The life-span of leadwood trees

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Radiocarbon analyses on 16 specimens of the leadwood tree, *Combretum imberbe*, showed that they live for several hundred years. The oldest specimen was more than 1000 years old when it died and had an extremely slow radial growth rate of 0.33 mm yr^{-1}, while a tree in a more favourable moisture position had a growth rate of 2 mm yr^{-1} and lived for some 300 years. Although a trunk diameter of 2.2 m was recorded, most trees die before their trunks reach a diameter of much more than 1 m and well before they reach an age of a thousand years. The dead trees can remain upright in the landscape for as much as 80 years, while dead logs survive in the environment for as long.

Introduction

The leadwood, *Combretum imberbe,* is a slow-growing deciduous tree that occurs in the bushveld from Zululand northeastwards to northern Namibia, Angola and Zambia.[1] The wood is extremely dense and heavy, and is not attacked by termites. As a consequence, dead specimens remain standing upright in the landscape for many years and are only eventually burnt down to ground level in fierce veld fires. It is not possible to distinguish annual rings in the wood.

The objective of the investigation reported here was twofold: to use radiocarbon dating to establish the life-span of the species and, where possible, to determine how long dead trees remain standing upright or otherwise survive in the veld. Samples of wood were collected from Swaziland, the Kruger National Park (KNP) and the adjacent lowveld (Table 1). One tree from the Okavango area in Botswana was also sampled.

The accurate dating of material with radiocarbon in the relevant time-range is, however, not straightforward. Owing to fluctuations of the ^{14}C level in the environment, the measured radiocarbon age does often not correspond to a unique historical date. This is especially true for material dating to the past 350 years, for which a single radiocarbon age is obtained for samples from two or more different calendar dates. The matter can be resolved by measuring several samples from different positions along the radius of the tree trunk. By applying a process called 'wiggle matching', accurate dating can then be achieved (see for instance, ref. 2). A portion of the actual calibration curve for converting radiocarbon ages into calendar dates is shown in Fig. 1 (*cf.* ref. 3). In it one can see that material dating to AD 1678, 1748, 1804 and even 1954 all have an apparent radiocarbon age of 200 years.

Note that radiocarbon ages are all given in years before AD 1950 (Before Present, BP). The apparent age of 200 years for a sample dating to the early 1950s is due to the dilution of the ^{14}C in the air by the combustion of fossil fuels that do not contain the radioactive isotope. After AD 1954, the testing of nuclear fusion bombs dramatically increased the ^{14}C content in the atmosphere, so that material dating to after this date shows an elevated ^{14}C level and can be pinpointed precisely to ±1 year.[4]

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Materials and method

Where possible, wood was collected from close to the inner core of the tree trunk for determining the age of the tree. Samples from the outer rim of the trunk of dead trees were collected to establish how long they had been dead. The sapwood of the species is only about 10 mm thick, so that it is easy to establish whether the bole is still complete.

A 25-g sample of the selected wood was reduced to matchstick-size slivers and rigorously treated with hot acid, alkali and acid to remove solubles. The purified material was then converted to carbon dioxide and the radioactivity measured in a high precision proportional counter for two or more days. The results were adjusted for variations in the initial carbon isotope ratio by means of the $^{13}C/^{12}C$ ratios and the ages given as years BP, that is, before AD 1950.

Samples taken from the outer rim of a trunk for dating typically contain ten or more annual rings, so that the date for the outermost ring needs a slight adjustment. Similarly, samples from near the inner core need to be extrapolated to the first annual ring.

Results

The full list of the radiocarbon analyses performed on 16 leadwood specimens is given in Table 1. The results obtained for the individual trees are discussed below. The first four specimens, from Swaziland, were submitted by T.E. Reilly.

LW 1: The dead tree was standing upright on an interfluve in the Hlane Game Sanctuary in central Swaziland. It was felled in 1972 and a disk of the bole supplied for analysis. The trunk had a

Table 1. Radiocarbon ages of the samples from the 16 leadwood specimens discussed in the text, expressed in years Before Present (BP), i.e. before AD 1950.

Specimen	Diameter (mm)	Sample position	Lab. no. (Pta-)	Radiocarbon age (yr BP)
LW 1	670	30–50 mm from centre	776	1050 ± 40
		50–60 mm from outer edge	5720	170 ± 18
		40–50 mm from outer edge	5685	203 ± 22
		30–40 mm from outer edge	5661	195 ± 14
		10–20 mm from outer edge	5655	123 ± 12
		0–10 mm from outer edge	784	160 ± 50
LW 2	1200	40 mm from inner core	1537	260 ± 30
		400 mm from centre	1310	110 ± 45
		Outer sapwood at 590 mm	1538	190 ± 40
LW 3	550	Core, 0–15 mm	2185	445 ± 15
		10–20 mm from outer rim	5771	100 ± 12
		0–5 mm from outer rim	5775	171 ± 18
LW 4	820	40–70 mm from centre	2189	369 ± 15
		138–150 mm from centre	6517	359 ± 15
LW 5	910	Wood from near core	1342	620 ± 45
		Outer annual rings (heartwood)	1341	210 ± 50
LW 6	980	Wood from near core	5783	315 ± 19
		Outer annual rings (heartwood)	5841	100 ± 23
LW 7	660	Inner core	7218	210 ± 20
		Outer annual rings (sapwood)	7219	85 ± 25
LW 8	–	Outer sapwood	2701	(121.8 ± 0.2%)*
LW 9	*c.* 400	Outer sapwood	5262	90 ± 20
LW 10	*c.* 400	Outer sapwood	5271	177 ± 13
LW 11	–	Outer sapwood	5542	90 ± 20
LW 12	500	0–50 mm from centre	7495	885 ± 15
		0–35 mm from outer rim	7472	350 ± 20
LW 13	2200	600 mm from outer edge	7515	475 ± 15
		0–17 mm from rim (heartwood)	7524	175 ± 20
LW 14	1100	0–45 mm from core	7530	355 ± 15
		0–10 mm from rim	7536	180 ± 20
LW 15	1100	300 mm from outer edge	7506	160 ± 15
LW 16	510	200 mm from outer edge	7543	255 ± 20
		0–15 mm from outer edge	7551	115 ± 20

* ^{14}C content above 'modern carbon' level; see text.

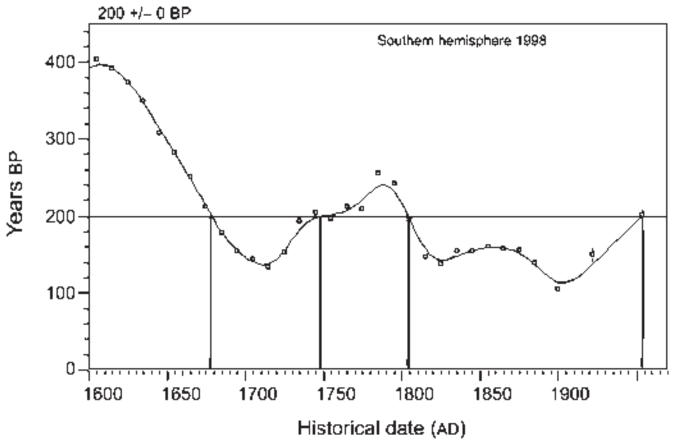

Fig. 1. Portion of the Pretoria calibration curve with which radiocarbon ages are converted to historical dates. On the *y*-axis the ages are given in years Before Present (BP), i.e. before AD 1950. The corresponding historical dates are shown on the *x*-axis. Often a radiocarbon age corresponds to more than one historical date. Thus an age of 200 years can date to 1678, 1748, 1804 or even 1954.

diameter of 680 mm and a 60 mm cavity at the core. To determine when the tree died, five successive 10-mm-thick samples were taken from the outer rim of the bole. The calibrated dates are plotted against the distance from the rim in Fig. 2. The results produced several possible calendar dates, but the correct allocation can be selected, since each sample cannot be younger than the overlying ones or older than those underlying it. The result shows a uniform radial growth rate over the outer 60 mm of 0.25 mm yr^{-1}, so that each 10 mm represents 40 years of growth.

The innermost sample close to the core gave a calibrated date of AD 1015 ± 16 and an average overall radial growth rate of 0.33 mm yr^{-1}. Extrapolation to the core indicates that the tree started growing in *c.* AD 910 and that it was 1040 years old when it died in *c.* AD 1950, 22 years before it was felled.

LW 2: This partially burnt stump stood alongside a stream in the Hlane Game Sanctuary and was sectioned in 1974. It had a diameter of 1.2 m and a *c.* 60 mm cavity around the core. Three samples were analysed, one from close to the core, one from 400 mm out and one from the sapwood on the rim. The possible calibrated dates are plotted in Fig. 3. Following the same reasoning as with the previous sample, a uniform radial growth rate of

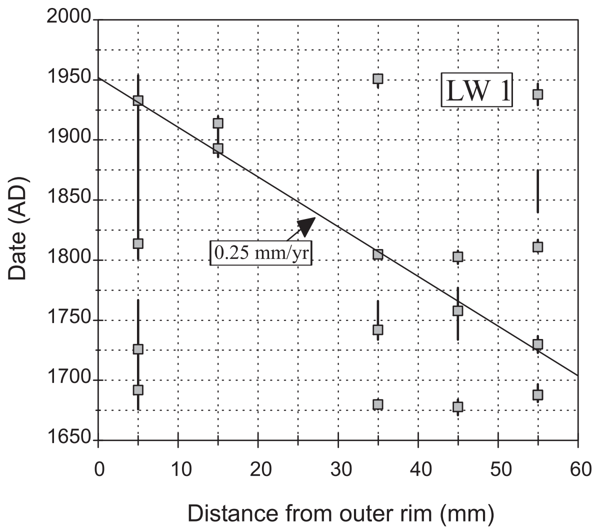

Fig. 2. Plot showing the possible historical dates for the samples from the outer 60 mm of the trunk of LW 1. The filled squares show the most probable dates, while the vertical bars give the possible ranges when the statistical errors of the measurements are taken into account. The diagonal line gives the only possible fit to the data, assuming a more or less uniform growth rate.

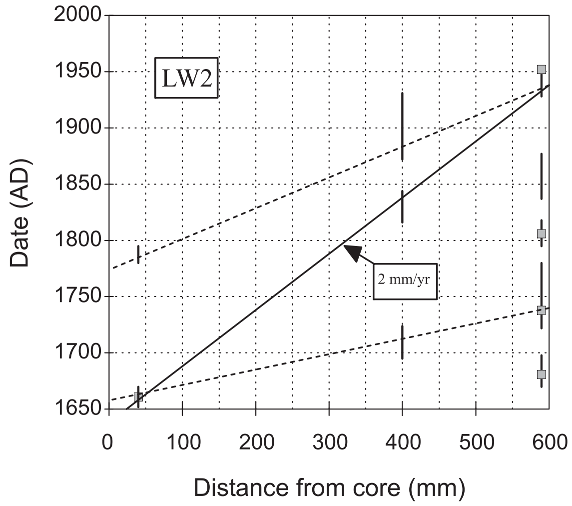

Fig. 3. Plot of the possible historical dates for the three samples analysed on the trunk of LW 2. The filled squares give the most probable dates, while the vertical bars show the possible ranges when the statistical errors of the measurements are taken into account. The full diagonal line gives the best fit to the data, indicating an average growth rate of 2 mm yr^{-1}. The other two possible date allocations (dashed lines) are much less probable and can be rejected.

2 mm yr^{-1} was arrived at and the tree was *c.* 300 years old when it died in *c.* 1940. The stump survived for a further 34 years before it was sectioned. The other, less probable radial growth rate of 4 mm yr^{-1} can be rejected in the light of the other results of this study.

The large difference in age and size between this specimen and the previous one shows the effect of moisture availability on the growth rate of the species.

LW 3: This upright dead tree in the Hlane sanctuary was felled in 1976. It had a trunk diameter of 550 mm. Three samples were analysed, one from the core, one 10–20 mm in from the rim and one from the first 5 mm of sapwood. The calibrated date for the 20 mm core sample is AD 1460 ± 9 and the outer two samples indicate that it died in AD 1935. This gives a radial growth rate of 0.55 mm yr^{-1} and an age of *c.* 500 years. The dead trunk survived for another 40 years.

LW 4: A living tree in the Hlane sanctuary that was cored in 1976. The trunk had a diameter of 820 mm and an irregular cavity around the centre. Two samples were analysed from the radial section, the one 40–70 mm from the centre and one 38–50 mm farther out. A plot of the possible calendar dates against the radial distance indicates an age of 476 years and a growth rate of 0.86 mm yr^{-1}.

LW 5: The *c.* 4-m log with a diameter of 914 mm at the base came from the farm Middlesex near Hoedspruit in the lowveld adjacent to the Kruger National Park. Samples from the core and the outer rim were submitted by A.C. le Roux. They gave calibrated dates of AD 1400 or AD 1335, and AD 1944 or older. Accepting the latter date, the radial growth rate was either 0.81 or 0.72 mm yr^{-1} and the tree was 555 or 620 years old.

LW 6: The stump of a tree with a diameter of 977 mm that stood on the farm Amsterdam near Hoedspruit and was felled in *c.* 1975 and submitted by C.E. Joubert. Samples from the core and the rim gave calibrated dates of AD 1644 ± 6 and AD 1904 ± 10, so that the radial growth rate was 1.8 mm yr^{-1} and the age *c.* 270 years or, since the sapwood was no longer present, perhaps 330 years.

LW 7: A 3.6-m-tall stump with a diameter of 660 mm at the base that stood in the Okavango Basin, away from the floodplain, Botswana, was sampled in 1996 by G. Schuurman. The sapwood from the rim gave a calibrated date of AD 1904; possible calibrated dates for the core are AD 1676, 1767 and 1804. The oldest date gives an age of 240 years and a growth rate of 1.4 mm yr^{-1}. The other possibilities are less likely.

The outer sapwood of four dead trees in the Kruger National Park was also dated.

LW 8: Upright standing dead tree near Letaba rest camp, collected in 1980 and submitted by C.F. Garbers. The radiocarbon content of the sample was 21.8% above the standard for modern carbon, indicating that the wood was formed after the pollution by nuclear weapon tests following 1954. Comparison with the atmospheric record shows that the sample dates to AD 1961 ± 1, so that the tree had been dead for some 18 years.

LW 9: Upright standing dead tree with a trunk diameter of *c.* 400 mm near the Letaba River, 20 km SE of Letaba camp, collected in 1990 by J.C.V. The sapwood gave a clear calibrated date of AD 1904, so that the tree had been dead for some 80 years.

Table 2. Summary of the dating results.

Specimen	Description	Diameter (m)	Age (yr)	Radial growth rate (mm yr^{-1})	Survival since death (yr)
LW 1	Upright dead tree	0.68	1040	0.33	22
LW 2	Standing stump	1.2	300	2.0	35
LW 3	Upright dead tree	0.55	500	0.55	40
LW 4	Core from living tree	0.82	476	0.86	–
LW 5	Loose log	0.914	555 or 620	0.81 or 0.72	–
LW 6	Stump of felled tree	0.977	270–330	1.8	70
LW 7	Upright stump	0.66	240	1.4	90
LW 8	Upright dead tree		–	–	18
LW 9	Upright dead tree	*c.* 0.40	–	–	80
LW 10	Loose log	*c.* 0.40	–	–	45
LW 11	Fragment	–	–	–	80
LW 12	Loose log	0.50	600	0.53 or 0.68	
LW 13	Burned stump	2.2	900	1.2 to 2.5	50
LW 14	Burned stump	1.1	–	–	–
LW 15	Living tree	1.1	–	1.0 to 2.1	–
LW 16	Loose log	0.51	250 or 120	0.8 or 1.8	90

LW 10: Log at Timbavati in the KNP, collected in 1990 by J.C.V. A sample of sapwood gave four possible calibrated dates, the latest of which indicates that the tree had been dead for at least 45 years.

LW 11: Crescent-shaped fragment from near Punda Maria, KNP, collected in 1990 by J.C. van Daalen. The sapwood gave a calibrated date of AD 1904, so that the tree had been dead for some 80 years.

The next five specimens, from near Letaba rest camp in the KNP, were sampled in 1997 by S. Woodborne.

LW 12: Loose log in Letaba camp, with a diameter of 500 mm and an irregular cavity in the middle. Two samples were analysed; the inner one gave a calibrated date of AD 1216 ± 12 whereas the sample from the outer rim dates to AD 1638 or AD 1543. This gives an average radial growth rate of 0.53 or 0.68 mm yr^{-1}. Extrapolation to the centre suggests that the tree started growing soon after AD 1100, but since the sapwood is no longer present no date can be given for when it died – although it must have lived for at least 600 years.

LW 13: This specimen and the next two stand above the bank of the Letaba River at Visvanggat just east of Letaba camp. The partially burnt 1-m-tall stump has a diameter of 2.2 m. Two samples were taken, one from the outer rim and one from 600 mm further in. The inner sample calibrates to AD 1445 ± 5, while the outer one gives multiple possible dates between AD 1941 and 1686. The results represent a radial growth rate of between 1.2 and 2.5 mm yr^{-1}. The faster growth rates derive from the older possible dates for the rim and are less probable, since it would imply that the tree had been dead for 200 to 300 years. Extrapolation of 1.2 mm yr^{-1} to the centre would suggest that the tree was some 900 years old when it died.

LW 14: Partially decayed stump with a diameter of 1.1 m at Visvanggat, KNP. Two samples from near the core and one from the outer rim were collected. The inner one gives three possible dates between AD 1528 and 1632 and the rim sample gives four dates between AD 1685 and 1943. In the light of this, it is not possible to give any reliable figures for age or growth rate, but the tree may have started growing in AD 1528 and probably died before 1954.

LW 15: Living tree at Visvanggat, KNP, with a diameter of 1.1 m and a deep cavity on the one side at the base. A sample was collected from within the cavity at 300 mm from the rim. It again produced multiple possible calendar dates, corresponding to ages between 305 and 64 years in 1997, and radial growth rates between 1.0 and 4.7 mm yr^{-1}. The latter figure seems improbable and a growth rate of 1.0, 1.6 or 2.1 mm yr^{-1} is the more likely.

LW 16: Dead log with a diameter of 510 mm near the rifle range at Letaba camp. The stump contained the cores of three separate saplings, probably from the same root stock, which grew together into a single trunk. A sample from the outer rim gave a single calibrated date of AD 1904, so that the tree has been dead for some 90 years or slightly fewer. A sample from one of the cores at 200 mm from the rim gave two possible calibrated dates of AD 1663, or, less likely, of AD 1788, which correspond to a radial growth rate of 0.8 or 1.8 mm yr^{-1} and could have been 250 or 120 years old.

Summary and conclusion

The information concerning age, growth rate and length of survival in the landscape of the leadwood trees is summarized in Table 2. Occasionally these trees can attain a trunk diameter of over 2 m (LW 13), but usually they die before the diameter reaches much more than 1 m. The wood of most trees tends to start rotting while the tree is still alive, forming a cavity in the centre of the trunk. The first specimen, LW 1, that was more thoroughly investigated than the others, shows that the leadwoods can reach an age of over 1000 years and attain an extremely low radial growth rate of 0.33 mm yr^{-1}. Under favourable moisture conditions the trees grow faster (LW 2: 2.0 mm yr^{-1}), but apparently do not live so long. Dead trees can survive upright in the landscape for many decades, but are eventually consumed by veld fires. Dead logs are also found lying in the veld for decades.

In view of the fluctuations in the radiocarbon level, especially over the five centuries prior to AD 1950, it is clear that three or more radial samples from the bole are necessary for determining the life span of slow-growing trees.

We thank Ted Reilly for supplying the disks and core of the trees from Swaziland (LW 1–LW 4), and Stephan Woodborne for collecting samples LW 12–LW 16 from the vicinity of Letaba in the Kruger National Park.

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