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RADIOCARBON DATING OF THE HISTORIC GRAND BAOBAB OF MAHAJANGA, MADAGASCAR

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ABSTRACT. The article reports the AMS (accelerator mass spectrometry) radiocarbon investigation of the historic Grand Baobab of Mahajanga. The largest African baobab of Madagascar exhibits a cluster structure, which consists of 6 fused ordinary stems and of 3 small binding stems. Two samples were collected from the largest stem and from a primary branch, out of which several tiny segments were extracted and dated by radiocarbon. The oldest dated sample segment had a radiocarbon date of 214 ± 17 BP, which corresponds to a calibrated age of 265 ± 25 calendar years. The dating results indicate that the Grand Baobab of Mahajanga is 275 ± 25 years old.

Keywords: *AMS radiocarbon dating, Adansonia digitata, dendrochronology, Madagascar, age determination, multiple stems.*

INTRODUCTION

The *Adansonia* genus, which belongs to the Bombacoideae, a subfamily of Malvaceae, consists of eight generally recognised species. One species originates from mainland Africa, six are endemic to Madagascar, while another

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grows only in northern Australia. The African baobab (*Adansonia digitata* L.) is certainly the best-known and widespread among these species. It is endemic to the arid savanna of mainland Africa between the latitudes 16º N and 26º S. The African baobab can also be found on several African islands and outside Africa, in different areas throughout the tropics, where it has been introduced [1-5].

In 2005, we started a complex research project for elucidating several controversial aspects related to the architecture, growth and age of the African baobab. This research relies on AMS radiocarbon dating of tiny wood samples extracted from different areas of big baobabs [6-14]. According to the obtained results, all superlative, i.e., very large and/or old baobabs, are practically multi-stemmed and exhibit preferentially closed or open ring-shaped structures. The oldest specimens were found to reach ages up to 2,500 years [11].

Since 2013 our investigations also include superlative individuals of the three best-known species of Madagascar, i.e., *Adansonia za* Baill. (Za baobab), *Adansonia rubrostipa* Jum. & H. Perrier (Fony baobab) and *Adansonia grandidieri* Baill (Grandidier baobab) [15-20]; each species is represented by over one million individuals. On the northwestern coast of Madagascar, between Diego Suarez and Mahajanga, there are located several thousand African baobabs. One specimen, namely the baobab of Mahajanga, is famous for its very large dimensions [21].

Here we present the investigation and AMS radiocarbon dating results of the historic African baobab of Mahajanga.

RESULTS AND DISCUSSION

The Grand Baobab of Mahajanga and its area. Mahajanga (formerly French Majunga) is a city, an administrative district and important seaport on the northwestern coast of Madagascar. It has a population of 250,000 inhabitants and is the capital city of the Boeny region. Mahajanga has a tropical savanna climate with two distinct seasons, a rainy wet season (from November to mid-April) and a sunny dry season (from mid-April to October). Cyclons can occur during the wet season and may produce considerable damage. The mean annual temperature is 26.3°C and the mean annual rainfall is 1476 mm.

The Grand Baobab of Mahajanga (in French, “le gros baobab de Majunga”) grows on the coast, at around 100 m from the sea. Today, the big baobab is protected by a fence in the centre of a large traffic roundabout, where two waterfront boulevards meet the main boulevard “Avenue of France”. The lower trunk is painted to protect against pests and the surroundings of the tree are concreted.

The historic baobab is the symbol of the whole city, with people usually sitting under it. It also appears on the emblem of Mahajanga.

In earlier times, the baobab was used as a place for announcing news to the community and also as a meeting place. In the 19th century, the baobab marked the site for public executions. According to tradition, every traveler must walk around the baobab seven times to receive the blessing of the Malagasy ancestors.

Two decades ago, the baobab was hit by a truck and several branches had to be cut. There have been many speculations about the age of the baobab. Usually, it is considered to be between 700 and 1500 years old.

The first photo of the "gros baobab" dates back to 1898, during the French administration (**Figure 1**). According to official measurements, the tree had then a circumference of 14.60 m at a height of 0.70 m above ground.

The GPS coordinates are 15º43.294' S, 046º18.300' E and the altitude is 8 m. In 2013, the big baobab had a height of 15.6 m, the circumference at breast height (cbh; at 1.30 m above mean ground level) was 21.21 m and the overall wood volume of around 180 m^3 (**Figures 2 and 3**). The circumference at 0.70 m was 22.72 m. In 2018, the circumference cbh was only 2 cm larger, reaching 21.23 m. The horizontal dimensions of the large canopy, which has several large branches, are 26.6 (NS) x 31.5 (WE) m.

The impressive trunk exhibits a cluster structure, which consists of 6 fused ordinary/common stems, out of which two are very large, and a further 3 smaller binding stems.

At present, the Grand Baobab is in a general state of decline, with several broken and damaged branches. It almost stopped growing during the last decades. The pavement and the intense traffic around the tree probably play an important role in this process.

Wood samples. Two wood samples were collected from the baobab with an increment borer. One sample, labelled MJ-1, with the length of 0.30 m, was collected from the exterior of a large stem, at the height of 1.90 m. A number of two tiny pieces/segments, each 10^{-3} m long (marked a and b), were extracted from determined positions of sample MJ-1. Another sample, labelled MJ-2, with the length of 0.34 m, was collected from a large primary branch, at the height of 2.20 m. Two segments (marked a and b) were extracted from this sample.

Figure 1. The first photograph of the baobab of Mahajanga taken in 1898.

Figure 2. General view of the Grand Baobab of Mahajanga.

Figure 3. The image shows the large trunk of the Grand Baobab surrounded by a fence.

AMS results and calibrated ages. Radiocarbon dates of the four sample segments are listed 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 displayed in Table 1. The 1σ probability distribution (68.3%) was selected to derive calibrated age ranges. For two segments (MJ-1b, MJ-2b), the 1σ distribution is consistent with three ranges of calendar years, while for one sample segment (MJ-2a) it corresponds to four ranges. In all these cases, the confidence interval of one range is considerably greater than that of the others; therefore, it was selected as the cal CE range of the segment for the purpose of this discussion.

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

Sample 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)**
MJ-1a	0.15 [1.90]	-	-	-	>Modern
MJ-1b	0.30 [1.90]	123 [± 16]	1712-1718 [4.3%] 1813-1835 [20.6%] **1885-1925 [43.3%]**	1905 [± 20]	120 [± 20]
MJ-2a	0.20 [2.20]	158 [± 18]	1695-1711 [12.3%] 1719-1726 [5.0%] **1836-1883 [22.8%]** 1925-... [18.1%]	1869 [± 24]	155 [± 25]
MJ-2b	0.34 [2.20]	214 [± 17]	1672-1680 [9.1%] **1733-1782 [52.8%]** 1797-1803 [6.3%]	1757 [± 24]	265 [± 25]

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

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 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 (MJ-1a), the age falls after the year 1950 CE, namely 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.

This approach for selecting calibrated age ranges and single values for sample ages was used in all our previous articles on AMS radiocarbon dating of large and old angiosperm trees [6-20, 22-26].

Dating results of sample segments. The sample MJ-1, with a length of only 0.30 m, was collected from a large stem. The diameter in the sampling direction is about 3.10 m, corresponding to radius of 1.55 m, which is also the distance to the theoretical pith of this stem. As mentioned, the wood of segment MJ-1a which originates from a depth of only 0.15 m, was formed after the year 1950. The segment MJ-1b, from a depth of 0.30 m, had a radiocarbon date of 123 ± 16 BP, which corresponds to a calibrated age of 120 ± 20 calendar yr. The sample MJ-1 was too short to provide significant information about the true age of the baobab. We also collected two samples from another stem, which were even shorter. This demonstrates that the stems have large hollow parts, very probably due to the state of decline of the baobab.

The sample MJ-2, with a length of 0.34 m, was extracted from a primary branch. The branch diameter in the sampling direction is 0.72 m. The segment MJ-2a, from a depth of 0.15 m, had a radiocarbon date of 158 ± 18 BP, which corresponds to a calibrated age of 155 ± 25 calendar yr. The segment MJ-2b from a depth of 0.34 m, which is also the sample end, had a radiocarbon date of 214 ± 17 BP corresponding to a calibrated age of 265 ± 25 calendar yr.

Age of the Grand Baobab of Mahajanga. The age of the baobab can be determined by extrapolating the age of the oldest dated segment, i.e., MJ-2b, to the calculated centre of the branch from which it originates. The sample segment MJ-2b, with an age of 265 ± 25 yr, was extracted from a distance of 0.34 m from the sampling point. The calculated centre of the branch is located at 0.36 m from the sampling point. These values indicate that the Big Baobab of Mahajanga is up to 300 yr old; more precisely, its age is of 275 ± 25 years.

This age value is in good agreement with the circumference measurements made over time, namely 14.60 m (at a height of 0.70 m) in 1898, 20.60 m (at 1.50 m) in 1979, 20.70 m (at 1.50 m) in 2011, 21.21 m (at 1.30 m) in 2013 and 21.23 m (at 1.30 m) in 2018. The mentioned values show that the Grand Baobab grew very fast when it was young, due to the sandy soil on limestone rock and also to the very high annual rainfall. The values also show that the Grand Baobab almost stopped growing at least over the last four decades and is probably close to the end of its life cycle.

We should mention that, at a distance of around 200 m, in a yard behind the MCB bank, grows another very large African baobab (GPS coordinates 15º43.292' S, 046º18.672' E). It also has a cluster structure and is composed of 10 fused stems (**Figure 4**). This baobab has a height of 18.1 m and a circumference cbh of 20.05 m.

Figure 4. The photograph shows the second largest baobab of Mahajanga.

CONCLUSIONS

The research presents the AMS radiocarbon investigation results of the historic Grand Baobab of Mahajanga, Madagascar. The baobab has a cluster structure and consists of 6 fused ordinary stems and 3 smaller binding stems. Two wood samples were collected from a large stem and from a primary branch, which were dated by radiocarbon. The oldest dated sample segment had a radiocarbon date of of 214 ± 17 BP, which corresponds to a calibrated age of 265 ± 25 calendar years. The dating results indicate that the Grand Baobab of Mahajanga is 275 ± 25 years old. It can be stated that the historic baobab of Mahajanga started growing around the year 1750 CE.

The baobab of Mahajanga is in a state of decline and measures should be taken to avoid further degradation of the tree.

EXPERIMENTAL SECTION

Sample collection. The wood samples were collected with a Haglöf CH 800 increment borer (0.80 m long, 0.0054 m inner diameter). A number of four segments of the length of 10^{-3} m were extracted from predetermined positions along the wood samples. The segments were processed and investigated by AMS radiocarbon dating.

Sample preparation. The acid-base-acid pretreatment method was used for removing soluble and mobile organic components [27]. The pretreated samples were combusted to CO_2 by using the closed tube combustion method [28]. Next, CO_2 was reduced to graphite on iron catalyst [29]. Eventually, the resulting graphite samples were investigated by AMS.

AMS measurements. AMS radiocarbon measurements 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. The obtained fraction modern values, corrected for isotope fractionation with the normalized $\delta^{13}C$ value of -25 $^{0}/_{00}$, were converted to a radiocarbon date.

Calibration. Radiocarbon dates were calibrated and converted into calendar ages with the OxCal v4.4 for Windows [30], by using the SHCal20 atmospheric data set [31].

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