STUDIA UBB CHEMIA, LXVII, 4, 2022 (p. 187-196)
(RECOMMENDED CITATION)
DOI:10.24193/subbchem.2022.4.12

RADIOCARBON DATING OF THE HISTORIC EMPEROR'S BEECH FROM MUNCEL, BAIA DE ARIES, ROMANIA

Adrian PATRUT[a,*], Victor BOCOS-BINTINTAN[b], Roxana T. PATRUT[a], Doriana PARTILA[c], Ileana-Andreea RATIU[a,d], Laszlo RAKOSY[e], Karl F. VON REDEN[f]

ABSTRACT. The article reports the AMS (accelerator mass spectrometry) radiocarbon dating results of the historic Emperor's Beech (Fagul Împăratului) from Muncel, Baia de Arieş, Romania. Two wood samples were collected from the large tree, out of which four segments were extracted and analysed by AMS radiocarbon. The oldest dated sample segment had a radiocarbon date of 233 ± 18 BP, which corresponds to a calibrated age of 365 ± 5 years. This value suggests an age of 420 ± 20 years for the Emperor's Beech. Thus, the historic beech started growing around the year 1600.

Keywords: *AMS radiocarbon dating, Fagus sylvatica, dendrochronology, age determination, Romania.*

INTRODUCTION

The European beech (*Fagus sylvatica* L.), which belongs to the genus *Fagus* of the Fagaceae family, subfamily Fagoideae, is one of the most important and widespread broadleaved trees in Europe. It is typically 25-40 m tall, reaches

[a] *Babeş-Bolyai University, Faculty of Chemistry and Chemical Engineering, 11 Arany Janos, RO-400028, Cluj-Napoca, Romania.*
[b] *Babeş-Bolyai University, Faculty of Environmental Science and Engineering, 30 Fantanele, RO-400294 Cluj-Napoca, Romania.*
[c] *Dr. Lazar Chirila High School, 41 22 Decembrie 1989, RO-515300 Baia de Aries, Romania.*
[d] *Babeş-Bolyai University, Raluca Ripan Institute for Research in Chemistry, 30 Fantanele, RO-400294 Cluj-Napoca, Romania.*
[e] *Babeş-Bolyai University, Faculty of Biology and Geology, 44 Republicii, RO-400015, Cluj-Napoca, Romania.*
[f] *NOSAMS Facility, Dept. of Geology & Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, U.S.A.*
* *Corresponding author: apatrut@gmail.com*

up to 1.5 m trunk diameter and has a lifespan of 150-250 years. Its natural range extends from southern Scandinavia in the north to Sicily in the south and from Spain in the west to northwest Turkey in the east. High summer temperatures, drought and moisture availability are limiting factors for the distribution of beech in Europe. The European beech requires a humid atmosphere with precipitation well distributed throughout the year and a well-drained soil. It tolerates winter cold, but it is sensitive to spring frost [1-3].

Covering about 21×10^6 ha, *Fagus sylvatica* is the most widespread species of deciduous tree from Europe, representing 10% of the forests of the continent. Currently, around a third of the European beech forests are located in the Carpathian Mountains (6.9×10^6 ha), out of which over 2.1×10^6 are found in Romania [2,3].

Romania also hosts several monumental beech specimens, such as the Emperor's Beech from Muncel, Baia de Arieş (Alba county), the Princess' Beech from a forest near Breaza (Prahova county) and the giant beech of the Iezer Mountains, Aninoasa forest management unit (Argeş county). The latter is a giant specimen and by far the largest known European beech, with a height of 46 m, a circumference of 9.36 m and a wood volume over 100 m^3 [2]. On the other hand, the oldest dated European beech is Michele, a small tree growing at an altitude of 1,940 m in Pollino National Park, Italy. It has a height of 12 m, a diameter of only 0.62 m, a measured age of 622 yr (ring counting) and an incredible estimated age of 725 yr [4].

In 2005, we started an extended research project for elucidating several controversial problems of the architecture, growth and age of the African baobab and other baobab species. The research is based on an original approach which is not limited to deceased or fallen trees, but also allows to investigate and date live trees. The method consists of AMS radiocarbon dating of tiny wood samples extracted from different areas of such trees [5-12]. We extended our research by dating trees that belong to other angiosperm tree species, including specimens from Romania [13-19].

Here we present the investigation and AMS radiocarbon dating results of the historic Emperor's Beech of Muncel, Baia de Arieş.

RESULTS AND DISCUSSION

***The Emperor's Beech and its area*.** The large historic beech is positioned in the area of Muncel village, which belongs to the Baia de Arieş mining town of the Western Carpathians in Alba county, Romania. The Muncel village is located on the National Road DN 75 Turda-Ştei, at 65 km west-south-west from Turda. The Emperor's Beech can be found next to a forest road, on a

hill at the height of around 40 m above the right shore of the Arieş river, near the Muncel village. The GPS coordinates are 46º22.327' N, 023º15.499' E and the altitude is 526 m. The mean annual rainfall is 1245 mm (Baia de Arieş station).

Figure 1. The Emperor's Beech, with its light brown foliage, can be observed on a hill, above the Arieş river and the Muncel village. The photograph was taken from the National Road DN 75, in February 2022.

The name of the historic tree comes from Franz Joseph I, the Emperor of Austria (1850 – 1918), who visited Transylvania in 1852 and would have even seen the beech.

The Emperor's Beech is also famous for its marcescent leaves which, although they dry up in the fall and turn brown, remain preserved during the winter. The leaves do not fall until the spring, when the new green leaves emerge (**Figure 2**). The cause of the marcescence is not yet sufficiently understood.

Figure 2. The impressive canopy of the Emperor's Beech, with marcescent leaves, in December 2009.

The Emperor's Beech was first mentioned in the scientific literature, as a monumental tree, in 1924, by the renowned botanist Alexandru Borza [20,21]. In 1995, the Emperor's Beech was declared a Natural Monument.

In fact, the beech grows at a distance of 3.5 m from the edge of the forest road, on a steep slope of over 50° toward the right bank of the Arieş river. The highest point of its base can be found at 3.2 m below the road, while the lowest point of the base is still 2.3 m below (**Figure 3**).

Figure 3. The Emperor's Beech grows very close to the forest road between Baia de Arieş and Muncel, on a steep slope toward the Arieş river. The photograph was taken in February 2022.

The Emperor's Beech has a maximum height h = 23.2 m. Its circumference at breast height (cbh; at 1.30 m above mean ground level), which was 5.33 m in 2009, decreased to 5.00 m in 2022. The cause of this decrease is the breaking of a large low branch around the year 2015, which also ruptured small pieces of the trunk. The tree forks at heights between 6.5 – 8 m into nine branches, out of which seven are still standing, while two are broken. The horizontal dimensions of the impressive canopy are 30.5 m (NS) x 24,6 m (SE). The current overall wood volume of the beech is 20 m^3, out of which 16 m^3 correspond to the trunk and 4 m^3 to the canopy.

Wood samples. One wood sample, labelled EB-1, with the length of 0.51 m, was collected from the trunk with an increment borer, at the height of 1.70 m above the highest point from the ground (and 2.85 m above the mean point). Three pieces/segments, each 10^{-3} m long (marked a, b and c), were extracted from determined positions of sample EB-1.

Another tiny sample, labelled EB-2, was extracted with a sharp instrument from the centre of a branch with a base diametre of 0.54 m, which fell to the ground around the year 2015.

AMS results and calibrated ages. Radiocarbon dates of the four 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.

Table 1. AMS Radiocarbon dating results and calibrated ages of samples collected from the Emperor's Beech.

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)
EB-1a	0.05 [2.85]	-	-	> 1950	> Modern
EB-1b	0.35 [2.85]	185 [± 23]	1666-1683 [14.2%] **1736-1784 [38.7%]** 1794-1802 [5.5%] 1936-... [9.9%]	1760 [± 24]	260 [± 25]
EB-1c	0.51 [2.85]	233 [± 18]	**1647-1664 [47.8%]** 1785-1794 [20.4%]	1655 [± 7]	365 [± 5]
EB-2	- [-]	183 [± 18]	1667-1683 [14.2%] **1736-1782 [39.5%]** 1796-1802 [4.0%] 1936-... [10.6%]	1759 [± 23]	255 [± 25]

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

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 segment (EB-1c), the 1σ distribution is consistent with two ranges of calendar years, while for two sample segments (EB-1b, EB-2) it corresponds to four ranges of calendar years. In all 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 2022 CE (for sample segments EB-1b and EB1-c) or the year 2015 CE, when the investigated low branch fell to the ground (for sample EB-2) 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 our previous articles on AMS radiocarbon dating of large and old angiosperm trees [5-19,22-25].

Dating results of samples (segments). The oldest dated segment EB-1c, which represents the deepest sample end with a depth in wood of 0.51 m, had a radiocarbon date of 233 ± 18 BP, which corresponds to a calibrated age of 365 ± 5 calendar yr. The segment EB-1b, with a depth of 0.35 m, had a radiocarbon date of 185 ± 23 BP, corresponding to a calibrated age of 260 ± 25 calendar yr. The negative radiocarbon date and the age of segment EB-1a shows that the Emperor's Beech grew the last 0.05 m in radius in less than 72 years. The sample EB-2, extracted from the fallen branch, had a radiocarbon date 183 ± 18 BP, which corresponded in the year 2015 to a calibrated age of 255 ± 25 calendar yr. This value shows that the fallen branch did not belong to the first generation of branches.

***Age of the Emperor's Beech*.** The oldest sample segment EB-1c corresponds to a depth in the wood of 0.51 m from the sampling point, at a height of 2.85 m above the mean ground level. At this sampling height, the diameter of the tree is 1.42 m, which corresponds to a radius of 0.71 m. Taking into account that young beeches grow fast, while old beeches grow much slower, we estimate that the Emperor's Beech grew its first 0.20 m in radius in around 50-60 years. Therefore, we consider that the Emperor's Beech is 420 ± 20 yr old and started growing around the year 1600.

CONCLUSIONS

Our research presents the AMS radiocarbon investigation results of the historic Emperor's Beech of Muncel, Baia de Arieş. Two wood samples were collected from the trunk and from a fallen branch, out of which four segments were extracted. The radiocarbon date of the oldest sample segment was 233 ± 18 BP, which corresponds to a calibrated age of 365 ± 5 years. This result, combined with the original position of the dated sample segment in the tree, indicates an age of 420 ± 20 years for the Emperor's Beech.

EXPERIMENTAL SECTION

Sample collection. The sample EB-1 was collected with a Haglöf CH 800 increment borer (0.80 m long, 0.0108 m inner diameter). A number of three tiny pieces/segments were extracted from predetermined positions along the sample. The small sample EB-2 was extracted with a sharp instrument from the centre of a fallen branch. The sample 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 [26]. The resulting samples were combusted to CO_2, which was next reduced to graphite on iron catalyst [27,28]. The resulting graphite samples were analysed 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 [29]. The obtained fraction modern values, corrected for isotope fractionation with the normalized $\delta^{13}C$ value of -25 $^{0}/_{00}$, were ultimately 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 IntCal20 atmospheric data set [31].

ACKNOWLEDGMENTS

The research was funded by the Romanian Ministry of Education CNCS-UEFISCDI under grant PN-III-P4-ID-PCE-2020-2567, No. 145/2021.

REFERENCES

1. T. Houston Durant, D. de Rigo, G. Caudullo, Fagus sylvatica and other beeches in Europe: distribution, habitat, usage and threats. In: "European Atlas of Forest Tree Species", **2016**, Publication Office of the European Union, Luxembourg, pp.94-95.
2. C.D. Stoiculesu, "Romanian beech forest in the European context under the influence of climate change" (in Romanian), Bucuresti, **2013**, 413 p.
3. I.A. Biris, *Bucovina Forestiera*, **2014**, *14(1)*, 77-85.
4. G. Piovesan, F. Biondi, M. Baliva, G. de Vivo, V. Marchian, A. Schettino, A. di Filippo, *Ecology*, **2019**, *0(0)*, e02737.
5. A. Patrut, K.F. von Reden, D.A. Lowy, A.H. Alberts, J.W. Pohlman, R. Wittmann, D. Gerlach, L. Xu, C. Mitchell, *Tree Phys.*, **2007**, *27*, 1569-1574.
6. A. Patrut, K.F. von Reden, R. Van Pelt, D.H. Mayne, D.A. Lowy, D. Margineanu, *Ann. Forest Sci.*, **2011**, *68*, 993-1003.
7. A. Patrut, S. Woodborne, K.F. von Reden, G. Hall, M. Hofmeyr, D. Lowy, R.T. Patrut, *PLoS ONE*, **2015**, *10(1)*, e0117193.
8. A. Patrut, S. Woodborne, K.F. von Reden, G. Hall, R.T. Patrut, L. Rakosy, P. Danthu, J-M. Leong Pock-Tsy, D.A. Lowy, D. Margineanu, *Radiocarbon*, **2017**, *59(2)*, 435-448.
9. A. Patrut, S. Woodborne, R.T. Patrut, L. Rakosy, D.A. Lowy, G. Hall, K.F. von Reden, *Nat. Plants*, **2018**, *4*, 423-426.
10. A. Patrut, R.T.Patrut, L. Rakosy, D.A. Lowy, D. Margineanu, K.F. von Reden, *Studia UBB Chemia*, **2019**, *LXIV*, *2 (II)*, 411-419.
11. A. Patrut, S. Woodborne, R.T. Patrut, G. Hall, L. Rakosy, C. Winterbach, K.F. von Reden, *Forests*, **2019**, *10*, 983-994.
12. A. Patrut, R.T.Patrut, L. Rakosy, I.A. Ratiu, D.A. Lowy, K.F. von Reden, *Dendrochronologia*, **2021**, *70*, 125898.
13. A. Patrut, K.F. von Reden, D.A. Lowy, S. Pasca, L. Kekedy-Nagy, I. Sovago, *Studia UBB Chemia*, **2010**, *LV*, *1*, 113-120.
14. A. Patrut, K.F. von Reden, V. Savu, D.A. Lowy, R. Mitea, I. Barbul, *Studia UBB Chemia*, **2011**, *LVI*, *1*, 145-155.
15. A. Patrut, N. Robu, V. Savu, R.T. Patrut, L. Rakosy, I.A. Ratiu, D.A. Lowy, D. Margineanu, K.F. von Reden, *Studia UBB Chemia*, **2018**, *LXIII*, *4*, 7-13.
16. A. Patrut, L. Rakosy, R.T. Patrut, V. Bocos-Bintintan, I.A. Ratiu, J. Bodis, S. Woodborne, *Studia UBB Chemia*, **2021**, *LXVI*, *3*, 255-263.
17. A. Patrut, K.F. von Reden, D.A. Lowy, R.T. Patrut, D.L. Vaida, D. Margineanu, *Nucl. Instrum. Methods Phys. Res. Sect. B.*, **2013**, *294*, 616-621.
18. A. Patrut, R.T. Patrut, L. Rakosy, I.A. Ratiu, D.A. Lowy, J. Bodis, K.F. von Reden, *Studia UBB Chemia*, **2018**, *LXIII*, *3*, 41-48.
19. A. Patrut, R.T. Patrut, V. Bocos-Bintintan, I.A. Ratiu, L. Rakosy, G. Zdrob, E. Vanca, K.F. von Reden, *Studia UBB Chemia*, **2022**, *LXVII*, *1*, 245-256.
20. Al. Borza, *Bul Grad. bot. Muz. Bot. Cluj*, **1924**, *4*, 1-24.

21. Al. Borza, *Apulum*, **1939-1942**, *I*, 248-256.
22. A. Patrut, D.H. Mayne, K.F. von Reden, D.A. Lowy, S. Venter, A.P. McNichol, M. L. Roberts, D. Margineanu, *Radiocarbon*, **2010**, *52(2-3)*, 727-734.
23. A. Patrut, K.F. von Reden, P. Danthu, J-M. Leong Pock-Tsy, L. Rakosy, R.T. Patrut, D.A. Lowy, D. Margineanu, *Nucl. Instrum. Methods Phys. Res. Sect. B,* **2015**, *361*, 591-598.
24. A. Patrut, R.T. Patrut, P. Danthu, J.M. Leong Pock-Tsy, L. Rakosy, D. Lowy, K.F. von Reden, *PLOS One*, **2016**, *11(1): e0146977.*
25. A. Patrut, A. Garg, S. Woodborne, R.T. Patrut, L. Rakosy, I.A. Ratiu, *PLOS One*, **2020**, *15(1): e0227352.*
26. N.J. Loader, I. Robertson, A.C. Barker, V.R. Switsur, J.S. Waterhouse, *Chem. Geol.*,**1997**, 136(3), 313–317.
27. Z. Sofer, *Anal. Chem.*, **1980**, *52(8)*, 1389-1391.
28. J.S. Vogel, J.R. Southon, D.E. Nelson, T.A. Brown, *Nucl. Instrum. Methods Phys. Res. Sect. B*, **1984**, *5*, 289-293.
29. M. L. Roberts, J. R. Burton, K. L. Elder, B. E. Longworth, C. P. McIntyre, K. F. von Reden, B. X. Han, B. E. Rosenheim, W. J. Jenkins, E. Galutschek, A. P. McNichol, *Radiocarbon*, **2010**, *52*, 228-235.
30. C. Bronk Ramsey, *Radiocarbon*, **2009**, *51*, 337-360.
31. P.J. Reimer, W.E.N. Austin, E. Bard, A. Bayliss, P.G. Blackwell, C. Bronk Ramsey, M. Butzin, H. Cheng, R. Lawrence Edwards, M. Friedrich, P.M. Grootes, T.P. Guilderson, I. Hajdas, T.J. Heaton, A. G. Hogg, K.A Hughen, B. Kromer, S.W. Manning, R. Muscheler, J.G. Palmer, C. Pearson, J. van der Plicht, R.W. Reimer, D.A. Richards, E.M. Scott, J.R. Southon, C.S.M. Turney, L. Wacker, F. Adolphi, U. Büntgen, M. Capano, S.M. Fahrni, A. Fogtmann-Schulz, R. Friedrich, P. Köhler, S. Kudsk, F. Miyake, J. Olsen, F. Reinig, M. Sakamoto, A. Sookdeo, S. Talamo, *Radiocarbon*, **2020**, *62(4)*, 727-757.