Using Lenses Attached to a Smartphone as a Macroscopic Early Warning Tool in the Illegal Timber Trade, in Particular for CITES-Listed Species

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Abstract: Wood anatomy is a key discipline as a tool for monitoring the global timber trade, particularly for wood listed in protected species conventions such as Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). One of the main barriers to reducing illegal trafficking of protected species is ensuring that customs officials with appropriate training in wood anatomy are equipped with simple tools, at both the origin and destination of shipments, so they can raise an early warning about wood suspected of contravening international treaties and immediately send samples to a specialised laboratory. This work explains how lenses attached to a smartphone, capable of achieving up to 400× magnification using the phone digital zoom, can be used to distinguish features that are not visible with traditional 10× or 12× lenses, enhancing the capacity to view features not typically observable in the field. In softwoods, for example, this method permits determination of the type of axial parenchyma arrangement, whether there are helical thickenings in axial tracheids and whether axial tracheids have organic deposits or contain alternate polygonal pits, and in the rays, if the tracheids are smooth-walled or dentate and if the cross-field pits are window-like. In hardwoods, it allows verification of the presence of tyloses and deposits in vessels, the type of perforation plates and whether the intervascular pitting is scalariform; in the rays it is possible to differentiate the types of ray cells; and in the axial parenchyma, to determine the presence of oil cells. In addition, unlike macroscopic analysis with a conventional magnifying lens, this type of lens can be used with the appropriate mobile application for the biometry of important elements such as ray height and vessel diameter.

Keywords: anatomy; endangered species; illegal trafficking; identification; wood

1. Introduction

From 1990 to 2015 the global forested area decreased from 31.6% to 30.6% [1]. Since 1990, 420 million hectares of forest have been lost due to changes in land use, even though the rate of deforestation has decreased in the last three decades. The estimated annual deforestation rate from 2015 to 2020 was 10 million hectares, compared to 16 million in the 1990s [2]. Illegal felling accounts for 15% to 30% of
global trade and has an estimated value of USD 50 to 152 billion a year [3]. It is estimated that 30% to 50% of the tropical timber traded internationally comes from illegally cleared forests [4].

Part of the solution to combat illegal logging is to prevent international trade in illegally harvested timber, at origin and destination. The Global Timber Tracking Network (GTTN), created to promote implementation of innovative tools to identify species, determine the geographical origin of wood and verify trade claims, and the Best Practice Guide for Forensic Timber Identification [5], are two good examples of initiatives designed to combat the trafficking of protected species.

In the coming years, illegal felling will remain a problem because of the high demand for wood [6], although the greatest cause of deforestation will continue to be the demand for agricultural land, the most significant contributor to large scale illegal harvesting [2].

The European Union has instigated actions to control the illegal market. In 2003, the European Union’s Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan was passed, proposing a range of measures to tackle illegal logging and the associated trade. In 2005, the EU passed Regulation (EC) No 2173/2005 on the establishment of a FLEGT licensing scheme for imports of timber and timber products into the European Community, requiring imports from countries with which a Voluntary Partnership Agreement (VPA) has been signed to be accompanied by a FLEGT licence issued by the producing country.

In 2010, Regulation (EU) No 995/2010 of the European Parliament and of the Council, of 20 October, was passed to govern products that have no FLEGT licence because there is no valid VPA or which are placed on the internal market for the first time. The regulation explains the obligations of operators who trade timber and timber products and is also known as the European Union Timber Regulation (EUTR).

All of these actions are hampered without the development of appropriate tools to inspect exports at origin and imports at the points of entry of timber. Customs officials and law enforcement agents in each country need to be equipped with early warning tools that enable them to stop shipments of suspected illegally traded timber.

Illegal timber traffickers are well aware of this situation and the difficulty of differentiating wood macroscopically, and as a result a significant part of the timber traded illegally has little trouble passing through checkpoints in some countries.

The species listed in the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) are undoubtedly at risk of over-exploitation, but there are many other tree species, red-listed or otherwise, that do not benefit from any legal protection. The IAWA Journal dedicated issue 32(2) to the role that wood science could play in combatting illegal logging, including anatomy, computerised assistance [7], infrared spectroscopy [8] and the use of molecular markers [9,10]. Since then, wood anatomists and specialists in other areas have continued to develop new methods to aid wood identification in the laboratory, e.g., using near infrared spectroscopy (NIRS) to distinguish *Swietenia macrophylla* King from similar species such as *Carapa guianensis* Aubl., *Cedrela odorata* L. and *Micropholis melinoniana* Pierre [11], DART (Direct Analysis in Real Time) TOFMS (Time-of-Flight Mass Spectrometry) to differentiate *Araucariaceae* [12], DNA in *Dalbergia* spp. [13] and direct analysis in real time and fourier transform ion cyclotron resonance mass spectrometry (DART-FTICR-MS) to distinguish between *Pterocarpus tinctorius* Welw. and *P. santalinus* L.f. [14].

However, laboratory identification by any of these techniques is the final stage of the process. Before wood is identified by a specialist, it must be inspected by customs agents, who normally have limited training in this area because of the difficulty of identifying wood at macroscopic level. Because of this, initiatives by CITES signatory countries have led to the publication of macroscopic identification guides that enable authorities to raise early warnings about timber shipments. A further complication is that CITES timbers sometimes comes from plantations outside the natural area of distribution of the species, e.g., *Swietenia* in Asia and *Cedrela* in Africa, and are therefore not subject to CITES trade restrictions. For their trade, however, clear proof of origin and legality is required. The provenance of these samples can be determined only by techniques other than wood anatomy, such as stable isotope
ratio analysis [15,16]. Moreover, other timbers are anatomically very similar to CITES-listed timbers (see Appendix A).

The Spanish authorities commissioned an initial document for wood identification of CITES-listed timbers for use by customs officials and law enforcement agents, written by Vales et al. [17]. The Ministry of the Environment of Canada published the CITES Identification Guide—Tropical Woods [18]. Richter et al. [19] published the widely used interactive database CITESwoodID. In all of these publications, the magnifications for macroscopic analysis were 10× or 12×.

In the current situation, the method of using traditional 10× or 12× magnifying lenses gives non-specialists little scope to easily recognise distinguishing anatomical features. However, lenses attached to a smartphone allow sufficient magnification to observe elements such as axial parenchyma arrangement, cross-field pits, helical thickenings and hexagonal pits in axial tracheids in softwoods, and scalariform perforation plates and pits in vessels, and homocellular or heterocellular rays and the presence of oil cells in the axial parenchyma in hardwoods, among other elements. In addition, using a smartphone camera with the appropriate lens has two clear advantages: on the one hand, it allows inspectors to quickly take digital photos that can be added to the inspection documentation or forwarded to a specialised laboratory, and, on the other hand, measurements of some features can be easily made. Inspectors will obviously require specialist training to use lenses for access to features that are visible only microscopically.

In view of this, we have prepared an early warning guide to timbers listed in CITES, with the support of the Ministry for the Ecological Transition and the Demographic Challenge of the Government of Spain. The methodology and the results of the guide are explained in this work [20].

The objective of this paper is to provide information about the use of lenses attached to a smartphone that allows up to 400× magnification using the phone digital zoom to complement traditional 10× and 12× magnifying lenses, and to show how this method can facilitate the work of agents responsible for tackling the trade of CITES-listed timbers so that, with appropriate training, they can decide whether or not to send samples to a specialist laboratory.

2. Materials and Methods

The species used for this work, all included in a CITES appendix, are shown in Table 1.

| Softwoods (Gymnosperms) | Date of Listing (Appendix) | Current Listing * (Appendix) |
|-------------------------|----------------------------|------------------------------|
| *Abies guatemalensis* Rehder | 01/07/1975 (I) | 01/07/1975 (I) |
| *Araucaria araucana* (Mol.) K.Koch | 01/07/1975 (II) | 13/02/2003 (I) |
| *Fitzroya cupressoides* (Molina) I.M.Johnston | 01/07/1975 (I) | 22/10/1987 (I) |
| *Pilgerodendron uviferum* (D.Don) Florin | 01/07/1975 (I) | (All populations) |
| *Pinus koraiensis* Sieb. and Zucc. | 14/10/2010 (III) | 14/10/2010 (III) |
| *Podocarpus nerifolius* D.Don | 16/11/1975 (III) | 23/06/2010 (III) |
| *Podocarpus parlatoresi* Pilg. | 01/07/1975 (I) | 01/07/1975 (I) |
| *Taxus chinensis* (Pilg.) Rehder | 12/01/2005 (II) | 26/11/2019 (II) |
| *Taxus cuspidata* Siebold and Zucc. | | |
| *Taxus fujana* Nan Li and R.R.Mill | 12/01/2005 (II) | 13/09/2007 (II) |
| *Taxus sumatrana* (Miq.) de Laub | | |
| *Taxus wallichiana* Zucc. | 16/02/1995 (II) | 13/09/2007 (II) |
All the samples have a confirmed provenance and are from the wood collections of the School of Forest Engineering and Natural Resources at Universidad Politécnica de Madrid, Spain (UPMAw), and Royal Botanic Gardens, Kew, United Kingdom (K-w).

Samples were prepared by sanding on the transverse section with a sanding sequence of 400, 800, 1200, 2000, 3000 in a dual platen Ecomet Buehler sander, using wet sanding. Other samples were prepared by hand with the same sanding sequence using a portable machine (Figure 1A), because this equipment is more useful for preparing samples in situ. Sample preparation time was less than three minutes. Sawdust was removed from the surface of the samples in a Branson Sonifier 450 water immersion ultrasonic device at 20 kHz for 5 to 8 min. The tangential and radial sections were obtained by splitting the sample using a hammer and a utility knife and were not sanded (Figure 1B). This is the ideal way to prepare samples to cover a clear area of approximately one square centimetre. However, given the difficulties involved in sanding because of the need to carry portable equipment, samples can also be prepared using a sharp single-sided razor.

The lenses used were a VicTsing 24× macro scope (Figure 1C) to observe general features in the transverse section and a Nurugo lens capable of magnifying up to 400× through a combination of the magnification provided by the lens and the smartphone digital zoom (Figure 1D) to observe specific features in the three sections. This lens also comes with a free application for biometry. To take the close-up photos for this work with the 400× lens, a support and a V-Type 4-Axis xyzr micrometer platform (Figure 1E) were used. Photos of 24× zoom can be taken without a support (Figure 1F), but to recognise certain features requiring greater magnification, a support should always be used. It is advisable to use plasticine to hold the wood sample in place on the micrometer platform or any
other support chosen, to ensure the wood sample remains parallel to the observation plane of the lens (Figure 1G).

Figure 1. Preparation, lenses and support. (A) Portable sander with 50 mm discs. (B) Obtaining tangential and radial sections by splitting the wood. (C) VicTsing macro scope 24× lens. (D) Nurugo 400× lens. (E) Support and 10 mm precision micrometric platform for observation with 400× lens. (F) Observation with no support using 24× lens. (G) Sample held in place with plasticine to ensure it remains parallel to the lens.

Scales are not shown in the photos because the optical magnifications were combined with the smartphone digital magnifications, and the application associated with the Nurugo lens does not permit the scale bar to be exported when photos are taken.
The IAWA hardwood and softwood lists [21,22] were used for the features described. Plants of the World Online [23] was used for nomenclature, geographical distribution and number of species per genus.

3. Results and Discussion

3.1. Softwoods

While microscopic identification of softwoods through their anatomy is complicated, particularly in families such as Cupressaceae where the genera have very similar anatomical features [24], macroscopic identification is almost impossible. However, large groups of softwoods can be differentiated without difficulty by observing certain macroscopic features. For example, wood with resin canals can be distinguished from wood that has none by observation with a 24× lens (Figure 2A). The presence of resin canals in softwoods is restricted to the family Pinaceae. The genera Cathaya Chun and Kuang, Larix Mill., Picea A.Dietr. and Pseudotsuga Carrière have both axial and radial resin canals, with thick-walled epithelial cells. In Pinus L., resin canals are axial and radial, with thin-walled epithelial cells, while Keteleeria Carrière and Nothotsuga H.H.Hu ex C.N.Page have only axial resin canals with thick-walled epithelial cells. No softwoods have exclusively radial resin canals. Traumatic resin canals occur in all these genera, normally in tangential rows. In Keteleeria and Nothotsuga, only traumatic axial resin canals occur, both in tangential rows and/or randomly in solitary arrangement. The other genera in Pinaceae can also form traumatic axial resin canals (Abies Mill., Cedrus Mill., Pseudolarix Gordon and Glend. and Tsuga (Endl.) Carrière), while in Cedrus traumatic resin canals can be axial and radial [25].

In genera other than Pinaceae, traumatic resin canals have been reported in Sequoia sempervirens (D.Don) Endl. [26], Sequoiadendron J.Buchholz [27], Microbiota Kom. [28] and Tetraclinis Mast. [29].

Among the softwoods listed in CITES, only Pinus koraiensis has normal axial and radial resin canals, and although observation using a lens will not differentiate it from other pines in the section Strobus (P. cembra L., P. lambertiana Douglas, P. monticola Douglas ex D.Don, P. strobus L., etc.) characterised by the presence of window-like cross-field pits and smooth-walled ray tracheids, customs agents can use a 400× lens for observations that will enable them to stop a shipment and send a sample to the laboratory (Figure 2B–D).

Within the genus Abies, only A. guatemalensis is listed in CITES. A 24× lens permits observation of the absence of resin canals (Figure 3A) and a 400× lens reveals axial parenchyma cells on the growth ring boundary, although these features also occur in other Abietoideae genera (Abies, Cedrus, Keteleeria, Nothotsuga, Pseudotsuga, Tsuga) [25]. The presence of pitted horizontal walls and distinctly nodular end walls of ray parenchyma cells could be used as early warning features, but they cannot be observed using a 400× lens. Abies is a difficult genus to differentiate. The anatomy of its species is so similar that differences between certain groups of species can be determined only through the biometry of some of their elements, such as ray height and other specific quantitative features [30].

Using a 24× lens, it is easy to distinguish the tangentially zonate arrangement of the axial parenchyma in Fitzroya cupressoides (Figure 3B) and the tangentially zonate or diffuse arrangement in Pilgerodendron uviferum (Figure 3C), although other genera of Podocarpaceae and Cupressaceae have the same type of arrangement, e.g., Callitris Vent., Calocedrus Kurz, Chamaecyparis Spach, Cryptomeria D.Don., Cupressus L., Juniperus L., Taxus Hayata, Taxodium Rich., Thuja L. [22], Tetraclinis [29], Actinostrobus Miq., Calocedrus, Chamaecyparis, Cupressus, Glyptostrobus Endl. [24] and a further species recently listed in CITES (Appendix II, 26 November 2019), Widdringtonia whytei Rendle, although its tangentially zonate axial parenchyma is sparser [24]. The characteristic colour and large number of growth rings per centimetre in Fitzroya Lindl., similar to Sequoia sempervirens and Thuja plicata Donn ex D.Don, in conjunction with axial tracheids without helical thickenings and the absence of resin canals, are sufficient to raise an early warning, although it would include other genera.

The absence of resin canals and axial parenchyma observed using a 24× lens and the presence of organic deposits in tracheids and alternate polygonal pits in axial tracheids seen with a 400× lens
(Figure 3D,E) permits an early warning for suspected *Araucaria araucana* wood, although these features could correspond to any of the 20 species of the genus *Araucaria* Juss. or the 17 accepted species of *Agathis* Salisb. Similar features occur in *Wollemia nobilis* W.G.Jones, K.D.Hill and J.M.Allen (*Araucariaceae*). This species was discovered in 1994 and its wood was described by Heady et al. [31], but it has never been traded.

**Figure 2.** Elements visible with 24× and 400× lenses in softwoods. *Pinus koraiensis* Sieb. and Zucc. (A) Axial resin canals (24× lens). (B) Thin-walled epithelial cells in axial resin canal (400× lens). (C) Axial resin canal in radial section (24× lens). (D) (a) Smooth-walled ray tracheid; (b) window-like cross-field pit (400× lens). (E) Dentate ray tracheid in *Pinus sylvestris* L. (400× lens).
Within the genus *Abies*, only *A. guatemalensis* is listed in CITES. A 24× lens permits observation of the absence of resin canals (Figure 3A) and a 400× lens reveals axial parenchyma cells on the growth ring boundary, although these features also occur in other *Abietoideae* genera (*Abies, Cedrus, Keteleeria, Nothotsuga, Pseudolarix* and *Tsuga*) [25]. The presence of pitted horizontal walls and distinctly nodular end walls of ray parenchyma cells could be used as early warning features, but they cannot be observed using a 400× lens.

*Abies* is a difficult genus to differentiate. The anatomy of its species is so similar that differences between certain groups of species can be determined only through the biometry of some of their elements, such as ray height and other specific quantitative features [30].

![Figure 3.](image)

**Figure 3.** Elements visible with 24× and 400× lenses in softwoods. (A) Growth rings in *Abies guatemalensis* (24× lens). (B) Tangentially zonate axial parenchyma in *Fitzroya cupressoides* (Molina) I.M.Johnston (24× lens). (C) Diffuse axial parenchyma in *Pilgerodendron uviferum* (D.Don) Florin (24× lens). *Araucaria araucana* (Mol.) K.Koch. (D) Organic deposits in axial tracheids (400× lens). (E) Alternate polygonal pits in axial tracheids (400× lens). (F) Diffuse axial parenchyma in *Podocarpus neriifolius* D.Don (24× lens). *Taxus cuspidate* Siebold and Zucc. (G) Growth rings (24× lens). (H) Helical thickenings in axial tracheids (400× lens).

Only two of the 115 species of the genus *Podocarpus* L’Hér. ex Pers. are listed in CITES: *P. neriifolius* (Figure 3F) and *P. parlatorei*. Their wood is very similar to that of the other species of *Podocarpus* and many
of the genera included in Podocarpaceae (Acmopyle Pilg., Afrocarpus (Buchholz and N.E.Gray) C.N.Page, Dacrycarpus (Endl.) de Laub., Dacrydium Sol. ex G.Forst., Falcifolium de Laub., Halocarpus C.J.Quinn, Lepidothamnus Phil., Nageia Gaertn., Parasitaxus de Laub., Pherosphaera W.Archer bis, Prumnopitys Phil., Retrophyllum C.N.Page and Saxegothea Lindl.). They can be differentiated from five genera of this family using a 400× lens because of their phyllocladoid pits, similar in appearance to window-like pits (Lagarostrobus Quinn, Manao Molloys, Microcachrys Hook.I., Phyllocladus Rich. ex Mirb., and Sundacarpus (J.Buchholz and N.E.Gray) C.N.Page), and from the species Prumnopitys andina (Poepp. ex Endl.) de Laub. [32].

Taxus L. is characterised by the absence of axial parenchyma and resin canals (Figure 3G) and the presence of helical thickenings in axial tracheids, easily observed using a 400× lens (Figure 3H). Other softwood genera have the same features as Taxus, e.g., all those included in Taxaceae (Amentotaxus Pilg., Cephalotaxus Siebold and Zucc. ex Endl., Pseudotaxus W.C.Cheng, Taxus, Torreya Raf.) except Austrotaxus Compton [33]. However, observation of helical thickenings with a 400× lens would allow inspectors to raise an early warning and send a sample to the laboratory.

3.2. Hardwoods

Wood identification using light microscopy is usually sufficient to identify a wood sample to genus level, but in some cases where CITES legislation requires identification to species level, it is difficult or impossible [34]. At macroscopic level the situation is more complicated. However, if inspectors are able to view distinctive features in addition to those observable under traditional magnifying lenses, they will be able to decide whether to detain a shipment and send samples to a specialised laboratory.

For example, the genus Aniba Aubl. has 49 species and only one, Aniba rosodora Ducke, is listed in CITES. A 400× lens can be used to distinguish tyloses in the vessels (Figure 4A), oil cells in the axial parenchyma (Figure 4B) and heterocellular rays with one row of upright and/or square marginal cells (Figure 4C). These last two features are not visible with a traditional magnifying lens. However, inspectors need to know that other species of Aniba, e.g., A. hypoglauca Sandwith, and other genera of Lauraceae, are anatomically similar [35].

Aquilaria poses fewer difficulties, despite its 21 species (distributed from Assam to southern China and New Guinea), and Gyrinops Gaertn., with nine species (from Sri Lanka to New Guinea), because they are all listed in CITES, in Appendix II. The description of their anatomy has recently been extended by Luo et al. [36]. Both of these genera are characterised by the presence of diffuse included phloem, parenchyma that is absent or very rare, at times scanty paratracheal, and rays that are exclusively uniseriate and occasionally partially biseriate. Their rays can be homocellular with all cells upright and/or square (Aquilaria malaccensis Lam.), heterocellular with procumbent body ray cells and one or more rows of upright and/or square marginal cells, and can even have procumbent, square and upright cells mixed throughout the ray (Gyrinops walla Gaertn.). The 24× lens permits observation of diffuse-porous wood and diffuse included phloem (Figure 4D), and the 400× lens reveals exclusively uniseriate rays (Figure 4E) and the type of cells that form them (Figure 4F). These three features are sufficient to alert inspectors, because few woods have included phloem, and its presence alongside other features such as uniseriate rays and fine intervessel pitting makes these two genera easily identifiable in the laboratory [34]. The combination of diffuse-porous wood, exclusively uniseriate rays and diffuse included phloem corresponds to only 43 possible species genera of the 7511 descriptions in InsideWood [35,37].

The genera Bulnesia Gay, with five species in South America, of which only B. sarmientoi is listed in CITES, and Guaiacum, with six species, all listed in CITES, distributed in Central America, the Caribbean and northern South America, correspond to very hard and heavy greenish black woods with an oily surface that are not difficult to identify. Both of these genera are characterised by the absence of tyloses and the presence of deposits, and homocellular storied rays with procumbent cells. In Guaiacum, the 400× lens shows the solitary vessels (Figure 5A), marginal axial (Figure 5(Aa)) and diffuse-in-aggregate axial parenchyma (Figure 5(AB)), and exclusively uniseriate rays (Figure 5B);
in *B. sarmientoi*, it shows vessels in radial or diagonal multiples of four or more (Figure 5C) and rays one to three cells wide (Figure 5D).

**Figure 4.** Elements visible with 24× and 400× lenses in hardwoods. *Aniba rosodora* Ducke, (A) Tyloses (400× lens). (B) Oil cells in axial parenchyma (400× lens). (C) Rays with one row of upright and/or square marginal cells (400× lens). *Aquilaria malaccensis* Lam. (D) Diffuse included phloem (24× lens). (E) Uniseriate rays (400× lens). (F) Rays with one row of upright and/or square marginal cells (400× lens).
Figure 5. Elements visible with 400× lens in hardwoods. *Guaiacum* spp. (A) Solitary vessels; (a) marginal axial parenchyma; (b) diffuse-in-aggregate axial parenchyma; (B) storied rays, exclusively uniseriate. *Bulnesia sarmientoi* Lorentz ex Griseb., (C) bessels in radial or diagonal multiples of 4 or more. (D) Storied rays, 1 to 3 cells wide. *Caryocar costaricense* Donn.Sm., (E) diffuse-porous wood; (a) tyloses; (b) diffuse axial parenchyma; (c) diffuse-in-aggregate axial parenchyma. (F) Tyloses. (G) Rays with more than 4 rows of upright and/or square marginal cells.

*Caryocar* L. comprises 16 species, all in tropical America. Only *C. costaricense* is listed in CITES. The *Caryocar* species commonly traded are *C. brasiliense* Cambess., *C. edule* Casar., *C. glabrum* (Aubl.) Pers. and *C. villosum* (Aubl.) Pers. [38]. Inspectors can raise an early warning based on the diffuse-porous wood (Figure 5E), presence of abundant tyloses (Figure 5(Ea),F), diffuse (Figure 5(Eb)) and diffuse-in-aggregate axial parenchyma (Figure 5(Ec)), rays with more than four rows of upright and/or square marginal cells (Figure 5G) and ray height > 1 mm, all observable with a 400× lens. These features correspond to 65 descriptions in InsideWood [35], but other features not visible with a 400× lens can be observed in the laboratory and permit good identification of the genus. The difficulty of this wood is that other species of the genus not listed in CITES have similar anatomical features.

*Meliaceae* Juss. is one of the most highly valued families for trade because of its timber. True mahogany (*Swietenia* spp.) and Spanish cedar (*Cedrela* spp.) are good examples of this, and the
genera Carapa Aubl., Entandrophragma C.DC., Guarea Allemão ex L., Khaya A.Juss., Toona M.Roem., among others, also provide very good quality red timber.

Both Cedrela spp. and Swietenia spp. have been traded for a long time and their wood is one of the most frequently analysed timbers at our laboratory in Madrid. All three species of Swietenia Jacq. are listed in CITES, facilitating the work both of wood anatomists [34] and inspectors. This was previously not the case of Cedrela, which comprises 18 species but had only three listed in CITES: C. odorata (in Appendix III since 2001) and C. fissilis Vell. and C. lilloi C.DC. also in Appendix III, listed in December 2010 at the request of the Bolivian authorities. However, all the species were added to Appendix II on 28 August 2020. Although this will facilitate the work of anatomists, inspectors will continue to have difficulty comparing timbers that are very similar not only to each other, but also to other genera of Meliaceae, such as the species of Toona, which are frequently traded internationally and cannot be differentiated from Cedrela by their macroscopic features. Inspectors should refer to the comparison of these timbers by Richter et al. [19] in the additional information about Swietenia spp. With the lenses used in this work, it is possible to observe without difficulty in both genera the diffuse-porous wood with vessels that are solitary and in multiples of two or three, without tyloses (Figure 6A,D), with gum deposits in Cedrela spp. (Figure 6Ba), reddish-brown deposits, sometimes white in Swietenia spp. (Figure 6E), marginal axial parenchyma visible even without a magnifying lens (Figure 6A,D) and scanty paratracheal axial parenchyma visible with a 400× lens in both genera (Figure 6Bb). Using the 400× lens, it is possible to observe in both genera rays with procumbent body ray cells and one row of upright and/or square marginal cells (Figure 6G,H), and at times in Swietenia spp., normal or irregularly storied rays (Figure 6F). When inspectors suspect red wood with these features, they may spend time examining wood that is not listed in CITES, but the additional macroscopic information in Richter et al. [19] and the 400× lens used in this work will eventually provide results, making inspections increasingly more accurate.

The genus Dalbergia is one of the most anatomically studied genera because of the quality of its wood for uses such as cabinetmaking, decorative wood veneer, marquetry, carvings, inlaying, furniture, turnery, sculpture, musical instruments (guitars, marimbas, pianos and xylophones) and boat interiors. Its inclusion in CITES in 1992 with a single species, D. nigra (Vell.) Allemão ex Benth. (in Appendix I), led to interesting studies attempting to differentiate it from the other species of the genus [39,40]. Unfortunately, the results showed that anatomy alone could not distinguish this wood from its congeneric species. The inclusion in 2017 of the 270 species of the genus greatly facilitated the work of anatomists and customs inspectors.

Microscopically, Dalbergia wood is generally recognisable by the presence of short, regularly storied rays, typically large vessels, abundance of diffuse and diffuse-in-aggregate axial parenchyma, and ventured pits [40]. With the lenses used in this work, all of these features are easily observable except the ventured pits, and several other features can also be verified, such as other types of axial parenchyma, whether the rays are uni- or biseriate and whether they contain one row of upright and/or square marginal cells, as sometimes occurs in D. nigra and D. retusa Baill. (Figure 7A–G).

Diospyros is a cosmopolitan genus comprising 732 species, of which only those from Madagascar are listed in CITES (since 2011). They are easily confused with other species of the genus that are not protected and it is virtually impossible to identify them by their anatomy alone. However, using a 400× lens, inspectors can raise an alert after identifying some anatomical features of the genus that are very difficult to observe with a traditional magnifying lens. The genus is characterised by diffuse-porous wood, with vessels in radial multiples of two or three or even four or more, without tyloses and frequently with deposits, and axial parenchyma in narrow bands (marginal and non-marginal), forming a typical reticulate pattern with rays (Figure 8A–C). Their rays are not usually storied, and this separates Diospyros spp. from Dalbergia spp. Only one of the Madagascan species, D. sakalavarum H. Perrier, has a rudimentary storied structure in its rays [19].
Figure 6. Elements visible with 24× and 400× lenses in hardwoods. *Cedrela odorata* L. (A) Vessels solitary and in multiples of 2 or 3 and marginal axial parenchyma (24× lens). (B) (a) Gum deposits; (b) scanty paratracheal axial parenchyma (400× lens). (C) Non-storied rays (400× lens). *Swietenia* spp. (D) Vessels solitary and in multiples of 2 or 3 and marginal axial parenchyma (24× lens). (E) White deposits (400× lens). *Swietenia macrophylla* King. (F) Storied rays (400× lens). (G) and (H) Procumbent body ray cells with one row of upright and/or square marginal cells in *Cedrela odorata* and *Swietenia* spp. (400× lens).
Diospyros is a cosmopolitan genus comprising 732 species, of which only those from Madagascar are listed in CITES (since 2011). They are easily confused with other species of the genus that are not protected and it is virtually impossible to identify them by their anatomy alone. However, using a 400× lens, inspectors can raise an alert after identifying some anatomical features of the genus that are very difficult to observe with a traditional magnifying lens. The genus is characterised by diffuse-porous wood, with vessels in radial multiples of two or three or even four or more, without tyloses and frequently with deposits, and axial parenchyma in narrow bands (marginal and non-marginal), forming a typical reticulate pattern with rays (Figure 8A–C). Their rays are not usually storied, and

**Figure 7.** Elements visible with 400× lens in hardwoods. *Dalbergia* spp. (A) *D. latifolia* Roxb. (B) *D. nigra*. (C) *D. retusa*. (D) *D. sissoo* Roxb. ex DC. (E) *D. stevensonii* Standl. (F) Storied rays in *D. nigra*. (G) Procumbent body ray cells with one row of upright and/or square marginal cells in *D. nigra*. 
this separates Diospyros spp. from Dalbergia spp. Only one of the Madagascan species, Diospyros sakalavarum, has a rudimentary storied structure in its rays [19].

**Figure 8.** Elements visible with 400× lens in hardwoods. Diospyros spp. (A) Axial parenchyma in marginal or in seemingly marginal bands and diffuse-in-aggregates forming a reticulate pattern with rays. (B) Non-storied rays. (C) Procumbent body ray cells with one row of upright and/or square marginal cells. Dipterix panamensis (Pittier) Record and Mell. (D) (a) White deposits in vessels; (b) lozenge-aliform axial parenchyma; (c) confluent axial parenchyma. (E) Rays 1 to 3 cells wide, storied. (F) Homocellular rays with procumbent cells. Gonystylus spp. (G) (a) Winged-aliform axial parenchyma; (b) confluent axial parenchyma. (H) Uniseriate rays, non-storied. (I) Procumbent body ray cells with one row of upright and/or square marginal cells.

_Dipteryx_ Schreb. comprises 13 species distributed across Central America and tropical South America. Only _D. panamensis_ is listed in CITES and it is difficult to distinguish from other species
of the genus, such as \textit{D. odorata}, traded as Cumarú \cite{19}. Gasson \cite{41} made a complete description of the genus \textit{Dipterex}, comparing the wood anatomy of the three genera of \textit{Dipterygeae} (\textit{Dipterex}, \textit{Pterodon} Aubl. and \textit{Pterodon} Vogel). The description of \textit{Dipterex} was based on nine species, including \textit{D. panamensis}, but does not distinguish between them. The difficulty of differentiating between the species of this genus is compounded by the similarity between \textit{Dipterex} and \textit{Pterodon}. Despite this, with the lenses used in this work, inspectors can observe diffuse-porous wood, normally with vessels that are solitary or sometimes in radial multiples of two, three, four or even more; absence of tyloses and presence of white and honey-coloured deposits; lozenge-aliform, winged-aliform and confluent axial parenchyma; and rays one to three cells wide, storied and formed exclusively of procumbent cells (Figure 8D–F). The 400× lens is particularly useful for the last three of these features.

\textit{Gonystylus} comprises four species, distributed in Southeast Asia to the southwest Pacific. All of them are listed in CITES, greatly facilitating the work of anatomists. A traditional magnifying lens is required to observe the diffuse-porous wood and the typical winged-aliform axial parenchyma, although observation is much easier with the lenses used in this work. Vessels are solitary and in radial multiples of up to four or more. Tyloses are absent and deposits are rare. The genus also has confluent parenchyma. The 400× lens permits observation of uniseriate rays, occasionally biseriate, normally with procumbent cells although sometimes with procumbent body ray cells with one row of upright and/or square marginal cells (Figure 8G–I). With the 400× lens it was not possible to find crystals in the ray cells.

\textit{Magnolia} Plum. ex L. comprises 320 species with a very broad distribution range, from Canada to Brazil, the Caribbean, India to the Kuril Islands and New Guinea. Only one species, \textit{M. liliifera} var. \textit{obovata}, is listed in CITES. It is native to Borneo, Malaysia and Thailand. There is no record of this wood being traded internationally and it very rarely reaches our laboratory. Based solely on anatomy, it would be impossible to differentiate from other species of the genus, although \textit{Magnolia} has high variability in its features, e.g., perforation plates can be simple or scalariform \cite{42} and the number of bars in the perforation plates varies from fewer than 10 to 20 or 40 \cite{35}. Even so, it is a distinctive wood, and inspectors can observe features using the two lenses (particularly the 400× lens) which, in conjunction with the shipping documentation, will allow them to raise an alert that could stop a shipment. The genus \textit{Magnolia} is easy to identify. A traditional magnifying lens provides very little information except for the diffuse-porous wood and marginal axial parenchyma. With a 400× lens, neither tyloses nor deposits are observed, and scalariform perforation plates with fewer than 10 bars are clearly seen, although Gasson et al. \cite{43} reported plates with 10 to 20 bars; scalariform intervessel pits and rays with procumbent body ray cells and 1–2 rows of upright and/or square marginal cells (Figure 9A–C) are also clearly visible.

\textit{Oreomunnea} Oerst. comprises four species (\textit{O. americana} Lundell, \textit{O. mexicana} (Standl.) J.-F.Leroy, \textit{O. munchiquensis} Lozano and F.González and \textit{O. pterocarpa}), all native to Central America. Only \textit{O. pterocarpa}, naturally distributed in Costa Rica, Mexico and Panama, is listed in CITES. It is traded only in the local area. It has diffuse-porous wood, with vessels visible without a magnifying lens, solitary and in multiples of two and three, with tyloses and without deposits. With a traditional magnifying lens its characteristic diffuse-in-aggregate and narrow tangential lines of axial parenchyma are visible. Gasson et al. \cite{43} and InsideWood \cite{35} described axial parenchyma in narrow bands or lines up to three cells wide and axial parenchyma in marginal or in seemingly marginal bands. Seen through the 400× lens, rays are clearly heterocellular with procumbent body ray cells and mostly 2–4 rows of upright and/or square marginal cells or with more than four marginal rows (Figure 9D,E). Prismatic crystals in chambered axial parenchyma cells are not visible with the 400× lens.

\textit{Caesalpinia} L. originally comprised 161 species, but since its first description in 1753 it has been divided into 30 different genera. \textit{Caesalpinia echinata} is now called \textit{Paubrasilia echinata} \cite{44}, forming a monospecific genus. This species was exploited for more than 500 years for its dye, until it was replaced by synthetic dyes in the mid-19th century \cite{45}. It is the most highly valued wood for the manufacture of violin bows \cite{46}. Despite its inclusion in a monospecific genus, the wood has features
similar to those of other genera of \emph{Caesalpinia} s.s., making identification to species level very difficult. It has diffuse-porous wood, with vessels that are solitary and in multiples of two and three, without tyloses and with deposits, axial parenchyma that is vasicentric, aliform, lozenge-aliform, confluent, marginal or in seemingly marginal bands, rays one to three cells wide, homocellular, with procumbent cells, and in the sample observed in this work, irregularly storied, although the literature varies with regard to this feature [34]. It is a distinctive timber due to its hardness and weight, and customs inspectors should be wary because it is so highly valued for violin bows. The 400× lens permits observation of all the features indicated (Figure 9F–H).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure9.png}
\caption{Elements visible with 400× lens in hardwoods. \textit{Magnolia liliifera} var. \emph{obovata} (Korth.) Govaerts. \emph{obovata}. (A) Diffuse-porous wood. (B) Scalariform perforation plate. (C) Scalariform intervessel pits. \textit{Oreomunnea pterocarpa} Oerst. (D) Axial parenchyma in narrow bands or lines up to 3 cells wide. (E) Procumbent body ray cells with mostly 2–4 rows of upright and/or square marginal cells and even with more than 4 rows. \textit{Paubrasilia echinata} (Lam.) Gagnon, H.C. Lima & G.P. Lewis (syn. \textit{Caesalpinia echinata} Lam.). (F) (a) Deposits; (b) lozenge-aliform axial parenchyma; (c) confluent axial parenchyma. (G) Irregularly storied rays. (H) Homocellular rays with procumbent cells.}
\end{figure}
Pericopsis Thwaites comprises five species, three in Africa (P. angolensis (Baker) Meeuwen, P. elata and P. laxiflora (Benth. ex Baker)) and two in Southeast Asia (P. mooniana Thwaites and P. ponapensis (Hosok.) Hosok.); only P. elata is listed in CITES, making it difficult to identify. Added to this is the risk of confusion recently observed with wood of the genus Acosmium Schott [19]. InsideWood [35] describes all the African species and P. mooniana, with no significant anatomical differences. P. elata wood is diffuse-porous, with vessels solitary or in radial multiples of two or three, without tyloses and with dark or white deposits, axial parenchyma that is vasicentric, aliform, lozenge-aliform, confluent, at times marginal or in seemingly marginal bands, homocellular rays one to three cells wide, storied and with procumbent cells. With the 400× lens these features are easily observed, and in conjunction with other features visible under the microscope, the wood can be identified without difficulty in the laboratory to genus level. However, the features observed with the 400× lens are sufficient for inspectors to raise an early warning (Figure 10A–C).

Platyniscium Vogel comprises 19 species distributed in South America, Central America and Mexico. Only P. parviflorum (syn. P. pleiostachyum) is listed in CITES, making it difficult to identify. This is further complicated by the impossibility of differentiating them macroscopically from other genera of Fabaceae such as Centrolobium Mart. ex Benth. which includes seven species from tropical South America. InsideWood [35] describes five species with similar anatomical features. Some of its features can be easily viewed with a 400× lens but are not observable with a traditional magnifying lens. Its wood is diffuse-porous, with deposits, axial parenchyma that is aliform, lozenge-aliform, winged-aliform and confluent, homocellular rays one to three cells wide, with exclusively procumbent cells, storied and irregularly storied. It also has storied axial parenchyma (Figure 10D,E).

Prunus L. comprises 311 species and only one, P. africana, is listed in CITES. Inspectors are unlikely to come across this wood because it is used only locally and mainly for its bark, which is in demand for treatment of benign prostate hyperplasia [47]. We do not believe it can be distinguished from the other species of the genus, but with a 400× lens it is easy to observe its diffuse-porous wood, vessels in radial multiples of two, three and even more than four, without tyloses and with deposits, although scarce, axial parenchyma that is diffuse and scanty paratracheal, rays 4 to 10 cells wide, with procumbent body ray cells and one row of upright and/or square marginal cells and also two to four rows (Figure 10F,G).

Pterocarpus Jacq. is a widely distributed genus with 41 accepted species, native to tropical and temperate Asia, the Pacific, Africa, Central America and South America. Only one species native to India, P. santalinus, and two from Africa, P. erinaceus Poir. and P. tinctorius are listed in CITES (Annex II). They are anatomically similar to other species of Pterocarpus, but direct analysis in real time and fourier transform ion cyclotron resonance mass spectrometry (DART-FTICR-MS) combined with multivariate statistical analysis has permitted differentiation between P. santalinus and P. tinctorius [14]. As a dalbergioid legume, its anatomy is similar to Dalbergia, particularly in the tangential section [34]. Using a 400× lens it is easy to distinguish features that are not visible with a traditional magnifying lens. Its wood is diffuse-porous, sometimes semi-ring-porous, with solitary vessels and in radial multiples of two and three, without tyloses and with deposits, axial parenchyma that is aliform, winged-aliform, confluent, in bands wider than the rays, seemingly marginal, rays exclusively uniseriate, sometimes partially biseriate of the same width, homocellular with procumbent cells, and storied (Figure 11A–C).

Quercus L. is a genus widely distributed in temperate forests of the northern hemisphere, reaching as far as Colombia and Malaysia. It has 456 accepted species, but only one, Q. mongolica, is listed in CITES, creating a problem for anatomical identification. The wood has a typical ring-porous pattern, with latewood vessels polygonal in outline and solitary, but arranged in radial formations in a dendritic pattern. The vessels have tyloses but lack deposits. Its axial parenchyma is in bands, marginal and non-marginal, forming a scalariform pattern with rays, and diffuse-in-aggregates. Its rays have two distinct widths, more than 5 mm high. The rays are multiseriate, 8 to 20 cells wide, forming a silvery appearance in the radial section. Rays are homocellular with procumbent cells (Figure 11D–F).
Figure 10. Elements visible with 400× lens in hardwoods. *Pericopsis elata* (Harms) Meeuwen. (A) (a) Marginal axial parenchyma; (b) confluent axial parenchyma; (c) lozenge-aliform axial parenchyma; (d) white deposits. (B) Storied rays, 1 to 3 cells wide. (C) Homocellular rays with procumbent cells. *Platymiscium parviflorum* Benth. (*syn. Platymiscium pleiostachyum* Donn.Sm.). (D) Winged-aliform and confluent axial parenchyma. (E) Homocellular rays with procumbent cells. *Prunus Africana* (Hook.f.) Kalkman. (F) Diffuse-porous wood with vessels in radial multiples of 2, 3, 4 or more. (G) Procumbent body ray cells with one row of upright and/or square marginal cells and also with 2 to 4 rows.
Figure 11. Elements visible with 400× lens in hardwoods. *Pterocarpus santalinus* L.f. (A) (a) Winged-aliform axial parenchyma; (b) confluent axial parenchyma. (B) Deposits. (C) Alternate polygonal pits. *Quercus mongolica* Fisch. ex Ledeb. (D) Ring-porous wood. (E) Latewood vessels polygonal in outline. (F) (a) Homocellular rays with procumbent cells; (b) tyloses; (c) vasicentric tracheids.

3.3. Biometry

The elements observed can be measured using the application associated with the 400× lens, Nurugo Box, available for Android and iOS. In softwoods, the application can be used to measure the number of coils per millimetre in the helical thickenings of the axial tracheids, and in hardwoods to measure the tangential diameter of the vessels, the number of vessels per square millimetre, the mean...
length of the vessel elements, ray height and the number of rays per millimetre. It is not possible to measure the diameter of the intervessel pits or the length of the fibres due to their small size.

The images shown in Figure 12 are screenshots, because the application does not yet allow images to be exported with the scale bar. The 1 mm$^2$ square in Figure 12B was drawn on the phone screen during equipment calibration.

![Figure 12. Biometry.](image)

- (A) Tangential diameter of vessel lumina (*Quercus mongolica*).
- (B) Vessels per square millimetre (*Cedrela odorata*).
- (C) Vessel element length (*Pterocarpus santalinus*).
- (D) Ray height (*Dipteryx panamensis*).
- (E) Rays per millimetre (*Dalbergia stevensonii*). Figure 12C,D are rotated 90° because the mobile application does not permit rotation of the scale.
Combined use of lenses attached to a smartphone therefore not only complement traditional observation under 10× magnification of macroscopic features such as those described in other publications [48], but also enables biometry and photo capture in situ. This considerably reduces the time normally required for these tasks and allows agents responsible for monitoring the international timber trade, especially of wood listed in the CITES appendices, to raise an early warning.

4. Conclusions

- Using lenses attached to a smartphone, agents responsible for monitoring the timber trade can, after suitable training, identify elements of the anatomical structure of wood they were previously unable to observe with traditional lenses at 10× and 12× magnifications.
- The appropriate application can be used for the biometry of some of the most important anatomical elements.
- Inspectors can take photos of anatomical features when using lenses attached to a smartphone and send them to a specialised laboratory immediately.
- The necessary equipment is very inexpensive and this method greatly facilitates the work of inspectors.
- This technique could be used in other areas of research that require the use of magnification for immediate diagnosis or in field work, both in forestry-related areas such as dendrochronology, botany and entomology, and in unrelated fields such as archaeology, sculpture and the textile industry.

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Appendix A

| Softwoods (Gymnosperms) | Similar Timbers |
|-------------------------|-----------------|
| Abies guatemalensis Rehder | Other Abies spp., Cedrus spp., Pseudolarix amabilis, Tsuga spp. [25] |
| Araucaria araucana (Mol.) K.Koch | Other Araucaria spp., Agathis spp., Wollemia nobilis * |
| Fitzroya cupressoides (Molina) I.M.Johnston | Sequoiadendron giganteum [18] |
| Pseudotsuga menziesii Voss | Almost all species of the families Cupressaceae and Podocarpaceae from temperate climate zones [19] |
| Podocarpus neriifolius D.Don | Pinus section Strobus (e.g., P. cembra, P. lambertiana, P. monticola, P. strobus, etc.) [22] |
| Taxus chinensis (Pilg.) Rehder | Other Podocarpus spp., Acrocladus pancheri, Afrocarpus spp., Dacrycarpus spp., Dacrydium spp., Falcatifolium spp., Halocarpus spp., Lepidothamnus spp., Nageia spp., Panaxiopsis usua, Pherosphaera spp., Prumnopitys spp., Retrophyllum ssp. and Saxeggothaea conspicua. |
| Taxus cuspidata Siebold | Other Taxus, Amentotaxus, Cephalotaxus, Pseudotaxus, Torreya |
| and Zucc. Taxus fuana Nan Li and R.R.Mill | Taxus sumatrana (Miq.) de Laub Taxus wollochiana Zucc. |
Table A1. Cont.

| Hardwoods (Angiosperms) | Similar Timbers |
|-------------------------|-----------------|
| *Aniba rosoloni* Ducke | Other *Aniba* (e.g., *A. hypoglauca*) and other genera of Lauraceae [38]. |
| *Aquilaria* Lam. and *Guaiacum* Gaern. | Other timbers with diffuse included phloem (e.g., *Antonia ovata*, *Bongania aquatica*, *Norrisia maior*, *N. malacrensis*) see [33]. |
| *Bulnesia sarmientoi* Lorentz ex Griseb. | Other *Bulnesia* spp., *Guaiacum* spp., *Chlorocardium rodiei*, *Handroanthus* spp. |
| *Caryocar costaricense* Donn.Sm. | Other *Caryocar* spp. (e.g., *C. brasiliense*, *C. edule*, *C. glabrum* and *C. villosum* are also traded [38]. |
| Cadrela P.Browne | *Toona* spp. | *Swietenia* spp. [19] |
| Dalbergia L.f. | *Diospyros* spp., *Platymiscium* spp. | *Dalbergia* spp., *Platymiscium* spp. |
| Diopros L. | | |
| *Dipteryx panamensis* (Pittier) Record and Mell | Other *Dipteryx* spp. (e.g., *D. odorata* are also traded) |
| *Gomotylyx* Teijm. and Binn. | *Alstonia* spp., *Antiaris* spp., *Brosimum alicastrum*, *Dyera costulata*, *Endospermum* spp., *Gambeya beguei*, *Jacaranda copia*, *Neolamarckia cadamba*, *Pterygota* spp., *Simarouba amara*, *Terminalia superba* [19] |
| *Guaiacum* Plun. ex L. | *Bulnesia* spp., *Chlorocardium rodiei*, *Handroanthus* spp. |
| *Magnolia liliifera* var. obovata (Korth.) Govaerts | Other *Magnolia* spp. |
| *Oreomunnea* pterocarpa Oerst. | Other *Oreomunnea* spp. |
| *Paubrasilia echinata* (Lam.) Gagnon, H.C. Lima and G.P. Lewis (syn. *Caesalpinia echinata* Lam.) | Other *Caesalpinia* spp., *Brosimum rubescens* [19] |
| *Pericopsis elata* (Harms) Meeuwen | Other *Pericopsis* spp., *Acosmium* spp. [19] |
| *Platymiscium parviflorum* Benth. (syn. *Platymiscium pleiostachyum* Donn.Sm.) | Other *Platymiscium* spp., *Dalbergia spruceana*, *Centrolobium* spp. |
| *Prunus africana* (Hook.f.) Kalkman | Other *Prunus* spp. |
| *Pterocarpus santalinus* L.f. | Other *Pterocarpus* spp., *Dalbergia lowelii*, *D. maritima* [19] |
| *Pterocarpus erinaceus* Poir. | Other *Quercus* spp. |
| *Pterocarpus tinctorius* Welw. | *Carapa guianensis*, *Cedrela* spp., *Entandrophragma angolense*, *E. Cylindricum*, *E. utile*, *Guarea* spp. *Knya* spp., *Toona* spp. |
| *Quercus mongolica* var. *pleiostachyum* (Hook.f.) Kalkman | |
| *Quercus phillyreoides* Welw. ex Ledeb. | |
| *Swietenia humilis* Zucc. *Swietenia macrophylla* King | |
| *Swietenia mahagoni* (L.) Jacq. | |

* Never traded.

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