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## Longevity of the Brazilian underground tree *Jacaranda decurrens* Cham.

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### ABSTRACT

Underground trees are a rare clonal growth form. In this survey we describe the branching pattern and estimate the age of the underground tree *Jacaranda decurrens* Cham. (Bignoniaceae), an endangered species from the Brazilian Cerrado, with a crown diameter of 22 meters. The mean age calculated for the individual was 3,801 years, making it one of the oldest known living Neotropical plants.

**Key words:** Bignoniaceae, cerrado, campo rupestre, longevity, underground trees.

### INTRODUCTION

The highest longevity estimates have been attributed to clonal plants, and their maximum age estimates indicate the slowest possible genet turnover rate in a population (de Witte and Stöcklin 2010). These estimates are an important assessment of the longevity of populations and can partly help indicate the stability of plant communities and ecosystem resilience (Steinger et al. 1996, Eriksson 2000, Körner 2003, Morris et al. 2008). Most reports on high plant longevity are from temperate climates in Northern Hemisphere. From South America, Lara and Villalba (1993) reported an individual of *Fitzroya cupressoides* (Mol.) Johnst. (Cupressaceae) with an age of 3,622 years from Chile, while in Brazil, Alves (1994) calculated 551 years for a 3m tall individual of *Vellozia kolbekii* R.J.V. Alves (Velloziaceae). One of the highest

age estimates (43,600 y) was attributed to a genet (not a single individual) of *Lomatia tasmanica* (Proteaceae) by Lynch et al. (1998).

In the Brazilian *Cerrado* biome, underground trees are a rare clonal growth form known for over a century (Lund 1835, Liais 1872, Warming 1892, Rawitscher et al. 1943). To date, this growth form has not been studied in *campo rupestre*, a peculiar open vegetation associated with quartzite outcrops in northeastern and southeastern Brazil.

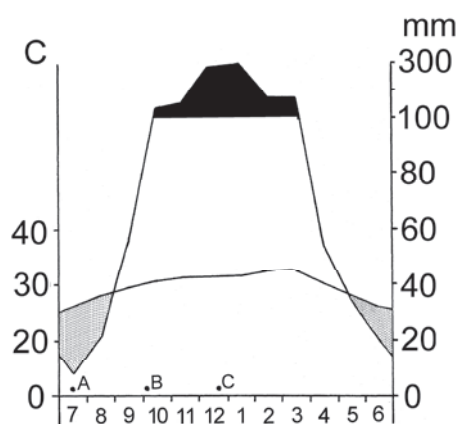
We estimated the age of a large individual of *Jacaranda decurrens* Cham. (Bignoniaceae), an endangered species restricted to the Brazilian Cerrado (Varanda et al. 1992, Mauro et al. 2007), which forms an underground tree in the study area.

### METHODS

The study area is in the Ouro Grosso range, county of Itutinga, Minas Gerais State, Brazil, (Lat. 21°18.487' S, Long. 44° 38.987' W, Alt.

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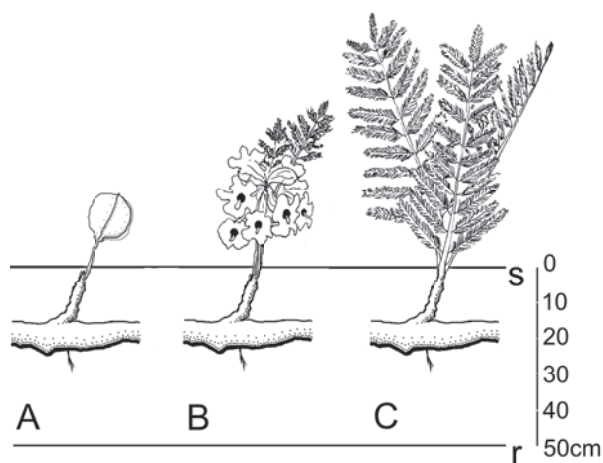
974m asl.). Monthly precipitation of <60 mm occurs in the study area from April to August (Fig. 1). There, underground trees grow in shallow white sand deposits associated with low Precambrian quartzite outcrops. The local climate has mild, arid winters and rainy summers, with an annual precipitation exceeding 1,600 mm. The sand deposits are overgrown by *campo rupestre* vegetation, with communities dominated by *Vellozia crinita* Goethart & Henrard where soil is shallow (Alves and Kolbek 2009), and underground tree vegetation where soil depth exceeds 1 m. In the study area, several species from unrelated plant families form underground trees (R.J.V. Alves and N.G. Silva, unpublished data), among which *Jacaranda decurrens* stands out by large, almost perfectly circular crowns which clearly correspond to single individuals or genets.



**Figure 1** - Climate diagram of São João Del Rei, 50 km N of the study area. Points A, B and C correspond to phenological phases described in Fig. 2.

*Jacaranda decurrens* is an obligate geophyte with small seasonal aerial branches growing from woody underground systems. The underground systems described by Rawitscher and Rachid (1946) were monopodial xylopodia with expressive secondary thickening. In contrast, the population studied herein exhibits horizontally spreading (sympodial) underground systems composed mainly by soboles. Aerial branches are less than 10

cm tall, seasonal, erect woody stems. At the end of the dry season, follicles open shedding seeds and the aerial branches die (Fig. 2 A). Subsequently rosettes of fernlike leaves emerge, congested at the apices of new branches, and panicles bearing ca. 10-20 flowers with tubulose violet corollas are borne on new aerial branches (Fig. 2 B). After flowering, the leaves grow to 50 cm length and last up to the end of the rainy season (Fig. 2 C).



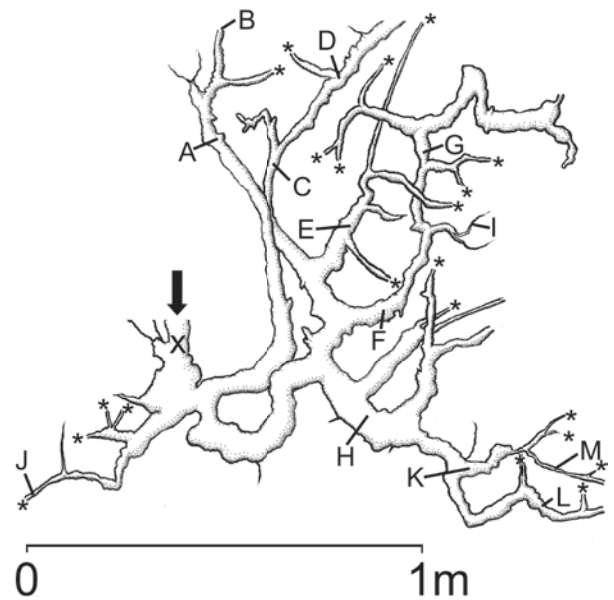
**Figure 2** - Schematic lateral view of sobole segment and aerial branch during phenological stages in underground trees of *Jacaranda decurrens*. A: Follicle ready to shed seed at the end of the arid season; B: Panicle and young leaf rosette during the early rainy season; C: Developed leaf rosette during vegetative season; s: soil level; r: bedrock. R. J. V. Alves, del.

In order to estimate longevity, we selected the largest circular genet of *J. decurrens* which did not intermingle with neighboring underground trees of the same species. Between 1989 and 2010 we excavated small portions of 15 circular genets in order to verify if above-ground ramets belonged to the same individual. In all cases the excavated parts were connected. We thus inferred that the selected genet was indeed a single individual.

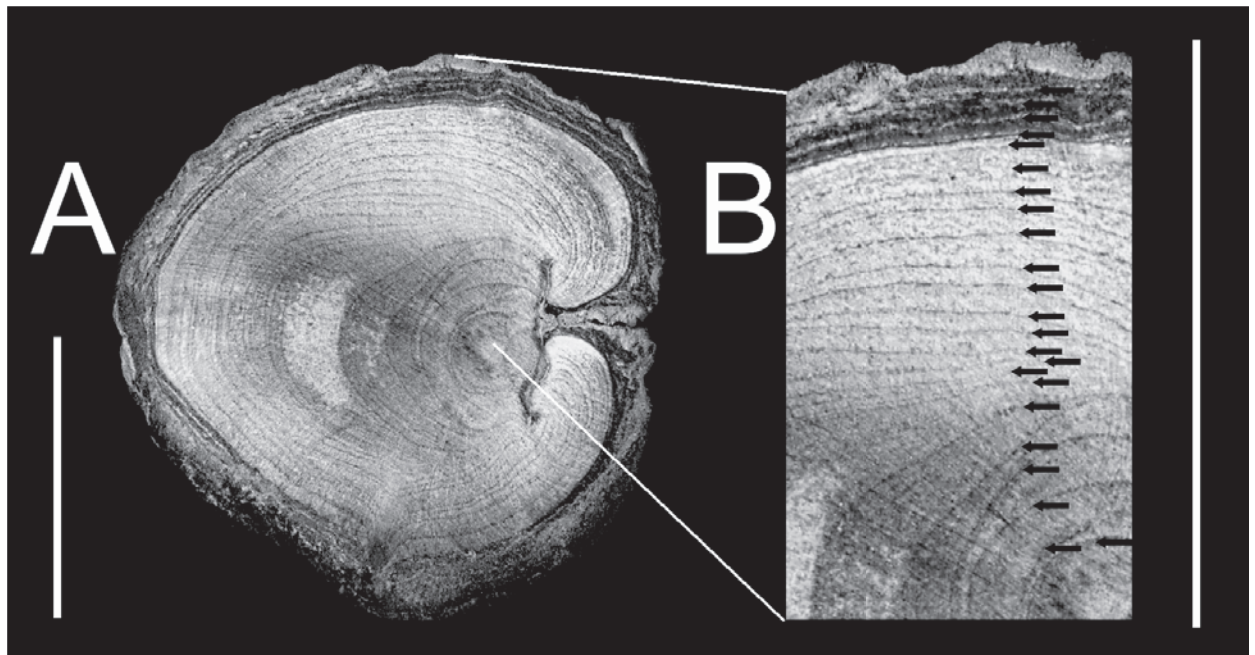
As the local climate has well defined dry and wet seasons, we assumed that sobole growth rings are annual.

To measure the underground growth rate, we cut five randomly selected peripheral ramets and

correlated their lengths (distances to apices) with the numbers of growth rings (Fig. 3, Fig. 4). In order to estimate genet age, using the annual diameter increment of the genet, we used the mean value of growth ring counts along 4 rays on each ramet segment. Next we excavated a peripheral ramet spanning over 1,5 m measured from the center toward the periphery of the crown. From the point of origin (Fig. 3:X) we marked points on the ramet, with distances of 0.5, 0.75 and 1.0m from X. We then measured the true ramet length, accompanying all curves, u-turns, etc., from point X to each selected point (Fig. 3: A-M). Thus, we correlated the mean annual growth rate of ramets to the annual distances they reached from the point of origin (increments in crown radius) (Table I). The age of the studied individual of *J. decurrens* was calculated by extrapolating the growth rate (assumed constant) to the crown radius. This procedure combined morphological and growth ring analyses (viz. Legère and Payette 1981, Suvanto and Latva-Karjanmaa 2005, de Witte and Stöcklin 2010).



**Figure 3** - Excavated ramet of *Jacaranda decurrens* used for growth rate measurements (Redrawn from photograph; December 2010). Arrow - Point of attachment of the ramet to the individual; X - Origin point of measurements; A-M: points of measurement; Asterisks - Points originating live aerial branches at sampling time. R. J. V. Alves, del.



**Figure 4** - Transversal section of sobole of *Jacaranda decurrens*. A: Entire section; B: selected segment. Growth rings are delimited by arrows. Scale bars = 10mm. (December 2010).

TABLE I

Estimates of growth rate and age of the studied genet based on ramet length per meter. Minimum, maximum and mean values are in bold. Segments as in Fig. 1.

segment	ramet length (cm) per meter of genet radius	years/m	Age (y)
X-A	246	362	3,982
X-B	215	317	3,484
X-C	331	486	5,351
X-D	267	392	4,314
X-E	<b>280</b>	<b>412</b>	<b>4,529</b>
X-F	238	351	3,857
X-G	236	347	3,816
X-H	235	346	3,808
X-I	237	348	3,833
X-J	<b>162</b>	<b>238</b>	<b>2,613</b>
X-K	211	311	3,418
X-L	199	293	3,223
X-M	197	290	3,186
Mean	<b>235</b>	<b>218</b>	<b>3,801</b>

## RESULTS

In the *campo rupestre* studied herein, *J. decurrens* forms underground trees with horizontally spreading primary soboles, 5-50cm below the surface, with secondary branches diverging upward and seasonally emerging at relatively regular intervals. The largest genet of *J. decurrens* had a circular crown 22m in diameter, occupying 380m<sup>2</sup>. No renewal buds were observed aboveground. Several other sympatric species of subterranean tree grow together with *J. decurrens* (Fig. 5).

In order to reach a distance of 1 m from the point of origin, branches span a mean distance of 234cm (162-331cm). All randomly excavated ramets were interconnected and integrated a chaotic growth pattern, changing directions frequently, performing loops, right angles, u-turns etc. (e.g. Fig. 3).

Samples of ramets with a mean length of 22cm had a mean of 33 growth rings (Table II). The mean yearly length increment of ramets based on these measurements is 0.68cm, which represents a mean

annual increment of the genet radius by 0.29cm. Assuming that the studied individual had an even radial growth, the mean age of the individual is ca. 3,801y, with a standard deviation of 61.6y (Table I).

TABLE II

Current growth rate estimate for ramets of the studied genet.

Ramet	A	B	C	D	E	mean
Ramet length (cm)	22.5	19	27	18.5	25.5	22.5
Mean no. of growth rings	32	30	41	29	33	33
growth rate cm/y	<b>0.70</b>	<b>0.63</b>	<b>0.66</b>	<b>0.64</b>	<b>0.77</b>	<b>0.68</b>

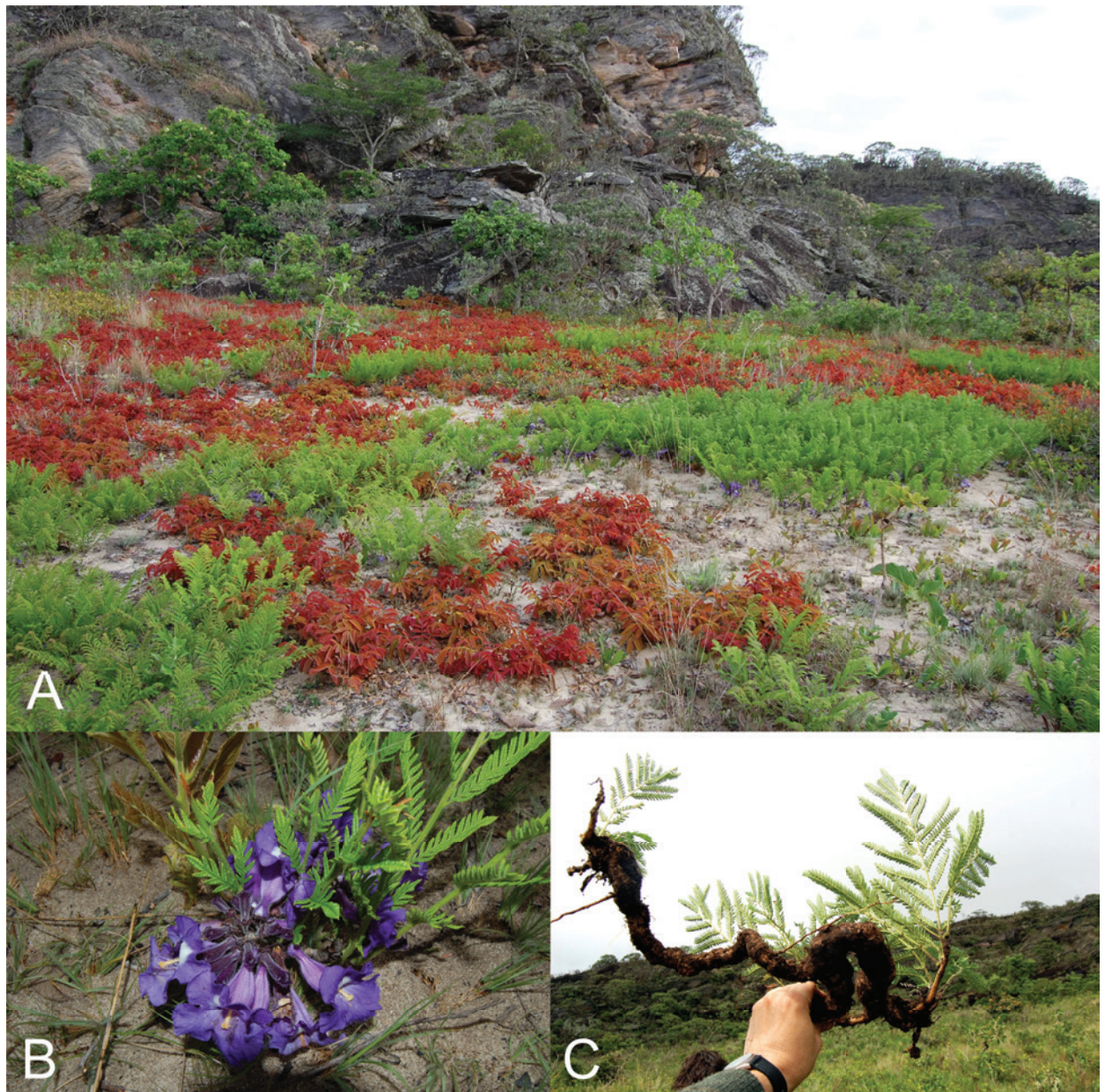
## DISCUSSION

In the tropics, seasonal droughts or floods have been cited as responsible for annual growth ring formation (Jacoby 1989). Monthly precipitation of <60 mm usually induces cambial dormancy and the consequent formation of annual growth rings in tropical trees (Worbes 1995). The seasonal climate with five arid months in the study area may be responsible for the growth rings found in *Jacaranda decurrens*, but further field and wood anatomy studies shall be necessary to demonstrate this.

Underground trees are very rare and a more precise dating does not justify the destructive digging up of an entire millenary individual. The conservative age estimate of 3,801 y for *Jacaranda decurrens* herein suggests that this is one of the oldest living Neotropical clonal plants recorded so far. As *J. decurrens* is used in popular medicine (Bertoni et al. 2006, Carvalho et al. 2009), the slow growth rate makes this species endangered by overexploitation.

For clonal plants and colonies, ages are usually estimated based on current growth rates, area and even on the somatic mutation rate of distinct genets (Ally et al. 2008, de Witte and Stöcklin 2010). Hence, direct measurements systematically





**Figure 5** - A: Entangled crowns of sympatric underground trees: *Jacaranda decurrens* (with light green leaves) and *Andira humilis* Mart. ex Benth. (Fabaceae, with red/orange leaves). Serra do Ouro Grosso near Itutinga, Minas Gerais, October 2009. B: Flowering ramet with young leaves. C: Detail of underground sobole.

underestimate the longevity of clonal plants, and a clonal colony can survive for much longer than an individual tree (de Witte and Stöcklin 2010). The chaotic changes of sobole direction in the diffuse underground system of *Jacaranda decurrens* are probably due to the lack of light and to soil characteristics. This means that the radial growth

of the genet is much slower than the annual length increment of ramets. Thus the ramets may be growing in circular cycles for millennia, and the studied genet could be much older than estimated herein. Extrapolation and modeling can also be used, especially in cases when clonal colonies break up into genets (de Witte et al. 2011).

In that sense our age estimate is rather of the minimum longevity of the living parts of the genet, and not the maximum age of the individual as postulated by de Witte and Stöcklin (2010).

In distinct habitat conditions, the same species may develop distinct life forms. For instance, in cerrado vegetation, Rawitscher and Rachid (1946, Fig. 2) registered *J. decurrens* with a vertical xylopodium, illustrating the apices of woody branches with renewal buds slightly aboveground arising from a half-emersed woody disc, making it a chamaephyte, a life form which the authors attempted to compare to *Welwitschia*. Some underground trees have a persistent initial taproot, but this may disappear with age, leaving only the diffuse systems (Rizzini and Heringer 1966). López-Naranjo and Pernia (1990) found a buried central trunk in *Anacardium humile* A. St.-Hil. but they did not detect growth rings.

The crown diameter of underground trees probably varies with the soil and climate types as well as with age. As the relationship between size and age is not always linear in clonal plants, estimating their age may not be very precise (de Witte and Stöcklin 2010), but it has been used with some success (e.g. Vasek 1980, Steinger et al. 1996, Reusch et al. 1998, Wesche et al. 2005). With an estimated 0.8 - 1My, a clonal colony of *Populus tremuloides* Michx., covering 43 ha in the Fishlake National Forest of the United States, is considered one of the oldest and largest organisms in the world (Mitton and Grant 1996).

Longevity is usually studied in upright trees, by dendrochronological methods such as counting tree rings and C<sub>14</sub> dating (de Witte and Stöcklin 2010). So far the oldest known living trees recorded are a 9,550y old *Picea abies* (L.) H. Karst. from Sweden (Kullman 2008, Owen 2008), and in the White Mountains of California, individuals of *Pinus longaeva* D. K. Bailey were dated as having 4,900y and 4,723y (Schulman 1958, Lanner 2007, Straka 2008).

Longevity has also been estimated by other methods for some non-tree life forms. C<sub>14</sub> dating showed *Welwitschia mirabilis* Hook. f. (Welwitschiaceae) from the Namib Desert can live 2,000y (Cooper-Driver 1994, Kellenberger et al. 2009). Some *Xanthorrhoeaceae* in Australia exceed 500y according to the count of constrictions on the stems performed by Lamont and Downes (1979), and some shrubby *Velloziaceae* from Brazil were found to have over 500y using a morphological study of inflorescence scars on the stem (Alves 1994).

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#### RESUMO

Árvores subterrâneas são uma forma rara de crescimento clonal. Neste estudo descrevemos o padrão de ramificação e estimamos a idade da árvore subterrânea *Jacaranda decurrens* Cham. (Bignoniaceae), uma espécie ameaçada do Cerrado Brasileiro, com um diâmetro de “copa” 22 metros. A idade média calculada para o indivíduo foi de 3.801 anos, o que o torna uma das mais longevas plantas Neotropicais.

**Palavras-chave:** Bignoniaceae, cerrado, campo rupestre, longevidade, árvores. subterrâneas.

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