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RADIOCARBON INVESTIGATION OF THE SOLITARY AFRICAN BAOBAB FROM DALKUT, DHOFAR, OMAN

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ABSTRACT. The article discloses the AMS (accelerator mass spectrometry) radiocarbon dating results of the well-known African baobab of Dalkut, Dhofar Governorate, Oman. The investigation shows that the baobab has a cluster structure and is composed of 3 perfectly fused stems. Three wood samples were collected from primary branches and one sample was collected from the exterior of a stem. Eight tiny segments were extracted from the samples and dated by radiocarbon. The oldest dated sample segment, which originates from a primary branch of the southern stem, had a radiocarbon date of 590 ± 18 BP, which corresponds to a calibrated age of 685 ± 15 years. This result indicates that the southern stem of the baobab of Dalkut is 800 ± 30 years old. According to other radiocarbon dating results, the two northern stems are younger and emerged from the southern stem around 550 years ago. The tree of Dalkut is a solitary baobab. The nearest baobab is over 150 km away, to the north.

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

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INTRODUCTION

The *Adansonia* genus, a subdivision of the Bombacoideae subfamily of Malvaceae, consists of eight generally recognised species. One species originates from mainland Africa, six species are endemic to Madagascar, while one species grows only in northern Australia. The African baobab (*Adansonia digitata* L.) is the best-known and most widespread of these species. Although 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 comprehensive research project aimed to clarify several controversial and poorly understood aspects related to the architecture, growth, and age of the African baobab. Our research relies on AMS radiocarbon dating of very small wood samples extracted especially from inner cavities, deep incisions in the stems, fractured stems or from the exterior of large baobabs. This methodology allows to investigate and date not only demised or fallen specimens, but also live and standing individuals [6-19].

According to our research, all superlative, i.e., large and/or old baobabs, are multi-stemmed and exhibit preferentially closed or open ring-shaped structures. The largest and oldest individuals may have wood volumes up to 300-500 m^3 and may reach ages up to 2,500 years [8, 9].

Since 2013 we extended our research on superlative individuals of the three best-known species of Madagascar, namely the fony (*Adansonia rubrostipa* Jum. & H. Perrier), the za (*Adansonia za* Baill.) and the Grandidier baobab (*Adansonia grandidieri* Baill.) [20-27].

The Sultanate of Oman has an interesting and unexpected African baobab population. With one exception, all specimens are located in southern Oman, in the Dhofar Governorate (region). Certain researchers consider these baobabs a botanical reminder of Dhofar's links with Africa.

The largest number of trees can be found in the wilayat (province) of Mirbat, in the so-called Baobab Forest of Wadi Hinna. Wadi Hinna is a small semi-arid valley (3 km^2) at the edge of the Dhofar Mountains (17º03' N, 54º36' E, altitude 300-360 m) and at 20 km from the coastal plain. The precipitation (annual rainfall 130 mm) falls almost exclusively during the rainy season (mid-June to mid-September), in which moist air from the Indian Ocean, i.e., the southwest monsoon (called khareef), encounters the mountains leading to clouds and dense fog [28]. The 106 trees of the Baobab Forest grow on a slope among huge stones of sedimentary rocks. In recent years, Wadi Hinna was divided into two parts, located at lower and higher altitudes, namely Wadi Hinna (with 73 baobabs) and Wadi Hasheer (with 33 baobabs), according to the stratigraphic origin and composition. Other 3 baobabs can be found lower than Wadi Hinna, just above the Salalah Plain (altitude 90 m), in Wadi Al Ghazir.

A well-known baobab grows completely isolated in the town and wilayat of Dalkut, close to the border with Yemen.

Finally, there is a single baobab in the extreme north, close to Al Zahaimi, in the wilayat of Sohar in the Al Batinah North Governorate.

Here we present the investigation and AMS radiocarbon dating results of the baobab of Dalkut.

RESULTS AND DISCUSSION

The baobab of Dalkut. As mentioned, Dalkut (also written Dhalkut, Dalqut, Dhalqut or Dhalkout) is a fishing town and also a wilayat in the Dhofar Governorate of Oman. The town of Dalkut is located below the Al Qamar Mountains and can be reached by descending the highway towards Dalkut Beach. Dalkut is positioned on the western side of Salalah, the capital of Dhofar, at 154 km (via the hairpin bend road) and 102 km (flight distance). The border with Yemen is at only 15 km (flight distance) toward west.

The annual rainfall in Dalkut is only 110 mm. The rain falls especially during the khareef season, when there is lot of fog and low visibility.

A main tourist attraction in Dalkut is the solitary baobab called by the locals “Hiroum Dheeri” (in Arabic, “The Tree from Very Far Away”), hinting at its allochthonous nature. The nearest baobab is in Wadi Hinna, over 150 km away.

The GPS coordinates of the baobab of Dalkut are 16º42.498’ N, 053º15.588’ E and the altitude is 67 m. It has a maximum height (h) of 13.5 m, the circumference at breast height (cbh; at 1.30 m above ground level) is 13.43 m and the total wood volume (V) is 60 m^3. Its height decreased to only 7.4 m after the tallest branch broke during the period of 2018-2019. The baobab is composed of 3 perfectly fused stems and has a cluster structure. The tri-stemmed trunk consists of two parts: the northern part has two stems, while the southern part is single-stemmed (**Figures 1 and 2**).

Figure 1. General view of the baobab of Dalkut taken from the east in 2022.

Figure 2. View of the baobab of Dalkut taken in 2017 before its tallest branch broke.

The wide canopy, with the horizontal dimensions of 24.20 (NS) x 29.50 (WE) m, has five primary branches with diameters up to 1.2 m.

We consider it highly possible that the current ground level around the baobab is 0.50 m higher than the initial ground level, due to the cement annexes/elements erected around the tree. In this case, the circumference cbh becomes 14.02 m and all height values increase by 0.50 m.

Wood samples. Four wood samples were collected from the 3 stems using an increment borer. Each sample has a code composed of a digit indicating the trunk it came from (1, 2, or 3) and a capital letter indicating whether it was collected directly from the stem or from a primary branch (S or B). Several tiny segments, each 10^{-3} m long, extracted from determined positions of the collected samples. The closest and youngest segment from each sample was noted by x, while the deepest and oldest segment was noted by y. An intermediate segment was noticed by i.

AMS results and calibrated ages. Radiocarbon dates of the eight 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 two sample segments (1By, 3Sx), the 1σ distribution is consistent with one range of calendar years. For one segment (3By), the 1σ distribution corresponds to two ranges of calendar years, for one segment (2By) it is consistent with three ranges, while for another segment (3Bi) it corresponds to 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 sample segment, called assigned year, from the selected range (marked in bold). Sample/ segment ages represent the difference between the current year 2024 CE and the assigned year, with the corresponding error. Sample ages and errors were rounded to the nearest 5 yr.

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 [6-27].

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

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)
Dk-1Bx	0.01 [2.50]	-	-	-	>Modern
Dk-1By	0.34 [2.50]	259 [± 10]	**1643-1655 [68.3%]**	1649 [± 6]	375 [± 5]
Dk-2Bx	0.01 [2.65]	-	-	-	>Modern
Dk-2By	0.60 [2.65]	206 [± 18]	1658-1683 [22.3%] 1743-1750 [5.3%] **1765-1799 [40.7%]**	1772 [± 17]	250 [± 15]
Dk-3Bx	0.01 [3.09]	-	-	-	>Modern
Dk-3Bi	0.15 [3.09]	193 [± 10]	1665-1676 [19.1%] 1743-1751 [11.2%] **1765-1784 [33.1%]** 1794-1797 [4.9%]	1774 [± 9]	250 [± 10]
Dk-3By	0.35 [3.09]	590 [± 18]	**1324-1355 [60.2%]** 1387-1405 [8.1%]	1649 [± 15]	685 [± 15]
Dk-3Sx	0.01 [1.40]	11 [± 10]	**1897-1903 [68.3%]**	1900 [± 3]	125 [± 5]

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

Dating results of sample segments. The baobab of Dalkut does not have fractured stems, deep entrances in the trunk, open false or normal cavities, nor an open or closed ring-shaped structure, to allow for the collection of very old samples, close to the age of the tree.

In such cases, we consider it is possible to investigate and date primary branches which are comparable in age to that of the stem from which they emerged. Thus, 3 samples, noted with the capital letter B, were extracted from 3 primary branches where each originates from one of the 3 stems.

The oldest sample segment was extracted from a primary branch which originates from the southern stem 3. Sample Dk-3B was collected at the height of 3.09 m above the ground and had a length of 0.35 m (**Figure 3**). The deepest segment Dk-3By, which represents the sample end, has a radiocarbon date of 590 ± 18 BP, which corresponds to a calibrated age of 685 ± 15 yr. At sampling height, the diameter of the primary branch (in sampling direction) is 0.95 m. The age of the oldest part of this primary branch can be calculated by extrapolating the position and age of the oldest sample segment, Dk-3By, to the theoretical point of maximum age of the branch; this corresponds to its center at sampling height, which is positioned at 0.475 m from the sampling point. Based on our previous research on growth rates of baobabs, we consider that this branch and also its corresponding stem 3 are 800 ± 30 yr old.

The intermediary segment Dk-3Bi, which originates from a distance of 0.15 m from the sampling point, has a radiocarbon date of 193 ± 10 BP, which corresponds to a calibrated age of 250 ± 10 yr.

The sample Dk-1B was extracted from a primary branch of the northern stem 1. It was collected at the height of 2.50 m above the ground and had a length of 0.34 m. The deepest and oldest segment Dk-1By, which represents the sample end, has a radiocarbon date of 259 ± 10 BP, which corresponds to a calibrated age of 375 ± 5 yr. At sampling height, the diameter of this primary branch (in sampling direction) is 1.04 m. Thus, the theoretical center of the branch at sampling height is located at 0.52 m from the sampling point. These results indicate that the branch and its corresponding stem 1 are 550 ± 30 yr old.

The sample Dk-2B originates from a primary branch of the northern stem 2. It was collected at the height of 2.65 m above the ground and had a length of 0.24 m. The deepest and oldest segment Dk-2By, which represents the sample end, has a radiocarbon date of 206 ± 18 BP, which translates to a calibrated age of 250 ± 15 yr. At sampling height, the diameter of this primary branch (in sampling direction) is 1.02 m. Consequently, the theoretical center of the branch at sampling height is located at 0.51 m from the sampling point. The results indicate that the branch and its corresponding stem 2 are also 550 ± 30 yr old.

For the nearest segments of the 3 samples (adjacent to the bark), namely Dk-1Bx, Dk-2Bx and Dk-3Bx, 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. These results show that there are no arguments to claim that the 3 dated primary branches would have stopped their growth.

Eventually, we extracted one sample directly from the largest stem 3. The sample Dk-3S was collected at the height of 1.40 m and had a length of only 0.16 m. The sample was too short to provide interesting information about the age of this stem. That is why we dated only the nearest segment Dk-3Sx. It has a radiocarbon date of 11 ± 10 BP, which corresponds to a calibrated age of 125 ± 5 yr. According to this result, the largest stem 3 stopped growing 125 years ago.

Figure 3. Collecting the oldest sample Dk-3B.

Age of the baobab of Dalkut. The dating result of segment Dk-3By indicates that the maximum age of the southern part of the baobab of Dalkut, that consists only of stem 3, is 800 ± 30 calendar yr, i.e., 770 – 830 yr. The results of segments Dk-1By and Dk-2By show that stems 1 and 2, which form the northern part of the baobab are both 550 ± 30 calendar yr, i.e., 520 – 580 yr old. It can be stated that the baobab of Dalkut started growing around the year 1225 CE.

CONCLUSIONS

The research presents the AMS radiocarbon dating results of the baobab of Dalkut from the Dhofar Governorate, Oman. Even if it is neither the biggest nor the oldest baobab in Oman, the baobab of Dalkut is likely the best known. It exhibits a cluster structure and is composed of 3 fused stems. Three wood samples were collected from primary branches, while one sample was extracted from the outer part of a stem. The oldest dated sample has a radiocarbon date of 590 ± 18 BP, corresponding to a calibrated age of 685 ± 15 years. This value indicates that the single-stemmed southern part of the baobab is 800 ± 30 years old. On the other hand, the results show that the double-stemmed northern part of the baobab is younger and emerged from the southern stem 550 ± 30 years ago. In addition, the results indicate that the southern stem stopped growing 125 years ago, while the two northern stems, as well as all primary branches, continue to grow.

The baobab of Dalkut is a solitary African baobab. The nearest baobab is over 150 km to the north in Wadi Hinna. We consider that the baobab of Dalkut was planted by an African traveler passing through the area 800 years ago, around the year 1225. This classifies the baobabs of the Arabian Peninsula as archaeophytes.

The current condition of the baobab is not good. Many branches are partially or totally broken. We also observed that this tree was periodically infested with mealybugs (Pseudococcidae), which may be negatively affecting its growth. The bark is heavily damaged and missing in some parts. Therefore, we speculate that the baobab of Dalkut could be close to the end of its life cycle.

EXPERIMENTAL SECTION

Sample collection. The investigated wood samples were collected with a Haglöf CH 800 increment borer (0.80 m long, 0.0108 m inner diametre). After each coring, the increment borer was cleaned and disinfected with methyl alcohol. The small coring holes were sealed with Steriseal (Efekto), a special polymer sealing product which prevents any infection of the trees. Several tiny segments of the length of 10^{-3} m were extracted from the collected 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. The resulting samples were combusted to CO_2 with MnO_2 as oxidant in a modified sealed combustion tube. The gaseous CO_2 was analyzed by ^{14}C AMS [29-31].

AMS measurements. The AMS radiocarbon measurements were performed at the Ede Hertelendi Laboratory of Environmental Studies (HEKAL), Debrecen, Hungary, by an EnvironMICADAS, which is a coupled AMS mini carbon dating system (200 kV power system) with enhanced gas ion source (GIS). The GIS allows measurements directly from gaseous CO_2. The EnvironMICADAS was developed and built by ETH Laboratory, Zürich, Switzerland, especially for Environmental studies [30,32].

The obtained fraction modern values were finally converted to a conventional radiocarbon date. The radiocarbon date values are corrected with the value -25‰ for $\delta^{13}C$ isotopic fractionation. 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 [33], by using the IntCal20 atmospheric data set [34].

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