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Dendrochoronological Study on the Common Trees in Wadi Allaqi Biosphere Reserve, South-East Egypt

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Original Article

Keywords: Dendrochronology, Wadi Allaqi, Acacia trees, Age scenarios, Growth rate

Posted Date: September 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2029451/v1

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Abstract

Background

Twenty-five increment cores and tree discs were sampled for 4 trees species in Wadi Allaqi, an extremely arid region in South-East Egypt. All the studied species form distinct tree-ring boundaries. Of those, 19 samples for *Acacia tortilis* subsp. *raddiana* (Savi) Brenan, 2 for each of *Balanites aegyptiaca* (L.) Delile, *Acacia ehrenbergiana* Hayne, and *Tamarix nilotica* (Ehrenb.) Bunge. So, the main aim of the current study is to achieve a longer temporal perspective on growth and longevity, marginal parenchyma wood samples.

Results

The growth ring boundaries of the acacias are differentiated by thin parenchyma bands, which run around the entire stem disc. Samples of *Acacia tortilis* subsp. *raddiana* were located in the up-, down- and mid-stream parts of this Wadi; and classified, based on the mean distance between the bands of marginal parenchyma, into 6 size classes. Longevity based on the marginal parenchyma bands indicated that *Acacia tortilis* subsp. *raddiana* grew slowly and some of its studied individuals reflected 2 age scenarios in the downstream part, while the measurement interval an established date of around 1884 or 1886 is suggested. Both scenarios grew fast over a long period of time, and so the chiefly recent growth dated back to 1885. Approximate dates for the midstream part dated back to 1648, while the overall growth for the upstream part dated back to 1482. Samples of *Balanites aegyptiaca* may be established between 1608 and 1715, while those of *Acacia ehrenbergiana* may be established between 1945 and 1975. *Tamarix nilotica* swiftly established itself, and a new ecosystem replaced the severe arid habitat after the water level in Wadi Allaqi dropped in the 1980s.

Conclusion

Two scenarios of age are probably true for the downstream part, implying a date of establishment between 1884–1886. *Balanites aegyptiaca* was thought to have been established around 1715 or 1608, whereas *Acacia ehrenbergiana* was thought to have been established around 1975 or 1945. It was also discovered that the outdated scenario for *Balanites aegyptiaca* and *Acacia ehrenbergiana* is more in line with asymptotic value and current growth, indicating larger possibility for future expansion.

1. Background

Growth rings of trees are of ecological significance because the periodicity of their formation can be related to age (Schweingruber, 1988). The age structure of a population infers the population pattern, which is crucial for a better understanding of ecosystem dynamics. The study of growth rings in the tropics is much more complex than in the temperate regions due to the greater number of species, habitat diversity, cambial activity rhythm and phenology, anatomical markers for growth rings and their respective degrees of distinction in addition a lack of clearly defined seasons (Islam et al., 2018; Silva et al., 2019). Wherever seasonal change in environmental conditions is dramatic, the effect on the cambium is probable to be dramatic, and the resulting growth ring becomes distinct. Indeed, tropical ring counts are not predictably direct age estimates, although many authors continue to assume their annularity (Prins and van der Jeugd, 1993). However, this research has aroused interest in tropical tree rings because of the need for a greater biological understanding of tropical forest dynamics (Nath et al., 2016; Farahat and Gaertner, 2019).

A broad variety of anatomical characters define the resulting growth ring, including earlywood-latewood transitions, bands of marginal parenchyma, alternating patterns of fiber and parenchyma, and ring-porous structure (Worbes, 1989). Such bands are of continuous marginal parenchyma, filled with amorphous substances such as crystals. Contrary, crystals have been identified as a common feature for many leguminous trees (Worbes, 1989). However, identifying and quantifying marginal parenchyma bands (growth rings) in dendrochronological research utilizing some species could be difficult. This confusion can be summarized with another wood parenchyma such as para-tracheal and apo-tracheal parenchyma, or difficulties in identifying rings when they are very narrow (Détienne, 1989). Other difficulties include identifying rings near the cambium or different numbers on different radii (Mariaux, 1981); difficulties in identifying rings near the dark heartwood, pith, and other colour variations in the wood (Gourlay, 1995). Other confusions include merging, missing, and dividing rings, as well as false and discontinuous rings (Fahn et al., 1968; Martin, 1995).

Kiyiapi (1994) found that, the average number of rings produced each year was 1.14 rings (0.88 year/ring). Concerning *Acacia* species, Gammadid (1989) was able to age four samples of *Acacia bussei* and reported that number of rings was approximately twice the tree's age, which may be attributed that to the bimodal rainfall pattern. Gourlay (1995) counted rings of some *Acacia* species of known planting date and generally found their number to be slightly less than or equal to the known age in locations with a single-mode rainfall pattern.

Martin and Moss (1997) reported that the relationship between ring count and age was likely to be unique to a particular geographical area, based on its climate. Even within one area, a high degree of variability in the relationship was present. This suggests that site characteristics may be important (e.g., water-holding capacity of soil and browsing pressure) and necessitates that sampling take account of a huge range of sites and ages. Lilly (1977); Argent et al. (2004) and February et al. (2006) reported that the transition from saplings to adults may be rare and episodic, depending on contingencies of climate, fire-free intervals, or collapse of a browser population.

Cartwright and Taylor (2008) reported that the woods of 15 Egyptian wooden archery bows from the collections of the British Museum, ranging in date from the Neolithic period to the New Kingdom, have been scientifically identified. Microscopical examination of millimeters-sized samples revealed that all the bows

were made from indigenous Egyptian woods (*Ziziphus spina-christi*, *Acacia spp.*, and *Tamarix spp.*). These three taxa's diagnostic anatomical traits indicated the ring boundaries growth is either distinct or indistinct.

In order to gain a better knowledge of *Acacia tortilis*' age, growth, and growth conditions in hyper-arid Eastern Desert of Egypt's, researchers are using pre- and post-bomb C_{14} concentration in wood samples, as well as the existence of narrow marginal parenchymatic bands in the wood (Anderson and Krzywinski, 2007). According to age scenarios, the investigated tree ages seem to be 200–650 years old. Radial growth might reach 2.4 mm per year; however it varies regionally and temporally based on calibrated dates according to post-bomb C_{14} content of investigated samples. There is a low correlation between the band pattern among trees and within sites. Marginal parenchymatic bands can reveal fine-scale variations in growing environment and historical tree management.

So, the main aim of the current study is to achieve a longer temporal perspective on growth and longevity, marginal parenchyma wood samples. Presence/absence inventories, tree detection, long-term comparison in between past and present of a period of 47 years (after water level dropped in the 1980s in Wadi Allaqi) of *Acacia tortilis* subsp. *raddiana* (Savi) Brenan, *Balanites aegyptiaca* (L.) Delile, *Acacia ehrenbergiana* Hayne, and *Tamarix nilotica* (Ehrenb.) Bunge were revealed in Wadi Allaqi Biosphere Reserve, South-East Egypt.

2. Materials And Methods

2.1. Samples collection and processing

Forty-nine plots were selected to represent 19 locations within Wadi Allaqi Biosphere Reserve (upstream, midstream, and downstream parts; including the different wadi tributaries). These plots were selected to represent a prevailing range of physiographic and environmental variations in this area (Fig. 1). The priority was to obtain samples of trees where the felling of tree was probable, and the preferred sample was a whole disc or log from the main stem of the tree. In the cases where trees unable to be felled, samples were collected as increment cores. Within these plots, 25 increment cores and tree discs were sampled during 2008–2010 of those 19 samples for *Acacia tortilis* subsp. *raddiana* (18 represent the upstream and midstream parts (each 9), while one represents the downstream part). Two samples were taken to represent each of *Balanites aegyptiaca*, *Acacia ehrenbergiana*, and *Tamarix nilotica*. *Acacia tortilis* subsp. *raddiana*, *Balnaites aegyptiaca*, and *Tamarix nilotica* have extremely hardwood, so we built a high-torque steel corer that is powered by an electrical drill and can take cores up to 300 mm long and 13 or 20 mm in diameter. In addition, a chain electrical saw was used for dead stem discs' samples (Gebrekirstos et al., 2008).

The samples were cut at breast height (143–150 cm height) wherever possible, or discs were cut between 0.5 and 1.5 m above the ground and dried at room temperature. The stem disk surfaces were sanded gradually using sandpaper of grit size series 80, 100, 120, 150, 210 and 240 µm (Gourlay and Grime, 1994). All discs were rough-planed, sanded, and finely polished to ensure that the fine scratches not confused with marginal parenchyma bands.

Parenchyma bands were identified and marked in two radii for each tree sample under a Wild M3C Wild Heerbrugg Switzerland Light Microscope at 10 magnification lenses. Images captured for each sample were collected using a micro digital camera 30 MP connected to microscope and got a serial code (UAC, MAC, and DAC) refer for *Acacia* at up-, mid-and downstream parts of Wadi Allaqi, respectively. Image tool analysis software (CMEIAS v.128) was used to measure band intervals. Mean and standard deviation were calculated for each sample. Nineteen samples of *Acacia tortilis* subsp. *raddiana* collected from these parts of Wadi Allaqi were classified depending on the means of the marginal parenchyma band interval, into 6 size classes as follows: I: 0.25 to < 0.4, II: 0.4 to < 0.6, III: 0.6 to < 1.0, IV: 1.0 to < 2.0, V: 2.0 to < 4.0 and VI: > 4.0 mm.

The estimated growth rate (GR in mm/year) was used to create age scenarios. Intervening GR was estimated, based on the time interval between the sample under consideration and the next youngest sample, while the overall GR was estimated based on the time interval between the oldest and sampled dates (2008–2010).

2.2. X-ray interaction with wood analysis

2.2.1. Scanning Electron Microprobe (SEM)

The crystals detected in these sections were examined by X-ray Scanning Electron Microscopy (SEM) of the type JEOL JEM 35, with a Link 860 Series Energy Dispersive X-Ray System and Back Scattered Detector. In the case of discs, two or more radii were examined under the modified light microscope at a magnification of x 10. For core samples, only one radius was sampled, prepared, and examined.

2.2.2. Sample for scanning electron microscope

One and 2 cm^3 thick cubes were taken from the discs using a band saw. The samples were air-dried at room temperature to stabilize the moisture content of the samples to be < 15%. Furthermore, the cubic surfaces were sanded gradually using sandpaper of grit size series of 80, 100, 120, 150, 210, and 240 µm. The narrow marginal parenchyma bands were identified, marked, and counted. Parenchyma bands that form a more or less continuous layer of varied width at the borders of a growth ring or are irregularly zonate are referred to as marginal parenchyma (Worbes, 1989). This feature can often delimit growth in tropical woods as it may appear more clearly defined than vessel boundaries or other anatomical features used to describe growth rings. Marginal parenchyma is commonly composed of < 5 rows of parenchymatous cells forming continued layer. They were stained with safranin to enable the examination of the crystal chains and their subsequent photography. Identification of peripheral parenchyma zones and crystalliferous chains in samples from these plots allowed annual growth rates to be calculated and compared to climatic variables. Cross-dating follows the technique of Stokes and Smiley (1968). As a result, rings were first measured and then cross-dating was verified and corrected with the CDendro 7.1 and CooReader Softwares.

3. Results

3.1. Sample Discs and Core Sampling

The growth ring boundaries of *Acacia tortilis* subsp. *raddiana* are distinguished by thin parenchyma bands, which go through the whole stem disc (Fig. 2). A thin parenchyma band and aggregation of vessels determine the boundaries of the tree-rings. Distinctness of the growth rings varies between species. Heartwood marginal parenchyma bands were less pronounced than sapwood bands in the examined species.

3.2. Ring Boundaries and General Anatomical Characteristics:

3.2.1. *Acacia tortilis* subsp. *raddiana*

Nineteen samples of *Acacia tortilis* subsp. *raddiana* were classified depending on the means of the marginal parenchyma band interval, into 6 size classes as follows (Table 1, Table S1, Fig. 3):

Table 1
Estimated ages (years) of *Acacia tortilis* subsp. *raddiana* at Wadi Allaqi. GR (mm/year): interfering growth rate during the period between the considered sample and the next youngest sample. Min, max, and mean refer to distance between bands. Overall GR is estimated through the period between 2008–2010.

Plot part	Code	Size Class	Ring width (mm)			Period		suggested date	GR	Overall GR
			Min	Max	Mean ± SD	Max	Min			
Downstream	DAC 01	V	2.16	5.46	3.98 ± 1.36	229	90	1884	4.02	1885
	DAC 02	VI	1.85	5.63	4.05 ± 1.08	267	88	1886	-	-
Midstream	MAC 09	I	0.14	1.59	0.38 ± 0.32	3529	311	-	-	-
	MAC 10	II	0.15	0.87	0.40 ± 0.22	3293	568	-	-	-
	MAC 11	IV	0.2	3.36	1.73 ± 1.33	2470	147	1722	-	-
	MAC 12	IV	0.27	2.1	1.00 ± 0.57	1830	235	1514	-	-
	MAC 13	IV	0.14	3.11	1.40 ± 0.81	3529	159	1655	-	-
	MAC 14	V	2.25	3.79	3.04 ± 0.61	220	130	1846	-	-
	MAC 15	V	2.07	4.72	3.09 ± 0.88	239	105	1848	1.37	1648
	MAC 16	I	0.14	0.35	0.25 ± 0.08	3529	1411	-	-	-
	MAC 17	IV	0.14	2.31	1.03 ± 0.74	3529	214	1528	-	-
	MAC 18	III	0.22	1.88	0.90 ± 0.46	2245	263	1459	-	-
	MAC 19	II	0.14	1.65	0.59 ± 0.41	3529	299	1171	-	-
Upstream	UAC 03	III	0.21	1.5	0.82 ± 0.43	2352	329	1406	-	-
	UAC 04	I	0.11	0.54	0.27 ± 0.13	4491	915	-	-	-
	UAC 05	III	0.23	1.31	0.72 ± 0.41	2148	377	1322	-	-
	UAC 06	IV	1.05	2.08	1.46 ± 0.39	470	238	1670	0.94	1482
	UAC 07	II	0.14	1.05	0.42 ± 0.30	3529	470	-	-	-
	UAC 08	V	0.50	4.29	3.29 ± 4.81	988	115	1858	-	-

Class I comprises three samples: UAC 04 at the upstream part (0.27 mm), MAC 09 (0.38 mm), and MAC 16 (0.25 mm) at the midstream part (Table 1). These samples were characterized by narrow marginal parenchyma. Growth rings of samples of UAC 04 and MAC 09 were less distinct to identify and had more prominent streaks of white-banded parenchyma because of prominent banded confluent parenchyma and numerous rays, while the bands of sample MAC 16 were distinct (Fig. 4).

Class II had three samples: UAC 07 at the upstream part (0.42 mm), MAC 10 (0.4 mm), and MAC 19 at the midstream part (0.59 mm). These samples were characterized by thin marginal parenchyma bands. Growth rings of samples MAC 10 and UAC 07 were less distinct and had more prominent streaks of white-banded due to prominent banded confluent parenchyma and numerous rays, while that of MAC 19 was more distinct and had marginal parenchyma bands, rays more clear and a net-like structure appear.

Class III comprises three samples: UAC 05 (0.74) and UAC 03 (0.82 mm) at the upstream part, and MAC 18 at the midstream part (0.9 mm). These samples were characterized by thin narrow marginal parenchyma bands. They were less distinct to identify and had prominent streaks of white-banded because of prominent banded confluent parenchyma and numerous rays.

Class IV has five samples: UAC 06 (1.46 mm), MAC 11 (1.73 mm), MAC 12 (1.0 mm), MAC 13 (1.4 mm), and MAC 17 (1.03 mm). These samples were characterized by thin slightly wider bands, with various distances in between bands. Growth rings of samples of MAC 12 and MAC 13 of marginal bands were

highly distinct; while that of samples UAC 06, MAC 11, and MAC 17 were less distinct to identify and had prominent streaks of white-banded because of prominent banded confluent parenchyma and numerous rays.

Class V has four samples: UAC 08 (3.29 mm), MAC 14 (3.04 mm), MAC 15 (3.09 mm), and DAC 01 (3.98 mm). The samples of this class were characterized by thin moderately wider marginal bands. Generally, the bands in these samples are distinct, although they had prominent streaks of white-banded that confluent with parenchyma and numerous rays.

Class VI has only one sample DAC 02 (4.05 mm) which was characterized by thin highly wider marginal parenchyma bands which are slightly less distinct to identify and had prominent streaks of white banded, due to prominent banded confluent parenchyma and numerous rays.

3.2.1.1. Estimation of tree ages

According to the diameter at breast height, the oldest tree recorded in Wadi Allaqi belonged to *Acacia tortilis* subsp. *raddiana*, with radius of 494 mm and a tree girth of 320–340 cm (Fig. 5). Regarding the mean time interval, two age scenarios were probably true for the downstream part, implying a year of foundation between 1884 and 1886 (Table 1), the total recent growth was dated back to 1885. The approximate dates for the midstream part implying the date of establishment between 1848 and 1458 with the exception of sample MAC 19 with suggested date of 1171. The upstream part scenarios implying the date of establishment between 1858 and 1322; the oldest scenario is more in line with recent growth, while the asymptotic value showed there is more room for growth in the future.

3.2.1.2. Sample correlations

The correlation coefficients between sample DAC 01 and DAC 02 were highly positive ($p < 0.01$); while DAC 01 correlated negatively with that UAC 03 in upstream part ($p < 0.001$). UAC 03 correlated positively with UAC 08 ($p < 0.05$). On the other hand, MAC 13 positively correlated with UAC 03 ($p < 0.05$), UAC 04 with MAC 11 ($p < 0.05$) and UAC 05 with UAC 07 ($p < 0.001$). MAC 12 positively correlated with MAC 16 ($p < 0.05$), while MAC 14 negatively correlated with MAC 15 ($p < 0.001$) (Table 2, Fig. 6).

Table 2
Correlation coefficient (*r*) between samples of *Acacia tortilis* subsp. *raddiana* at upstream, midstream, and downstream parts. Bold values are significant at $p < 0.05$, Bold and underlined values are significant at $p < 0.001$.

Code	Downstream		Upstream						Middlestream									
	DAC 01	DAC 02	UAC 03	UAC 04	UAC 05	UAC 06	UAC 07	UAC 08	MAC 09	MAC 10	MAC 11	MAC 12	MAC 13	MAC 14	MAC 15	MAC 16	MAC 17	MAC 18
DAC 02	**0.58**																	
UAC 03	-0.71	0.04																
UAC 04	-0.26	0.10	0.14															
UAC 05	-0.48	**-0.49**	0.31	**0.46**														
UAC 06	-0.08	-0.24	0.01	0.27	-0.20													
UAC 07	-0.40	0.21	0.40	0.27	0.78	**-0.57**												
UAC 08	0.07	0.32	**0.47**	0.23	-0.04	0.39	0.11											
MAC 09	-0.32	-0.46	-0.24	-0.11	0.06	0.17	-0.30	-0.22										
MAC 10	-0.34	0.25	0.04	0.11	0.45	0.21	0.20	0.19	-0.10									
MAC 11	0.25	0.23	-0.17	0.**48**	0.27	0.29	0.34	0.28	-0.16	0.39								
MAC 12	-0.03	-0.14	-0.07	-0.05	0.11	-0.24	-0.29	-0.28	-0.09	0.04	-0.16							
MAC 13	-0.02	0.20	**0.48**	0.19	0.11	0.00	0.23	0.42	-0.02	-0.07	0.00	-0.27						
MAC 14	0.31	0.27	-0.12	0.08	0.19	-0.22	**0.47**	0.10	-0.27	-0.24	0.34	-0.39	**0.47**					
MAC 15	-0.45	0.00	0.39	0.26	0.19	-0.08	0.13	0.37	0.03	**0.58**	0.24	**0.46**	-0.05	-0.83				
MAC 16	0.16	0.08	-0.03	0.15	-0.44	-0.26	-0.25	0.08	0.08	-0.16	-0.25	**0.46**	-0.18	-0.42	0.28			
MAC 17	0.05	-0.10	-0.03	0.05	-0.23	0.35	-0.28	-0.21	-0.20	-0.13	0.01	0.09	-0.11	-0.27	-0.10	-0.11		
MAC 18	0.25	-0.31	0.26	-0.04	0.20	-0.44	-0.05	0.17	-0.25	-0.42	-0.31	0.33	0.24	-0.21	0.36	0.13	-0.12	
MAC 19	-0.33	-0.43	-0.30	-0.01	-0.02	-0.14	-0.25	-0.29	**0.57**	0.22	-0.08	**0.47**	-0.22	-0.43	0.41	0.31	-0.15	-0.05

3.2.2. Balanites aegyptiaca

Two samples of *Balanites aegyptiaca* in the upstream part, had mean distance between bands of 0.78 ± 0.38 mm for sample UBA 01 and 1.06 ± 0.30 mm for UBA 02. Because of large banded confluent parenchyma and numerous rays, the growth ring borders were marked by thin slightly less broadly marginal parenchyma bands with varying distances between them that were less apparent to distinguish and had significant, white-banded streaks. The thin parenchyma band and the aggregation of vessels characterize the tree-rings of this species (Figs. 7 & 8). Age scenarios for this species at upstream part are likely, implying an established date of around 1652 or 1715. The two proposed fast growth over a continuous period the overall recent growth which dated back to 1608. The upstream scenarios for *Balanites aegyptiaca* suggest establishment either around 1715 or 1608; the oldest scenario is, however, in better agreement with recent growth, and the asymptotic value shows greater potential for continued growth. Because of high asymptotic value, the largest tree observed in this part of the upstream part has a radius of 310 mm and hence the oldest scenario is the predicted age.

3.2.3. Acacia ehrenbergiana

Two samples of *Acacia ehrenbergiana* within the downstream part had the mean distance in between bands of 1.7 mm (DAE 01) and 0.17mm (DAE 02) (Table 3). The growth rings were characterized by thin, slightly less spaced marginal parenchyma bands with varying distances between them. The marginal parenchyma bands were less distinct, to identify and had prominent streaks of white-banded because of the prominent banded confluent parenchyma and

numerous rays. When the rings are crossed with rays, the rays appear broader (Fig. 9). Age scenarios used to estimate the age of trees as presented in (Table 3) for *Acacia ehrenbergiana* at the downstream part, scenarios are probable, suggesting an establishment date around either (1): 1975 and (2): 1658 based on mean measurement interval. The two proposed fast growth over a continuous period and so as the overall recent growth which backs to 1945. The scenarios for this species suggest establishment either around 1975 or 1945. The oldest scenario is, however, in better agreement with recent growth, and the asymptotic value shows greater potential for continued growth. Because of high asymptotic value (the largest tree observed in this part of the downstream part has a radius of 60 mm and the oldest scenario is the predicted age.

Table 3
Estimated ages (years) of *Balanites aegyptiaca*, *Acacia ehrenbergiana* and *Tamarix nilotica* at Wadi Allaqi. Min, max, and mean refer to the distance between bands. Overall GR is estimated through the period between 2008–2010.

Species	Code	Band (mm)			Period		Age	GR	Overall
		Min	**Max**	**Mean**	**Max**	**Min**	(year)	(mm/year)	GR
Balanites aegyptiaca	UBA 01	0.3	0.86	0.78	356	-	1652	0.87	1608
	UBA 02	0.51	1.52	1.06	293	-	1715	-	-
Acacia ehrenbergiana	DAE 01	0.53	4.37	1.67	35	-	1974	0.92	1945
	DAE 02	0.09	0.3	0.17	351	-	1658	-	-
Tamarix nilotica	DTN 01	1.65	5.14	2.66	-	-	1999	-	1999
	DTN 02	1.7	4.3	2.47	-	-	1990	-	1990

3.2.4. Tamarix nilotica

The two *Tamarix nilotica* samples were taken in the downstream part: DTN 01 (2.66 mm) and DTN 02 (2.47 mm) (Table 3). Growth rings of these samples were characterized by a thin annual ring in highly polished cross-sections and have various spaces between bands. In addition to the multiple rays, the rings had noticeable white streaks banded throughout.

4. Discussion

The current study's findings indicated that the distinctness of 25 tree sampled rings was rated from low to high; and all of them were utilized to estimate their age scenarios and growth rates. Although no cross-dating was not the target of current study, the distinctness of some species rings could encourage us in the future studies of cambial activity of these tree species and then cross-date these species using standard protocols in dendrochronology for accurate dating. Salem (2006) studied the growth rate of several tree species along Wadi Allaqi using tree ring analysis, where he recorded that most tree species are too difficult to core. *Acacia* species, the species that could be cored, and the tree-ring estimation was less accurate (Shaltout et al., 2010).

The measured tree ring widths depending on the distance between the marginal parenchyma bands indicated that *Acacia tortilis* subsp. *raddiana* grows slowly. For individuals of some studied trees in the present study, age scenarios were used to estimate the age of trees at the downstream part. Two scenarios are probable, implying the date of establishment of approximately 1884 or 1886, with a recent growth dated back to 1885. The approximate dates for the midstream part dated back to 1648, while for the upstream part dated back to 1482. The suggested establishment for *Balanites aegyptiaca* was around 1715 or 1608, while for *Acacia ehrenbergiana* was either around 1975 or 1945. *Tamarix nilotica* swiftly established itself, and a new ecosystem replaced the severe arid habitat after the water level in Wadi Allaqi dropped in the 1980s. The long-term trend in tree growth was well captured by these age scenarios (Zeide 1993). The growth rate is depicted by bell-shaped curve, which means that it increases at first and declines after that in the tree's life. On the other hand, trees can live for > 1000 years in some species (Higgins et al., 2000; Abdoun et al., 2005). According to recent research using C_{14} dating, some *Acacia nigrescens* and *Acacia nilotica* individuals are < 100 years old (February et al., 2006). Longevity estimates of > 100 years are depending on mortality rates in the Mojave Desert (> 100 years; Cody, 2000) and repeat photography in Arizona (> 100 years; Bowers et al., 1995) and are expressed as general assertions (150 years; Pellew, 1983). As a result, this figure shouldn't be used for all acacias. In the Negev Desert, Ward and Ward and Rohner (1997) investigated *Acacia raddiana* estimating its age depending on a Serengeti size-age connection in which large trees are ≥ 200 years old, according to recent statistics (Wiegand et al., 1999). This assumption suggests that long-term environmental influences are stable, resulting in the water-limited circumstances that characterize desert habitats. Short-term growth fluctuation is predictable and does not contradict growth curve model's long-term tendencies. Comparing with the previous results and considering the high aridity of Wadi Allaqi (rainfall < 30 mm/year), our results of most samples were 0.2 to 2.2 mm/year, and lifespan is approximately 200 years, which lie within the ranges previously cited above and agrees with the range of Anderson and Krzywinski (2006).

In the present study, the distances between bands varied among samples, and the width of rings varied considerably between years and among the species (in average maximum ring widths). At midstream part, there is a short distance between bands (ranged between (0.14 to 4.72 mm) compared with the upstream part which ranged from (0.11 to 4.29 mm) and the downstream part (1.85 to 5.63 mm). Some relatively long distances also appear especially near mountains. Narrow, parenchymatic bands like those present in all *Acacia tortilis* subsp. *raddiana* wood cores have been successfully used as time markers for dendro-chronological dating and in climatological studies elsewhere (Gourlay, 1995; Eshete and Stahl, 1999). Such methods seem to be applicable to *Acacia tortilis* subsp *raddiana* wood from the extremely arid area of Wadi Allaqi. Marginal parenchyma was formed on slightly regular basis, and the band patterns of trees correlated with each other, either between or within sites.

The low correlations within sampled plots and a negatively correlation between samples indicated that local factors are changeable and influence growth condition, and thus the established of marginal parenchyma bands. Within the three-stream parts of Wadi Allaqi, these factors affect the band formation. Annual rainfall in the Wadi Allaqi area rarely exceeds 5 mm and is highly variable in both time and space. Precipitation comes in discontinuous cloudbursts, varying from one to 15 days in the year, and rainless in many years (Abdou et al., 2016). Since the rainfall is very local and there are so few measuring stations, rain occurrences were unable to be correctly recognized. The water amount received by the soil based on the catchment areas of the receiving basin, which are controlled by land topography, and retained based on the texture and depth of the surface deposits (Kassas, 1955). During the previous decades, rainfall was recorded in south Aswan in autumn 1982, October 1987, December 1990, October 1992, May 1993, October 1994, and November 1996, which caused strong torrents in the surrounding wadis (Salem, 2006). Autumn rain events indicate that the Southeastern Desert is a transitional zone where the precipitation pattern gradually changes from predominantly winter rains in the north (i.e., Mediterranean climate) to predominantly summer rains in the south (i.e., Tropical climate) (IDRC, 1997). Generally, the overall amount of rainfall from 1960 to 2013 ranged from 0 to 0.8 mm/month (Carlquist, 2001; Yacoub, 2018). However, the negative correlations could be due to the contrasting conditions in downstream (DAC), midstream (MAC) and upstream (UAC). To clarify this points, a further study needs to carry out.

The growth conditions varied between plots and were shown by the loss of between-plot band correlations. Within plots, however, regional variables are probable to influence all trees by the same way, unless local landscape variability has a large impact. Phenology and temperature, according to (Gourlay and Grime, 1994), are associated with band formation and cambial activity. Seasonal temperature changes exist in Wadi Allaqi (Ayyad and Ghabbour, 1985), therefore one might predict ordinary band formation, especially at the high altitudes among cold winter temperatures (e.g., Eiqat core area in the upstream part). The absence of ordinary band formation shows that the temperature in Wadi Allaqi does not create major regular variations or is insufficiently cold to establish a spell of consistently cold temperatures in the winter (Fahn et al., 1968).

The present results revealed that the outdated scenario for *Balanites aegyptiaca* and *Acacia ehrenbergiana* is more in line with the new growth, while asymptotic value indicates that there is more room for expansion in the future because of the high asymptotic value, the greatest tree in the upstream part with a radius of 310 mm for *Balanites aegyptiaca*, and 60 mm for *Acacia ehrenbergiana*, hence the outdated scenario for them is the predicted age.

Tamarix has a great resilience to sand erosion and wind. Meanwhile, the *Tamarix*'s internal directional growth (eccentricity) is influenced by wind–sand erosion. Understanding the relationship between eccentric growth, surface cracks, and growth stress is crucial to comprehending the *Tamarix*'s active defense mechanism. This can interpret a function mechanism of the self-adaptive process for *Tamarix* wind–sand erosion stress. Under external environmental stress, the cambium cell division rate increases in Wadi Allaqi (Han et al., 2013). The structure and appearance of *Tamarix* trunks were altered by environmental stimulation. *Tamarix* that was stimulated throughout its growth produced broad rings in rainy years and very thin narrower rings in dry years. *Tamarix* 's atypical growth was linked to environmental encouragement. The core, or pith, was located on the windward aspect of the building. These findings are consistent with Farahat and Gartner [6], who studied *Moringa peregrina* species (see also Farahat and Gartner (2019).

Dendrochronology can and must serve as a key bridge toward the formation of a fuller understanding of Egypt and the ancient world around it, even if it is not a panacea for all of the chronological and environmental concerns. This development will not occur quickly or easily; a project of this magnitude will be protracted, hard, and fraught with difficulties (including scientific and logistical). Furthermore, regardless of its importance, dendrochronology must be used in conjunction with other tools, such as historical records (e.g., king lists), archaeological interpretations, C_{14} dating, Sothic cycles, and synchronisms with other cultures, on which the problematic chronologies currently in use are based. Only by combining dendrochronology with other types of research can we fully fulfil dendrochronology's potential for Egypt and nearby regions, and so provide specific dates for other historians to discuss (Creasman, 2014; Kuniholm, 2014).

5. Conclusions

The current study detected the presence/absence inventories, tree detection, long-term comparison in between past and present through 47 years (after water level dropped in the 1980s in Wadi Allaqi) of *Acacia tortilis* subsp. *raddiana*, *Balanites aegyptiaca*, *Acacia ehrenbergiana* and *Tamarix nilotica* in Wadi Allaqi Biosphere Reserve. Nineteen samples of *Acacia tortilis* subsp. *raddiana* collected from the up-, mid- and down-stream parts of Wadi Allaqi were classified depending on means of the marginal parenchyma band interval, into 6 size classes. Our results indicated that the growth ring boundaries of *Acacia tortilis* subsp. *raddiana* are differentiated by thin parenchyma bands around the whole stem. Regarding the mean time interval, two scenarios of age are probably true for the downstream part, implying a date of establishment between 1884–1886. *Balanites aegyptiaca* was thought to have been established around 1715 or 1608, whereas *Acacia ehrenbergiana* was thought to have been established around 1975 or 1945. *Tamarix nilotica* swiftly established itself, and a new ecosystem replaced the severe arid habitat after the water level in Wadi Allaqi dropped in the 1980s. It was also discovered that the outdated scenario for *Balanites aegyptiaca* and *Acacia ehrenbergiana* is more in line with asymptotic value and current growth, indicating larger possibility for future expansion.

Abbreviations

UAC, samples of *Acacia tortilis* subsp. *raddiana* in upstream part

MAC, samples of *Acacia tortilis* subsp. *raddiana* in midstream stream

DAC: samples of *Acacia tortilis* subsp. *raddiana* in downstream

UBA: samples of *Balanites aegyptiaca* in the upstream part

DAE: samples of *Acacia ehrenbergiana* in downstream part

DTN: samples of *Tamarix nilotica* in downstream part

Declarations

Acknowledgments

The Authors acknowledged the help of Prof. Emad A. Farahat, Head of Botany and Microbiology Department, Faculty of Science, Helwan University, for reading the first draft of this manuscript.

Funding

This work was funded by the Springer nature-Egypt agreement.

Author Contributions

Conceptualization, K.H.S.; Methodology, A.H.S. and M.G.S.; Statistical analysis, A.H.S., M.G.S., Y.M.A.-S. and K.H.S.; Writing—original draft preparation, A.H.S., M.G.S., Y.M.A.-S. and K.H.S.; Writing—review and editing, Y.M.A.-S. and K.H.S..; Funding acquisition, Y.M.A.-S., M.G.S. and K.H.S. All authors have read and agreed to the published version of the manuscript.

Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Conflicts of Interest

The authors declare no conflict of interest.

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Table S1

Table S1 is not available with this version.

Figures

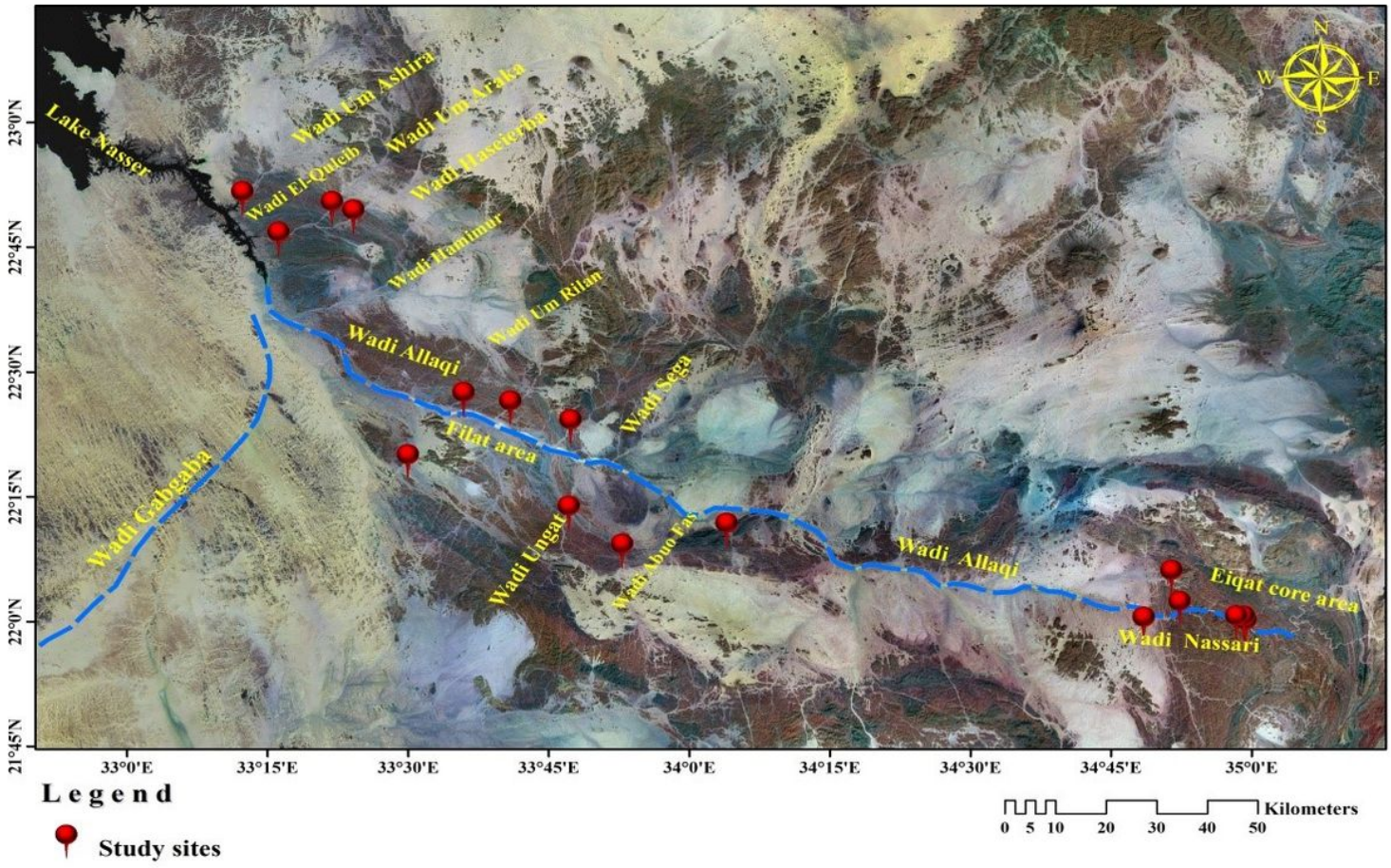

Figure 1

General map of south Egypt showing of Wadi Allaqi.

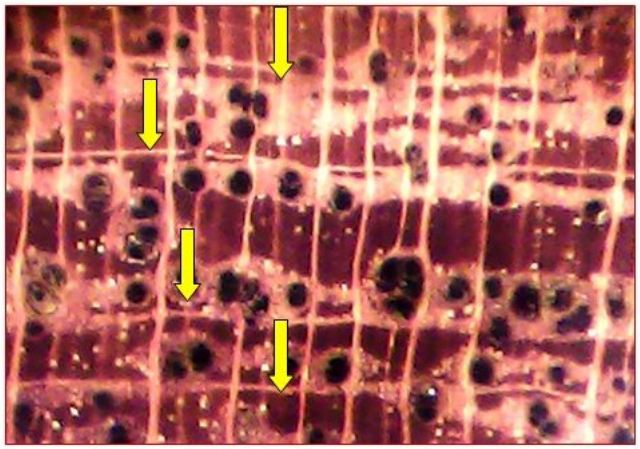

Figure 2

Marginal parenchyma bands in *Acacia tortilis* subsp. *raddiana*wood. Yellow arrows indicate the marginal parenchyma bands (horizontal white lines) in the tree sample wood. Rays appear as crossed white lines like borders, under a Wild M3C Wild Heerbrugg Switzerland light microscope.

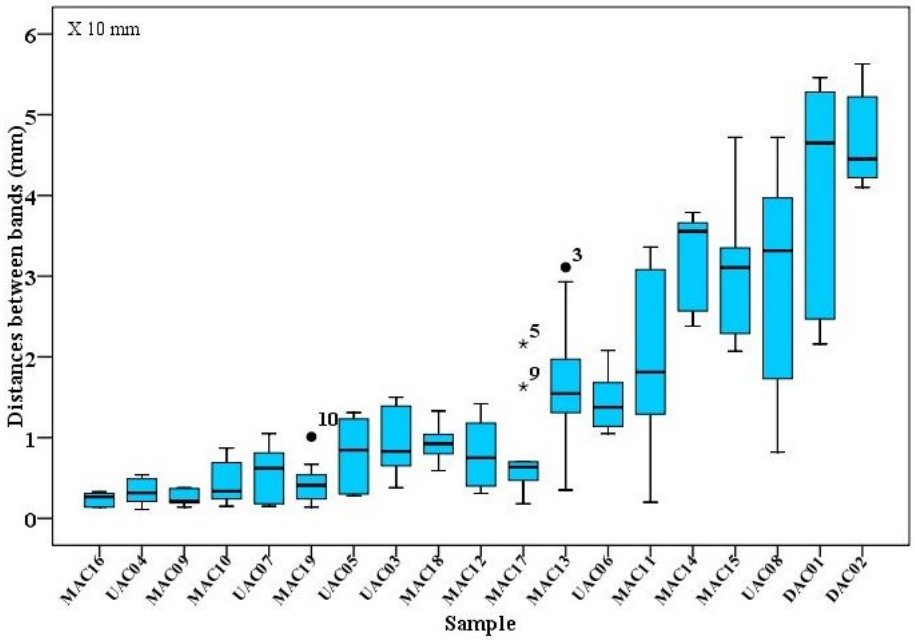

Figure 3

Boxplot of the distance between parenchymatic bands of 19 investigated samples of *Acacia tortilis* subsp. *raddiana*. DAC, MAC, and UAC refer to the samples at the down-, mid-and upper-stream parts of Wadi Allaqi, respectively.

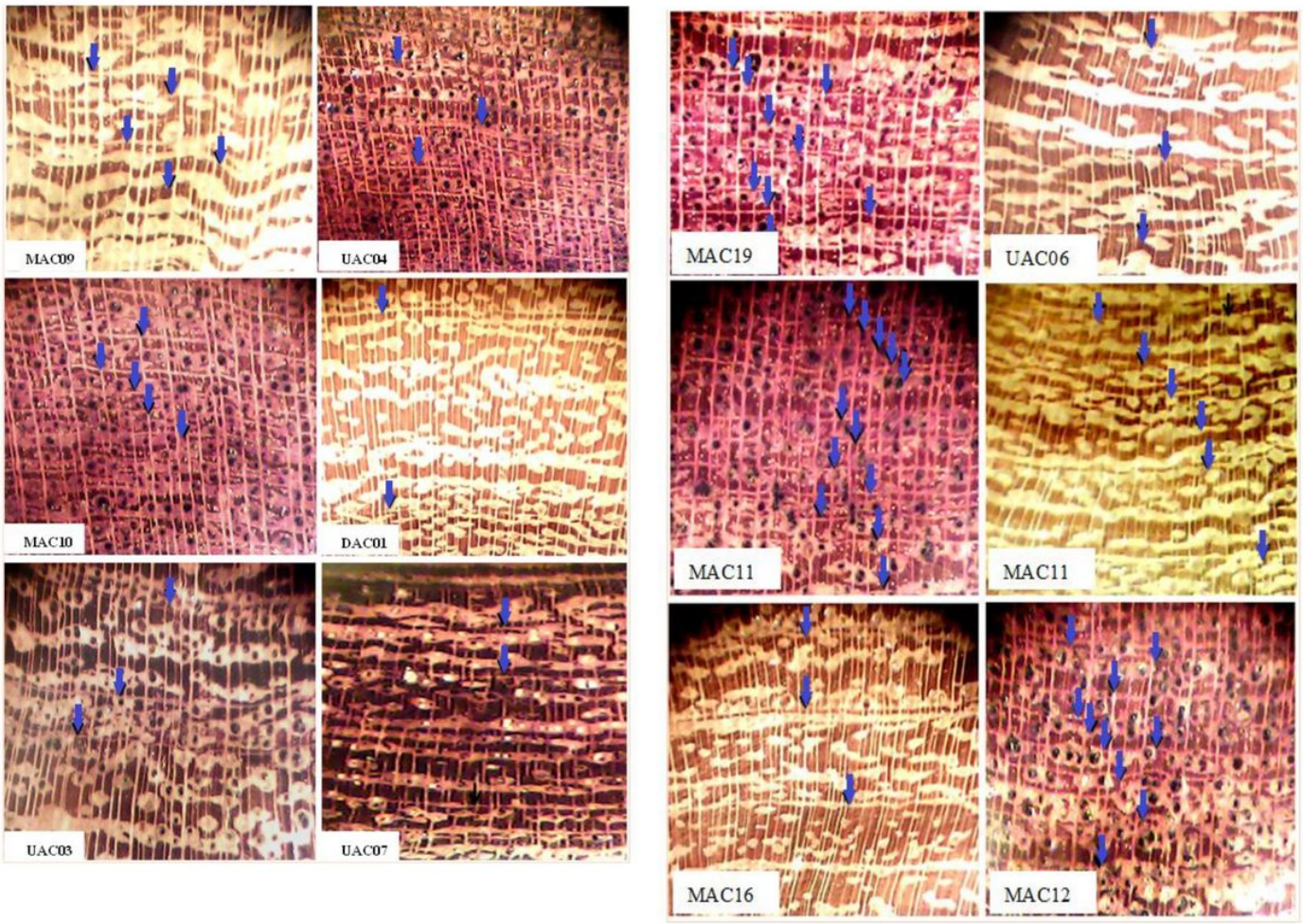

Figure 4

Marginal parenchymatic bands (indicated by blue arrows) in *Acacia tortilis* subsp. *raddiana* wood (as examples of the 19 samples).

Figure 5

Trunk girth (circumference) up to 330-340 cm of an older tree of *Acacia tortilis* subsp. *raddiana*.

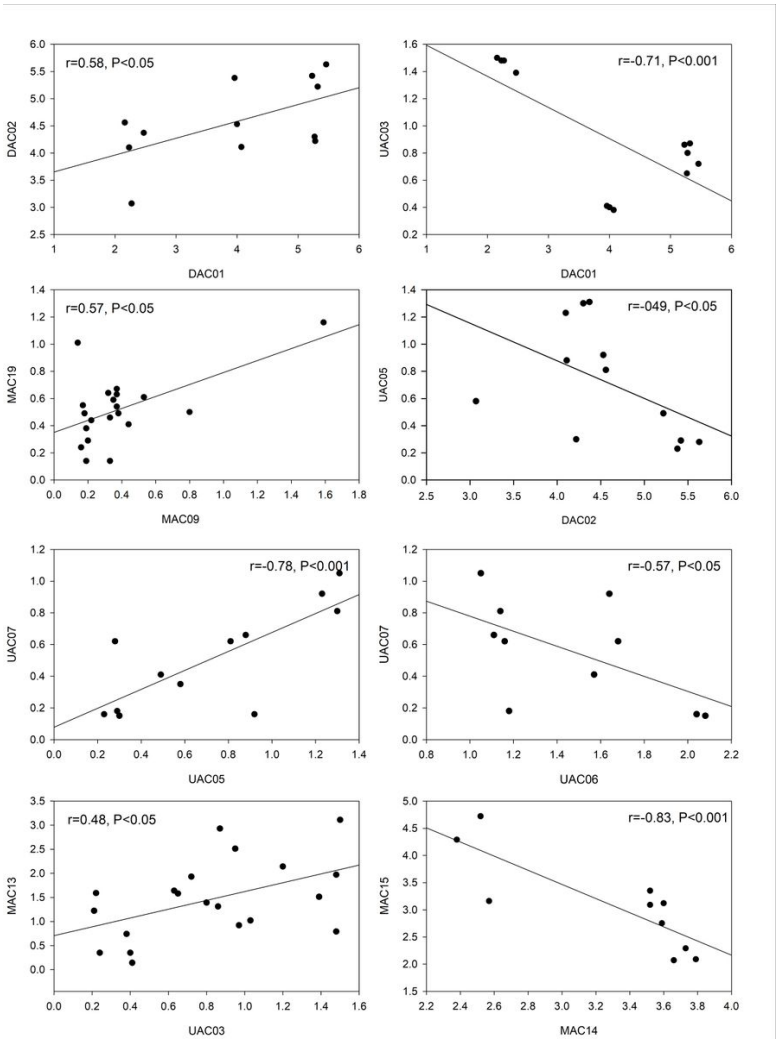

Figure 6

Example of simple linear correlation between samples of *Acacia tortilis* subsp. *raddiana*at upstream, midstream, and downstream parts.

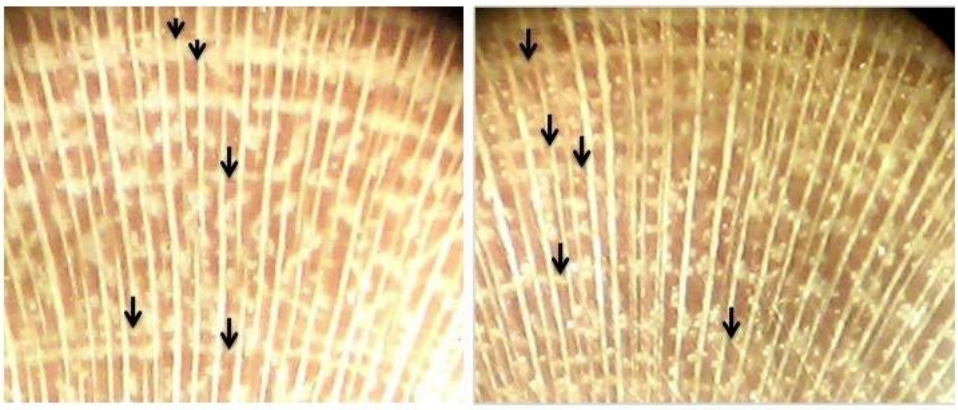

Figure 7

Cross-sections of *Balanites aegyptiaca*. Arrows indicate the boundaries of growth rings.

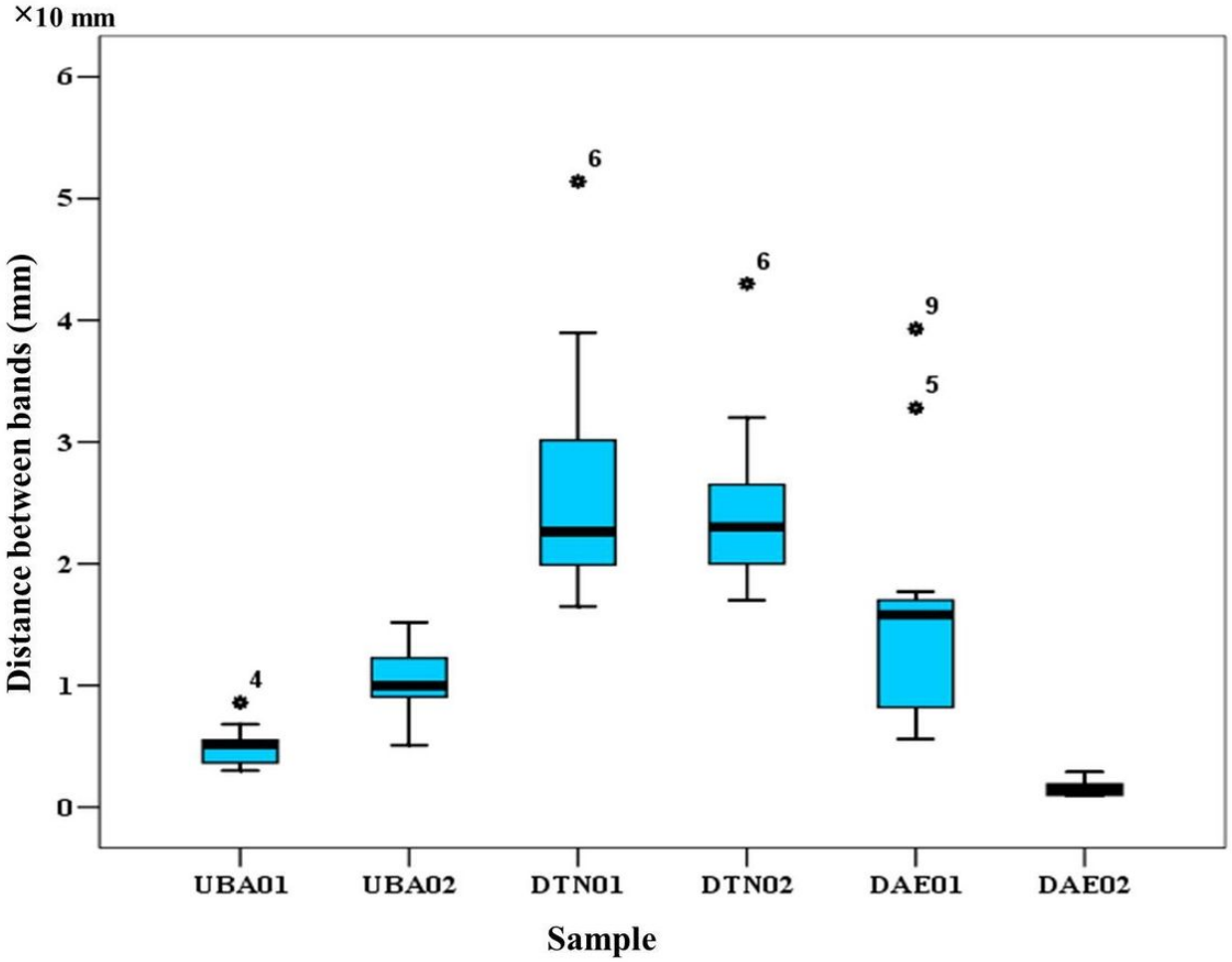

Figure 8

Boxplot of the distance between parenchymatic bands of the investigated samples of *Balanites aegyptiaca* (UBA 01, UBA 02), *Acacia ehrenbergiana* (DAE 01, DAE 02), and *Tamarix nilotica* (DTN 01, DTN 02).

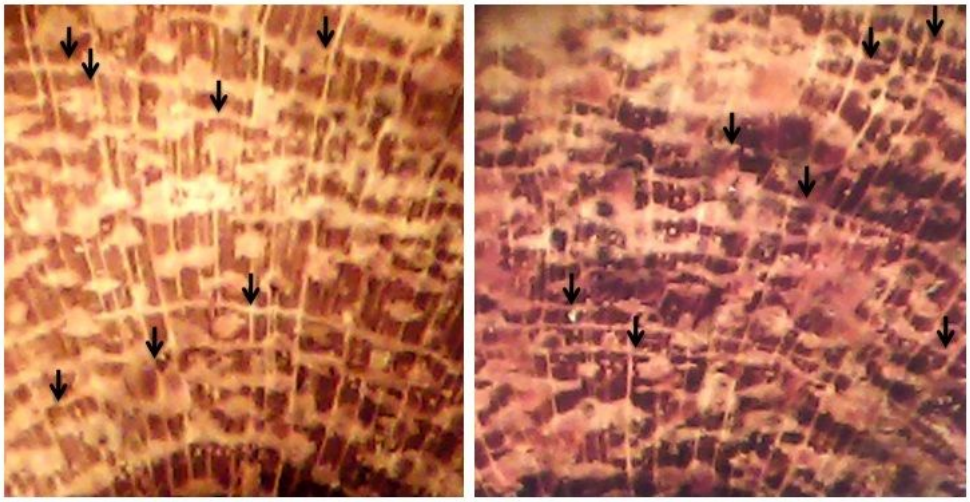

Figure 9

Cross-sections of *Acacia ehrenbergiana*. The arrows indicate the annual growth boundaries.