Anatomy of ring-forming plants in Egyptian deserts

Emad Farahat, Holger Gärtner

Kessel Publishing House
www.forestrybooks.com
www.forstbuch.de

Prof. Emad Farahat
Helwan University, Faculty of Science
Botany and Microbiology Department
Mansour street, Helwan University Metro station
11795 Ein-Helwan
Egypt
E-Mail: Emad.farahat@science.helwan.edu.eg

Dr. Holger Gärtner
Swiss Federal Research Institute WSL
Landscape Dynamics / Dendrosciences
Zürcherstrasse 111
8903 Birmensdorf
Switzerland
E-Mail: holger.gaertner@wsl.ch

Cover pictures:
From left to right (plant morphology and stem cross section below)
Otostegia fruticose, Echiochilon fruticosum, Ferula marmarica

Eifelweg 37
53424 Remagen-Oberwinter
Germany
Tel: +49-2228-493
Fax: +49-3212-1024877
email: webmaster@forstbuch.de
Internet:
www.forestrybooks.com
www.forstbuch.de
Printed in Germany
www.business-copy.com

ISBN: 978-3-910611-06-1

Contents

Introduction

Plant anatomy is the study of the tissue and the internal (anatomical) structure of plants and their parts. An accurate description and detailed knowledge of the anatomical structure of plant parts such as stems, branches, or roots allow an accurate analysis of internal physiological processes and the effects of environmental factors on them. Dendrochronology is a discipline in science dealing with the study of annual rings of trees, shrubs, and herbs in determining their calendar dates and chronological order. It includes two important sub-disciplines: dendroclimatology and dendroecology. Dendroclimatology is using tree-ring characteristics (e.g., ring width or density) as proxies to reconstruct and analyze past climate variability, while dendroecology is the application of various tree-ring parameters to analyze ecological and environmental changes in the past. Both sub-disciplines increasingly evolved and are used to improve our understanding of the ecological performance of plants i.e., their annual and intra-annual growth and its relationship to the prevailing environment. To achieve that, identifying ring-forming plants and collecting respective wood samples is the first step in this aspect. The annual growth and wood characteristics of tree species in southern Mediterranean countries, and their relation to climate variables are two important topics for scientists in this region (e.g., Farahat and Gärtner, 2019). Field excursions were done to collect perennial plants from Egyptian deserts to analyze their anatomical structure with a special focus on ring boundaries to show their dendrochronological potential. In this book, we introduce information on the anatomy of 96 growth-ring forming species, representing a subset of 300 species collected so far. These species are multi-stemmed trees, shrubs, or subshrubs, and perennial or short-lived herbs (8, 55, and 33 species, respectively) belonging to 80 genera and 33 families.

We would like to make clear that we cannot definitely confirm the annual nature of growth-ring formation in the presented samples. This requires further investigations as repeated pinning or punching covering the entire vegetation period to document wood formation (i.e., xylogenesis) during a whole calendar year (e.g., Gärtner and Farahat, 2021). Such studies would emphasize the annual nature of the rings of the studied species and their potential use in dendrochronology. Finally, we hope from this work to introduce baseline information that could improve our understanding of the plant growth-environment relationships in Egyptian deserts, and in addition, to encourage new studies in dendroecology in the Southern Mediterranean that may add novel findings to science.

Acknowledgments

This study was supported partially by the Egyptian Science and Technology Development Fund (STDF) (grant no.: 25341, 2018) and the Scientific Exchanges programm of the Swiss National Science Foundation (grant no.: IZSEZ0_213304, 2022). We are grateful to the Administration of Saint Catherine protectorate (Sinai) and Saluga and Ghazal protectorates (Aswan) for providing permissions to sample plants. We thank Dr. Ibrahim Elgamal (Saint Catherine protectorate) for his guidance during wood collection and for providing some images of the collected plants. Our thanks extend to Profs. Monier Abd El-Ghani (Cairo University), Loutfy M. Hassan and Tarek M. Galal (Helwan University) for their help in the identification of some samples. We express our gratitude to Dr. Alan Crivellaro for his kind revision of the first draft of the book.

Study area

Egypt is part of the Sahara of North Africa and occupies the northeastern corner of Africa and the Sinai Peninsula (Said 1962). About 95% of Egyptian land is desert. The country (Fig. 1) is divided into eight phytogeographical regions

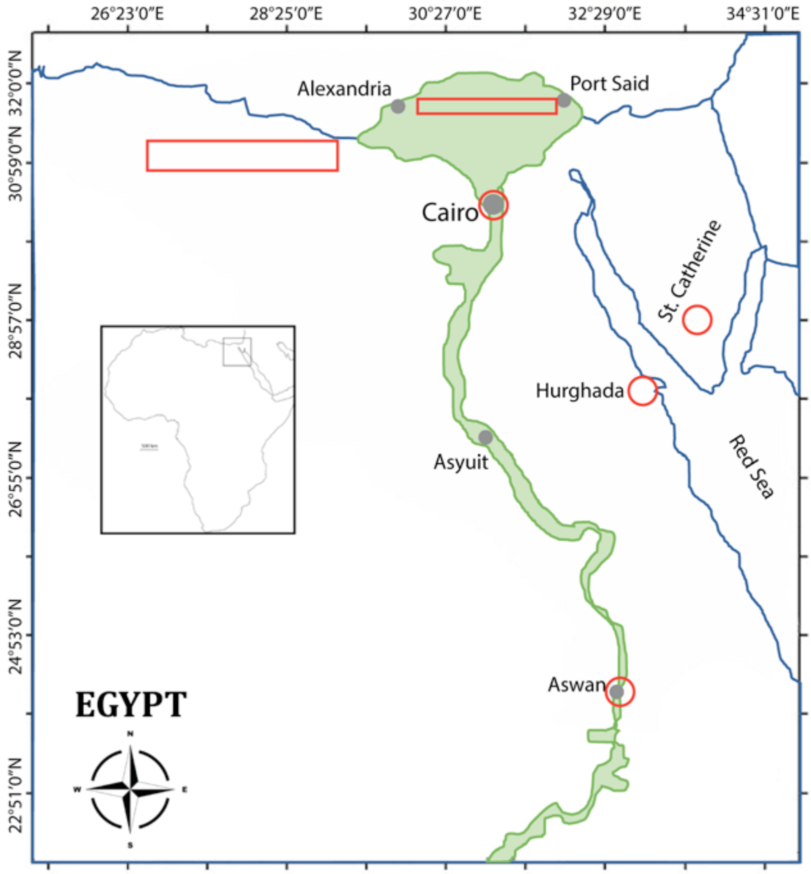


Fig.1. Location map indicating the main plant sampling sites (red rectangulars and circles).

(Wickens 1977). These regions represent three deserts (1- the Eastern deserts, 2- the Western Desert, and 3- the Sinai Peninsula), the Nile valley including its delta and the Fayoum depression, desert Oasis, the Mediterranean coastal strip from Libyan boundaries eastwards to Rafah on the Egyptian-Palestinian border, the Red Sea coastal lands, and Gebel Elba.

The Egyptian deserts are among the most arid parts of the world. In each phytogeographical region, there is a variety of landforms that support plant growth. For example, plains, wadis, oases and springs, salt marshes, sand dunes, rocky ridges, ruderal areas, mountains, and agricultural lands. More details on each phytogeographical region and its physiographic features are available in Zahran and Willis (2009), and Abd El-Ghani et al. (2017). Rainfall does not exceed 10 mm/year in most parts of the country. The maximum rainfall is averaging 150 mm/year along the Mediterranean coast. This quantity decreases rapidly as one goes south until it reaches 30 mm at Cairo. Further to the south, rain decreases reaching 3 mm or even less (Zahran and Willis, 2009, Abd El-Ghani et al., 2017). We collected our samples in the following areas: Saint Catherine (Sinai), Hurghada (Eastern Desert), Mediterranean coastal strip (from Rosetta to Marsa-Matrouh),

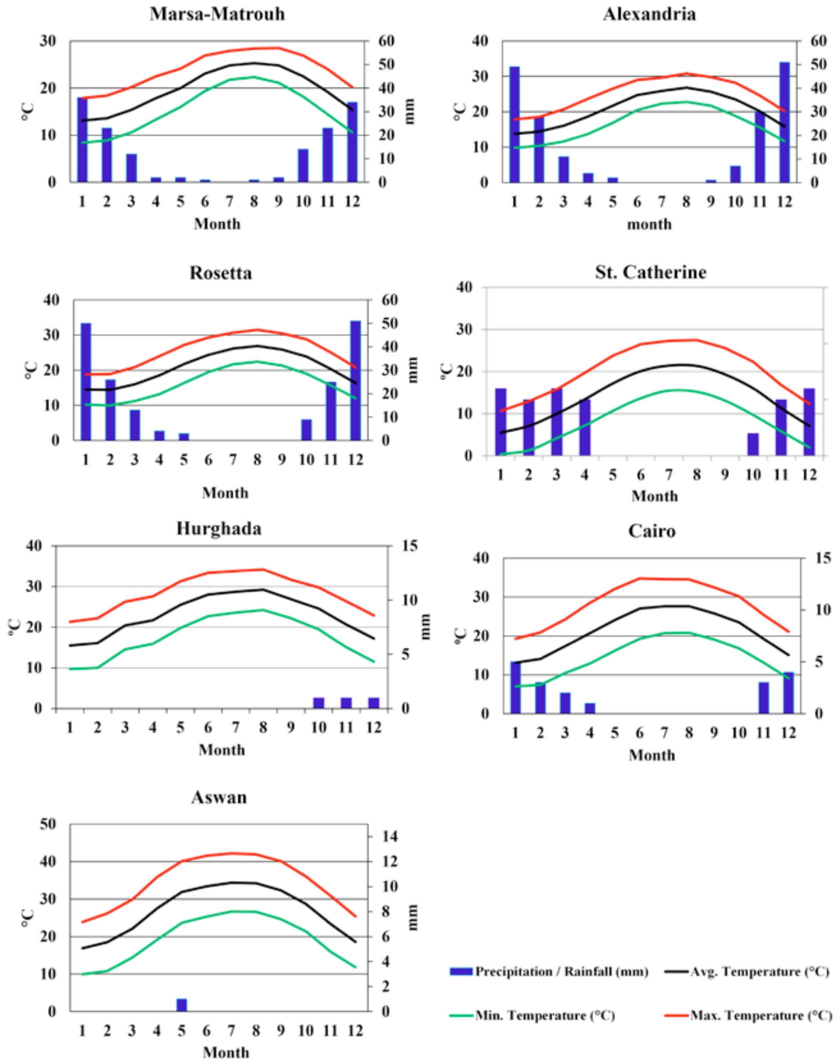


Fig. 2. Climate diagrams of the main sites of wood collection in Egypt
(Source: Climate data organization, https://en.climate-data.org, accessed on 20 February 2020).

Aswan (The Nile and Western desert regions), and Cairo (Nile region). Since there is a gradual variability in climate parameters (temperature and precipitation) among the phytogeographical regions, **Fig. 2** shows the climate diagrams of the main sites of wood sampling.

Habitat variability in the study area

The habitat types in our study area are diverse **(Fig.3a-i)**. For instance, along the Mediterranean coast we sampled plants growing on inland and coastal sand dunes, sandy plains, rocky ridges, cliffs, saline habitats, roadsides, ruderal areas, and lakeshores. In Hurghada and Saint Catherine, we sampled plants from desert wadis, mountains, and gorges. In Aswan and Cairo, we sampled plant species from river islands and river banks, the desert, and ruderal habitats among the agricultural lands.

Strategy of plant sampling

The formation of distinct rings in the wood of tropical and sub-tropical (i.e. southern Mediterranean) plants is enhanced by seasonal fluctuations of climatic factors. Rozendaal and Zuidema (2011) reported that, in most cases, precipitation represents the main limiting factor for tree growth in tropical and subtropical regions. During the dry season, precipitation is either very low or absent, causing leaf shedding and cambial dormancy. This stage of the tree growth cycle induces the formation of distinct ring boundaries (Tarelkin et al., 2016). However, not all plants in tropical or Mediterranean regions can form distinct xylem rings (Groenendijk et al., 2014; Tarelkin et al., 2016; Balzano et al., 2019). This is because of the less distinct seasonality in climate conditions that make ring boundaries indistinct and/or not reliable. Moreover, climatic fluctuations within the growing season cause false rings, wedging rings, and intra-annual density fluctuations in wood (Worbes, 2002; Balzano et al., 2019). Hence, to carry out any dendrochronological studies on tropical and sub-tropical wood plant species, the annual nature of the rings should first be proven.

Hence, our strategy to collect wood samples for this study is to select: 1-woody plants (perennial trees, shrubs, and herbs), 2- plants in regions with a distinct dormant growth season i.e. dry out during a certain period (e.g. summer) and then re-sprout again in fall or winter, 3- plants that are receiving water from natural sources (i.e. groundwater, precipitation, and/or dew) even if it grows close to any artificial water resource. We collected the samples, whenever possible, from the main stems of the plant, branches, and root collar. This was depending on the stem characteristics (e.g. habit, height, branching). Since most desert shrubs and perennials do not have a single stem i.e., multi-stemmed, we collected our samples from the main twigs. Hereafter, we refer to stems and twigs as a stem. It is worth noting that we were only allowed to collect samples from stems or branches of plants in the visited protectorate. Moreover, we described the wood material that we collected only. We present here the anatomical description for ring formation in addition to a simple morphological description, but not taxonomic information, for the species. The main sources of the morphological description are Täckholm (1976) and Boulos (1999, 2000 & 2003).

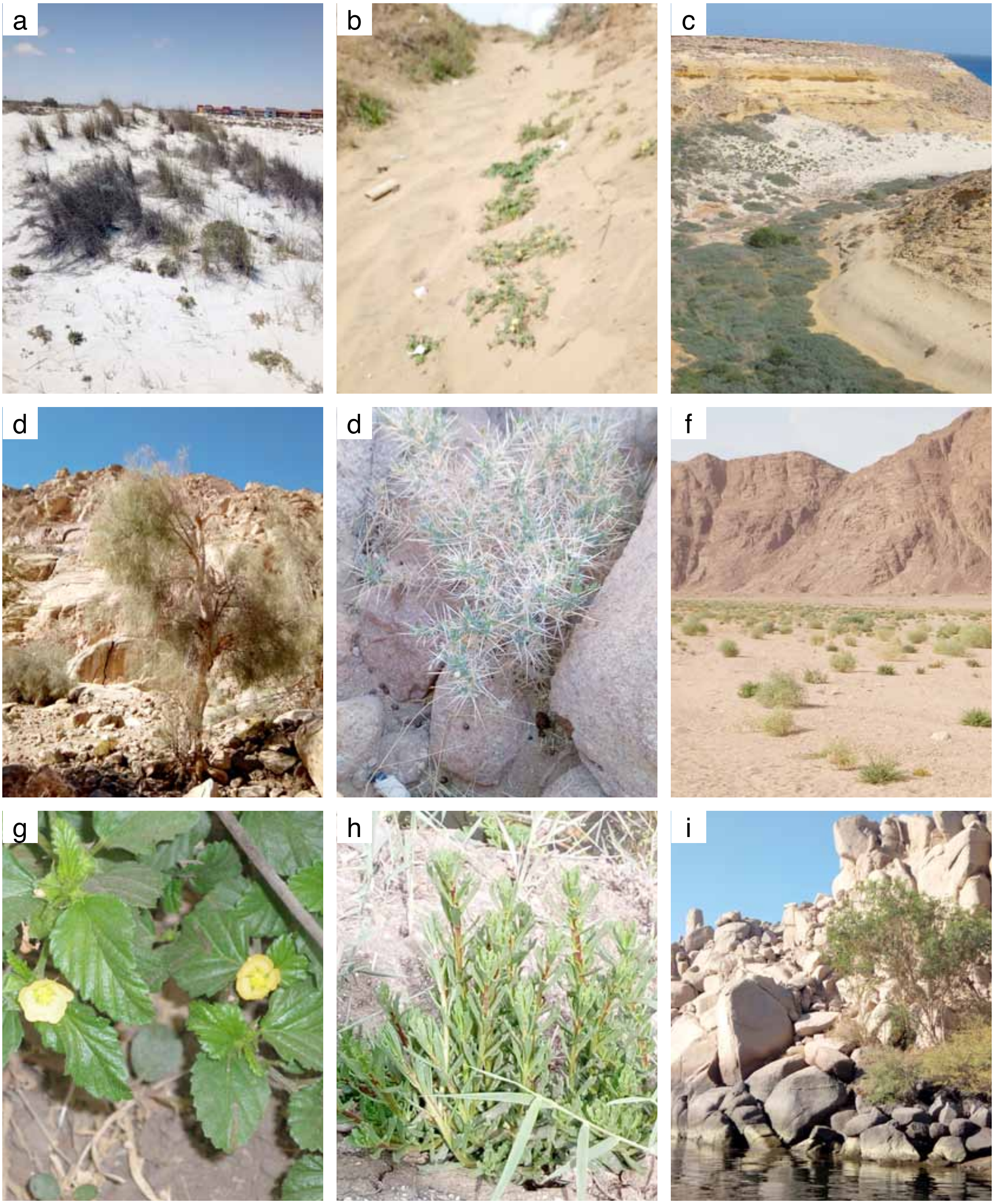


Fig. 3. Different habitats of wood collection, a) costal sand dunes, b) inland sand dunes, c) rocky coastal cliffs, d & e) rocky mountains, f) sand plains, g) ruderal habitats, h) lakeshore and i) granite Nile island

Sample collection, sectioning, and processing

Samples of about 300 perennial plants were collected from the study area. Whenever possible, we took samples from the main stem, the stem base, the root collar, or the main branch. All samples were directly preserved in ethanol (40%) using plastic zip-lock bags. In the laboratory, for each sample, we took a 3-4 cm long segment and placed it in the holder of the lab-microtome (**Fig. 4**, Gärtner et al., 2015) for sectioning. The samples were sectioned in transverse (cross-section) direction with a thickness of 15–20 µm. Dense wood samples were boiled before sectioning either in water or a water: glycerol solution (1:1) for 10-60 minutes. For small specimens, we used carrot or cork as a supporter (Gärtner and Schweingruber, 2013).

Then, each section was transferred to a glass slide, stained with a Safranin-Astra blue mixture, dehydrated with ethanol (96% and dehydrated ethanol), and rinsed with Xylol to prepare the subsequent embedding in Canada balsam (Schweingruber, 2007). All micro sections were oven-dried at 60 °C for 24-48 h before taking micro-photos under a microscope (Olympus B41X) using a Canon EOS1200D camera and EOS utility software. Micro-photos were taken at 40, 100, 200, and 400x magnification. All determinations of ray width were done based on tangential sections, even though these sections are not shown.

The description of the anatomical ring structure is following the descriptive criteria nominated in Crivellaro and Schweingruber (2015) and other notices concerning the anatomy of plant families in Schweingruber et al. (2011, 2013).

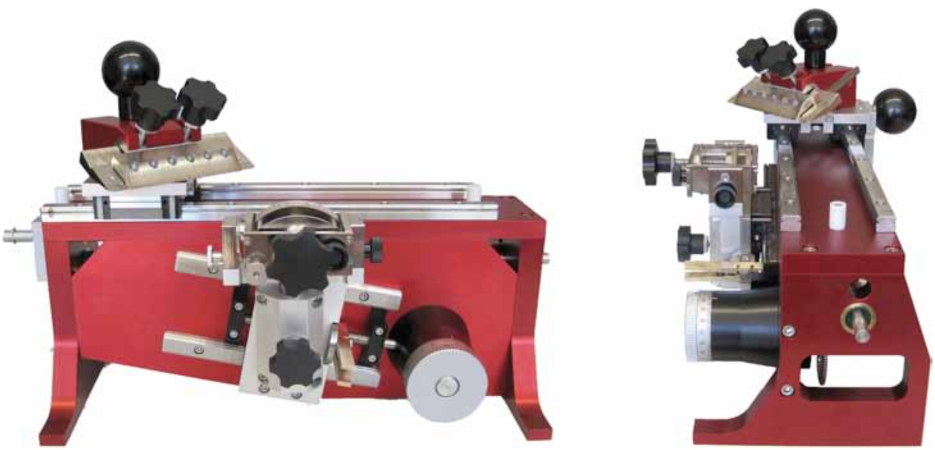


Fig. 4. WSL-Lab-microtome used for sectioning all wood samples presented in this book.

Main notices and comments

During sample processing (from collection to descriptions), we observed some interesting basics that we want to mention here:

1 At first, as mentioned above, the formation of distinct rings in plants does not only rely on the plant species but mostly on the environmental conditions at the site of collection. For instance, Schweingruber et al. (2011) reported that *Crucianella maritima* collected from the Mediterranean coast of Spain had no distinct rings, while the ones we collected from the northwestern Mediterranean coast of Egypt had distinct rings. The same was true for *Fagonia cretica* which is forming distinct rings in Egypt, while it does not in Switzerland (Schweingruber et al. 2013)

2 Ring distinctness varies greatly within individual species of the same family (e.g. Apiaceae) and depends on local growth conditions (Schweingruber et al., 2011).

3 Respecting the climate conditions of the sample areas, we noticed that the main driver for ring-formation in the collected plants is a pronounced dry season (which occurs in summer). Most of the sampled perennials dry out or turned in a dormant stage in summer, then it starts growing again in fall or winter. This regrowth is depending on the analyzed species, which is a re-sprouting from the root or stem system in most cases.

4 Another important fact is the presence of obvious contradictions in the description of plant life forms in the main books of Egyptian flora (Täckholm 1976; Boulos 1999, 2000, 2003) and what we observe in the field or what was described in the other Floras.

For instance, *Malvastrum coromandelianum* was described as annual in the abovementioned books, while it was recorded as a long-lived woody herbaceous plant in Flora of Zimbabwe and Flora of Mozabique. Moreover, by examining the stem anatomy of this species in the present study area, there were up to ten distinct rings in a cross-section. We may attribute the reason for the occasionally incorrect descriptions of the life forms of some Egyptian plants to the scarcity of auto-ecological studies compared to the huge number of papers that concentrate on the phytosociology of plants only. In many recent studies, authors usually transcript the life forms of species from previous studies without real observation in the field.

5 We think that despite the species might be perennial, their age is determined by many environmental factors, particularly water resources and micro-climate. This may explain the disappearance of perennials after a long dry season.

Finally, the anatomical descriptions presented in this book are mentioned for the analyzed plant material that was collected for this study.

The order of species presented in this book is arranged according to their taxonomical order in the Egyptian flora.

Anatomical descriptions

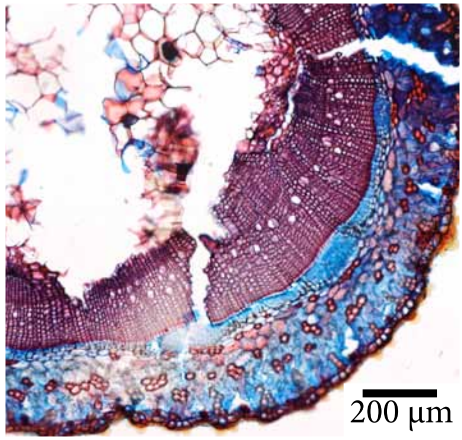
Snow covers trees
in St. Catherine, Egypt.

Plant morphology and habitat:

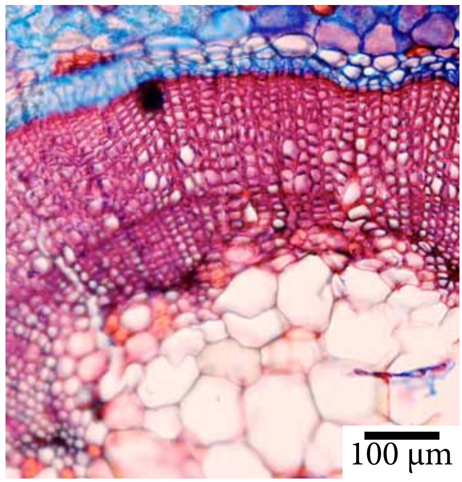
Shrub up to 1 m; stems richly branching, erect, not climbing. It grows in desert sand plains. It distributes in North Africa, Palestine, Sinai, Arabia and Iraq.

Ring characteristics and anatomy:

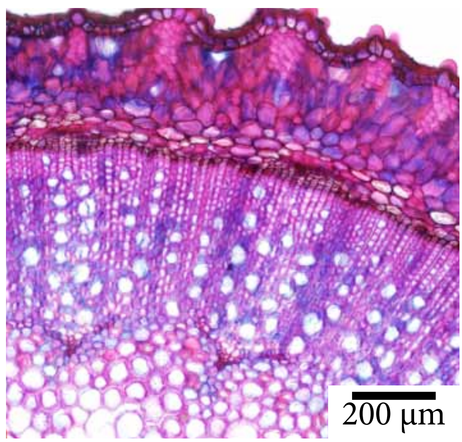
Twig of the plant analyzed is round with a diameter of 2.4 mm. Rings are distinct, two rings were found in the oldest twig. Xylem/bark proportion is 1:1. Wood ring-porous. Ring boundaries are characterized by thick-walled, flattened fibers. The following ring is indicated by bigger earlywood vessels. Earlywood vessels show an average diameter of 77 µm. Vessels are solitary and arranged irregularly. Axial parenchyma is rare. Rays are mostly uniseriate.



Ring boundary is indicated by flattened, thick-walled fibers at the end of a ring and the earlywood vessels of the next ring.



Distinct ring boundary above pith.



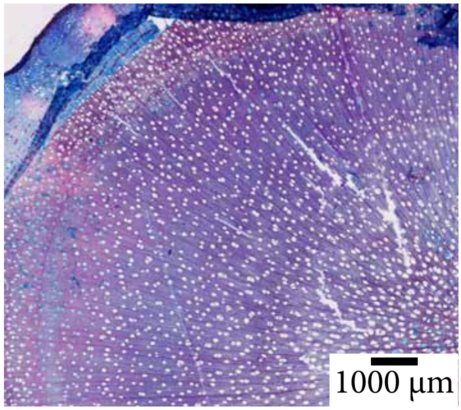
One year old twig showing one complete ▶ ring.

Plant morphology and habitat:

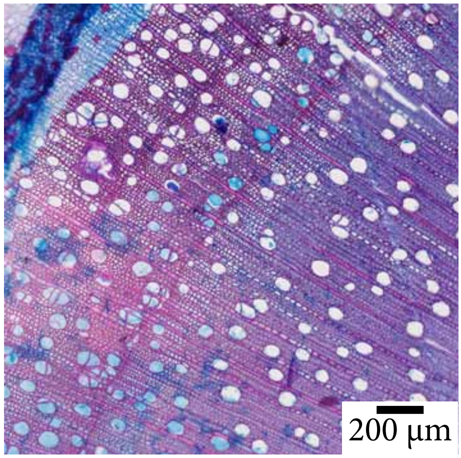
Shrub or tree, up to 12 m. deciduous. sometimes evergreen: leaves up to 18 x 6 cm, alternate, petiolate, broadly ovate-lanceolate, serrulate, apex acuminate. Female flowers in catkins up to 8 cm; female trees less common in Egypt than male trees. It spreads along water canals and naturalized in Egypt, India and China.

Ring characteristics and anatomy:

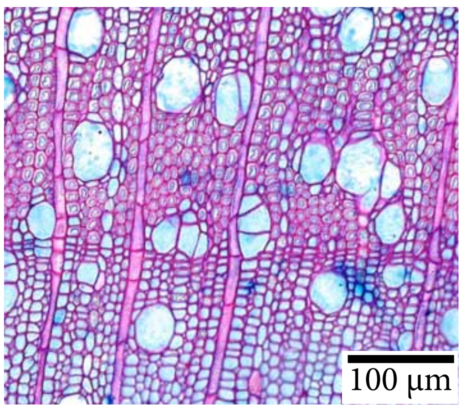
Twig round with a diameter of 2.0 cm. Rings are distinct, three rings were found in the oldest twig. Xylem/bark proportion is >2:1. Wood diffuse-porous. Ring boundaries are characterized by one or two lines of flattened, thick-walled fibers. Earlywood vessels have an average diameter of 74.9 µm. Vessels are mostly solitary and arranged irregularly. Axial parenchyma is rare. Rays are mostly uniseriate.



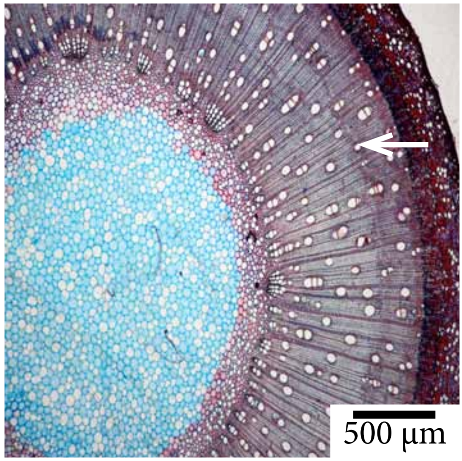
Three-year-old twig. Narrow flattened, thick-walled fibers indicate ring boundaries.



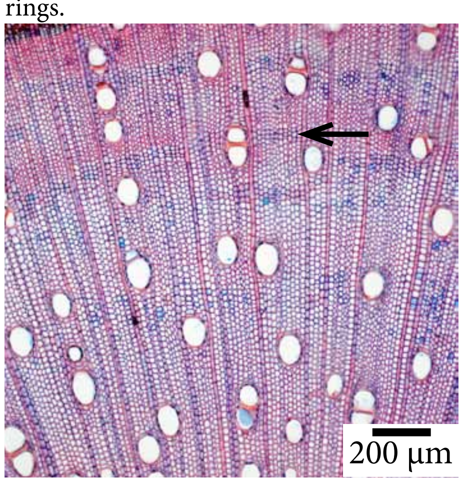
Ring boundary with flattened marginal fiber layer.



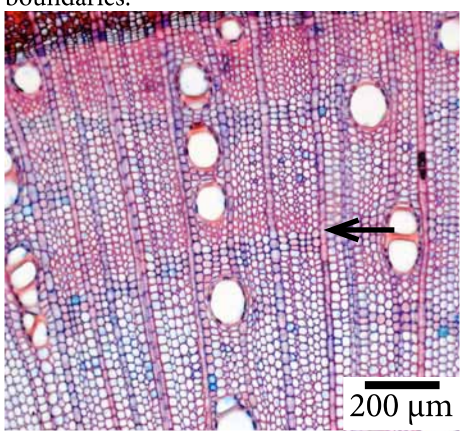
Magnified ring boundary showing flattened fibers and earlywood vessels.



Twig cross-section with three distinct rings.



Diffuse-porous wood with distinct ring boundaries.



Enlarged view showing marginal flattened fibers at ring boundaries.

Plant morphology and habitat:

Shrub up to 4 m and it grows in rocky cliff and wadi sides. It distributes in Southeast Mediterranean region, Egypt (Sinai), Tropical Northeast Africa, and Arabia to India.

Ring characteristics and anatomy:

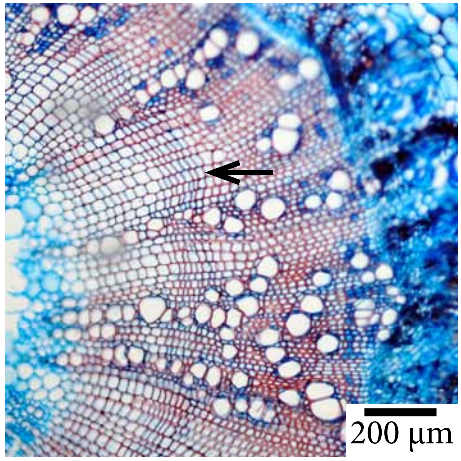
Twig of the plant analyzed is round with a diameter of 7.8 mm. Xylem/bark proportion is >2:1. The plants analyzed showed two rings. Wood diffuse-porous. Ring boundary are characterized by tangential layer of flattened fibers. Earlywood vessels large solitary or in small radial groups (2-3 cells). Earlywood vessels with average diameter of 70.9 μm. Axial parenchyma lignifiedin marginal bands. Ray width is 1-3-seriate.

Plant morphology and habitat:

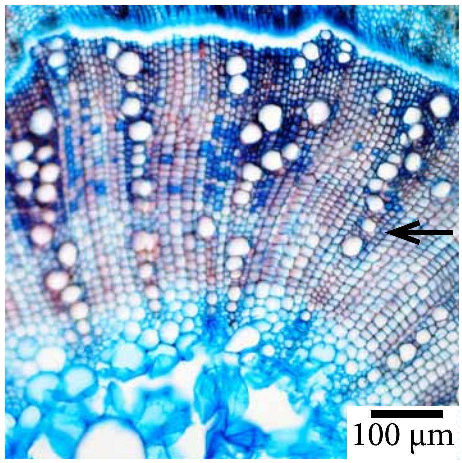
Perennial herb up to 80 cm, woody at the base: stems erect or ascending: leaves broadly obovate, serrate, green with hooked hairs on the upper surface, densely white pubescent on the lower. It grows in rocky wadis and slopes. It distributes in North Africa, extending to Southeast Spain, Sudan, Ethiopia, Palestine, Arabia and Iran eastwards to India.

Ring characteristics and anatomy:

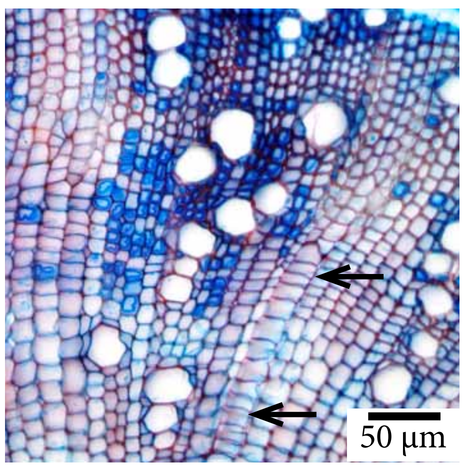
Twig of the plant analyzed is round with a diameter of 1.9 mm. Xylem/bark proportion is 1:1. Rings are distinct, two rings were found in the oldest twig. Wood ring-porous. Ring boundaries are characterized by thick-walled, flattened fibers. Vessels are mostly solitary or in a few short radial multiples. Earlywood vessels with average diameter of 59.1 μm. Axial parenchyma is pervasive and not lignified. Blue stained and filled fibers are indicating tension wood in the rings appears blue due to less lignified cell walls and the g-layer inside the fibers. Rays are unlignified.



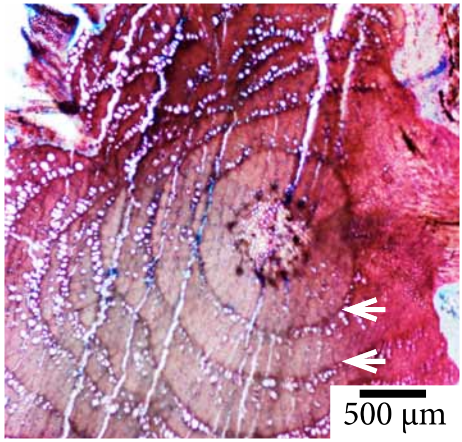
Two-year-old stem with distinct ring boundaries.



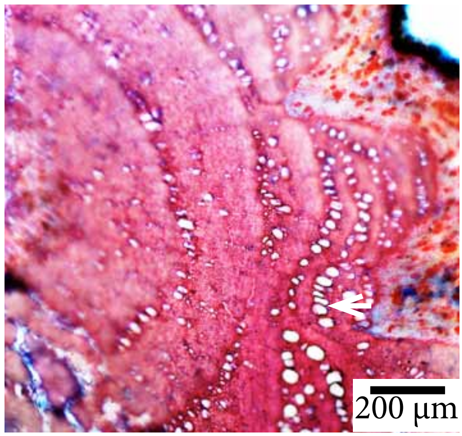
Wood ring-porous.



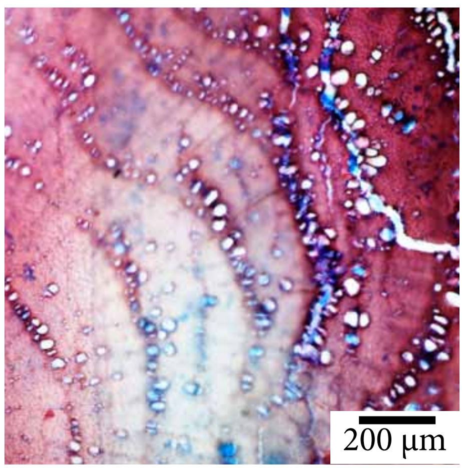
Enlarged view showing flattened fibers and latewood vessels at ring boundaries. Blue-stained cells with blue detached layer are tension wood, homogeneously blue cells are axial parenchyma. ▶



Eight-year-old stem with distinct growth rings and thick-walled fibers.



Earlywood vessels arranged at ring boundaries with thickened fibers.



Enlarged view for the ring boundaries.

Plant morphology and habitat:

Deciduous shrub with spinescent twigs, up to 120 cm. It grows in desert wadis and rocky slopes. It distributes particularly in North Africa, southwestern Europe and Asia.

Ring characteristics and anatomy:

Twig of the plant analyzed is lobed in cross-section with a diameter of 4.4 mm. Xylem/bark proportion is >2:1. The plants analyzed showed many rings. Wood ring-porous. Ring boundaries are determined by the presence of earlywood vessels arranged in tangential bands at the boundary of the ring then followed by thick-walled fibers that appear as ground tissues. Vessels with average diameter of 49.7 μm. Fibers very thick-walled. Axial parenchyma is vasicentric and apotracheal.