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RADIOCARBON DATING OF THE VERY LARGE EGG BAOBAB FROM THE ANDOMBIRY FOREST, MADAGASCAR

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ABSTRACT. The article discloses the AMS (accelerator mass spectrometry) radiocarbon dating results of the Egg baobab, a superlative Grandidier baobab (*Adansonia grandidieri*) from the Andomiry Forest, Atsimo-Andrefana region, Madagascar. The investigation of the baobab shows that it consists of 5 perfectly fused stems and exhibits a closed ring-shaped structure with a very large false cavity inside. The calculated overall wood volume of the Egg baobab is 450 m^3. Two wood samples were collected from the exterior of the stems, out of which nine tiny segments were extracted and dated by radiocarbon. The oldest sample segment had a radiocarbon date of 921 ± 24 BP, which corresponds to a calibrated age of 840 ± 25 years. According to this value the Egg baobab is 875 ± 75 years old.

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

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INTRODUCTION

The *Adansonia* genus, which belongs to the Bombacoideae subfamily of Malvaceae, is represented by eight or nine species. One or two species are endemic to the tropical arid savanna of the African continent, six species have a natural distribution in Madagascar, while one species is found in Australia [1-5].

In 2005, we started a research project in order to elucidate several controversial aspects concerning the architecture, growth and age of the African baobab (*Adansonia digitata* L.). The research is based on an original approach, which is not limited to demised or fallen trees, but also allows to investigate live and standing individuals. This methodology consists on AMS radiocarbon dating of tiny wood samples extracted from inner cavities, incisions/entrances in the trunk, fractured stems and from the exterior of the trunk/stems of large baobabs [6-19]. We found that all very large African baobabs are multi-stemmed and most of them exhibit ring-shaped structures. The oldest individuals can live over 2,000 years [9, 10].

In 2013, we extended our research to the most emblematic three species of Madagascar, i.e., the fony (*Adansonia rubrostipa* Jum. & H. Perrier), the za (*Adansonia za* Baill.) and the Grandidier baobab (*Adansonia grandidieri* Baill.) [22-27].

The Grandidier baobab, named Reniala by natives (in Masikoro, i.e., “Mother of the Forest”), is the largest and most famous of the six Malagasy species. According to the classical description, *A. grandidieri* is represented by big trees with massive cylindrical trunks and flat-topped crowns with almost horizontal large branches [1,2,4]. However, the shape and dimensions of mature and old individuals exhibit considerable variation and the differences depend especially on their location.

According to the latest research, the total population of *A. grandidieri*, spreading over an area of 26,232 km^2 along the Mangoky river and in the western part of the Menabe region, amounts to 1.2-1.3 million mature individuals [20, 21].

The largest *A. grandidieri* can be found in the Morombe area and in particular in the so-called Andombiry Forest. The forest has a trapezoidal shape and is bounded by four villages: Belitsaka, Andombiry, Ankoabe and Isosa. In previous articles, we presented the investigation and radiocarbon dating results of several monumental *A. grandidieri* specimens, namely Tsitakakoike, the Pregnant baobab, the House baobab [22], the Big Reniala of Isosa [23], the Giant of Bevoay [24], the baobab A 257 and the baobab A 215 [25].

Here we present the investigation and AMS radiocarbon dating results of another superlative specimen, the so-called Egg baobab.

RESULTS AND DISCUSSION

The Egg baobab and its area. The very large tree that we named the Egg baobab (le baobab oeuf), due to its shape that resembles a flat-bottomed egg, is located in the dry deciduous Andombiry Forest, in the Morombe district, Atsimo-Andrefana region of southwestern Madagascar.

The Egg baobab can be found on the side of a dirt road between the villages of Isosa and Andombiry. Its GPS coordinates are 21º35.138' S, 043º30.525' E and the altitude is 18 m. The mean annual rainfall is 458 mm (Morombe station). The tree has a maximum height of 17.5 m, the circumference is 25.02 m at breast height (cbh; at 1.30 m above ground level), reaching a

Figure 1. General view of the Egg baobab taken from the north.

Figure 2. Another view of the Egg baobab taken from the west.

maximum value of 29.20 m at the height of 4.2 m (**Figures 1 and 2**). It has an overall wood volume of 450 m^3, out of which 400 m^3 belongs to the trunk and 50 m^3 to the canopy.

The Egg baobab has the third largest circumference at breast height of all live Grandidier baobabs, after Tsitakakantsa (29.05 m), which is located at 1.2 km and the A 257 baobab (25.70 m), located at only 0.3 km. But, the Egg baobab has the greatest maximum circumference of all *A. grandidieri* individuals. Its shape is similar to that of the famous Pregnant baobab (le baobab enceinte), located at a distance of 1.5 km, which we presented previously [22] and which is currently in a state of decline.

Five large primary branches, with diametres up to 2.5 m, emerge quasi-horizontally from the trunk, at heights of 7.2 – 9.0 m. Other branches emerge somewhat vertically from the top of the trunk, which is 10.5 m tall.

The horizontal dimensions of the canopy are 33.5 (WE) x 26.2 m (NS) (**Figure 3**). According to the on-site visual inspection and to the digital photograph analysis, the trunk consists of 5 perfectly fused stems (**Figure 4**). Due to its old age, the Egg baobab no longer produces pods.

Figure 3. The image shows the impressive canopy of the Egg baobab.

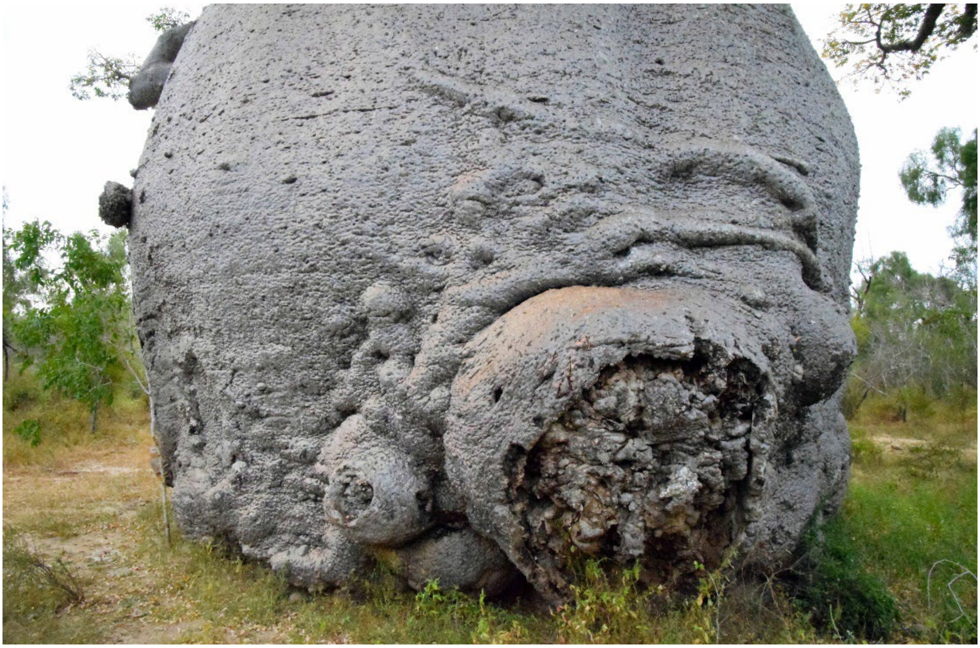

Figure 4. The trunk is covered by burls and traces of wounds.

Wood samples. Two wood samples were collected from two different stems using an increment borer. The longest sample, labelled Eb-1, with the length of 0.86 m, was collected from the exterior of a stem facing north, at the height of 1.60 m. A number of six tiny segments, each 10^{-3} m long (marked a to f), were extracted from determined positions of sample Eb-1. Another sample, labelled Eb-2, with the length of 0.62 m, was collected from an opposite stem facing south, at the height of 1.61 m. Three tiny segments (marked a to c) were extracted from this sample.

AMS results and calibrated ages. Radiocarbon dates of the nine sample segments are presented in Table 1. The radiocarbon dates are expressed in ^{14}C 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 listed in Table 1. The 1σ probability distribution (68.3%) was selected to derive calibrated age ranges. For one sample segment (1e), the 1σ distribution is consistent with one range of calendar years. For four segments

Table 1. AMS Radiocarbon dating results and calibrated ages of samples collected from the Egg baobab

Sample/ segment code	**Depth[1] [height[2]] (m)**	**Radiocarbon date [error] (^{14}C yr BP)**	**Cal CE range 1σ [confidence interval]**	**Assigned year [error] (cal CE)**	**Sample age [error] (cal CE)**
Eb-1a	0.10 [1.60]	-	-	-	>Modern
Eb-1b	0.25 [1.60]	209 [± 22]	1670-1687 [14.2%] **1731-1782 [45.5%]** 1796-1806 [8.6%]	1756 [± 25]	265 [± 25]
Eb-1c	0.40 [1.60]	360 [± 24]	1506-1519 [9.3%] **1524-1591 [51.7%]** 1618-1628 [5.0%]	1557 [± 35]	465 [± 35]
Eb-1d	0.60 [1.60]	694 [± 26]	1297-1320 [29.7%] **1354-1386 [38.5%]**	1370 [± 15]	655 [± 15]
Eb-1e	0.75 [1.60]	921 [± 24]	**1156-1211 [68.3%]**	1183 [± 25]	840 [± 25]
Eb-1f	0.86 [1.60]	700 [± 25]	1295-1318 [30.8%] **1355-1385 [37.5%]**	1370 [± 15]	655 [± 15]
Eb-2a	0.20 [1.61]	129 [± 21]	1710-1719 [6.5%] 1813-1836 [18.7%] 1855-1866 [7.0%] **1881-1925 [36.1%]**	1903 [± 20]	120 [± 20]
Eb-2b	0.40 [1.61]	348 [± 24]	**1510-1583 [61.2%]** 1623-1631 [7.0%]	1545 [± 35]	480 [± 35]
Eb-2c	0.62 [1.61]	660 [± 23]	**1316-1358 [53.7%]** 1383-1394 [14.6%]	1337 [± 20]	685 [± 20]

[1] Depth in the wood from the sampling point.
[2] Height above ground level.

(1d, 1f, 2b, 2c), the 1σ distribution corresponds to two ranges of calendar years, while for two segments (1b, 1c) it is consistent with three ranges and for another segment (2a) with four ranges. 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).

For obtaining single calendar age values of sample segments, we derived a mean calendar age of each sample segment, called assigned year, from the selected range (marked in bold). Sample/segment ages represent the difference between the current year 2023 CE and the assigned year, with the corresponding error. Sample ages and errors were rounded to the nearest 5 yr.

For one sample segment (1a), the age falls after the year 1950 CE, i.e. the ^{14}C activity, expressed by the ratio $^{14}C/^{12}C$, is greater than the standard activity in the reference year 1950. Such values, which correspond to negative radiocarbon dates, are termed greater than Modern (>Modern). In such cases, the dated wood is young, being formed after 1950 CE.

We used this approach 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 [6-19, 22-27].

Dating results of sample segments. The circumference of the Egg baobab at the sampling height is 25.71 m, which translates to a diametre of 8.18 m and a radius of 4.09 m. This value also represents the distance from the exterior of both sampled stems to their theoretical pith.

For the segments extracted from the longest sample Eb-1 which was collected from the exterior, the age values of the dated segments increase with the depth in the wood from Eb-1a to Eb-1e, after which the ages decrease to Eb-1f. The oldest dated sample, i.e., Eb-1e, has a radiocarbon date of 921 ± 24 BP, which translates to a calibrated age of 840 ± 25 calendar yr.

This anomalous age sequence is characteristic to baobabs that exhibit a closed ring-shaped structure with a false cavity inside. In this architecture, for wood samples collected from the exterior of the trunk, as well as for samples collected from the inner cavity walls (if the false cavity has an accessible opening), the age sequence increases from the sampling point up to a point of maximum age, after which it decreases in the opposite direction [11, 14]. For sample Eb-1, segment ages show that the point of maximum age is located between the segments Eb-1d and Eb-1f, i.e., between 0.60 and 0.86 m from the sampling point, closer to segment Eb-1e, i.e. 0.75 m. Therefore, the maximum age in the direction of sample Eb-1 is around 875 ± 75 calendar yr. The walls of the false cavity, which is defined by 5 fused stems and is completely closed toward the exterior, have a depth of 0.70-0.80 m.

In the case of the shorter sample Eb-2, ages of all dated sample segments increase with the depth in the wood, thus showing that the point of maximum age was not reached.

Architecture of the Egg baobab. Our research has revealed that all large baobabs, including the *A. grandidieri* specimens, are multi-stemmed. We also found that superlative baobabs exhibit preferentially a novel architecture, in which the multiple stems define at ground level a circle or an ellipse, with an empty space between them. We called 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 named false cavity. In the case of baobabs with a closed RSS, for long samples collected from the exterior toward the false cavity, as well as for samples collected from the false cavity walls toward the exterior of the trunk segment ages show a continuous increase from the sampling point up to a certain distance into the wood, after which they decrease toward the opposite part [9,11].

The segments which originate from sample Eb-1 show such an anomalous age sequence, which demonstrates that the Egg baobab possesses a closed RSS with a false cavity inside. The dating values also suggest that, at the height of 1.60 m, the diametre of the false cavity is around 6.70 m.

Age of the Egg baobab. The dating results of segments extracted from sample Eb-1 indicate that the age of the respective stem, which corresponds to the area (point) of maximum age, is 875 ± 75 calendar yr, i.e., 800 – 950 yr. The Egg baobab consists of five perfectly fused stems and its shape is highly symmetrical. This indicates that the ages of the five stems are identical. One can state that the stems of the Egg baobab started growing quasi-simultaneously around the year 1150 CE.

CONCLUSIONS

The research discloses the AMS radiocarbon dating results of a superlative Grandidier baobab, namely the Egg baobab from the Andombiry Forest, Morombe district, Atsimo-Andrefana region, Madagascar. The Egg baobab is composed of 5 perfectly fused stems and has a closed ring-shaped structure with a very large false cavity inside. Two wood samples were collected from the outer part of the trunk. The oldest dated sample has a radiocarbon date of 921 ± 24 BP, corresponding to a calibrated age of 840 ± 25 years. This value indicates that the Egg baobab is 875 ± 75 years old.

EXPERIMENTAL SECTION

Sample collection. The two investigated wood samples were collected with a Haglöf CH 900 increment borer (0.90 m long, 0.0108 m inner diametre). A number of nine tiny segments of the length of 10^{-3} m were extracted from predetermined positions along the samples. The segments were processed and investigated by AMS radiocarbon dating.

Sample preparation. The α-cellulose pretreatment method was used for removing soluble and mobile organic components [28]. The resulting samples were combusted to CO_2, which was next reduced to graphite on iron catalyst [29,30]. The resulting graphite samples were analysed by AMS.

AMS measurements. The radiocarbon measurements were performed at the AMS Facility of the iThemba LABS, Johannesburg, Gauteng, South Africa, using the 6 MV Tandem AMS system [31]. 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 v4.4 for Windows [32], by using the SHCal20 atmospheric data set [33].

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