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Stem diameter and bark surface area of the fluted trunk of *Balanites maughamii* (Balanitaceae)

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ABSTRACT

Balanites maughamii Sprague (Balanitaceae) is a woodland tree used and harvested for bark products in the traditional medicine trade of South Africa. The tree has a distinctively fluted and buttressed stem, especially in mature individuals. This short communication quantifies the relationship between two diameter measurements D1 and D2 that respectively exclude and include the bark surface contained in the convolutions of the flutes at five height intervals up the stem to 2 m. Regressions show D1 to be an accurate predictor of D2 ($r^2 = 0.97–0.99$) over a range of tree sizes, hence obviating the necessity to measure both D1 and D2. The circumference and bark surface area on the stem was determined to estimate the quantity of bark that can potentially be harvested. At least 69% of the stem circumference and bark surface area was estimated to be contained within the convolutions of the flutes.

INTRODUCTION

Balanites maughamii Sprague (Balanitaceae) is a medium to large, slow-growing deciduous tree ranging from 8–20 m tall (Pooley 1993). The stem is straight and the trunks of older trees are distinctively fluted and buttressed (Pooley 1993; Van Wyk & Van Wyk 1997). The grey bark has medicinal value and is harvested and sold to consumers in traditional medicine markets in KwaZulu-Natal (KZN), Gauteng and Mpumalanga (Botha *et al.* 2001; Grace 2002; Williams 2003) (Figure 1). Based on the total amount of bark harvested (m^2), *B. maughamii* was ranked third out of 36 tree species harvested for bark in the woodlands of southern Maputaland, KZN (Twine 2004). A detailed population study there revealed that 55% of all individuals [diameter at breast height (dbh) > 10 cm] had harvest wounds, and the mean amount of bark harvested per individual was 1.09 m^2 (Twine 2004).

In KZN, the species is classed as declining and considered to be heavily exploited for bark products (Cunningham 1988; Netshiluvhi 1999; Grace 2002). Its legal status in KZN is described as 'controlled' by Von Ahlefeldt *et al.* (2003), i.e. written permission is required from the land owner/holder for this species to be harvested or collected from the wild. The turnover from 23 traders in the Isipingo and Victoria Street informal herbal medicine markets in Durban was estimated to be 187 fifty kg bags per annum (± 1995) (Netshiluvhi 1999). On the Witwatersrand, 56% of the *muti* shops sold the bark (Williams *et al.* 2001), and a volume equivalent to ≈ seven 50 kg bags were present between 17 of the 100 traders surveyed in the Faraday Street traditional medicine market in Johannesburg in January 2001 (Williams 2003). On the western boundary of the Kruger National Park, 29% of the vendors sold *Balanites maughamii* bark and considered it a readily available resource (Botha *et al.* 2001). The mean price per 50 kg bag of *B. maughamii* bark bought by *muti* shops in Johannesburg in 1995 was R66.70 ± R33.50 [± standard deviation (SD)] (n = 15), and in 2001 a bag cost ≈ R100.

As part of an extensive investigation into the relationship between tree size and bark thickness of six tree species, including *Balanites maughamii*: 1, to determine the size of trees targeted by commercial bark harvest-

FIGURE 1.—*Balanites maughamii* individual repeatedly harvested for bark on communal land in the Ingwavuma region of KwaZulu-Natal in 1998. Parts of stem, including buttresses have been removed.

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ers from the thickness of the bark sold in the *muti* markets; 2, the mean wet and oven-dry bark thickness per tree size class; and 3, the mean harvestable bark mass per stem (Williams *et al.* 2005, in press a, b), various aspects of the tree stem profile were measured. These aspects included: 1, approximate height of the tree and branch-free bole length; and 2, diameter of the stem at five height intervals. Bark thickness was also measured. Data collected for *B. maughamii* are a subset of the original study. This short communication describes specific aspects of the *B. maughamii* tree stem profile related to the fluted trunk, including: 1, the relationship between two measurements around the stem that respectively include and exclude the bark surface area contained in the convolutions of the flutes; 2, the number of flutes observed at 1.3 m above ground (where dbh is normally measured); and 3, the percentage of the stem enclosed within the flutes.

METHODS

Between March and May 1998, 39 *Balanites maughamii* stems were measured at six sites in three South African provinces (Table 1). At each sample site, a population of trees was located and individuals were selected from five stem diameter classes based on diameter at breast height (dbh) ranging between 10 cm and 60 cm. A minimum of five and a maximum of ten trees were measured per diameter class (not per site). None of the individuals had suffered any prior harvesting damage, and the bark on the bole was intact. *Balanites* individuals larger than 60 cm dbh were found in communal lands; however, these trees were not sampled as bark harvesters had previously removed whole sections of the bark, fluted stems and buttresses. The method used for assessing vertical height was a direct estimate using a 2 m height pole, with 0.5 m intervals. The number of pole lengths was counted by eye to estimate tree height and branch-free bole length. After the 22 *Balanites* stems were measured, the number of flutes at dbh were counted and their depth was categorized (subjectively, shallow or deep).

It is standard practise in forestry to measure tree stem girth with a forestry diameter tape. The tape is calibrated in π centimetres so that a circumference measurement is converted directly to a diameter measurement (Philip 1983), and the measurement is thus recorded as a diameter dimension rather than a circumference. Two diameter readings were taken at five height intervals (0.5 m, 1.0 m, 1.3 m, 1.5 m and 2.0 m, abbreviated as $D_{0.5}$, $D_{1.0}$, $D_{1.3}$, $D_{1.5}$ and $D_{2.0}$ respectively) from the *Balanites maughamii* stem: 1, a circumference measurement around the stem that excludes the area inside the flutes (diameter 1, D1); and 2, a circumference measurement into the convolutions of the flutes, measuring along the entire bark surface (diameter 2, D2) (Figure 2). Hence D1 is the typical stem diameter measurement taken by foresters, usually at breast height (1.3 m, dbh), whereas D2 is a hypothetical diameter, where the flutes are pushed out to form a circle. Initially, only D1 was measured, but after six samples, D2 was also measured.

TABLE 1.—Sample sites and no. individuals sampled per site

Province	Area in the province	Ownership and management regime	*n*
Limpopo	Western Soutpansberg	Private farm 1 (south of Wyllie's Poort)	17
Limpopo	Western Soutpansberg	Private farm 2 (north of Wyllie's Poort)	13
Mpumalanga	Nelspruit	Protected area	2
KwaZulu-Natal	Ingwavuma	Communal land	3
KwaZulu-Natal	Zululand	Protected area	1
KwaZulu-Natal	Zululand	Private protected area	3

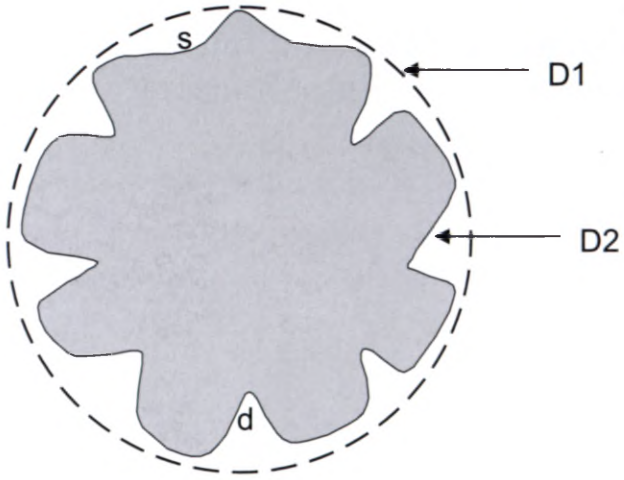

FIGURE 2.—Schematic representation of a cross section through *Balanites maughamii* tree stem showing measurements D1 and D2. D1: measurement around stem that excludes bark surface in flutes; D2: measurement in concave convolutions of flutes, thereby measuring entire bark surface. Measurements were made using a forestry diameter tape, calibrated in π centimetres, which converts a circumference measurement of a stem directly into a 'diameter' measurement. Measurements of D1 at 1.3 m above ground (dbh) were used to construct stem diameter classes. s, subjective classification of shallow flutes; d, deep flutes.

RESULTS AND DISCUSSION

The *Balanites maughamii* individuals measured, ranged in height from 4 to 12 m, with a mean of 8 ± 2 m (SD). Branch-free bole length was 2.9 ± 1.4 m (SD). The dbh of the largest tree sampled was $D1_{1.3}$ = 59.2 cm and $D2_{1.3}$ = 260.0 cm (circumference equals 186 cm and 817 cm respectively), from a site in a private protected area in KZN.

There was a very strong positive relationship between D1 and D2 at all height intervals up the stem (Figure 3A–E), especially at $D_{0.5}$ ($r^2 = 0.988$, $p < 0.0001$, Figure 3A). No branching occurred on the stem below 0.9 m, hence results for $D_{0.5}$ were not affected by the response of the tree to branching. The quadratic regressions were only slightly better fits than the linear regressions (results not shown). For example, $r^2 = 0.988$ for the quadratic equation at $D_{0.5}$, whereas $r^2 = 0.979$ for the linear equation at the same height.

These results show that by measuring D1 at a particular stem height, D2 can be accurately estimated, hence obviating the necessity to measure both D1 and D2. When compared with the *observed* D2, the D2 *predicted* by the quadratic regression equations was slightly

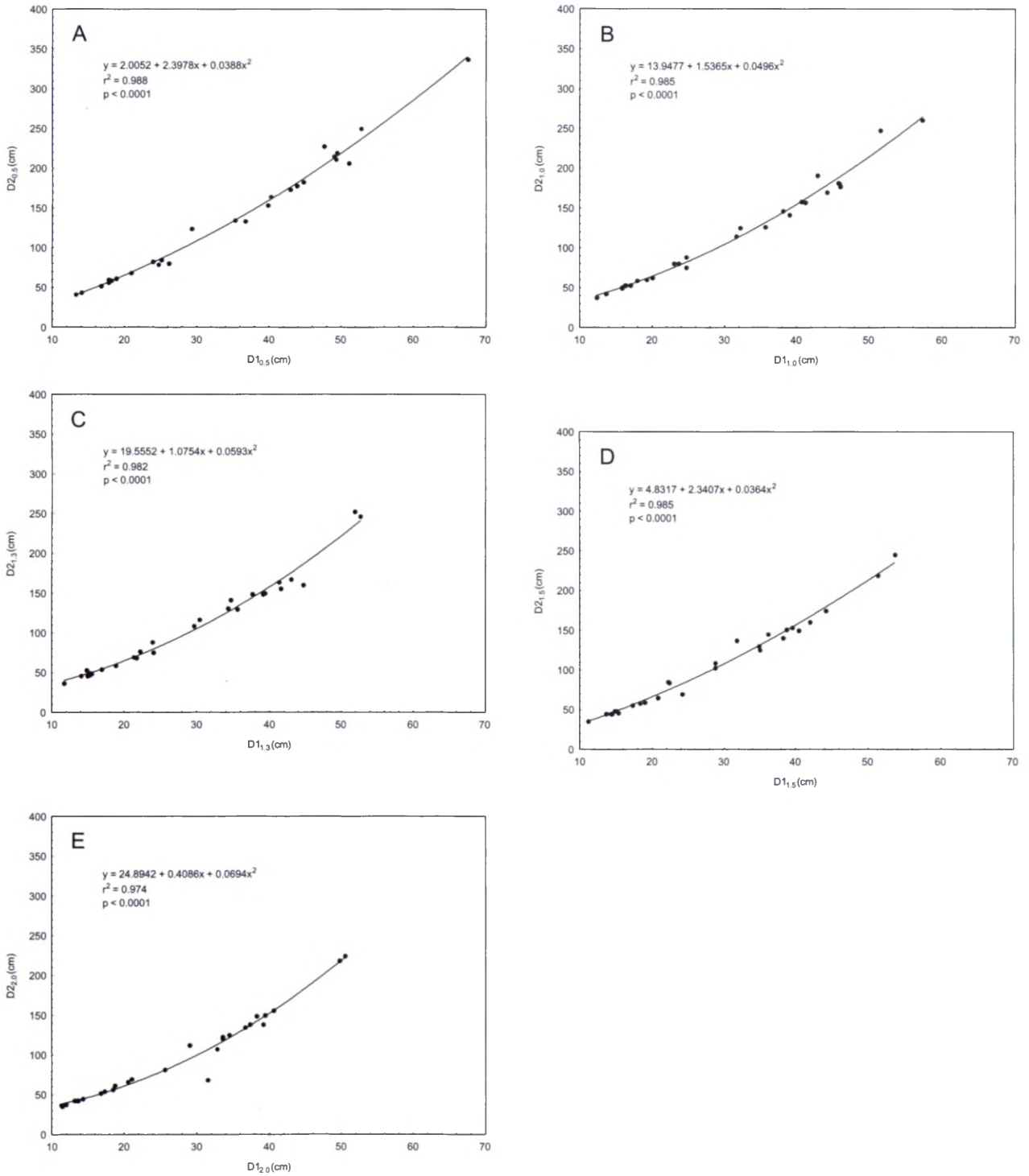

FIGURE 3.—Relationship between stem diameter 1 (D1) and stem diameter 2 (D2) measured at A, 0.5 m; B, 1.0 m; C, 1.3 m; D, 1.5 m; and E, 2.0 m above ground [n = 28 (all graphs)]. To obtain circumference, multiply D1 or D2 by π.

overestimated [mean percentage error = 0.35 ± 5.99% (SD), n = 154]. By contrast, the linear regression equations tended to underestimate the predicted D2 [–1.22 ± 9.04% (SD), n = 154].

By converting the observed D2 measurements back to circumferences, the area of bark (m^2) on the stem could be estimated. The mean amount of bark up to 2 m on the stem ranged from 3.3 ± 0.6 m^2 (SD) (n = 10) on trees in the 10–19 cm diameter class (D1), to 16.1 ± 0.7 m^2 (SD) (n = 4) on trees in the 50–59 cm diameter class (Table 2).

As the dbh of *Balanites maughamii* individuals increased, the number and depth of flutes at $D_{1.3}$ was observed to increase (Table 3), thus increasing the proportion of the bark surface area within the convolutions of the flutes. Trees in the 10–20 cm and 20–30 cm stem diameter classes (D1) generally had two shallow flutes and one deep one. As tree size increased, the shallow flutes became deeper until there were 2 or 3 and 4 or 5 deep flutes in the 30–40 cm and 40–50 cm classes respectively. Trees larger than 50 cm had more than six deep flutes with sometimes as many as 10 per stem as the trees approached 60 cm dbh.

TABLE 2.—Estimated mean bark area (m^2) up to 2 m height per stem size class

Size-class (dbh, cm) (D1)	Mean estimated bark area (m^2)	SD	Min.	Max.	n
10–20	3.29	0.60	2.38	4.24	10
20–30	5.13	0.80	4.04	6.84	8
30–40	9.16	1.01	7.62	10.51	7
40–50	10.98	0.22	10.83	11.31	4
50–60	16.11	0.79	15.15	16.67	4

dbh, diameter at breast height; SD, standard deviation.

Most of the trunk circumference is contained within the concave sections of the flutes (Figure 4). At 0.5 m above ground, 73.0 ± 4.0% (SD) of the stem was within the flutes. The percentage decreased gradually with increasing height up the stem until it was 70.3 ± 4.3% (SD) at 2 m (Figure 4). Furthermore, in trees with larger dbh, a greater percentage of stem was enclosed within the flutes. Similarly, more than two thirds of the bark surface area is within the flutes [mean = 72 ± 3% (SD), n = 31]. The proportion of the bark inside the flutes varied according to tree size, with up to 79% of the bark area found in the flutes of trees in the 50–59 cm stem diameter class (D1), and decreasing to 69% in flutes of trees in the 10–19 cm stem diameter class.

CONCLUSION

Despite the buttresses in the *Balanites maughamii* stems, it appears that the diameter measurement D1 is an acceptable predictor of D2. Hence, the bark surface area can be estimated as well as the amount of bark that can potentially be removed from the stems. Because most of the bark area is contained within the convolutions of the flutes, the tree trunks are difficult to ring-bark. Even when harvesters remove whole sections of the flutes/buttresses, including the timber, they usually leave behind some of the bark at the base of the flute. This may potentially enable wound recovery following harvesting and probably makes the species more resilient to harvesting.

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TABLE 3.—Observed number and depth of flutes per measured tree at $D_{1.3}$ (dbh). Individual trees are enclosed in parentheses in column three

Size-class (dbh, cm) (D1)	No. trees measured (n = 15, out of 39)	Observed number and depth of flutes per tree at $D_{1.3}$ (dbh)
10–20	1	(1d, 2s)
20–30	4	(1s); (1d, 2s); (1d, 2s); (1d, 3s)
30–40	6	(2d); (3d); (3d); (3d); (3d, 1s); (4d)*
40–50	2	(4d); (5d)
50–60	2	(6d); (10d)

* dbh (diameter at breast height) of individual tree = 39.4 cm; s, no. of shallow flutes; d, no. of deep flutes (subjective descriptions of flute depth).

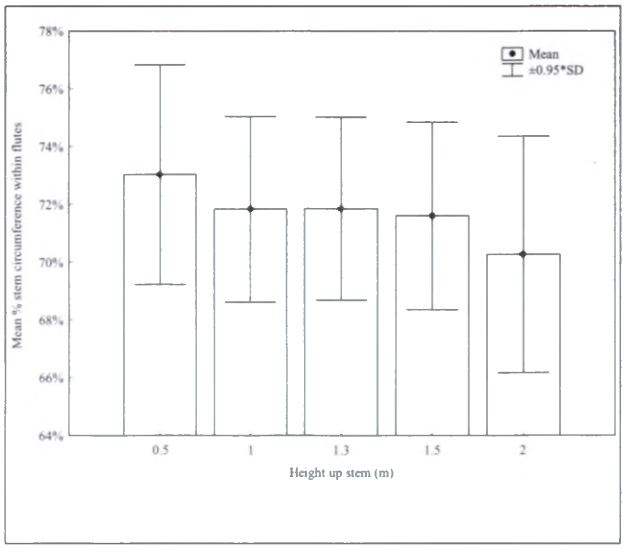

FIGURE 4.—Mean percentage of stem circumference contained within concave sections of flutes at five height intervals up stem to 2 m, including diameter at breast height (dbh, 1.3 m). Means calculated for trees ranging from 11.7 cm to 52.7 cm dbh. SD, standard deviation.

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