South African Journal of Botany 2003, 69(3): 428–433
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SOUTH AFRICAN JOURNAL
OF BOTANY
ISSN 0254–6299

A dendrochronological assessment of two South African *Widdringtonia* species

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Received 9 October 2002, accepted in revised form 6 May 2003

In southern Africa long-term regional rainfall data sets are very limited such that the variability of rainfall across the region is poorly understood. With available climate records so limited the development of strong proxy records are vital to develop drought management plans. In our continuing efforts to develop such proxy records we present the results of an investigation into the dendrochronological potential of *Widdringtonia nodiflora* and *Widdringtonia schwarzii*. We sampled *W. schwarzii,* from the area it is endemic to, the Baviaanskloof wilderness area, in the Langkloof region of the Eastern Cape Province. *Widdringtonia nodiflora* samples were collected from the Grootvadersbosch Nature Reserve near Heidelberg in the Western Cape Province. The results indicate that inconsistencies in ring width combined with poorly defined ring boundaries and converging rings make cross-dating between different trees from the same locality an impossible task for both species using manageable sample numbers. Without cross-dating, chronology development is an equally impossible task for both *W. nodiflora* and *W. schwarzii*. As with *W. cedarbergensis, W. schwarzii* may avoid drought stress by accessing deep water. This may explain the many false rings and poorly defined ring boundaries apparent in this species. This study concludes the dendrochronological assessment of all of the *Widdringtonia* species with only two South African conifers not evaluated (*Podocarpus henkelii* and *P. elongatus*). *Widdringtonia cedarbergensis* is the only South African conifer that has been successfully cross-dated, however, there are no significant correlations between ring width indices and climate variables for this species.

Introduction

Southern Africa is home to over 150 million people of whom more than 60% derive their livelihoods from agriculture. The socio-economic consequences of droughts on these communities, often farming in marginal rainfall areas, are enormous. In this regard the El Nino/Southern Oscillation (ENSO) has been the cause of severe regional droughts at least four times in the last fifteen years. Despite government awareness of the consequences of these droughts, forward planning is seriously hampered by a lack of regional rainfall data sets covering the last 100 years (Tyson 1986). These limited regional climate records inhibit the definition of future climate ranges and more accurate drought management and planning.

For much of the Northern Hemisphere, dendrochronological techniques allow access to good climate records, often going back many thousands of years. AE Douglas initially developed dendrochronology as a science in the southwestern United States of America (Fritts 1976). His research on Ponderosa pine, a conifer, influenced subsequent dendrochronological studies on similar species. Within South Africa there are no indigenous *Pinus* species, however, there are two coniferous genera i.e. three *Widdringtonia* species and four *Podocarpus* species. The influence of AE Douglas directed our initial dendrochronological research to focus on these seven species with evaluations of two *Podocarpus* species (*P. falcatus* and *P. latifolius*) and one *Widdringtonia* species (*W. cedarbergensis*) thus far being completed (Curtis *et al.* 1978, Dunwiddie and La Marche 1980, February and Stock 1998a, 1998b).

The basic principle of dendrochronology, as the name suggests, involves building time series from the annual rings of trees. These time series must be datable to a specific year (one ring per year). Variations in the width of rings, consistent within a tree and between trees from across an, often broad, geographical area, form the basis for cross-dating (Fritts 1967, 1976). Once cross-dated, the ring widths of a number of trees from the same locality are measured and combined to form a chronological series. It is this chronology that is ultimately correlated with regional climate records to form the basis for climate reconstruction from tree rings.

The methods for developing good quality climate reconstructions from South African trees are well documented on a number of species (Curtis *et al*. 1978, February and Stock 1998b). Of all the species thus far evaluated *W. cedarbergensis* currently provides the only two well-dated ring width index chronologies for South Africa (Dunwiddie and La Marche 1980, February and Stock 1998a). These chronologies, however, have not correlated with rainfall or temperature sufficiently to reconstruct climate through time (Zucchini and Hiemstra 1983, February and Stock 1998b). As a result the application of dendrochronology as an important tool in developing regional climate reconstructions for South Africa is still an elusive goal. Of the seven South African conifers, two *Widdringtonia* species (*W*. *schwarzii* and *W. nodiflora*) and two *Podocarpus* species (*P*. *henkelii* and *P. elongatus*) have not previously been evaluated for dendrochronology. This paper presents results from an investigation into the dendrochronological and dendroclimatological potential of *W. schwarzii* and *W. nodiflora* to conclude an evaluation of all of the South African *Widdringtonia* species.

Methods

Fifteen whole-trunk cross sections of *W. nodiflora* were obtained from the Grootvadersbosch Nature Reserve between Swellendam and Heidelberg in the Western Cape Province of South Africa. Nutrient poor sands, composed primarily of quartz arenite (sandstones) of the Table Mountain Group (Tankard *et al.* 1982), dominate the geology of this reserve. The reserve lies in the transition zone between winter and all year rainfall regions with a mean annual rainfall of approximately 1 050mm. Mean monthly maximum of the hottest and coldest months are 38°C and 27°C respectively, frost is common at higher elevations during winter. The predominant vegetation is mesic mountain fynbos, a sclerophyllous vegetation type dominated by proteoid and ericoid elements, but characterised by restioids (Moll and Jarman 1984, Taylor 1996). Typically, *W. nodiflora* trees grow in the fynbos to which fires are endemic and a keystone process with a return interval of around 15 to 20 years (Cowling and Richardson 1995). *W. nodiflora*, a resprouter, is killed by fire, as a result the trees used for this study had all been top-killed by a fire in May 1995 (Pauw and Linder 1997).

Sampling for *W. schwarzii* was carried out at Diepkloof in the Baviaanskloof Nature Reserve, Eastern Cape Province. We removed disks from three dead trees and took two 13mm diameter cores from each of a further seven living trees. The geology of this area is dominated by extremely steep sided quartz arenite kloofs. The primary vegetation is xeric mountain fynbos (Moll and Jarman 1984, Taylor 1996). *W. schwarzii* is a long lived re-seeder that typically grows in cracks in the exposed cliff faces on the steeper sides of the kloof or in the stream bed at the bottom of the kloof. As the trees we felled had been killed by fire it is possible that this growth habit is used as protection from the fires inherent to the biome. Mean annual rainfall is low at around 400mm, primarily falling in winter.

All trees from both Baviaanskloof and Grootvadersbosch were felled as close to the ground as possible to derive the maximum possible age from the cross-section. In Diepkloof the cores were taken at breast height, parallel to the slope, and from both sides of each of the living trees. In the laboratory a belt sander (Makita 6” Japan) was used to prepare the surface of the cores and discs for microscopy, using progressively finer grit paper from 60 through 400units. Ages were determined on cross-sections by carefully tracing the circumference of each ring using a Wild M3C (Germany) microscope (Curtis *et al.* 1978). Ages of the cores were determined through cross-dating and finally measuring prior to using the program COFECHA to verify the cross-dating (Holmes 1983). Ring widths were measured with a computer linked Henson incremental measurement machine (Bannister model, America) in conjunction with a Bausch and Lomb (Germany) stereoscopic microscope with cross hairs, normally at 15–30X magnification (Robinson and Evans 1980). Cross-dating following the technique described by Stokes and Smiley (1968) was extremely difficult and not always successful. As a result, a refinement on this technique was adopted, whereby rings were first measured and then, where possible, cross-dating was verified and corrected with the computer program COFECHA.

Results

Although promising in the field, both the *W. schwarzii* and the *W. nodiflora* trees we sampled revealed a similar pattern of unclear ring structures and poorly defined ring boundaries (February and Stock 1998a,1998b). The outermost and innermost rings of the samples are particularly indistinct and all are narrow, poorly defined and uniformly light in colour with little or no late wood (Figures 1 and 2). Patches of what we tentatively term late-wood cells show no reduction in lumen diameter, but rather show a slight discolouration of the cell wall. Rings do not always clearly indicate the end of a growth season between late-wood year t and early-wood year t + 1 by a reduction in lumen diameter and an increase in cell wall thickness (Figure 1).

Typically the *W. schwarzii* specimens show lobate and strip growth as well as false rings, while the *W. nodiflora* specimens have converging rings. In both species, however, clearer rings often grouped together in the middle portion of the disks and in such areas ring width was measurable with relative ease. The earliest and latest growth areas in the disks could not be measured, as the rings are extremely narrow and poorly formed (Figure 2). These particular growth areas often had no late wood, and could not be traced around the circumference of the disk as advocated by Curtis *et al.* (1978). For the same reasons, it was not possible to accurately determine the ages of the *W. schwarzii* trees from the cores. Many of these same problems were also manifest in *W. nodiflora* in that the ages for eight of the fifteen trees used for the study could not be determined because of poor definition and wedging out of the growth rings (Figure 3). Ring counts for the seven trees with the most discernible rings resulted in age estimates of 16 years for the youngest, four trees around 20 years, one around 28 years and one older than 30 years.

It was not possible to cross-date any of the W. *schwarzii* trees collected for this study either between two radii in the

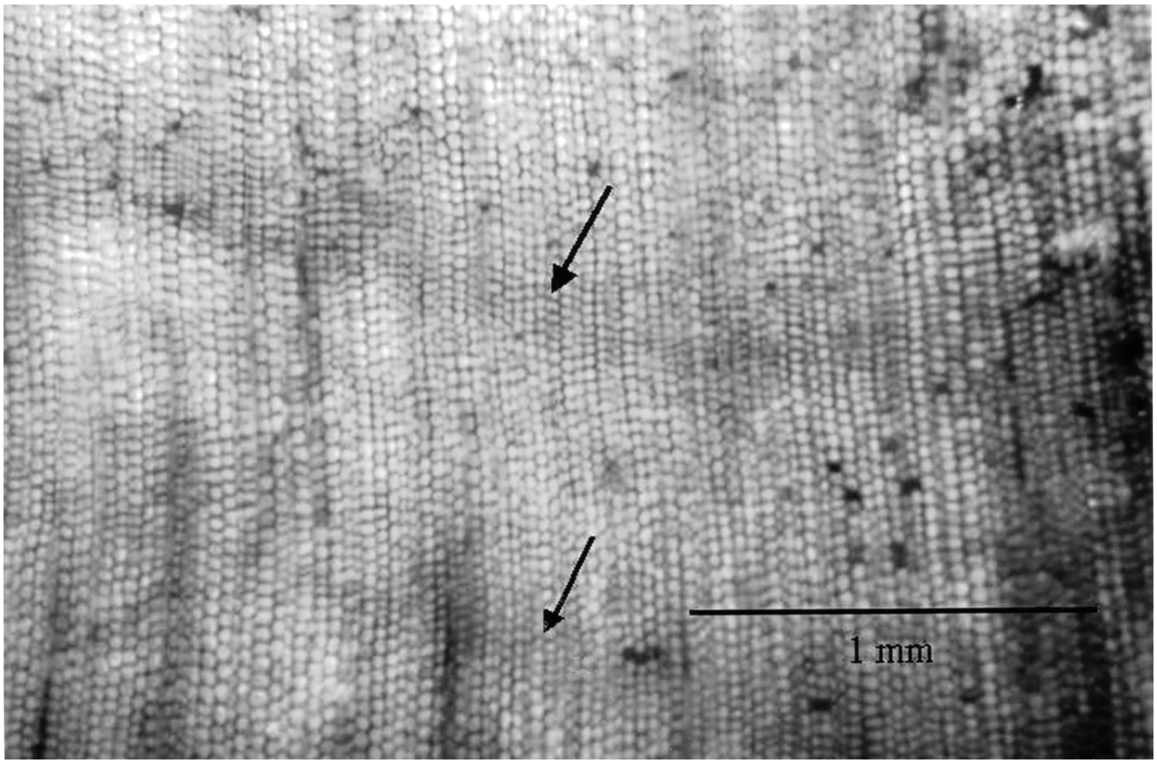

Figure 1: Arrows mark the ring boundaries on a section of *W. schwarzii* illustrating how the late wood cells show no reduction in lumen area but rather a slight discolouration of the cell wall

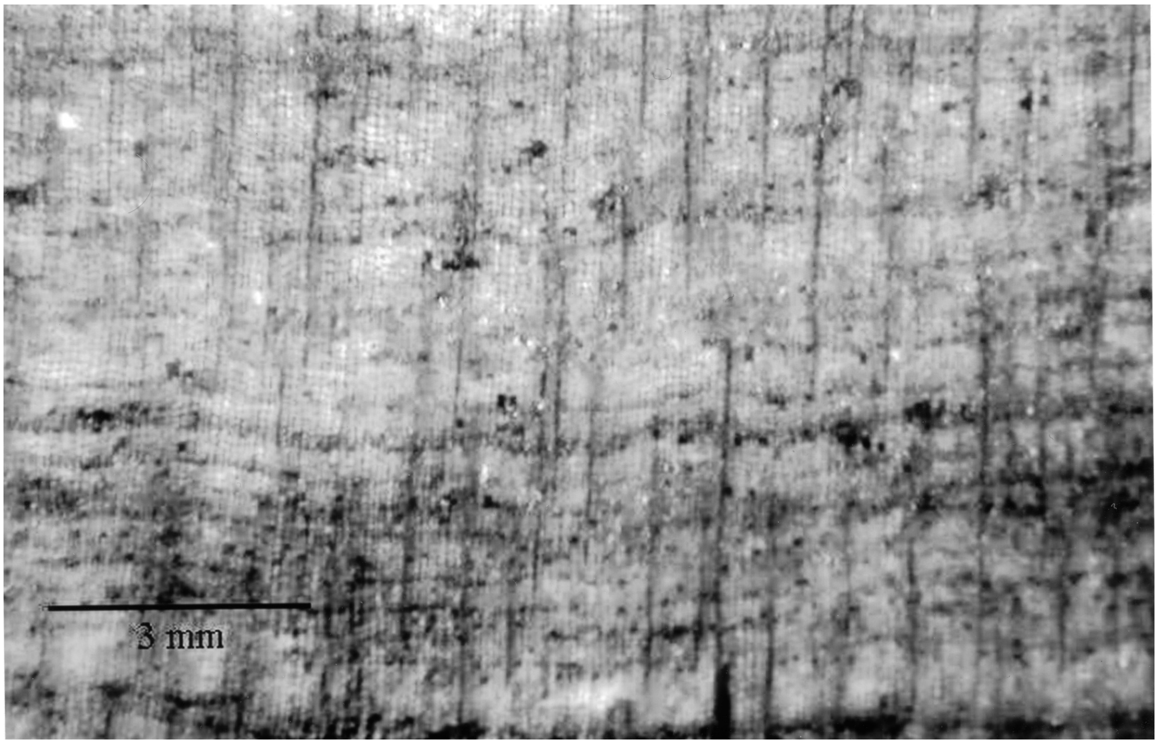

Figure 2: A section of *W. schwarzii* with extremely narrow and poorly formed rings. These rings could not be traced around the circumference of the disk and therefore, could not be measured or counted

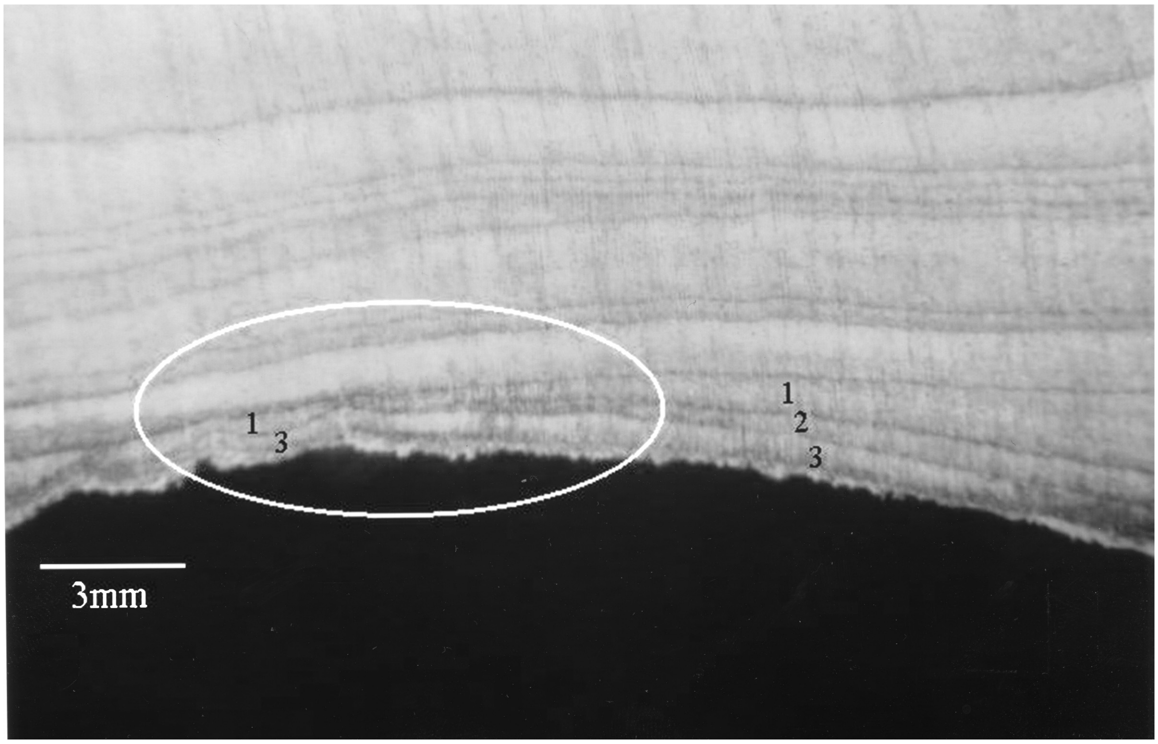

Figure 3: A section of *W. nodiflora* illustrating rings wedging out from left to right

same specimen or between trees from the same location. Using the computer program COFECHA as an aid to cross-dating did not improve results. Of the seven *W. nodiflora* samples with the most discernible rings one disc cross-dated perfectly within itself while the rest showed varying patterns of similarity (Figure 4). While this cross-dating does suggest some promise for the dendrochronological potential of *W. nodiflora* there is absolutely no cross-dating nor are there similar patterns in ring width between trees from the same site.

Discussion

Despite following each individual ring around the circumference of the discs as suggested by Curtis *et al.* (1978) these results suggest that significant correlations in ring width indices for both *W. nodiflora* and *W. schwarzii* are not possible. Precise dating is therefore not possible for either of these two *Widdringtonia* species. The variable results in age estimates for *W. nodiflora* are also interesting in that all of these trees should have re-sprouted at the same time after the previous fire in 1976 and had supposedly been killed by the same fire in May 1995. It would be expected that age determination would be consistent around 19 years as all trees were growing together in the fynbos, yet the ages differ quite considerably (16–35 years). The suggestion is that the older tree survived the previous fire and the youngest sent up a shoot three years later than the rest or the sample was taken high up on the plant thereby losing the three years. This variance within the stand of *W. nodiflora* does suggest that ring counts could be used to determine short-term fire frequencies and temperatures within a particular area and the effects these would have on stand dynamics.

Precise dating, however, is only one aspect of dendrochronological research. The other two aspects are in cross-dating and chronology development (Fritts 1976, Cook and Kairiukstis 1990). Even though one specimen of *W. nodiflora* does cross-date within itself over a period of 16 years (571a and b, Figure 4) these results suggest that inconsistencies in ring width combined with poorly defined ring boundaries and converging rings make cross-dating between different trees from the same locality an impossible task for both species. Without cross-dating, chronology development is an equally impossible task. Without these basic tenets of dendrochronology it is not possible to significantly relate ring width measures to climate for both *W. nodiflora* and *W. schwarzii*.

Research on *W. nodiflora* from Malawi and Zimbabwe resulted in conflicting results with the Malawi sample showing indistinct growth rings unsuitable for dendrochronology whereas the Zimbabwe sample had well-defined rings (Guy 1970, Storry 1975). There are, however, no ring width index chronologies for this species and the Zimbabwean results have yet to be confirmed. Combined with this, *W. nodiflora* on Mulange and in Zimbabwe is a small scrubby tree growing as a resprouter after fire. The larger Widdringtonias in both Zimbabwe and Malawi are now regarded as a separate species, viz. *W. whytei.*

In addition to the problems outlined above, *W. nodiflora* is revealed as being extremely short-lived, only surviving for about 20–30 years between fire intervals in the fynbos to which it is endemic (Pauw and Linder 1997). There is nothing to gain from developing a climatically informative tree ring chronology from such a short-lived species.

One of the distinguishing features of *W. schwarzii* is the extensive root system evident for many of the trees growing on the steep rocky sides of the kloof. These individuals all had an extremely long exposed tap-root extending down to the river bed. The rocky nature of the area, combined with the extremely shallow soils, meant that we could often follow individual root systems down the cliff sides to the river base, a vertical drop of up to 14m in places. In two of the samples it was apparent that the majority of the tree's biomass was in the root system. This growth strategy suggests that these trees avoid moisture stress through extensive root systems sourcing water at the base of the rock bands in which they grow. The result is that the rings of these trees are very difficult to measure accurately. We therefore conclude that the dendrochronological and climatological potential of the species is limited.

Conclusions

Without cross-dating between trees from the same site chronology development is an equally impossible task for both *W. nodiflora* and *W. schwarzii*. *Widdringtonia cedarbergensis* remains the only one of all of the South African conifers which has been successfully cross-dated (Dunwiddie and La Marche 1980, February and Stock 1998b). As a result it is also the only South African conifer from which a successful chronology has been developed. As with *W. cedarbergensis, W. schwarzii* may be able to avoid drought stress by accessing deep water. This may explain the many false rings and poorly defined ring boundaries apparent in this species.

This study concludes the dendrochronological assessment of all of the South African *Widdringtonia* species. Of the seven conifer species represented in South Africa it is only *P. elongatus* and *P. henkelii* that have as yet not been evaluated for dendrochronology. The lack of success in obtaining any long climate reconstructions from the South African conifers have led us to look elsewhere for this rather elusive record. In Zimbabwe, Stahle *et al.* (1996, 1997) have derived chronologies for *Canthium burttii* from Hwange National Park and *Pterocarpus angolensis* from Sikumi and Mzola forests. The results for these two species are the only ones for southern Africa that correlate rainfall with a ring width index chronology. However, Stahle *et al*. (1996, 1997) confirmed the cross-dating of *C. burttii* only as far back as 1960. As is the case with *W. nodiflora*, there is nothing to gain from developing a climatically informative tree ring chronology from such a short-lived species. There is, however, a good chance that *P. angolensis* tree ring chronologies will provide a long rainfall history for southern Africa.

With European colonial occupation some 300 years ago came many non-indigenous tree species such as *Quercus* spp. and *Pinus* spp. Our current research efforts are concentrated on these introduced species.

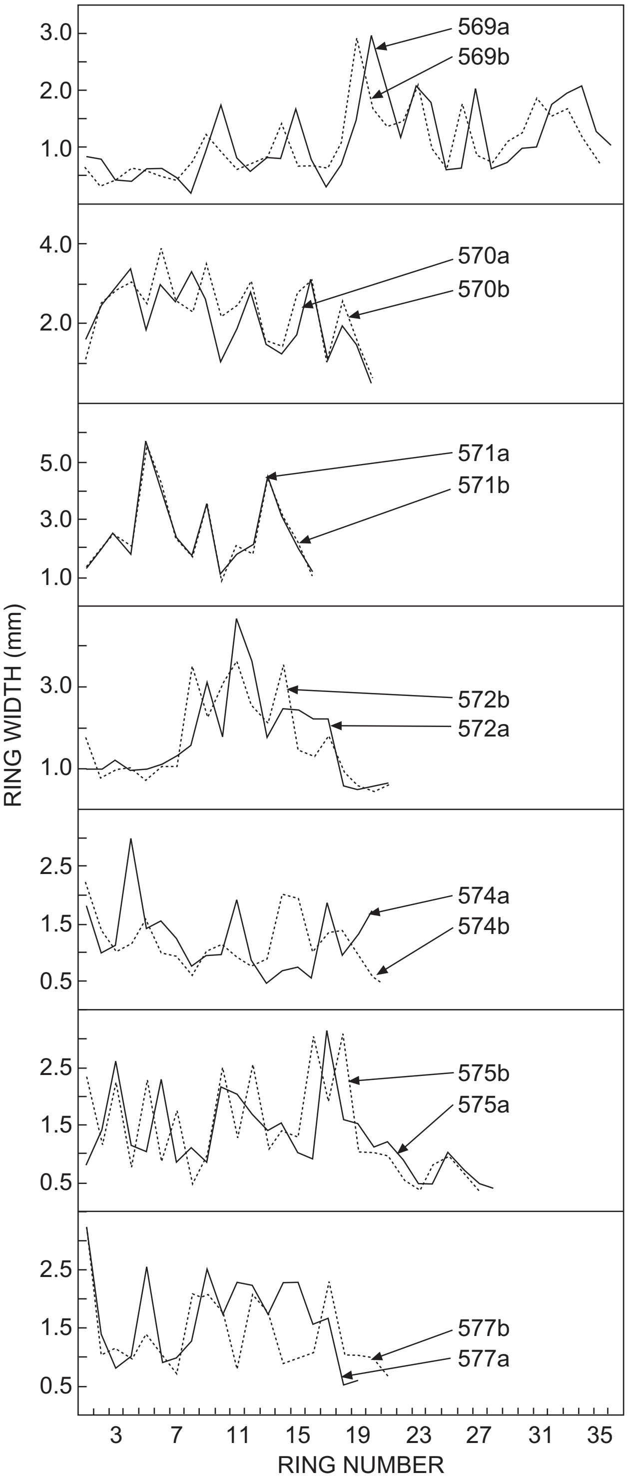

Figure 4: Ring width measures for two radii per tree for each of the seven *W. nodiflora* trees with the most discernible rings illustrating cross-dating within the same tree but lack of cross-dating between trees

Acknowledgements — This research was partly supported by the British Council Academic Exchange Programme and the Mellon Foundation. The warden, Derek Clark, and staff of the Baviaanskloof Nature Reserve assisted with the sampling. Nigel Wessels of Western Cape Nature Conservation and Aleck McKirdy assisted with the sampling at Grootvadersbosch. David Stahle constructively reviewed the manuscript.

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Edited by AE van Wyk