



Borassus aethiopum Mart. (Arecaceae) in Limpopo province with a key to South African palms

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Background: *Borassus aethiopum* Mart. commonly occurs in many parts of tropical Africa, and in South Africa it is restricted to the Leydsdorp region where it is conspicuous along the Selati River. The species is sometimes considered to have been introduced to South Africa because of its disjunct distribution. It has remained poorly studied and little is known about the local populations of this palm.

Objectives: This study provides a descriptive treatment and documents the population structure of *B. aethiopum* in this area, and presents a key to the six indigenous palm species of South Africa.

Method: All accessible populations were surveyed and documented, and eight transects were randomly placed to gather data on size-class distributions. *Borassus aethiopum* and other indigenous palm species were compared morphologically.

Results: The population structure analyses of *B. aethiopum* revealed a monotonic decline, but the permutation index suggested that the species is prone to recruitment events. This is supported by patches that are dominated by specific height classes. Leaf shape and size, fruit size and geographical distribution were the diagnostic characters most useful to recognise the species of South African indigenous palms.

Conclusion: *Borassus aethiopum* is distinguishable from other South African palms based on stem, leaf and fruit characters. It is considered as indigenous to Granite Lowveld as the palm is part of the natural vegetation and is characterised by a size-class distribution reflecting a stable population.

Introduction

The Flora of Southern Africa (FSA) comprises more than 30 000 plant species with 60% endemism (Van Wyk & Smith 2001). Despite this diversity, palms are poorly represented in South Africa, with only six indigenous species. Two species are endemic: *Jubaeopsis caffra* Becc. (monotypic genus), which is endangered and restricted to coastal Pondoland (Hurter et al. 2007), and *Raphia australis* Oberm. & Strey, which is considered vulnerable and restricted to the Maputaland coastline from just south of Kosi Bay to 50 km north of Maputo in Mozambique (Matimele et al. 2016). The other four species are widespread in parts of Africa: *Borassus aethiopum* Mart., *Hyphaene coriacea* Gaertn., *H. petersiana* Klotzsch ex Mart. and *Phoenix reclinata* Jacq. (Klopper et al. 2006). Approximately 320 exotic palm species are cultivated in South Africa (Glen 2002) and it has been found that some of these species, such as *Livistona chinensis* R.Br., have become naturalised (Siebert, Zobolo & Dowe 2010).

Amongst the taxonomic treatments of South African palms were those in 'Flora Capensis' (Wright 1897) and a book on the indigenous palms of southern Africa (Wicht 1969). The only recent treatment including some of the South African Arecaceae was in Flora Zambesiaca (Dransfield 2010). This included *B. aethiopum*, that is one of three *Borassus* species that are found in Africa and Madagascar (five worldwide). The other two African species are *B. akeassii* Bayton, Ouedraogo & Guinko and *B. madagascariensis* (Jumelle & Perrier) Bojer ex Jumelle & Perrier (Bayton 2007).

The first mention of *B. aethiopum* occurring in Limpopo (Northern Transvaal), South Africa, was made by Hutchinson and Dalziel (1936). It has often been debated whether *B. aethiopum* in South Africa occurred here naturally or was introduced (Schmidt, Lotter & McClelland 2007). It was reported by Burt Davy (of the then Transvaal Department of Agriculture) that a couple of trees of an original grove of about 50 remained at Sutherland Reef Mine near Leydsdorp in 1906 (Dyer 1952). Dyer speculated that *B. aethiopum* was introduced in the latter part of the 1800s based on the population structure, which was dominated by a colony of young plants and only a few mature individuals. He later provided evidence to the contrary when he reported on observations made by a certain

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Mr Heinrich Altenroxal of the Thabena Farming Association that adult plants were used extensively for mine timbers which could have depleted the populations. Present thought recognises *B. aethiopum* as an indigenous species of South Africa (Bayton 2007).

Research on South African palms has generally been very limited, and the uncertainty regarding the origin of *B. aethiopum* has left it rather unobserved as no previous research has been conducted to understand the population in South Africa. The palm is a common feature of the landscape along the Selati River in South Africa and this study aims to determine the size and structure of the population, provide a detailed species description and construct a key to distinguish it from other palms indigenous to South Africa.

Material and methods

Distribution records were obtained from the National Herbarium in Pretoria (PRE) and A.P. Goossens Herbarium (PUC). Further locality records were obtained from field visits in October 2016 and 31 points were logged (Figure 1a). At each point, all the plants in a 100 m radius were recorded, which varied between 1 and 64 individuals. Plants were classified as sub-juveniles (no stem; < 1 m tall), juveniles (no flowers or fruit; leaf bases still attached to stem; 1 m – 8 m) and mature plants (flowers or fruit present; leaf bases have

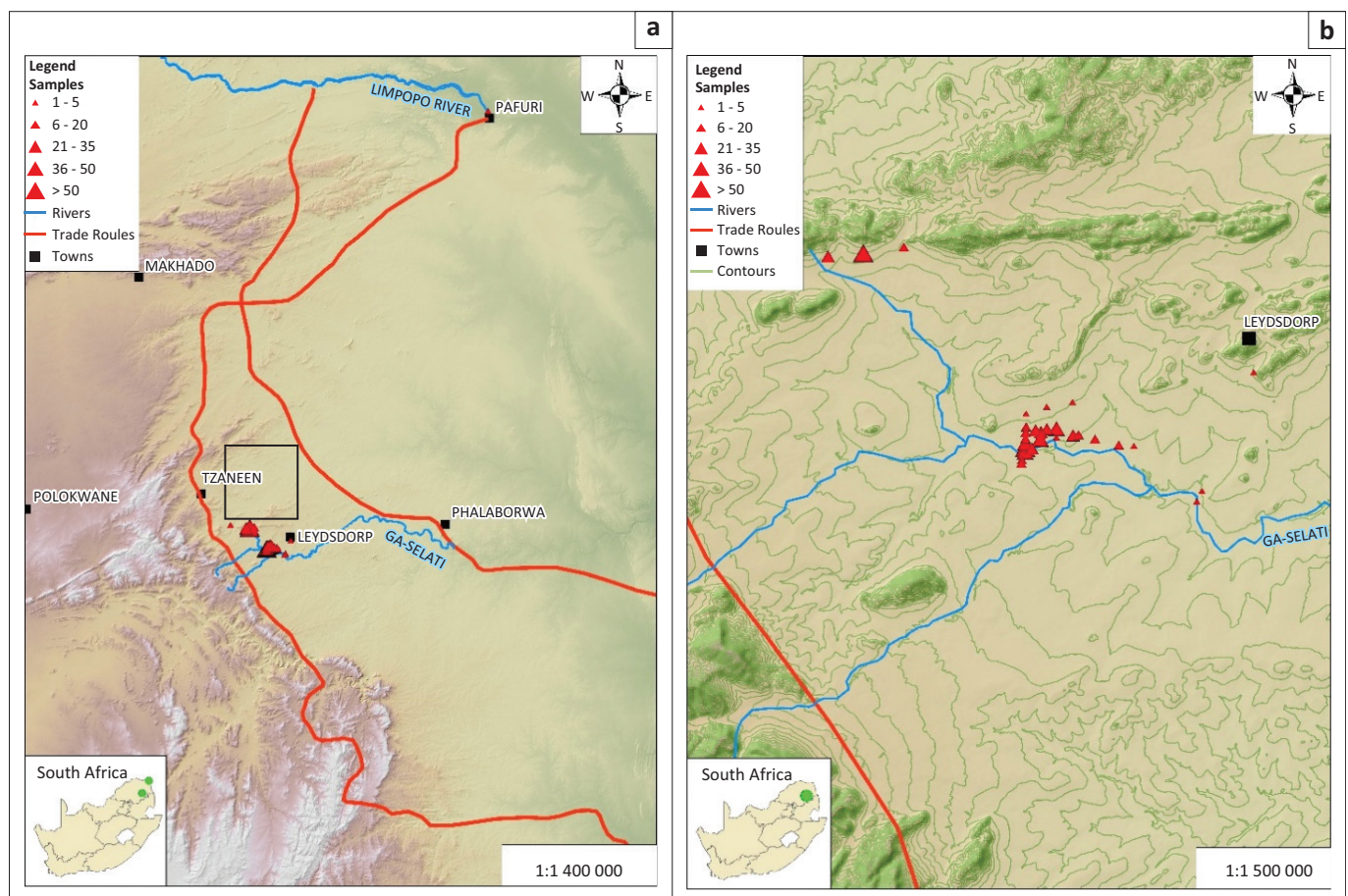
been shed and there is a swelling on the stem; 8 m – 12 m tall). Binoculars were used to determine whether palms were male or female. These census data allowed for the construction of a distribution map and to characterise the population. Data were also collected regarding the number of inflorescences per female plant and fruits per female plant.

Eight transects of 100 m were randomly placed. Plants up to 4 m height were measured with a measuring stick and those with heights above 4 m were determined by using a clinometer. Height class distributions were compiled. Sturge's rule was applied to determine the size-class distribution and frequency intervals for the population graphs (Scott 2009). Stability between successive size classes was determined using quotient analysis; likelihood that any two trees within a population originate from the same size class was assessed by Simpson's Index of Dominance (SDI) and Permutation Index (PI) was calculated for the population to calculate the degree of deviation from a monotonic decline or from an inverse-J curve (Siebert et al. 2018).

Results and discussion

Taxonomic treatment

Borassus aethiopum Mart., Hist. Nat. Palm. 3: 220. (1838);
Borassus flabellifer L. var. *aethiopum* (Mart.) Warb. in



Source: S. van Eeden, Geography and Environmental Management, North-West University

FIGURE 1: (a) Distribution of *Borassus aethiopum* in South Africa (from Pafuri to Leydsdorp) based on herbarium specimens and field observations. Major trade routes are indicated in red and are based on De Vaal (1984). (b) Distribution of clumps along the Selati River. Clump sizes are accounted for under sample size intervals.

Pflanzenw. Ost-Afrikas B: 20 (1895). Type: Ghana, Weija, 24 April 1957 (♂ and ♀), *Tomlinson s.n.* (BH, neo. designated by Bayton 2007).

Borassus sambiranensis Jum. & H. Perrier, Ann. Mus. Colon. Marseille sér. 3, 1: 67 (1913). Type: Madagascar, Antsiranana province, Ambanja, 28 March 2003 (♂), *Bayton & Ranaivojaona 55* (K-000300224, neo. designated by Bayton 2007).

Borassus deleb Becc., *Webbia* iv: 339 (1914). Type: Sudan, unknown locality and date (♀), *Salvago Raggi, s.n.* (FI, holo.).

Description

Stems solitary, 20 m – 25 m tall, straight, with conspicuous swelling half way up the stem (Figure 2a), up to 80 cm in diameter; dioecious; young palms covered with dry leaf sheaths (Figure 2b). *Leaves* 18–27 in the crown, palmate lamina up to 190 cm long, 1 m – 3 m wide, coriaceous, bluish-green; petiole and sheath 130 cm – 220 cm long, petiole 3.2 cm – 9.0 cm wide, with large, recurved teeth on the margin extending along the margin of the first segment, teeth 0.4 cm – 2.8 cm long; yellow-orange in distal portion becoming black towards trunk, petiole of immature leaf completely black; costa 80 cm – 170 cm long; adaxial hastula up to 2.9 cm high, abaxial hastula rudimentary; segments 86 cm – 120 cm, 4.7 cm – 11.0 cm wide, linear, margin entire or splitting longitudinally in older leaves, apex acute; shortest segments 45 cm – 92 cm long, leaf divided to 58 cm – 92 cm; commissural veins 8–15 per cm; dense indumentum on the ribs on some of the immature leaves. *Male inflorescence* branched to two orders, upper subtending branches terminating in 1–3 rachillae; rachillae green-brown and catkin-like, flowering part 37 cm – 50 cm long, 2.3 cm – 3.8 cm in diameter, sometimes with mamilliform apex; rachilla bracts form pits containing a cincinnus of 8–14 male flowers. *Male flowers* 0.2 cm – 0.7 cm long, exerted individually from the pits, subtending bracteoles 0.8 cm × 0.5 cm, calyx 0.4 cm × 0.2 cm, shallowly divided into three sepals; three petals 0.15 cm × 0.10 cm; stamens 6; filaments 0.02 cm × 0.04 cm; anthers 0.02 cm × 0.05 cm, pistillode minute; ovary vestigial. *Female inflorescence* spicate, flowering part 36 cm – 160 cm long, 10–28 flowers arranged in spirals. *Female flowers* 3 cm × 3 cm, bracteoles 2 cm in diameter, overlapping sepals 1.5 cm × 2.0 cm; inrolled petals 1.0 cm × 1.5 cm, three stigmas, ovary globose; six vestigial stamens. *Fruits* large drupes (Figure 2c), 7 cm – 18 cm × 7 cm – 12 cm, ovoid, flattened at apex, mesocarp fragrant, yellow to orange brown at maturity (Figure 2d), perianth segments persist, pyrenes 1 cm – 3 cm, 6.4 cm – 10.9 cm × 4.2 cm – 5.7 cm, somewhat bilobed, some with one or two external longitudinal furrows. Description based on Bayton (2007) and the specimens examined.

Etymology

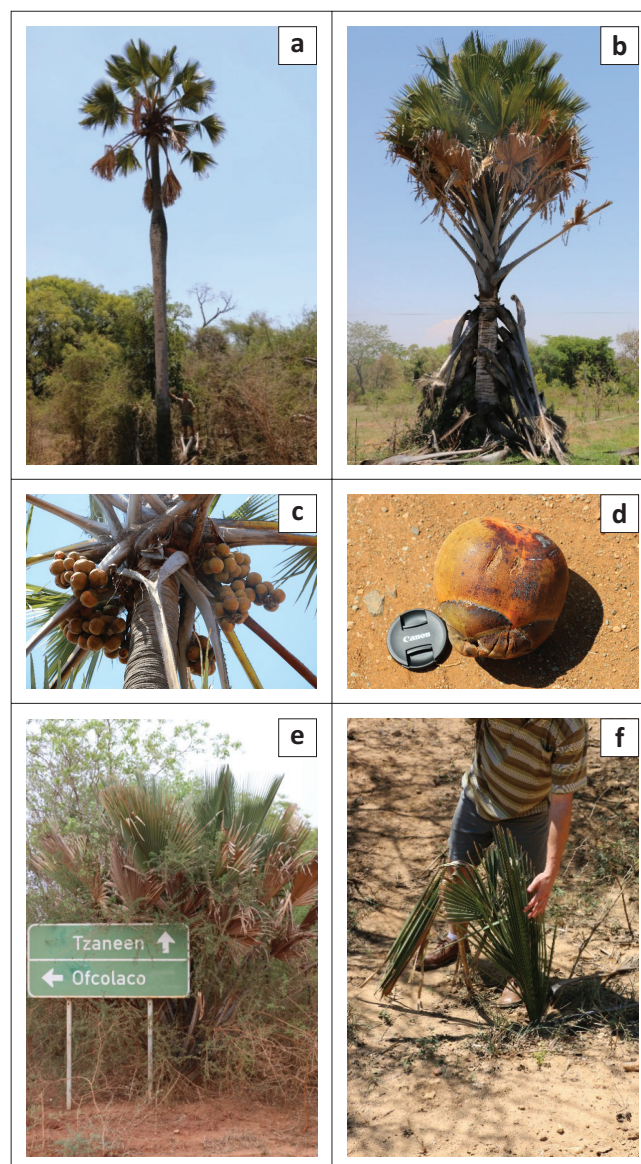
Borassus is the Greek name for the immature female spadix of the date palm, and *aethiopum* indicates that the species occurs in Africa south of Egypt (Schmidt et al. 2007). Common names used for the tree in South Africa include Borassus Palm, Selati Palm, African Fan Palm, *Borassuspalm* (Afrikaans), *Mopalamo* (Northern Sotho).

Uses

The palm has varied uses in Africa (Ali et al. 2010). In the Khangela village and surrounding settlements near Tzaneen where the palm is cultivated, people indicated that they consume the fruit and that the palm is mainly cultivated for its cultural significance. It is believed that the spirit of Chief Magoeba, the last chief of the Batlou tribe, was housed in the stem swelling of a prominent specimen near Leydsdorp (Esterhuysen, Von Breitenbach & Sohng 2001).

Distribution

The palm is distributed along floodplains on sandy, well-drained alluvial soils of the Selati River near Leydsdorp in Limpopo province (Figure 1b) and along the Limpopo River at Crooks Corner near Pafuri in the Kruger National Park (Figure 1a). From here, it extended northwards into Zimbabwe, Mozambique and Zambia, and up into parts



Source: Photos taken by S.J. Siebert

FIGURE 2: *Borassus aethiopum*. (a) A 12-m-tall reproductive specimen with swelling on the stem. (b) Specimen nearing maturity (8 m tall) and shedding leaf sheaths. (c) Female plant with ripe orange fruit. (d) Fruit. (e) Juvenile, Cloete & Siebert 2. (f) Sub-juvenile.

of tropical Africa (Bayton 2007; Dransfield 2010). In Limpopo, the palm is only found in the Lowveld Bioregion, with the small population in the Kruger National Park occurring in Lowveld Riverine Forest and the Leydsdorp populations associated with Granite Lowveld (Mucina & Rutherford 2006).

Phenology

Flowers and fruits are produced throughout the year (Orwa et al. 2009). Our survey of 18 flowering female plants revealed that the number of inflorescences per plant is 2–4 per flowering event. Fruiting plants carried a mean of 20 ± 9 fruits per spike (Figure 2c).

Maturity

Field observations confirmed the findings of Dyer (1952) regarding the shedding of all leaf bases at more or less the same time from the stem (Figure 2b). The remarkable swelling of the stem (Figure 2a) at a certain post-juvenile stage seems to be connected in some way with the attainment of reproductive maturity, as individuals that lack the swelling were never recorded to carry any flowers or fruits. Dalziel (1937) reported that the swelling of the stem appears at about 50 years and according to Coates Palgrave (2002), it happens at 30–40 years.

Mature plants in the Leydsdorp area drop their leaf bases at approximately 8 m height (7 m according to Coates Palgrave [2002]), form a swelling on the trunk and then flower for the first time. We estimate the age of maturity for these specimens at approximately 47–53 years, which is in accordance with Dalziel (1937), taking into consideration the establishment years of the seedling and assuming that growth is constant throughout the palm's life. Our estimate was based on the growth rate of a single, known roadside palm (Cloete & Siebert 2) that grew 4.5 m in 30 years, which equated to approximately 15 cm per year. However, these predictions of reproductive age are much less than the matrix model prediction (on average 114 years) made by Barot et al. (2000).

Dispersal

It is generally accepted that the fruits are eaten by elephants and in this way, the seeds are distributed (Orwa et al. 2009; Zona & Henderson 1989). It makes sense that fruit could have easily been dispersed by elephant from Zimbabwe to Pafuri (Kruger National Park) in South Africa across the Limpopo River (Figure 1). However, considering the distance between the disjunct populations at Pafuri and Leydsdorp (200 km), seed dispersal by elephants over this distance should be highly unlikely as Bunney, Bond & Henley (2017) reported a maximum seed dispersal distance by elephant of 65 km. A most likely explanation would be that these two disjunct populations are the result of local extinction of intervening populations, or the intervening habitat being unsuitable. Elsewhere in Africa, *B. aethiopicum* is characterised by such wide distributions, and similarly with high local abundance (Salako et al. 2018b).

The alternative view for the disjunction is that the palm is an introduced species (Dyer 1952), possibly as the area where the palms are found are situated along an ancient trade route (Figure 1) between Delagoa Bay (Maputo) and Zimbabwe (De Vaal 1984). Evidence exists that trade was taking place between Islamic traders and people from the Limpopo area as far back as the 8th century (Wood 2000) and various ancient smelters are known from the Gravelotte–Tzaneen–Leydsdorp region of the Murchison Range dating back to the 15th century (Miller et al. 2001). These activities would certainly have attracted traders from the north to trade cattle for iron, copper tools or artefacts (De Vaal 1985; Miller et al. 2001), which has been well reported for Mapungubwe along the Limpopo River, on the border with Zimbabwe (Prinsloo & Colombari 2008). The postulate is that seeds were discarded at this halfway mark (Figure 1).

It is also worth considering that *Borassus* seems to have a preference for alluvial areas with seasonal rainfall – they are often found on floodplains and in gallery forest – and these areas are also popular with farmers and as the location for human settlements. Therefore, it may be that *Borassus* and people share a habitat preference. Both cohabitation and the socio-economic value of the palm (Salako et al. 2018a) may be an explanation for current *Borassus* distributions; therefore, the interpretation of past historical plant movements based on current distributions is presented here with caution.

Diagnostic characters

Borassus aethiopicum is geographically and ecologically separated from *Jubaeopsis caffra* and *Raphia australis*. *Jubaeopsis caffra* is found on sandstone cliffs and on the northern banks of the Msikaba and Mntentu rivers in Pondoland, while *Raphia australis* is restricted to the swampy forests of Maputaland. *Borassus aethiopicum* can, however, be distinguished morphologically from *J. caffra* and *R. australis* in that the leaves of *B. aethiopicum* are costa-palmate, while those of *J. caffra* and *R. australis*, and similarly for *Phoenix reclinata*, are pinnately compound. *Hyphaene coriacea* and *H. petersiana* also have costa-palmate leaves and can be distinguished from *B. aethiopicum* in that the leaves of *B. aethiopicum* are 3 m – 4 m long, while those of *Hyphaene* species are 1.5 m – 2.0 m long; and the fruit of *B. aethiopicum* is 7 cm – 17 cm in diameter, yellow to orange brown in colour and that of the *Hyphaene* species is 4 cm – 5 cm in diameter and reddish brown in colour.

Key to the native palms of South Africa

- 1A. Leaves costa-palmate.....2
- 1B. Leaves pinnate4
- 2A. Stem to 25 m tall; leaves 3 m – 4 m long; fruit 7 cm – 17 cm in diameter, yellow to orange brown when mature*Borassus aethiopicum*
- 2B. Stem to 7 m tall; leaves 1.5 m – 2.0 m long; fruits 4 cm – 5 cm in diameter, reddish brown when mature3
- 3A. Fruit ovate to pear-shaped and ridged, with distinctly narrow base; stems up to 5 m tall; multi-stemmed; mainly a coastal distribution.....*Hyphaene coriacea*

- 3B. Fruit globose-oblong, without ridges; stems up to 7 m tall; usually solitary; associated with the drier interior *Hyphaene petersiana*
- 4A. Single stemmed; leaves 6 m – 10 m long, hooked spines on the margin of leaflets; fruit covered with overlapping scales *Raphia australis*
- 4B. Multi-stemmed; leaves less than 6 m long, margin of leaflet entire or crenulate; fruits smooth 5
- 5A. Petiole without spines; leaves up to 6 m long, silvery blue-green at a distance, bright green nearby, pinna reduplicate, margin entire; monoecious; fruit round, 20 mm in diameter; restricted in distribution to northern banks of Msikaba and Mtentu rivers, Pondoland *Jubaeopsis caffra*
- 5B. Petiole with long, sharp spines at the base; leaves up to 4 m long, light to dark green, induplicate pinnate, margin minutely crenulate; dioecious; fruit ovate, 15 mm in diameter; widely distributed throughout tropical and subtropical Africa *Phoenix reclinata*

Population description

Vegetation

In the Leydsdorp region, the populations are associated with other Lowveld tree species such as *Albizia versicolor* Welw. ex Oliv. (Fabaceae), *Combretum collinum* Fresen. (Combretaceae), *Diospyros mespiliformis* Hochst. ex. A.DC. (Ebenaceae), *Peltophorum africanum* Sond. (Fabaceae), *Philenoptera violacea* (Klotzsch) Schrire (Fabaceae), *Sclerocarya birrea* Hochst. (Anacardiaceae) and *Trichilia emetica* Vahl. (Meliaceae). Common shrubs include *Dichrostachys cinerea* (L.) Wight & Arn. (Fabaceae), *Flueggea virosa* (Roxb. ex Willd.) Dalzell (Euphorbiaceae) and *Phyllanthus reticulatus* Poir. (Euphorbiaceae). Commonly encountered invasive aliens include *Chromolaena odorata* (L.) R.M.King & H.Rob. (Asteraceae), *Lantana camara* L. (Verbenaceae), *Melia azedarach* L. (Meliaceae) and *Thevetia peruviana* K.Schum. (Apocynaceae). The palm typically forms groves (aggregates) within the vegetation (Salako et al. 2018a) and is not evenly distributed as part of the matrix as is the case with the other species mentioned above.

Population structure

A total of 614 plants were recorded in the Leydsdorp area (Table 1), of which 25% were sub-juveniles (< 1 m, no stem), 43% were juveniles (non-reproductive, with stem bearing leaf sheaths) and 32% were adults (reproductive, stem with swelling; 1:1.3 male:female). The size-class distribution showed variation in the quotient (0.8–1.4; Figure 3), which is indicative of an unstable population (Siebert et al. 2018). The palm population is probably subjected to recruitment events

TABLE 1: Number of individuals per life stage as recorded for *Borassus aethiopum* in the Leydsdorp area during October 2016.

Life stage	Individuals
Mature male	86
Mature female	110
Juveniles	264
Sub-juveniles	154
Total	614

Note: The number of dead adults was 8.

as a result of rainfall that coincide with fruit maturity and fall (Barot, Gignoux & Menaut et al. 1999), which is reflected by the formation of groves of the same age.

The population has an SDI value slightly above 0.1 (i.e. 0.18), which reveals that size frequency is not steeper than what would be expected from an exponentially declining population. This is an indication that individuals are evenly distributed amongst the size classes, but this needs to be considered with PI values that are based on the assumption that an ideal undisturbed population should represent a monotonic decline (PI = 0). This was, however, not typical for *B. aethiopum* (PI = 2), which has a discontinuous population, where larger individuals (3.1 m – 5.0 m tall) show a higher frequency than the previous size class. This could be explained by recruitment events as sub-adult and adult plants of the same size are often found in separate clumps creating patches of high local abundance (Salako et al. 2018b). Established sub-juveniles (0.1 m – 1.0 m tall) and juveniles (1.1 m – 3.0 m tall) were also not associated with these clumps and were found further away (Figure 2f). This is in accordance with the Barot et al. (1999) model that predicted distance-dependent survival rates to explain these outward shifts because of extreme intraspecific competition between seedlings (Barot & Gignoux 2003).

Conclusion

Borassus aethiopum is distinguishable from other South African palms based on stem, leaf and fruit characters and geographical distribution. It is one of three indigenous species with costa-palmate leaves. It can be confused with *Hyphaene petersiana* as both have a single stem containing a swelling. However, *B. aethiopum* can be distinguished by its larger leaves and fruit.

The occurrence of *B. aethiopum* in southern Zimbabwe makes its occurrence in South Africa logical. However, its association with the ancient trade routes that ran through South Africa and Zimbabwe will always cast doubt over its natural occurrence in both these countries. *Borassus aethiopum* is a tropical African palm, and regardless of whether it was dispersed by humans or animals, it should be recognised as indigenous to the Granite Lowveld as the palms are part of

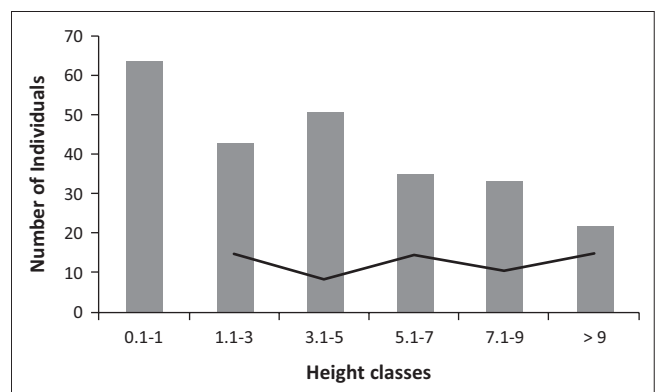


FIGURE 3: Height classes (m) and quotient analyses (solid black line) of *Borassus aethiopum* in the Leydsdorp area (Limpopo province).

the natural vegetation and are characterised by a size-class distribution reflecting a stable population.

Specimens examined

SOUTH AFRICA. LIMPOPO. – 2231 (Messina): At the confluence of the Luvuhu and Limpopo rivers, Pafuri, (–DD), 12 April 2014, *Zambatis & Zambatis* GZ1546 (KNP). – 2330 (Tzaneen): Road from Tzaneen to Leydsdorp, half way on right, Police Station, (–DC), October 1946, *Kettlitz* PRE36392 (PRE). – 2430 (Pilgrim's Rest): 7.5 miles southwest of Leydsdorp, (–AB), 5 November 1948, *Codd & Dyer* 4701 (PRE); Leydsdorp, Farm Harmony, along edges of pivot field, (–AB), 31 October 2016, *Cloete & Siebert* 1 (PRE, PUC); Leydsdorp, T-junction of Ofcalaco–Gravelotte–Tzaneen roads, (–BA), 31 October 2016, *Cloete & Siebert* 2 (PRE, PUC).

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

S.J.S. planned and coordinated the study and wrote the article. M.S. contributed to the writing of the article and was responsible for the taxonomic treatment and construction of the key.

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References

- Ali, A., Alhadji, D., Tchegang, C. & Saiuml, C., 2010, 'Physico-chemical properties of palmyra palm (*Borassus aethiopus* Mart.) fruits from Northern Cameroon', *African Journal of Food Science* 4(3), 115–119.
- Barot, S. & Gignoux, J., 2003, 'Neighbourhood analysis in the savanna palm *Borassus aethiopus*: Interplay of intraspecific competition and soil patchiness', *Journal of Vegetation Science* 14(1), 79–88. [https://doi.org/10.1658/1100-9233\(2003\)014\[0079:NAITSP\]2.0.CO;2](https://doi.org/10.1658/1100-9233(2003)014[0079:NAITSP]2.0.CO;2)
- Barot, S., Gignoux, J. & Menaut, J.C., 1999, 'Seed shadows, survival and recruitment: How simple mechanisms lead to dynamics of population recruitment curves', *Oikos* 86(2), 320–330. <https://doi.org/10.2307/3546449>
- Barot, S., Gignoux, J., Vuattoux, R. & Legendre, S., 2000, 'Demography of a savanna palm tree in Ivory Coast (Lamto): Population persistence and life-history', *Journal of Tropical Ecology* 16(5), 637–655. <https://doi.org/10.2307/3546449>
- Bayton, R.P., 2007, 'A revision of *Borassus* L. (Arecaceae)', *Kew Bulletin* 62(4), 561–585.
- Beccari, O., 1914, 'Studio sui *Borassus* e descrizione di un genere nuovo asiatico di Borasseae', *Webbia* 4, 293–385. <https://doi.org/10.1080/00837792.1914.10669572>
- Bunney, K., Bond, W.J. & Henley, M., 2017, 'Seed dispersal kernel of the largest surviving megaherbivore – the African savanna elephant', *Biotropica* 49(3), 395–401. <https://doi.org/10.1111/btp.12423>
- Coates Palgrave, K., 2002, *Trees of southern Africa*, Struik, Cape Town, p. 1212.
- Dalziel, J.M., 1937, *The useful plants of West Tropical Africa*, The Crown Agents for the Colonies, London, p. 496.
- De Vaal, J.B., 1984, 'Old trading footpaths and wagon roads in the Eastern and Northern Transvaal', *Contree* 16, 5–15.
- De Vaal, J.B., 1985, 'Trade along the oldest routes', *Contree* 17, 5–14.
- Dransfield, J., 2010, 'Arecaceae (Palmae)', *Flora Zambesiaca* 13(2), 35–69.
- Dyer, R.A., 1952, 'A note on the distribution of the palms of South Africa with special reference to *Borassus* in the Transvaal', *South African Journal of Science* 48, 215–220.
- Esterhuysen, N., Von Breitenbach, J. & Sohng, H., 2001, *Remarkable trees of South Africa*, Briza, Pretoria, p. 202.
- Glen, H.F., 2002, *Cultivated plants of southern Africa*, Jacana, Johannesburg, p. 428.
- Hurter, P.J.H., Von Staden, L., Victor, J.E. & Van Wyk, A.E., 2007, *Jubaeopsis caffra* Becc., *National assessment: Red list of South African plants*, version 2017.1, viewed 21 November 2017, from <http://redlist.sanbi.org/species.php?species=3416>
- Hutchinson, J. & Dalziel, J.M., 1936, *Flora of West Tropical Africa*, vol. 2, Crown Agents for the Colonies, London, p. 544.
- Jumelle, H.L. & Perrier de la Bâthie, H., 1913, 'Palmyres de Madagascar', *Annales du Musée Colonial de Marseille sér 3.1*, 1–91.
- Klopper, R.R., Chatelain, C., Bänninger, V., Habashi, C., Steyn, H.M., De Wet, B.C. et al., 2006, *Checklist of the flowering plants of sub-Saharan Africa. An index of accepted names and synonyms*, Southern African Botanical Diversity Network Report No. 42, SABONET, Pretoria, p. 894.
- Martius, C.F.P.von., 1838, *Historia naturalis palmarum*, vol. 3, T.O. Weigel, Leipzig, p. 568.
- Matimele, H.A., Massingue, A.O., Raimondo, D., Bandeira, S., Burrows, J.E., Darbyshire, I. et al., 2016, *Raphia australis*, IUCN Red list of threatened species 2016, viewed 04 October 2018, from <https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T30359A8.5955288.en>
- Miller, D., Killick, D. & Van Der Merwe, N.J., 2001, 'Metal working in the Northern Lowveld, South Africa AD 1000–1890', *Journal of Field Archaeology* 28(3–4), 401–417. <https://doi.org/10.1179/jfa.2001.28.3-4.401>
- Mucina, L. & Rutherford, M.C., 2006, *The vegetation of South Africa, Lesotho and Swaziland*, Strelitzia 19, SANBI, Pretoria, p. 807.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. & Anthony, S., 2009, *Agroforestry Database: A tree reference and selection guide*, version 4.0, viewed 01 March 2018, from <http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp>
- Prinsloo, L.C. & Colomban, P., 2008, 'A Raman spectroscopic study of the Mapungubwe oblates: Glass trade beads excavated at an iron age archaeological site in South Africa', *Journal of Raman Spectroscopy* 39(1), 79–90. <https://doi.org/10.1002/jrs.1816>
- Salako, V.K., Kénou, C., Dainou, K., Assogbadjo, A.E. & Kakai, R.G., 2018a, 'Impacts of land use types on spatial patterns and neighbourhood distance of the agroforestry palm *Borassus aethiopus* Mart. in two climatic regions in Benin, West Africa', *Agroforestry Systems* February, 1–15. <https://doi.org/10.1007/s10457-018-0205-y>
- Salako, V.K., Vihotogbé, R., Houéhanou, T., Sodé, I.A. & Kakai, R.G., 2018b, 'Predicting the potential impact of climate change on the declining agroforestry species *Borassus aethiopus* Mart. in Benin: A mixture of geostatistical and SDM approach', *Agroforestry Systems* June, 1–18. <https://doi.org/10.1007/s10457-018-0262-2>
- Scott, D.W., 2009, 'Sturge's rule', *Wiley Interdisciplinary Reviews: Computational Statistics* 1(3), 303–306. <https://doi.org/10.1002/wics.35>
- Schmidt, E., Lotter, M. & McClelland, W., 2007, *Trees and shrubs of Mpumalanga and the Kruger National Park*, Jacana, Johannesburg, p. 702.
- Siebert, S.J., Struwig, M., Knoetze, L. & Komape, D.M., 2018, '*Celtis sinensis* Pers. (Ulmaceae) naturalised in northern South Africa and keys to distinguish between *Celtis* species commonly cultivated in urban environments', *Bothalia* 48, a2288. <https://doi.org/10.4102/abc.v48i1.2288>
- Siebert, S.J., Zobolo, A.M. & Dowe, J.L., 2010, '*Livistona chinensis*, a first record of a naturalized palm in South Africa', *Bothalia* 40, 55–102.
- Van Wyk, A.E. & Smith, G.F., 2001, *Regions of floristic endemism in southern Africa: A review with emphasis on succulents*, Umdaus Press, Hatfield, p. 199.
- Warburg, O., 1895, 'Die Palmen Ostafrikas und ihre Verwerthung', in H.G.A. Engler (ed.), *Pflanzenwelt Ost-Afrikas und der Nachbargebiete, Theil B, Die Nutzpflanzen Ost-Afrikas*, p. 27, Dietrich Reimer Verlag, Berlin.
- Wicht, H., 1969, *The indigenous palms of southern Africa*, Cape Town, Citadel Press, p. 62.
- Wood, M., 2000, 'Making connections: Relationships between international trade and glass beads from the Shashe-Limpopo area', *Goodwin Series* 8, 78–90.
- Wright, C.H., 1897, 'Palmae', in W.T. Thiselton-Dryer (ed.), *Flora capensis: Being a systematic description of the plants of the Cape colony, Caffraria, & Port Natal (and neighbouring territories)*, vol. 7, pp. 28–30, Haemodoraceae to Liliaceae, Reeves and Co., Kent.
- Zona, S. & Henderson, A., 1989, 'A review of animal-mediated seed dispersal of palms', *Selbyana* 11, 6–21.