

RADIOCARBON INVESTIGATION OF A SUPERLATIVE GRANDIDIER BAOBAB, THE BIG RENIALA OF ISOSA

ROXANA T. PATRUT^{a,b*}, ADRIAN PATRUT^a,
JEAN-MICHEL LEONG POCK-TSY^c, STEPHAN WOODBORNE^d,
LASZLO RAKOSY^b, PASCAL DANTHU^e, ILEANA-ANDREEA RATIU^a,
JENÖ BODIS^a, KARL VON REDEN^f

ABSTRACT. The article discloses the accelerator mass spectrometry (AMS) radiocarbon dating results of the Big Reniala of Isosa, which is a massive Grandidier baobab (*Adansonia grandidieri* Baill.) of Madagascar. The investigation of this baobab shows that it consists of 5 perfectly fused stems and exhibits a cluster structure. The calculated wood volume of the tree is 540 m³, which makes the Big Reniala of Isosa the largest individual of all *Adansonia* species and also the biggest known angiosperm in terms of volume. Several samples were collected from the outer part of the stems. The oldest dated sample had a radiocarbon date of 934 ± 24 BP, which corresponds to a calibrated age of 845 ± 25 years. This value indicates an age of 1000 ± 100 years for the big Reniala of Isosa.

Keywords: AMS radiocarbon dating, *Adansonia grandidieri*, tropical trees, multiple stems.

INTRODUCTION

The *Adansonia* genus, which belongs to the Bombacoideae subfamily of Malvaceae, consists of eight or nine species. One or two species originate from the tropical (semi-)arid savanna of the African continent, six species are endemic to Madagascar and one species can be found only in Australia [1-5].

^a Babeş-Bolyai University, Faculty of Chemistry and Chemical Engineering, 11 Arany Janos, RO-400028, Cluj-Napoca, Romania

^b Babeş-Bolyai University, Faculty of Biology and Geology, 44 Republicii, RO-400015, Cluj-Napoca, Romania

^c DP Forêt et Biodiversité, Antananarivo, Madagascar

^d iThemba LABS, Private Bag 11, WITS 2050, South Africa

^e CIRAD, Unité HortSys, Université de Montpellier, Montpellier, France

^f NOSAMS Facility, Dept. of Geology & Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, U.S.A.

* Corresponding author: roxanapatrut@yahoo.com

In 2005, we started an extensive research program to elucidate several controversial or poorly understood aspects of the architecture, development and age of the African baobab (*Adansonia digitata* L.). The research is based on our novel methodology, which is not limited to demised specimens, but also allows to investigate and date live individuals. This original approach is based on AMS (accelerator mass spectrometry) radiocarbon dating of tiny wood samples collected from inner cavities, deep incisions/entrances in the trunk, fractured stems and from the outer part/exterior of the trunk/stems of large baobabs [6-13]. We found that typically, all large African baobabs are multi-stemmed and preferentially exhibit ring-shaped structures. The oldest African baobabs were found to have ages of over 2,000 years. Thus, the African baobab becomes the longest living angiosperm [9,11,13-15].

In 2013, we extended our research on the *Adansonia* genus by starting to investigate large individuals of the most representative three species of Madagascar, i.e., *Adansonia rubrostipa* Jum. & H. Perrier (Fony baobab), *Adansonia za* Baill. (Za baobab) and *Adansonia grandidieri* Baill. (Grandidier baobab), which grow in the west and south [5,16-19].

The Grandidier baobab, which is called Reniala by natives (in Masikoro, i.e., “Mother of the Forest”), is certainly the biggest and most famous of the six Malagasy *Adansonia* species. *A. grandidieri* is represented by large trees with massive cylindrical trunks and flat-topped crowns with almost horizontal, large branches [1,2,5].

Until 1998, it was believed that the distribution of *A. grandidieri* is restricted to only 5 locations in southwestern Madagascar. Thus, according to the IUCN Red List, *A. grandidieri* was classified as endangered [20]. However, new investigations based on photo-interpretation of very high resolution satellite images, which were subsequently validated by field investigations, showed that *A. grandidieri* is present in a much wider area and its population is much larger than previous estimates. According to this recent study, the total population of *A. grandidieri*, which covers an area of 26,232 km² along the Mangoky river and in the western part of the Menabe region, is around 1.2-1.3 million mature individuals [16,20].

The largest *A. grandidieri* are located in the Morombe area, especially in the so-called Andombiry Forest, which is surrounded by four villages: Belitsaka, Andombiry, Ankoabe and Isosa. In a previous article, we presented the AMS radiocarbon dating results of three famous *A. grandidieri* specimens, namely Tsitakakoike, the Pregnant baobab and the House baobab [18].

Here we disclose the investigation and AMS radiocarbon dating results of another very large specimen, the Big Reniala of Isosa.

RESULTS AND DISCUSSION

The Big Reniala of Isosa and its area. The very large baobab is located in a dry deciduous forest at only 100 m from the Morombe-Toliara road (at km 28.3 from Morombe) and at 1.5 km SW from the village Isosa, in the Morombe district, Atsimo-Andrefana region of southwestern Madagascar. Its GPS coordinates are 21°37.976' N, 043°34.474' E and the altitude is 21 m. Mean annual rainfall in the area is 458 mm (Morombe station).



Figure 1. General view of the Big Reniala of Isosa taken from the east (October 2018).

The baobab has a maximum height of 21.6 m and the circumference at breast height (cbh; at 1.30 m above ground level) is 23.22 m (**Figure 1**). The huge trunk forks at heights between 12.2 and 14.5 m into several large branches with diametres up to 2 m. The columnar trunk is almost cylindrical, having a circumference of 24.20 m at the base and 21 m at the height of 12 m.

According to a careful visual inspection and to the analysis of photographs, the trunk consists of 5 perfectly fused stems. The horizontal dimensions of the very impressive canopy are 45.2 (NS) x 37.2 (WE) m (**Figure 2**).

The calculated overall wood volume of the tree is 540 m³, out of which 485 m³ belongs to the trunk and 55 m³ to the canopy. By this value, the Big Reniala of Isosa becomes not only the largest *Adansonia grandidieri* in terms of volume (larger than the famous Tsitakakoike and Tsitakakantsa from the same forest), but also the largest individual of all *Adansonia* species and the largest known angiosperm.

The baobab of Isosa flushes leaves only in December, two months later than the other Grandidier baobabs of the area. It does no longer produce pods, which suggests an old age for all stems.



Figure 2. The image shows the impressive canopy of the baobab of Isosa (April 2019).

Wood samples. Several wood samples were extracted from 3 stems, by using two increment borers of different lengths (0.90 and 1.50m). Three samples (labelled 1, 2 and 3) were considered to be sufficiently long, namely 0.844, 0.785 and 1.117 m, for investigation. These samples were collected at convenient heights, between 1.38 and 1.52 m. A number of three tiny pieces/segments, each of the length of 10⁻³ m (marked as a, b, c), were extracted from determined positions of each sample.

AMS results and calibrated ages. Radiocarbon dates of the 9 sample segments are listed in Table 1. The radiocarbon dates are expressed in ¹⁴C yr BP (radiocarbon years before present, i.e., before the reference year 1950). Radiocarbon dates and errors were rounded to the nearest year.

Calibrated (cal) ages, expressed in calendar years CE (CE, i.e., common era), are also shown in Table 1. The 1-σ probability distribution (68.2%) was selected to derive calibrated age ranges. For one sample segment (2a), the 1-σ distribution is consistent with one range of calendar years. For the other eight segments, the 1-σ distribution is consistent with two or three ranges of calendar years. In these cases, the confidence interval of one range is considerably greater than that of the other(s); therefore, it was selected as the cal CE range of the segment for the purpose of this discussion. For obtaining single calendar age values of sample segments, we derived a mean calendar age of each segment from the selected range (marked in bold). Sample/segment ages represent the difference between the year 2019 CE and the mean value of the selected range, with the corresponding error. Sample ages and errors were rounded to the nearest 5 yr. This approach was used for selecting calibrated age ranges and single values for sample ages in all our previous articles on AMS radiocarbon dating of large and old angiosperm trees, especially of baobabs [6-15,17-19].

Table 1. AMS Radiocarbon dating results and calibrated calendar ages of samples/segments collected from the Big Reniala of Isosa.

Sample (Segment)	Depth ¹ [height ²] (10 ⁻² m)	Radiocarbon date [error] (¹⁴ C yr BP)	Cal CE range 1-σ [confidence interval]	Sample age [error] (cal yr CE)
1a	30 [138]	254 [± 19]	1650-1670 [41.8%] 1748-1754 [7.8%] 1783-1795 [18.6%]	360 [± 10]
1b	55 [138]	420 [± 20]	1458-1497 [63.6%] 1602-1606 [4.6%]	540 [± 20]
1c	84 [138]	629 [± 16]	1324-1342 [44.1%] 1390-1398 [24.1%]	685 [± 10]
2a	30 [143]	270 [± 18]	1644-1667 [68.2%]	365 [± 10]
2b	55 [143]	410 [± 17]	1461-1500 [52.9%] 1598-1610 [15.3%]	540 [± 20]
2c	78 [143]	618 [± 18]	1326-1341 [28.9%] 1390-1404 [39.3%]	620 [± 10]
3a	40 [152]	339 [± 21]	1510-1575 [54.7%] 1622-1636 [13.5%]	475 [± 30]
3b	75 [152]	604 [± 22]	1328-1338 [11.6%] 1390-1414 [56.6%]	620 [± 10]
3c	114 [152]	934 [± 24]	1070-1076 [4.6%] 1148-1203 [63.6%]	845 [± 25]

¹ Depth in the wood from the sampling point.

² Height above ground level.

Dating results of samples (segments). The oldest segments of the two samples collected with the shorter increment borer, namely 1c and 2c, which represent sample ends both, exhibit close ages. Their radiocarbon dates of 629 ± 16 BP and 618 ± 18 BP correspond to calibrated ages of 685 ± 10 and 620 ± 10 calendar yr. The oldest segment of the sample collected with the longer increment borer, i.e. 3c, which is also the sample end, has a radiocarbon date of 934 ± 24 BP. This value corresponds to a calibrated age of 845 ± 25 calendar yr. The lower ages of the other segments extracted from the three samples are in accordance with their positions in the stems.

Architecture of the baobab of Isosa. Our long-term research has revealed that large African baobabs are always multi-stemmed [9,13]. This statement is also valid for the large Malagasy baobabs, including the Grandidier baobabs [18]. As mentioned, the Big Reniala of Isosa consists of 5 perfectly fused stems.

Our research has also identified a new type of architecture that enables African baobabs to reach old ages and large sizes. In this novel architecture, the multiple stems define at ground level a circle or an ellipse, with an empty space between them; we named it ring-shaped structure (RSS). The most frequent is the closed RSS, in which the fused stems are disposed in a ring with a natural empty space inside, that we termed false cavity. For baobabs with a closed RSS, the age sequence of long samples collected from the false cavity walls toward the exterior of the trunk, as well as of samples collected from the exterior toward the false cavity, shows a continuous increase from the sampling point up to a certain distance into the wood, after which it decreases toward the opposite part [9,12]. The large Grandidier baobabs that we have previously dated have/had such a closed RSS [13].

In the case of the Big Reniala of Isosa, the age sequence of the samples, which were collected from the exterior of 3 different stems, shows a continuous increase with the depth in the wood, see Table 1. This fact demonstrates that the multi-stemmed Grandidier baobab of Isosa exhibit a cluster structure.

Age of the Big Reniala of Isosa. The age sequences of the samples collected from 3 different stems demonstrate that these stems and probably all 5 stems of the baobab belong to the same generation and have comparable ages. The age of the baobab can be estimated by extrapolating the age of the oldest dated sample segment, i.e., 3c, to the presumptive pith of the corresponding stem. Sample segment 3c, which has an age of 845 ± 25 yr, originates from a depth of 1.13 m in the wood. The corresponding stem has a diameter of around 3.50 m. Consequently, the presumptive pith is located at a distance of 1.75 m from the sampling point. In a conservative estimate, the age of the Big Reniala of Isosa is of 1000 ± 100 years.

CONCLUSIONS

The research presents the AMS radiocarbon investigation results of a very large Grandidier baobab, namely the Big Reniala of Isosa, Madagascar. The baobab consists of 5 fused stems and has a cluster structure. The wood volume of the Grandidier baobab of Isosa is 540 m^3 , which makes it the largest individual of all baobab species and also the biggest known angiosperm in terms of volume. Several wood samples were collected from the outer part of different stems. The oldest dated sample has a radiocarbon date of $934 \pm 24 \text{ BP}$, which corresponds to a calibrated age of $845 \pm 25 \text{ years}$. This value indicates that the Big Reniala of Isosa is $1000 \pm 100 \text{ years}$ old. It can be stated that the impressive baobab of Isosa started growing around the year 1000 CE.

EXPERIMENTAL SECTION

Sample collection. Samples 1 and 2 were collected with a Hagl f CH 900 increment borer (0.90 m long, 0.0108 m inner diameter). Sample 3 was collected with a modified Hagl f increment borer (1.50 m long, 0.0108 m inner diameter). A number of three tiny pieces/segments, of the length of 10^{-3} m , were extracted from predetermined positions along each wood sample. The segments were processed and investigated by AMS radiocarbon dating.

Sample preparation. The modified α -cellulose pretreatment method was employed for removing soluble and mobile organic components [21]. The resulting samples were combusted to CO_2 , which was next reduced to graphite on iron catalyst [22,23]. The resulting graphite samples were analysed by AMS.

AMS measurements. The AMS radiocarbon measurements of samples 1 and 2 were performed at the NOSAMS Facility of the Woods Hole Oceanographic Institution (Woods Hole, MA, U.S.A.) by using the Pelletron   Tandem 500 kV AMS system [24]. The measurements of sample 3 were done at the AMS Facility of iThemba LABS, Johannesburg, Gauteng, South Africa, using the 6 MV Tandem AMS system [25]. In all cases, the obtained fraction modern values were finally converted to a radiocarbon date. The radiocarbon dates and errors were rounded to the nearest year.

Calibration. Radiocarbon dates were calibrated and converted into calendar ages with the OxCal v4.3 for Windows [26], by using the SHCal13 atmospheric data set [27].

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