.5
15	6.0	2.9; 9.2	5.6	4.7; 6.4	6.7	2.7; 10.7	5.7	2.7; 8.6	7.2	5.5; 8.9
16	6.2	3.1; 9.4	5.7	5.0; 6.6	6.9	3.0; 10.9	6.0	3.0; 8.9	7.6	5.9; 9.2
17	6.5	3.3; 9.6	5.9	5.1; 6.7	7.1	3.2; 11.0	6.3	3.3; 9.2	8.0	6.3; 9.6
18	6.7	3.6; 9.8	6.1	5.3; 6.8	7.3	3.4; 11.2	6.6	3.6; 9.5	8.3	6.6; 10.0
19	6.9	3.8; 10.0	6.2	5.5; 7.0	7.5	3.6; 11.4	6.9	3.9; 9.8	8.7	7.0; 10.4
20	7.1	4.0; 10.2	6.4	5.7, 7.1	7.7	3.8; 11.6	7.2	4.2; 10.1	9.1	7.4; 10.8
21	7.3	4.2; 10.4	6.5	5.9; 7.2	7.9	4.0; 11.8	7.5	4.5; 10.4	9.5	7.7; 11.2
22	7.5	4.4; 10.6	6.7	6.1; 7.4	8.1	4.2; 12.0	7.8	4.8; 10.7	9.9	8.1; 11.6
23	7.8	4.7; 10.8	6.9	6.2; 7.5	8.3	4.4; 12.2	8.1	5.1; 11.1	10.2	8.4; 12.0
24	8.0	4.9; 11.0	7.0	6.4; 7.7	8.5	4.6; 12.4	8.4	5.4; 11.4	10.6	8.8; 12.4
25	8.2	5.1; 11.3	7.2	6.6; 7.8	8.7	4.8; 12.6	8.7	5.6; 11.7	11.0	9.2; 12.8
26	8.4	5.3; 11.5	7.3	6.7; 7.9	8.9	5.0; 12.8	9.0	5.9; 12.0	11.4	9.5; 13.2
27	8.6	5.5; 11.7	7.5	6.9; 8.1	9.1	5.2; 13.0	9.3	6.2; 12.4	11.7	9.9; 13.6
28	8.8	5.8; 11.9	7.7	7.1; 8.3	9.3	5.4; 13.2	9.6	6.5; 12.7	12.1	10.2; 14.0
29	9.0	6.0; 12.1	7.8	7.2; 8.4	9.5	5.6; 13.4	9.9	6.7; 13.0	12.5	10.6; 14.4
30	9.3	6.2; 12.3	8.0	7.4; 8.6	9.7	5.8; 13.6	10.2	7.0; 13.3	12.9	10.9; 14.9
35	10.3	7.3; 13.4	8.8	8.1; 9.5	10.7	6.8; 14.7	11.7	8.3; 15.0	14.8	12.6; 16.9
40	11.4	8.3; 14.5	9.6	8.8; 10.4	11.8	7.7; 15.8	13.2	9.6; 16.7	16.7	14.3; 19.0
45	12.5	9.4; 15.6	10.4	9.4; 11.4	12.8	8.6; 17.0	14.7	10.9; 18.5	18.6	16.0; 21.1
50	13.5	10.4; 16.7	11.2	10.0; 12.6	13.8	9.4; 18.1	16.2	12.1; 20.3	20.5	17.7; 23.3
55	14.6	11.5; 17.8	12.0	10.6; 13.4					22.4	19.3; 25.4
60	15.7	12.5; 18.9	12.8	11.2; 14.4					24.3	20.9; 27.6
65									26.2	22.6; 29.7
70									28.1	24.2; 31.9

E. transvaalense due to the irregular shedding of the bark on the bole, and hence the actual thickness of the bark cannot be predicted with as much confidence as for the other species.

The present study aims to provide information that will facilitate conservation and trade monitoring efforts with respect to tree population studies and the harvesting of bark for the medicinal plant trade and domestic use. Commercial bark harvesters tend to select individuals in the larger size-classes to maximise their returns (Botha *et al.* 2001), and the tables are a useful guide to the sizes of trees from which bark traded in a medicinal plant market is likely to have been harvested. Additionally, the tables serve as a guide for quantitative assessments of bark thickness in tree populations if the actual bark thickness cannot be measured on site but the dbh can.

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