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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.

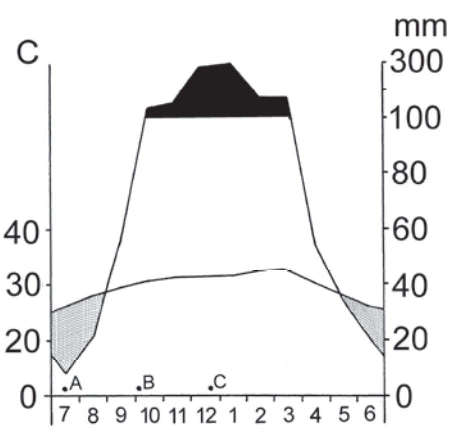

Figure 1 - Climate diagram of São João Del Rei, 50 km N of the study area. Points **A**, **B** and **C** correspond to phenological phases described in Fig. 2.

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. Areial 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 tubulous 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).

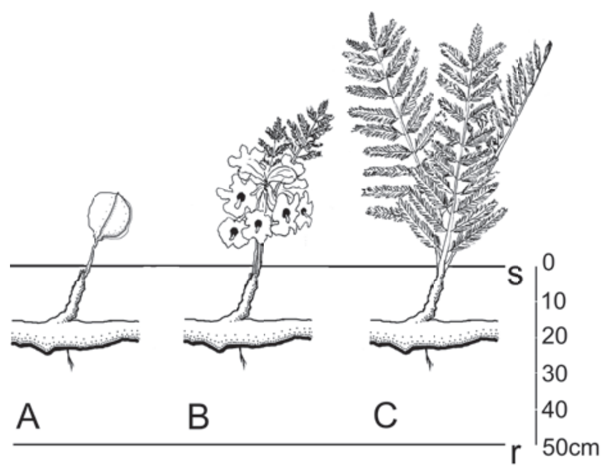

Figure 2 - Schematic lateral view of sobole segment and aerial branch during phenological stages in underground trees of *Jacaranda decurrens*. **A**: Follicle ready to shed seed at the end of the arid season; **B**: Panicle and young leaf rosette during the early rainy season; **C**: Developped leaf 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).

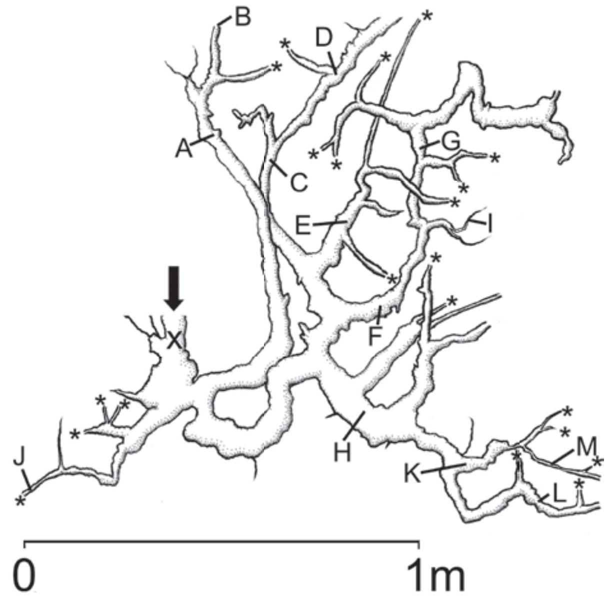

Figure 3 - Excavated ramet of *Jacaranda decurrens* used for growth rate measurements (Redrawn from photograph; December 2010). Arrow - Point of attachment of the ramet to the individual; **X** - Origin point of measurements; **A**-**M**: points of measurement; Asterisks - Points originating live aerial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

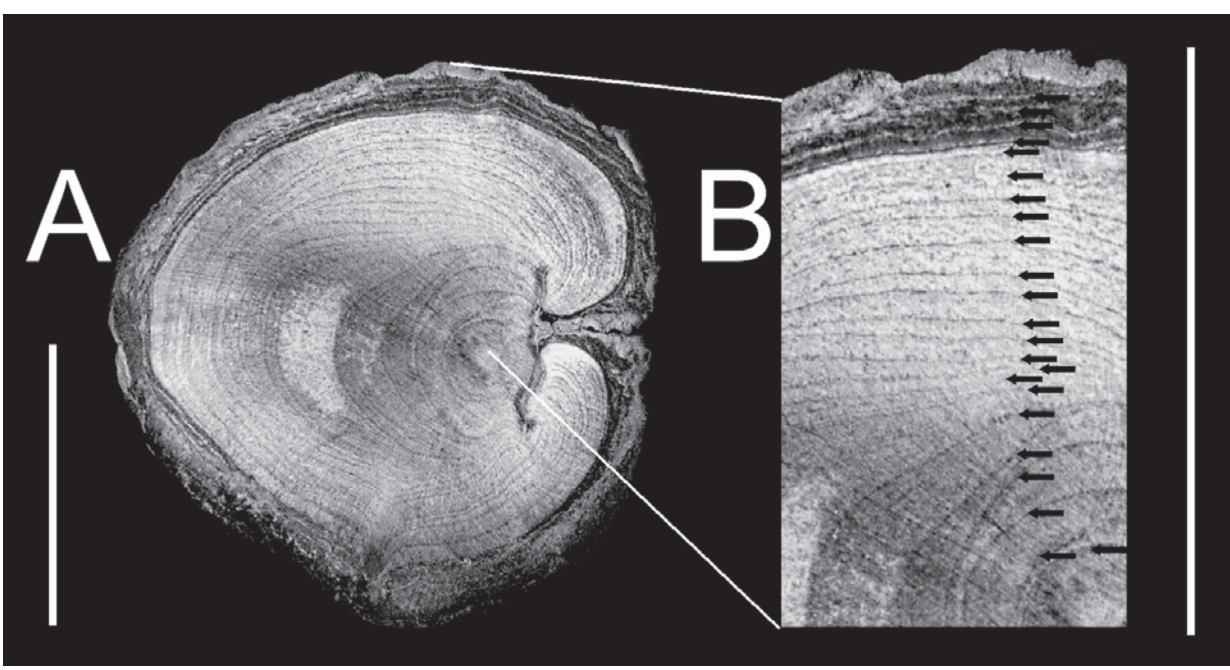

Figure 4 - Transversal section of sobole of *Jacaranda decurrens*. **A**: Entire section; **B**: selected segment. Growth rings are delimited by arrows. Scale bars = 10mm. (December 2010).

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	**280**	**412**	**4,529**
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	**162**	**238**	**2,613**
X-K	211	311	3,418
X-L	199	293	3,223
X-M	197	290	3,186
Mean	**235**	**218**	**3,801**

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^2. 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	**0.70**	**0.63**	**0.66**	**0.64**	**0.77**	**0.68**

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

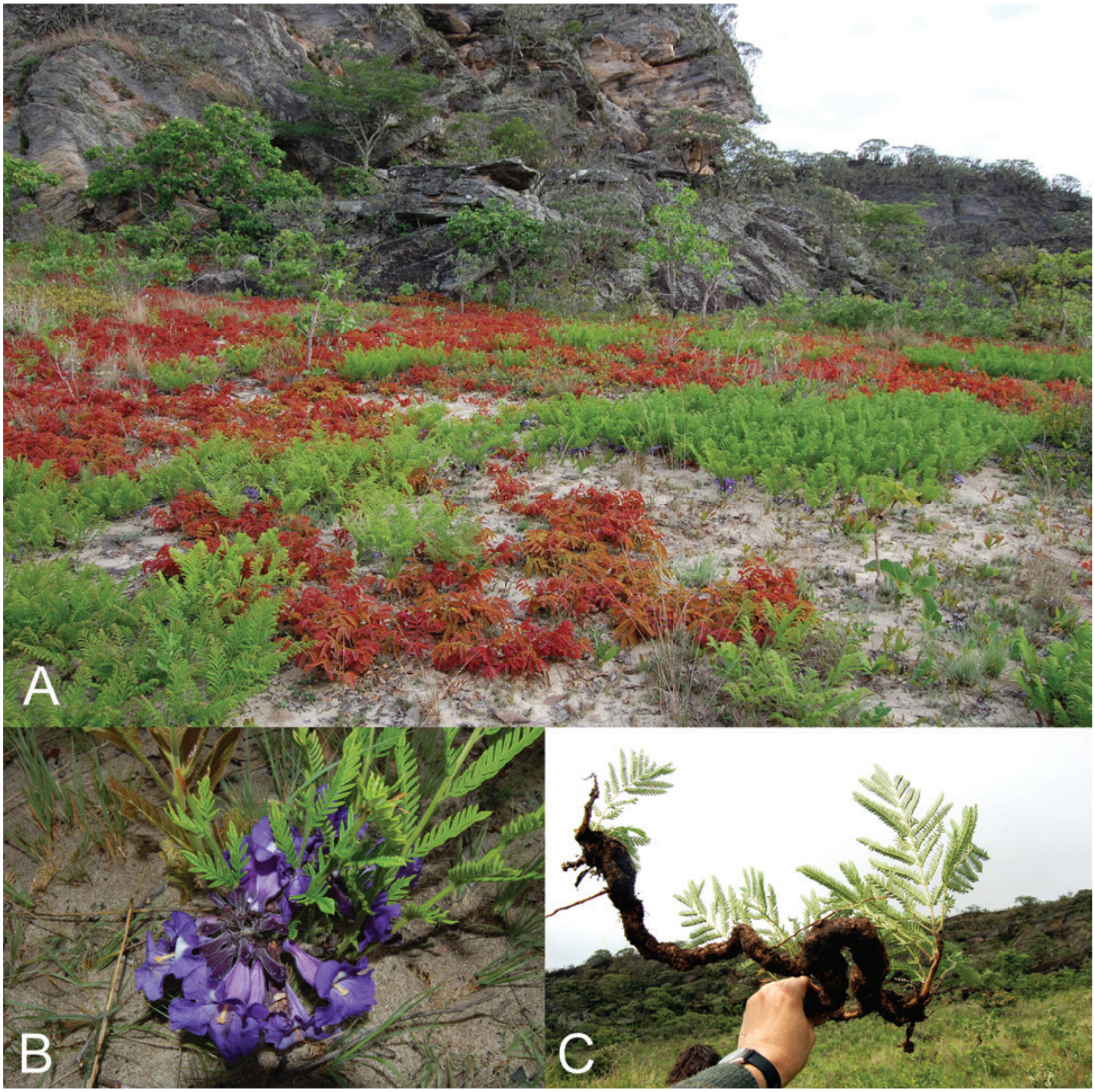

Figure 5 - A: Entangled crowns of sympatric underground trees: Jacaranda decurrens (with light green leaves) and Andira humilis Mart. ex Benth. (Fabaceae, with red/orange leaves). Serra do Ouro Grosso near Itutinga, Minas Gerais, October 2009. **B**: Flowering ramet with young leaves. **C**: Detail of 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 Stőcklin (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_{14} 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_{14} 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 Nepotropicais.

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

REFERENCES

Ally D, Ritland K and Otto SP. 2008. Can clone size serve as a proxy for clone age? An exploration using microsatellite divergence in *Populus tremuloides*. Mol Ecol 17: 4897-4911.

Alves RJV. 1994. Morphological age determination and longevity in some *Vellozia* populations in Brazil. Folia Geobot Phyto 29: 55-59.

Alves RJV and Kolbek J. 2009. Vegetation strategy of *Vellozia crinita* (Velloziaceae). Biologia 65: 254-264.

Bertoni BW, Telles PC, Malosso MG, Torres SCZ, Pereira JO, Carrim AJI, Barbosa EC and Vieira JDG. 2006. Enzymatic Activity of Endophytic Bacterial Isolates of *Jacaranda decurrens* Cham. (Carobinha-do-campo). Braz Archives of Biol and Technol 49: 353-359.

Carvalho CA, Lourenço MV, Bertoni BW, França SC, Pereira PS, Fachin AL and Pereira AMS. 2009. Atividade antioxidante de *Jacaranda decurrens* Cham., Bignoniaceae. Rev Bras Farmacogn 19: 592-598.

Cooper-Driver GA. 1994. *Welwitschia mirabilis* - a dream come true. Arnoldia (summer): 1-10.

De Witte LC, Scherrer D and Stöcklin J. 2011. Genet longevity and population age structure of the clonal pioneer species *Geum reptans* based on demographic field data and projection matrix modelling. Preslia 83: 371-386.

De Witte LC and Stöcklin J. 2010. Longevity of clonal plants: why it matters and how to measure it. Ann Bot 106: 859-870.

Eriksson O. 2000. Functional roles of remnant plant populations in communities and ecosystems. Global Ecol Biogeogr 9: 443-449.

Jacoby GC. 1989. Overview of tree-ring analysis in tropical regions. IAWA Bull 10: 99-108.

Kellenberger R, Kneubuhler M and Kellenberger T. 2009. Spectral characterisation and mapping of *Welwitschia mirabilis* in Namibia. Geoscience and Remote Sensing Symposium, IEEE Int 4: 362-365.

Körner C. 2003. Alpine plant life: functional plant ecology of high mountain ecosystems. Berlin: Springer-Verlag, 344 p.

Kullman L. 2008. Early postglacial appearance of tree species in northern Scandinavia: review and perspective. Quat Sci Rev 27: 2467-2472.

Lamont BB and Downes S. 1979. The longevity, flowering and fire history of the grass trees *Xanthorrhoea preissii* and *Kingia australis*. J Appl Ecol 16: 893-899.

Lanner RM. 2007. The Bristlecone Pine Book: A Natural History of the World's Oldest Trees. Missoula: Mountain Press Publishing Company, 118 p.

Lara A and Villalba R. 1993. A 3620-year reconstruction of temperature from *Fitzroya cupressoides* tree rings in southern South America. Science 260: 1104-1106.

Legère A and Payette S. 1981. Ecology of a black spruce (*Picea mariana*) clonal population in the hemiarctic zone, northern Quebec - population dynamics and spatial development. Arctic Alpine Res 3: 261-276.

Liais E. 1872. Climats, Géologie, Faune et Géographie Botanique du Brésil. Paris: Garnier Frères, 658 p.

López-Naranjo HJ and Pernia NE. 1990. Anatomia y ecologia de los organos subterraneos de *Anacardium humile* A. St.-Hil. (Anacardiaceae). Rev Forest Venez 24: 55-76.

Lund PW. 1835. Bemaerkinger over vegetationen paa de indre Hojsletter af Brasilien, isaer i plantehistorisk Henseende. Kgl Danske Videnskab Selsk Skrifter 6: 145.

Lynch AJJ, Barnes RW, Cambecèdes J and Vaillancourt RE. 1998. Genetic Evidence that *Lomatia tasmanica* (Proteaceae) is an Ancient Clone. Aust J Bot 46: 25-33.

Mauro C, Pereira AMS, Silva CP, Missima J, Ohnuki T and Rinaldi RB. 2007. Estudo anatômico das espécies de cerrado *Anemopaegma arvense* (Vell.) Stellf. ex de Souza (catuaba), *Zeyheria montana* Mart. (bolsa-de-pastor) e *Jacaranda decurrens* Chamisso (caroba) - Bignoniaceae. Rev Bras Farmocogn 17: 262-265.

Mitton JB and Grant MC. 1996. Genetic Variation and the Natural History of Quaking Aspen. BioScience 46: 25-31.

Morris WF, Pfister CA and Tuljapurkar S. 2008. Longevity can buffer plant and animal populations against changing climatic variability. Ecology 89: 19-25.

Owen J. 2008. Oldest living tree found in Sweden. Natl Geogr News, April 14.

Rawitscher FK, Ferri MG and Rachid M. 1943. Profundidade dos solos e vegetação em campos cerrados do Brasil Meridional. An Acad Bras Cienc 15: 267-294.

Rawitscher FK and Rachid M. 1946. Troncos subterrâneos de plantas brasileiras. An Acad Bras Cienc 18: 261-280.

Reusch TBH, Stam WT and Olsen JL. 1998. Size and estimated age of genets in eelgrass, *Zostera marina*, assessed with microsatellite markers. Mar Biol 133: 519-525.

Rizzini CT and Heringer EP. 1966. Estudo sôbre os ecossistemas subterrâneos difusos de plantas campestres. An Acad Bras Cienc 38: 85-112.

Schulman E. 1958. "Bristlecone Pine, Oldest Known Living Thing." Nat Geogr 113: 354-372.

Steinger T, Körner C and Schmid B. 1996. Long-term persistence in a changing climate: DNA analysis suggests very old ages of clones of alpine *Carex curvula*. Oecologia 105: 94-99.

Straka TJ. 2008. Biographical Portrait: Edmund P. Schulman (1908-1958). Forest Hist Today (spring): 46-49.

Suvanto LI and Latva-Karjanmaa TB. 2005. Clone identification and clonal structure of the European aspen (*Populus tremula*). Mol Ecol 14: 2851-2860.

Varanda EM, Zuniga GE, Salatino A, Roque NF and Corcuera LJ. 1992. Effect of ursolic acid from epicular waxes of *Jacaranda decurrens* on *Schizaphis graminum*. J Nat Prod 55: 800-803.

Vasek FC. 1980. Creosote bush - long-lived clones in the Mojave desert. Am J Bot 67: 246-255.

Warming E. 1892. Lagoa Santa. Contribuição para a Geographia Phytobiológica. Portuguese transl. By E. Löfgren. Belo Horizonte. Minas Gerais: Imprensa Oficial do Estado de Minas Gerais, 282 p.

Wesche K, Ronnenberg K and Hensen I. 2005. Lack of sexual reproduction within mountain steppe populations of the clonal shrub *Juniperus sabina* L. in semi-arid southern Mongolia. J Arid Env 63: 390-405.

Worbes M. 1995. How to measure growth dynamics in tropical trees - a review. IAWA J 16: 337-351.