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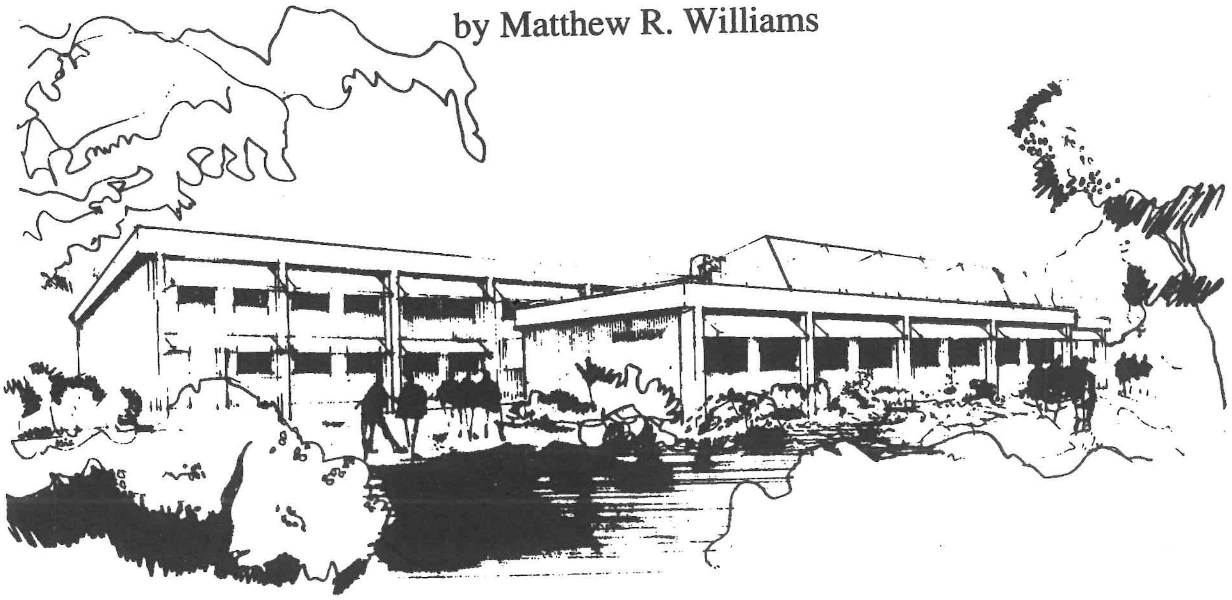
GRASSTREES AND WOODY PLANTS AS BIO-INDICATORS OF PAST GROWING CONDITIONS AND THE PATCHINESS OF PAST FIRES

by Matthew R. Williams



Final report to the Department of Conservation and Land Management

April 2001

15 pp

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Introduction

Grasstrees (Xanthorrhoeaceae) are common Australian plants that are extremely fire tolerant and often require burning to reproduce (Staff and Waterhouse 1981, Lamont *et al.* 2000). They consist of a simple or branched caudex surrounded by a supporting stem of dead leaf bases, each branch having a terminal head of living leaves. Dead but yet unburnt leaves bend downwards beneath the living leaves to form a skirt around the upper part of the stem. This skirt is typically burnt back to the leaf bases during fire and as result the outer portion of the stem consists of a layer of charcoal caused by successive fires.

Removing this outer charcoal surface, which is only a few millimetres thick, reveals the unburnt portion of the leaf bases. These have been found to bear a pattern of alternating cream and brown bands that together represent a single year's growth (Swanborough *et al.* 1999; Ward *et al.* 2001). Each band corresponds to the leaf bases laid down during the spring-summer growth flush (cream) or during autumn-winter (brown), and are thus analogous to the earlywood and latewood forming the tree rings of coniferous trees. Typically, cream bands are thicker than brown bands, resulting primarily from a greater number of leaf bases although individual leaf bases are also slightly larger (Eldridge et al. 2000). A further feature of the leaf bases is that some have a blackened core, resulting in additional black bands superimposed on the annual bands. These black bands have been found to be caused by past fires (Ward *et al.* in press). The physical and/or chemical basis of these bands is currently under investigation (Colangelo 2000a), but it is known that the black band forms when the oldest (i.e. outermost) living leaves are burnt during a fire, a process that is usually enhanced by the dry skirt of dead leaves. Together, these banding patterns offer potential for determining a site's fire history by enabling past fires to be accurately dated.

A number of research projects are currently investigating these banding patterns. This research focuses on: validating the technique for reconstructing fire history; reconstructing the frequency of past fires and relating this to historical records; examining the annual growth cycle and growth responses of grasstrees in relation to water availability, nutrition, fire and fire-induced flowering; establishing the physical and chemical basis of both the annual and fire bands; and devising suitable stains to enhance the visibility of annual and fire bands (Colangelo 2000b).

Validating the grasstree dating technique is directly analogous to the challenge that faced A E Douglass when he pioneered the science of dendrochronology in the south-western United States in the 1930s. Douglass (1935) observed that the pattern of ring widths in a number of adjacent trees showed consistent features, and in particular that narrow rings (caused by drought) provided markers that could be matched between trees (Fritts 1975). This process of matching growth rings between trees, enabling the accurate dating of rings and the subsequent combination of tree ring width series across many trees, became known as cross-dating. Cross-dating formed the basis of dendrochronology, and established the technique as a means of reconstructing past growing conditions. Although the major focus of dendrochronology has been the reconstruction of past climate by examining ring widths and the chemical composition of individual growth rings, the technique has also, by recording partial tree girdling (scarring) caused by fire, enabled the reconstruction of fire history.

In the case of grasstrees, matching of fire scars between different plants is also crucial to constructing accurate fire histories. This process differs from the current studies of Ward *et al.* (2001), who do not seek to accurately date each fire, but measure a sample of annual growth bands in order to estimate average annual growth, thus enabling fires scars to be allocated to a particular decade.

If accurate cross-dating can be established then it may also be possible to reconstruct the patchiness of past fires. By obtaining a sufficient sample of grasstrees within an area the prevalence of each fire can be quantified by determining the proportion of grasstrees that had been burnt in each fire.

Aim

This project examined the feasibility of establishing cross-dating of fire scars between grasstree stems in order to accurately reconstruct fire history and to assess the patchiness of past fires.

Methods

A study site was established at in the south-west corner of Dryandra woodland (Fig. 1). Dryandra was chosen because grasstrees from drier areas typically have more visible annual bands, as well as having fewer fire scars (Ward, pers. comm.). Both of these properties potentially simplify the cross-dating process. Approximately 15 grasstrees at Dryandra were prepared for measurement. Measurements at Dryandra were conducted during September and October 1999 and in April 2000.

Each plant was permanently marked with an aluminium tag and its position within the site mapped. Height, diameter, size of skirt and the presence of a flowering spike were recorded. For those plants planned to be assessed for banding, the skirt of dead leaf bases was removed by cutting or burning off. For those plants where the skirt was removed by burning, measurement was conducted on the next visit to the site as the skirt may smoulder for many hours. The dense skirts of plants at Dryandra adhere to the stem and usually require burning to remove.

An additional sample of three grasstrees was later obtained from Eagle track, near Hovea Falls in John Forrest NP (116° 08' E, 31° 54' S). This sample was selected because of their generally clear pattern of fire bands, presence of multiple stems and close proximity. Although multiple stems may complicate between-grasstree cross-dating, multiple stems will always burn at the same time so they enable the technique to be tested on stems that are known to have identical fire histories. Plant 1 was a large individual with three stems; plant 2, only three metres away, had two stems; plant 3, some 30 metres distant, was a single-stemmed plant set among sheet granite. It was expected that plant 3 would be slower growing and probably have experienced fewer fires. Measurements at John Forrest NP were conducted during June 2000.

Grasstrees were sanded using a conventional angle grinder with sanding disc attachment powered by a portable generator. The outer blackened portion of the leaf bases were ground off to expose fire scars and annual bands. Wetting the stem with water then enhanced the visibility of bands. For each plant, the distance from the crown to each fire scar was measured. Where possible, the annual bands were also measured and used to estimate average annual growth of each grasstree.

Results

At the Dryandra site, difficulties were encountered in identifying and measuring bands. First, grasstrees at Dryandra had an extremely persistent skirt that, even after burning, required considerable further grinding. Although it was clear that no fire scars were present in the skirt zone, identifying annual bands in this region was not possible. Second, the presence of partial and incomplete black bands made interpretation difficult. Whether these bands were fire scars or from some other cause could not be determined. Third, the absence of clear annual bands and the presence of sections of rotting leaf bases (varying over 2-30 cm 3 cm in width) meant that a continuous record could not be obtained for individual grasstrees. As a result of these difficulties, no plant at Dryandra gave a useable record of annual or fire bands.

At JFNP, it was also not possible to obtain a complete record of annual bands for each plant. However, average annual growth was estimated from a sample of 5 years growth (ie between 6 clear annual bands), usually near the upper portion of the plant. This is the technique described by Ward *et al.* (2001). Fire scars were then dated using the assumption that each year's growth was equal to the average. The fire-scar record for each individual plant was then compiled by measuring the distance to each fire scar from the base of the living leaves.

The measurements were used to create a diagrammatic representation of each plant's fire history (Figs 2-4). For multiple-stemmed plants there is good correspondence between fire scars on different stems of the same plant (Figs 2,3), although there is some uncertainty, ranging from 1 and 3 years, in establishing the actual fire year. The stem deformation that occurs following branching is a partial explanation of this lack of accurate cross-dating within each plant.

By averaging the distances between fire scars for each stem, a single sequence was derived for each plant. It was then possible to attempt cross-dating of fire scars between plants. Although there was substantial agreement between plants 1 and 2, the sequence for plant 3 did not correspond. On the basis of this initial comparison, the annual growth rate of plant 3 was revised from 13.5 mm/yr to 12.0 mm/yr to achieve better matching of fire scars. The fire years revealed by these three stems enable a 'concensus' fire history to be devised (Fig. 5).

For many of the fire scars in the sequence, the actual year of fire is uncertain, with a range of up to 4 years for some fires. This fire chronology must therefore be viewed as very tentative.

Discussion

The validity of the assumption that annual height growth is constant during the lifetime of a plant was examined by Eldridge et al. (2000). They found that average band width (and hence annual growth increments) was relatively constant over the lifetime of most of the nine plants they examined, but that long-term trends in annual increments were present in some plants. Thus, using a small sample of clearly visible bands to estimate average annual growth rate will be inadequate to devise accurate fire histories. As the south-west region has experienced a 25% reduction in average annual rainfall since 1915 (Pittock, 1988) it is unlikely that current growth rates are representative of those in the past.

Nonetheless, the potential exists to construct fire histories if a method can be developed to enhance the visibility of bands, particularly annual bands. Currently, the method used to identify bands is subjective, but could be made objective by using measurements of leaf-base thickness to identify the cream and brown bands.

Substantial sample sizes would be needed, however, to provide an adequate basis for cross-dating. Eldridge et al (2000), in a one year project, was able to measure only 9 plants for study, although she recommends alternative techniques that should permit greater sample sizes to be obtained. An adequate sample size, based on dendrochronological studies, is about 20-30 plants at each study site (Fritts, 1977; Ogden, 1978).

Conclusions

Cross-dating of annual bands and fire scars in grasstrees is complicated by the indistinctness of many of the annual bands, which may only be clearly visible, if at all, on a portion of the stem. Development of better staining techniques, and/or measuring leaf base thickness may provide a better means of identifying the sequence of annual bands in grasstrees.

It would certainly be easier to cross-date fire scars that occur in an irregular sequence. For example, a sequence like fire – long unburnt – fire – long unburnt – fire – long unburnt – fire would be an ideal pattern for matching fire scars, because there could be little doubt to which fire any particular fire scar corresponded.

Substantial sample sizes, around 20-30 plants per site, will be needed to establish cross-dating. Considerably larger samples will be needed to quantify the patchiness of past fires.

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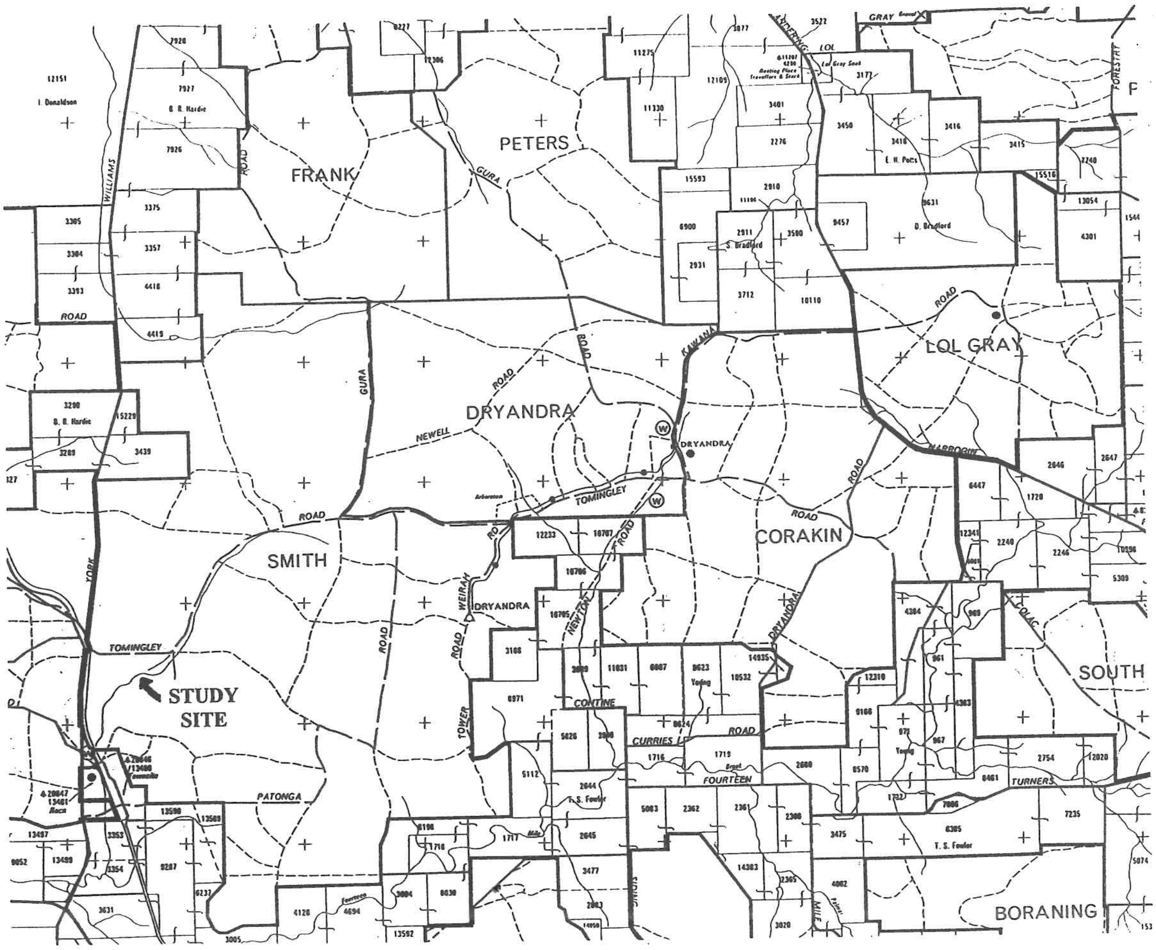

Figure 1. Dryandra study site, near the junction of Tomingley Rd and the York-Williams Road. Scale 1:100 000 (1 cm = 1 km).

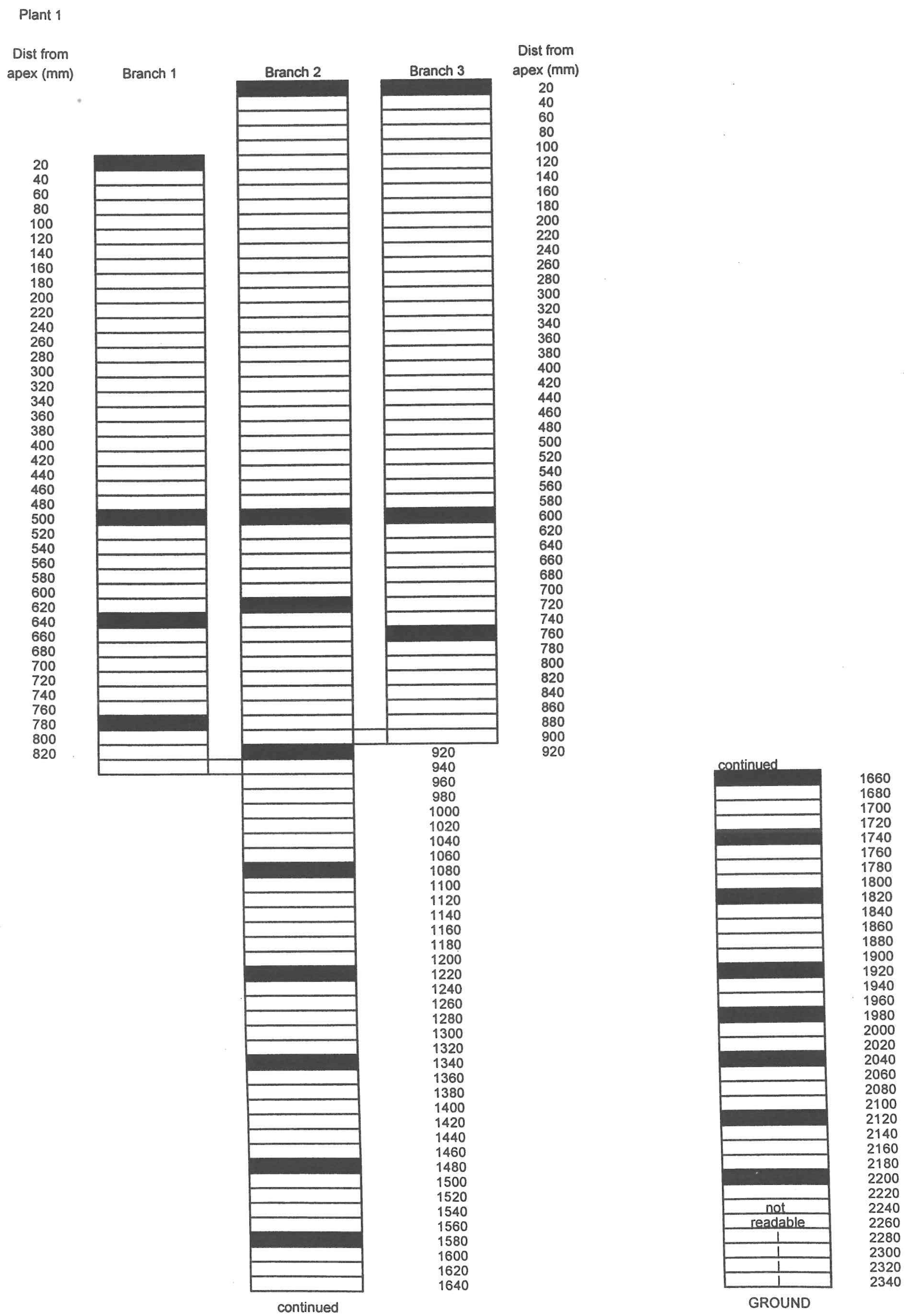

Figure 2. Graphic depicting the pattern of annual bands and fire scars on a grasstree (plant 1) near Hovea Falls, John Forrest NP. Each cell represents a single year's growth based on an average growth rate of 20.0 mm/y and assuming constant annual growth. Fire scars are coloured black.

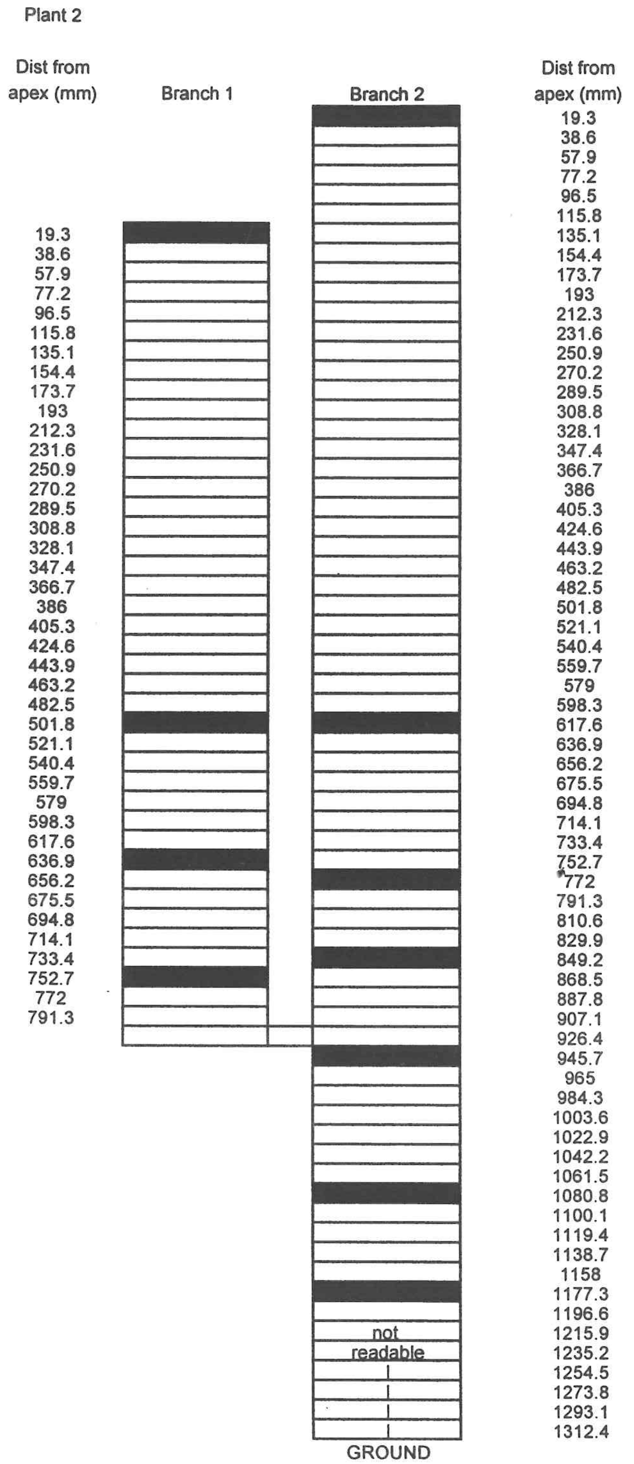

Figure 3. Graphic depicting the pattern of annual bands and fire scars on a grasstree (plant 2) near Hovea Falls, John Forrest NP. Each cell represents a single year's growth based on an average growth rate of 19.3 mm/yr and assuming constant annual growth. Fire scars are coloured black.

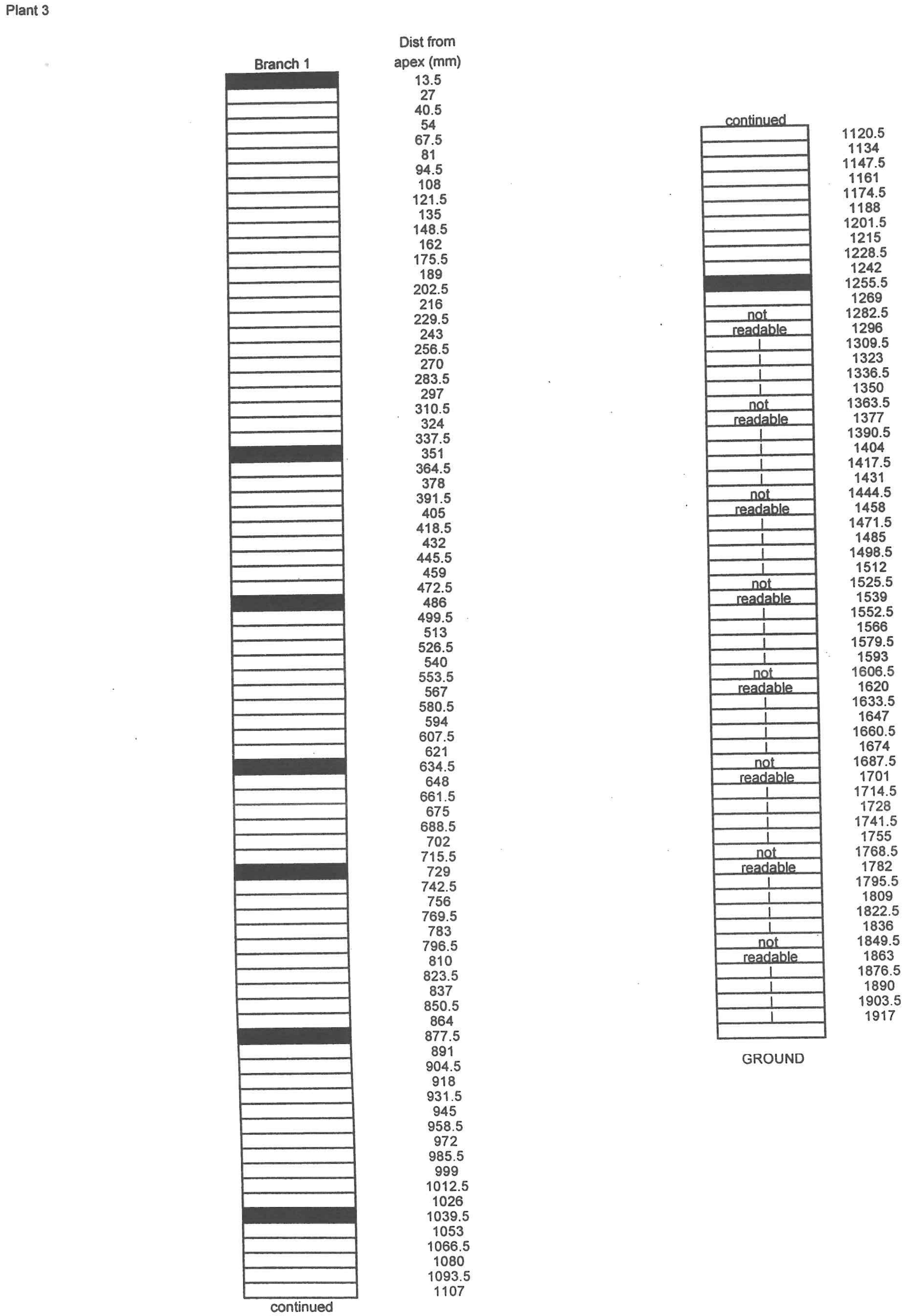

Figure 4. Graphic depicting the pattern of annual bands and fire scars on a grasstree (plant 3) near Hovea Falls, John Forrest NP. Each cell represents a single year's growth based on an average growth rate of 12.0 mm/y and assuming constant annual growth. Fire scars are coloured black.

Estimated year	Plant 1	Dist from apex (mm)	Plant 2	Dist from apex (mm)	Plant 3	Dist from apex (mm)	Estimated fire history
1999		20		19.3		12	1999
1998		40		38.6		24	
1997		60		57.9		36	
1996		80		77.2		48	
1995		100		96.5		60	
1994		120		115.8		72	
1993		140		135.1		84	
1992		160		154.4		96	
1991		180		173.7		108	
1990		200		193		120	
1989		220		212.3		132	
1988		240		231.6		144	
1987		260		250.9		156	
1986		280		270.2		168	
1985		300		289.5		180	
1984		320		308.8		192	
1983		340		328.1		204	
1982		360		347.4		216	
1981		380		366.7		228	
1980		400		386		240	
1979		420		405.3		252	
1978		440		424.6		264	
1977		460		443.9		276	
1976		480		463.2		288	
1975		500		482.5		300	
1974		520		501.8		312	
1973		540		521.1		324	
1972		560		540.4		336	
1971		580		559.7		348	1971 or 1970
1970		600		579		360	
1969		620		598.3		372	
1968		640		617.6		384	
1967		660		636.9		396	
1966		680		656.2		408	
1965		700		675.5		420	
1964		720		694.8		432	
1963		740		714.1		444	1963
1962		760		733.4		456	
1961		780		752.7		468	
1960		800		772		480	
1959		820		791.3		492	1959
1958		840		810.6		504	
1957		860		829.9		516	
1956	Branching	880		849.2		528	
1955		900		868.5		540	1955 or 1954 or 1953
1954		920	Branching	887.8		552	
1953		940		907.1		564	
1952		960		926.4		576	
1951		980		945.7		588	
1950		1000		965		600	
1949		1020		984.3		612	
1948		1040		1003.6		624	
1947	Branching	1060		1022.9		636	1947 or 1946
1946		1080		1042.2		648	
1945		1100		1061.5		660	
1944		1120		1080.8		672	
1943		1140		1100.1		684	
1942		1160		1119.4		696	1942 or 1941 or 1940 or 1939
1941		1180		1138.7		708	
1940		1200	not	1158		720	
1939		1220	readable	1177.3		732	
1938		1240		1196.6		744	
1937		1260		1215.9		756	
1936		1280		1235.2		768	
1935		1300		1254.5		780	
1934		1320		1273.8		792	
1933		1340	GROUND	1293.1		804	1933
1932		1360		1312.4		816	
1931		1380		1331.7		828	
1930		1400		1351		840	
1929		1420		1370.3		852	
1928		1440		1389.6		864	
1927		1460		1408.9		876	1927 or 1926
1926		1480		1428.2		888	
1925		1500		1447.5		900	
1924		1520		1466.8		912	
1923		1540		1486.1		924	
1922		1560		1505.4		936	
1921		1580		1524.7		948	1921
1920		1600		1544		960	
1919		1620		1563.3		972	
1918		1640		1582.6		984	
1917		1660		1601.9		996	1917
1916		1680		1621.2		1008	
1915		1700		1640.5		1020	
1914		1720		1659.8		1032	
1913		1740		1679.1		1044	1913
1912		1760		1698.4		1056	
1911		1780		1717.7		1068	

Estimated year	Plant 1	Dist from apex (mm)	Dist from apex (mm)	Plant 3	Dist from apex (mm)	Estimated fire history
1910		1800	1737		1080	
1909		1820	1756.3		1092	1909
1908		1840	1775.6		1104	
1907		1860	1794.9		1116	
1906		1880	1814.2		1128	
1905		1900	1833.5		1140	
1904		1920	1852.8		1152	1904
1903		1940	1872.1		1164	
1902		1960	1891.4		1176	
1901		1980	1910.7		1188	1901
1900		2000	1930		1200	
1899		2020	1949.3		1212	
1898		2040	1968.6		1224	1898 or 1897 or 1896
1897		2060	1987.9		1236	
1896		2080	2007.2		1248	
1895		2100	2026.5		1260	
1894		2120	2045.8	not	1272	1894
1893		2140	2065.1	readable	1284	
1892		2160	2084.4		1296	
1891		2180	2103.7		1308	
1890		2200	2123		1320	1890
1889		2220	2142.3		1332	
1888	not	2240	2161.6	not	1344	
1887	readable	2260	2180.9	readable	1356	
1886		2280	2200.2		1368	
1885		2300	2219.5		1380	
1884		2320	2238.8		1392	
1883		2340	2258.1		1404	
	GROUND			not	1416	
				readable	1428	
					1440	
					1452	
					1464	
					1476	
				not	1488	
				readable	1500	
					1512	
					1524	
					1536	
					1548	
				not	1560	
				readable	1572	
					1584	
					1596	
					1608	
					1620	
				not	1632	
				readable	1644	
					1656	
					1668	
					1680	
					1692	
					1704	

Figure 5. Graphic depicting the pattern of annual bands and fire scars on three grasstrees (plant 1-3) near Hovea Falls, John Forrest NP. Multiple stems within a single grasstree have been combined, by averaging distances between fire scars, to form a notional single stem. Each cell represents a single year's growth based on the average growth rate of each plant and assuming constant annual growth. Fire scars are coloured black. Estimated year of growth (left) and estimated date of each past fire (right) have been determined by counting backwards from the date of measurement.