IDENTIFICATION OF IMPORTANT IRANIAN HARDWOODS BY VESSEL-RAY PITS AND VESSEL ELEMENT SHAPES (MACERATION PROCESS)

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For the identification of small to large wood samples and various types of composites that may not provide enough of all surfaces necessary to reveal diagnostic characteristics, such as sawdust, decayed wood fragments, archeological wood, and even large wood samples, morphological and anatomical characteristics of vessels are very useful. In this research, morphological and anatomical characteristics of vessels of important Iranian hardwoods which are concentrated in the Hyrcanian zone have been studied and photographed. Wood chips (match size) were placed in equal parts of glacial acetic acid and hydrogen peroxide and were put in the oven at 60°C for 48 hours, then counted and stained on microscope slides. The results showed that identification of many wood genera via morphological and anatomical characteristics of vessel elements in the maceration process is feasible but much depends on practice and experience. Spiral thickening, perforation plates, apparent shape and size of vessel elements, and vessel-ray pits are most important characteristics in the identification of wood genera. Inter-vessel pits or vessel-fiber pitting cannot be as helpful as the above features. We strongly recommend that all wood anatomists use macerated vessel morphological and anatomical characteristics as anatomical features in their description.

Keywords: Hardwood identification; Maceration process; Vessel element shapes; Vessel-ray pits

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INTRODUCTION

Wood identification is of value in a variety of contexts – commercial, forensic, archeological, and paleontological (Wheeler and Baas 1998) and can be difficult because of the high diversity and similarity of many genera. Wood anatomists commonly use macroscopic and microscopic features in identification but seldom examine the dissociated cells in detail, although many wood genera, especially wood fragments are identifiable by vessel morphological and anatomical characteristics.

Vessel morphological and anatomical characteristics of wood (in macerated form) have not been included in most wood atlases, but the valuable book "Fiber Atlas" (Ilvessalo-Pfäffli 1995) and most references in it have made it clear that these characteristics can be very useful. Pulp and paper components can be disintegrated by boiling and shaking with water to view tracheids, fibers and vessel elements, as well as by using a microscope to identify plants which have been used in paper making (Strelis and Kennedy 1967; Parham and Gray 1990; Ilvessalo-Pfäffli 1995; Adamopoulos 2006).

The anatomical characteristics of macerated samples can be very helpful in identification of various types of large to small wood samples that may not provide enough of all the surfaces necessary to reveal diagnostic characteristics. Examples are sawdust (Tsoumi 1985), wood fragments (Hoadley 1990; Miller 1991), veneer, small pieces of historical and archeological wood (Safdari 2008), and decayed, stained, or finished wood and wood with preservatives, which would not have the original color and natural texture. In addition, some anatomical features, such as vasicentric and vascular tracheids are important in identification of genera such as *Quercus*, *Eucalyptus* and *Fraxinus*, and are more obvious in macerated form than in radial sections (IAWA Committee 1989).

According to previous studies, fibers (shape and size) and parenchyma cells are very similar in various genera and cannot be used for hardwood identification, but vessel shape (morphology) and other anatomical characteristics (vessel-ray pits and intervessel pits) are more diverse than other hardwood components and can be useful for identification (Parham and Gray 1990; Ilvessalo-Pfäffli 1995; Adamopoulos 2006).

In the present study important Iranian hardwoods are identified via vessel anatomical characteristics by the maceration process. Because of the different climates in the five regions of Iranian forest: Hyrcanian, Iran-toran, Zagros, bank of Persian Gulf, and Oman, many different species of trees and shrubs occur (Sagheb-Talebi et al. 2004). The most important commercial wood originated in the Hyrcanian zone and the species in this zone are very similar to European species.

The purpose of this paper is to study the morphological and anatomical characteristics of vessels in macerated wood of the Hyrcanian zone species of Iran to develop an identification process.

EXPERIMENTAL

In this research, prominent woody species of the Hyrcanian zone of Iran (Fig. 1) which were used in a previous study (Safdari and Devall 2008). (*Acer insigne*, *Tilia* rubra (*platyphyllus*), *Carpinus betulus*, *Prunus avium*, *Prunus divaricata*, *Sorbus torminalis*, *Alnus subcordata*, *Buxus hyrcana*, *Parrotia persica*, *Ulmus glabra*, *Ulmus campestris*, *Zelkova carpinifolia*, *Albizzia julibrissin*, *Fraxinus excelsior*, *Juglans nigra*, *Pterocarya fraxinifolia*, *Quercus castaneifolia*, *Eucalyptus* spp., *Morus alba*, *Robinia pseudoacacia*, *Gleditschia caspica*, *Diospyrus lotus*, *Ficus carica*, *Populus* spp., *Salix* spp., *Fagus orientalis* and *Platanus orientalis*) have been selected. The samples chosen were sound and without defects such as reaction wood, decayed or spiral grain, as recommended by Hoadley (1990).

From the above species, three discs at diameter at breast height were taken, and at most 10 splinters (match size) in a longitudinal direction near the pith, the middle and near the bark have been obtained by using a chisel. The splinters were cut longitudinally in a radial plane to obtain early- and latewood vessels.

The splinters were treated with 30% hydrogen peroxide and glacial acetic acid 1:1 at 60 °C for 48 h in glass-lidded test tubes. This time can be reduced to two hours if one or two drops of hydrogen peroxide are added to test tubes and they are boiled in a beaker, but the quality of the former is better. After this treatment the wood turns white or light yellow

(Franklin 1945). The yellow samples were in the oven longer and their solutions had to be refreshed. Then the test tubes were decanted and white samples were washed in water using paper filters. After complete removal of the acid odor, the cleaned splinters were placed in a small beaker and defibered with a small magnet on an electrical magnetic plate.

The ISO 9184-1 standard (ISO 1990), which is designated for the analysis of pulp and paper, was used for the preparation of the micro slides. The white wood samples were diluted by eye. The rolled bleached fiber was diluted to 0.05% (wt./vol) and 0.5 ml suspension was transferred by sampler or pipette onto a clean slide and the water was removed with a pipette. The micro slides were dried at room temperature. A hot plate was not used because heat causes water to evaporate too fast and fibers move toward each other and stick together.

After 24 hours, the surface of the micro slide has whitish sediments, and it was ready for the addition of safranin. One or two drops of aqueous safranin were added and the slide was covered with a cover slip. The micro slides were ready for examination at this time, but because of the presence of bubbles, were not photographed. After 24 hours the micro slides were ready for photographing. The terminology which was used to describe these results was used in the Fiber Atlas (Ilvessalo-Pfäffli 1995) and the IAWA list of microscopic features for hardwood identification (IAWA Committee 1989).

Figure 1. The distribution of Iranian northern forests (Hyrcanian zone) (after Mohammadi and Lohmander 2008).

RESULTS AND DISCUSSION

Wood vessels were categorized according to three salient features (spiral thickening – perforation plate and ring-porous wood vessels or short and wide vessel elements) which are important in identification (Table 1-4).

Spiral thickening of various species is not identical and a genus can be identified by the type of spiral thickening (distinct, faint or prominent, close or wide spacing and swirl) (Table 1 and Fig. 2). The vessels of *Prunus avium* and *Prunus divaricata* are similar in this group and can be mistaken for each other (Table 1 and Fig. 2).

The number of bars in a perforation plate and its thickening can be used to distinguish genera with scalariform perforation plates (Table 2 and Fig. 3, first row).

The characteristics of latewood vessels (especially the presence of spiral thickening) in ring-porous wood species, the shape of vessel elements and ray parenchyma pits and their kind of grouping in the vessel wall as well as longitudinal parenchyma pits can be useful in identification of this category of genera (Table 3 and Fig. 3, second and third row). Other genera which cannot be placed in the above three categories are: *Populus*, *Salix*, *Fagus*, *Platanus*, *Juglans*, *Pterocarya*, *Diospyrus* and *Ficus* (Table 4 and Fig. 6).

The ray pits of *Populus* are fairly oval and very similar to those of *Salix* and *Carpinus* (Fig. 2 and 6). The shape of the inter-vessel pits of *Carpinus* makes this species different from the other in addition vessel elements of *Carpinus* are more linear than those of *Populus* and *Salix* (Fig. 2 and 6). The genera: *Populus* and *Salix* are very similar but can be distinguished by their ray-vessel pits. The ray parenchyma of *Salix* is smaller and occurs in vertical, horizontal, or square groups while those of *Populus* occur in horizontal groups of 2-3 rows (Wilson and White 1986; Parham and Gray 1990; Ilvessalo-Pfäffli 1995).

The morphological and anatomical characteristics of vessels of *Fagus* are very similar to those of *Platanus*; gash-like pits on vessels are the most important feature in identification, of the two species (Fig. 6). *Fagus* tends to have much less vessel pitting than *Platanus* (Parham and Gray 1990). Sometimes the presence of scalariform perforation plates on latewood vessels of *Platanus* and *Fagus* (Wilson and White 1986) causes an error in identification and these species can be mistaken for *Parrotia.* The point is that all vessels in *Parrotia* have *scalariform* perforation plates but in *Fagus* they are rarely in the narrow vessels (Ilvessalo-Pfäffli 1995) or latewood vessel elements (Wilson and White 1986) and also the shape of the vessels in *Parrotia persica* is more linear (Fig. 3). In addition to vessel shape and pits of ray paranchyma, the vasicentric tracheids are the most important feature in identification of some genera, such as *Eucalyptus* and *Quercus* (Fig. 5).

The parenchyma and fiber in all these genera are very similar and cannot be helpful in identification. But vessel elements' shape and vessel-ray pits are the most important features in identification of macerated hardwoods. Because wood components are disintegrated in chemical solvent, naturally some pits (inter-vessel pits, vessel- fiber pits and vessel longitudinal parenchyma pits) on the vessel wall are not clear, and their shape and grouping are not as diverse as vessel-ray pits and cannot be as useful as the previous features (vessel shape and vessel-ray pits) in identification. The vasicentric tracheid is a beneficial anatomical feature in identification, but vascular tracheids cannot be useful in identification because of their similarity to fibers and vessels.

Identification of some genera: *Alnus* (scalariform perforation plates and tiny vessel-ray pits) *Populus*, *Salix* and *Carpinus* (specific vessel-ray pits) *Quercus* (because of the presence of vasicentric tracheids) *Fagus*, *Platanus* and *Parrotia* (gash-like or scalariform vessel-ray pits) *Eucalyptus* (the presence of vasicentric tracheids, vessel shape and large oval vessel-raypits) are very easy and reliable with the maceration process. This is because the vessel shapes and vessel-ray pits in these genera are very different from other pits (fiber-vessels and inter-vessels pits). The inspection of wood or wood fragments and the recording of their color and figures before maceration and knowledge of the geographical origin can aid us in identification. We strongly recommend that wood anatomists show vessel element morphology and other anatomical characteristics in the maceration process as a microscopic feature in their description.

CONCLUSIONS

1. The maceration process has advantages and disadvantages. The advantage is that this procedure is suitable for wood fragments which cannot provide three sections (cross, tangential and radial), and for brittle or decayed wood.
2. It is suitable in the situation, for example, when one is certain that the wood is *Tilia*, *Populus*, *Alnus* or *Diospyrus*, but one cannot be distinguished from the other.
3. This procedure is faster than sectioning and can be helpful, especially for heavy wood species such as *Parrotia*, *Carpinus*, and *Buxus*, in which the preparation before sectioning takes several hours.
4. The disadvantages are that this procedure is not appropriate for those wood samples of unknown geographical origin.
5. Sometimes because of lack of other important anatomical features, vessel morphology and anatomy are not sufficient, and the identification is uncertain.
6. Photography of pits on vessel wall is not as easy as wood sectioning, and detecting the kind of pits (inter-vessel pits, fiber vessel pitting or vessel-ray pitting) is difficult.
7. The identification of wood genera via vessel elements is very dependent on practice and experience and keeping the morphology of vessel elements and vessel anatomical characteristics in mind is very important.

Table 1. Identification of Important Iranian Hardwoods with Spiral Thickening in all Vessel Elements (earlywood and latewood); see Fig. 2

Species	Spiral thickenings	Vessel- ray pits	More description
Acer insigne	Distinct, often close and swirled	Crowded, small ovals in horizontal groups	Spiral thickenings in *Tilia* are more obvious and ray parenchyma pits are smaller than in *Acer*. The vessel elements of *Tilia* generally are more slender and taller than those of *Acer*
Tilia rubra	Prominent, widely spaced	Small ovals in horizontal groups	
Carpinus betulus	Faint, widely spaced	Large ovals in horizontal groups	The ray parenchyma pits of *Carpinus* are very similar to *Populus*. Intervessel pits in *Populus* are hexagonal but in *Carpinus*, pits are oval in shape
Sorbus torminalis	Faint, widely spaced and swirled	Small ovals in horizontal or diagonal groups	Vessels are slender and tall and ray pits are oblique oval and tend to be fragmented
Prunus avium	Faint, widely spaced	Small ovals in horizontal or diagonal groups	The spiral thickenings of *Prunus divaricata* are more obvious
Prunus divaricata	Prominent, widely spaced	Small ovals in horizontal or diagonal groups	

Vessels of the shaded species are similar in appearance.

Table 2. Identification of Important Iranian Hardwoods with Scalariform Perforation Plates in Vessel Elements; see Fig. 3.

Species	Number of bars	Vessel- ray pits	More description
Parrotia persica	Mostly 12 – 17	Gash-like (scalariform)	Rarely occurs that *Parrotia'*s vessels mistaken for *Fagus*'s vessels, see Fig. 6. In addition to the linear shape of vessels of *Parrotia*, all vessels in *Parrotia* have a scalariform perforation plate but in *Fagus* they are often found in the narrow vessel elements (Ilvessalo- Pfäffli 1995) or latewood vessels (Wilson and White 1986)
Alnus subcordata	Mostly 12 – 25 sometimes branched	Very small in horizontal groups	Similar to *Betula* but intervessel pits in *Betula* are often confluent (Ilvessalo-Pfäffli 1995)
Buxus hyrcana	Mostly 5 – 10	Very fine in horizontal groups and vessel wall seems bare	The pits on the vessel wall are not as abundant as the other two species

Table 3. Identification of Important Iranian Ring-Porous Hardwoods (short and wide vessel elements); see Fig. 4 and Fig. 5.

Species	Vessel shape: Oblong	Vessel shape: Drum	Spiral thickening in latewood vessels	Vessel-ray pits	Pits to longitudinal parenchyma	More Description
Albizzia julibrissin	-	+	–	Small ovals in long and short horizontal rows	Similar to ray pits but in longitudinal series	Inter-vessel pits tend to be confluent
Gleditschia caspica	-	+	Very distinct (+)	Small longitudinal pits but in horizontal rows	In longitudinal series (curved line)	Earlywoods are usually fragmented. Vessels frequently show confluent aperture. Spirals in latewood vessels sometimes show knife marks
Morus alba	-	+	Very distinct (+)	Oval and fairly large in small groups	Oval and fairly large, in longitudinal groups	Earlywood usually fragmented. Pit apertures on latewood vessels are slit-like
Robinia Pseudoacacia	-	+	Very distinct (+)	Ovals fairly large, in small groups	Oval and fairly large in longitudinal groups	Earlywood vessels are very short and wide, unlike other ring-porous species Pits on latewood vessels are oval and somewhat rhomboid in shape

Vessels of the shaded species are similar in appearance.

Table 3. continued

Species	Vessel shape: Oblong	Vessel shape: Drum	Spiral thickening in latewood vessels	Vessel-ray Pits	Pits to longitudinal parenchyma	More description
Fraxinus excelsior	-	+	-	Small in long horizontal rows. The pit border of early wood vessels is not easily visible	Same as ray pits but in longitudinal series (curved line)	Large earlywood usually fragmented and with small bordered pits The observation of vasicentric tracheids is not as easy as *Querqus* and is not abundant but can be a dignostic feature (Ilvessalo-Pfäffli 1995)
Ulmus glabra *Ulmus campestris* *Zelkova Carpinifolia*	+		+	Oval and fairly large in short horizontal rows	Similar to ray pits but in longitudinal series	Vascular tracheids with spirals resemble vessels
Eucalyptus spp.	+	+	-	Large ovals in short horizontal rows	In longitudinal series (Continuous line)	Vasicentric tracheids are an important feature in identification. Some vessel elements have long tails
Quercus castanaefolia	-	+	-	Large ovals in short horizontal rows (the largest among the species)	In longitudinal series (Continuous line)	Vasicentic tracheids are an important feature in identification, but can occur in some species because of low water availability (Carlquist et al. 1985)

Vessels of the shaded species are similar in appearance.

Table 4. Identification of Other Important Iranian Hardwoods, see Fig. 6.

Species	Vessel-ray pits	Pits to longitudinal parenchyma	More description
Populus spp.	Oval and fairly large in short horizontal rows	Not important	Rays of Salix consistently have upright cells along the margins where as Popoulus rays don't (Wilson and White 1986; Parham and Gray 1990) Some times vessels of Populus mistaken with Carpinus, the distinguish point is intervessel pits in Populus are polygonal but in Carpinus are oval
Salix alba			
Fagus orientalis	Gash-like (scalariform)	Not important	Fagus tends to have much less vessel pitting than Platanus (Parham and Gray1990). The bars of both species rarely have scalariform perforation plates (mostly 10-15 bars) and only in narrow vessels or latewood vessels (Wilson and White 1986)
Platanus orientalis	Gash-like (scalariform)	Not important	
Diospyrus lotus	Very tiny and in squarish arrangements (5-6 rows)	Similar to ray pits but in longitudinal lines	-
Ficus carica	Tiny ovals in long and short horizontal rows (2-3)	Very frequent in squarish arrangement	-
Juglans nigra	Large ovals and in long and short horizontal rows and sometimes resemble reticulate thickening (gash- like pits)	In longitudinal series (big oval)	Large earlywood tends to be fragmented and often vessels have reticulate thickening (gash like pits)
Pterocarya fraxinifolia	Large ovals and in short and long horizontal rows	Same as ray pits (large ovals) but in longitudinal series and sometimes curved lines	

Vessels of the shaded species are similar in appearance.

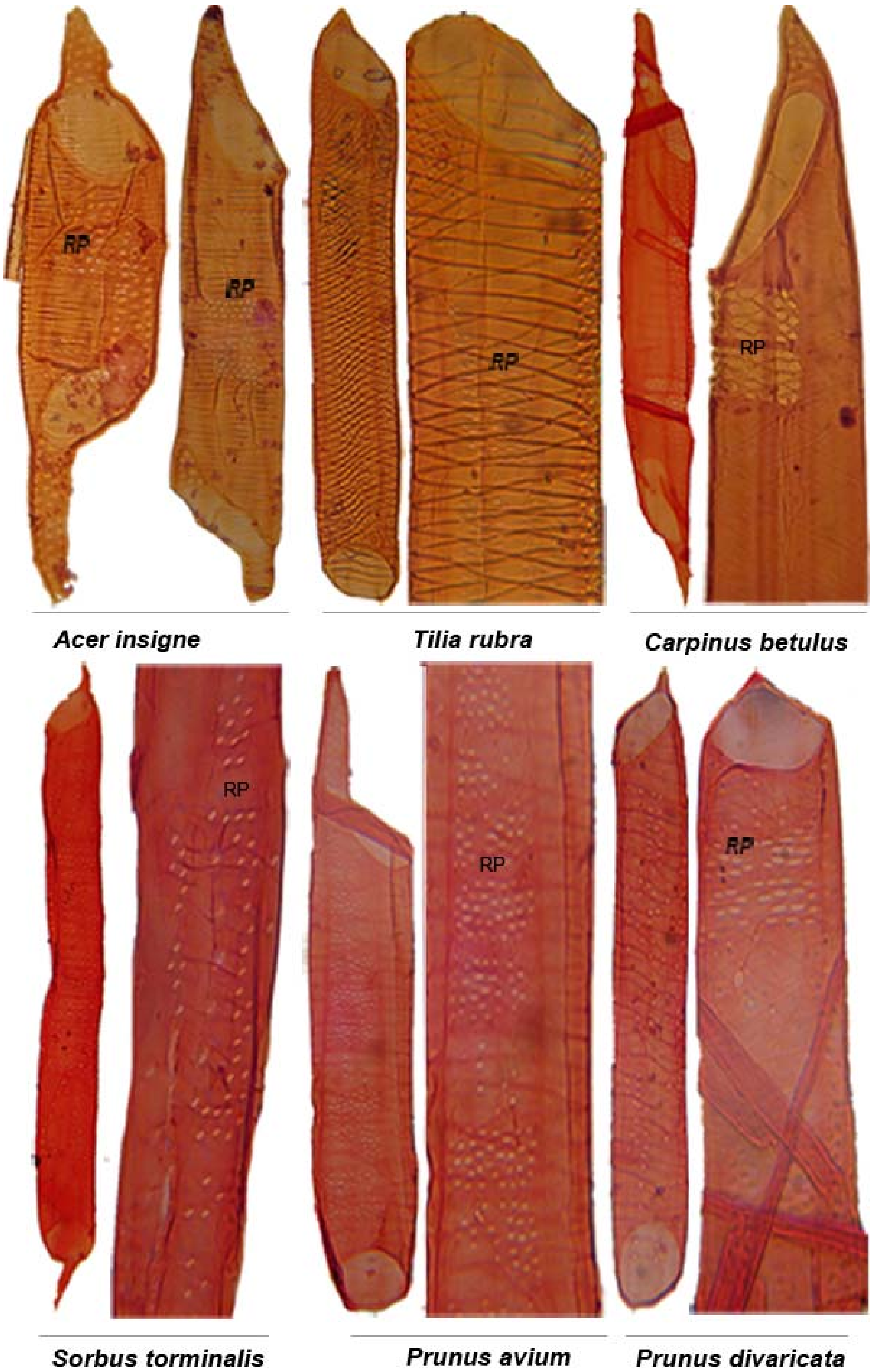

Figure 2. Hardwood vessels with spiral thickenings in all vessel elements (see table 1). RP stands for vessel-ray pits.

Figure 3. Hardwood vessels with scalariform perforation plates in the first row (see table 2) and vessels of ring - porous hardwoods in the second and third rows (see table 3). RP stands for vessel-ray pits and LP for longitudinal parenchyma.

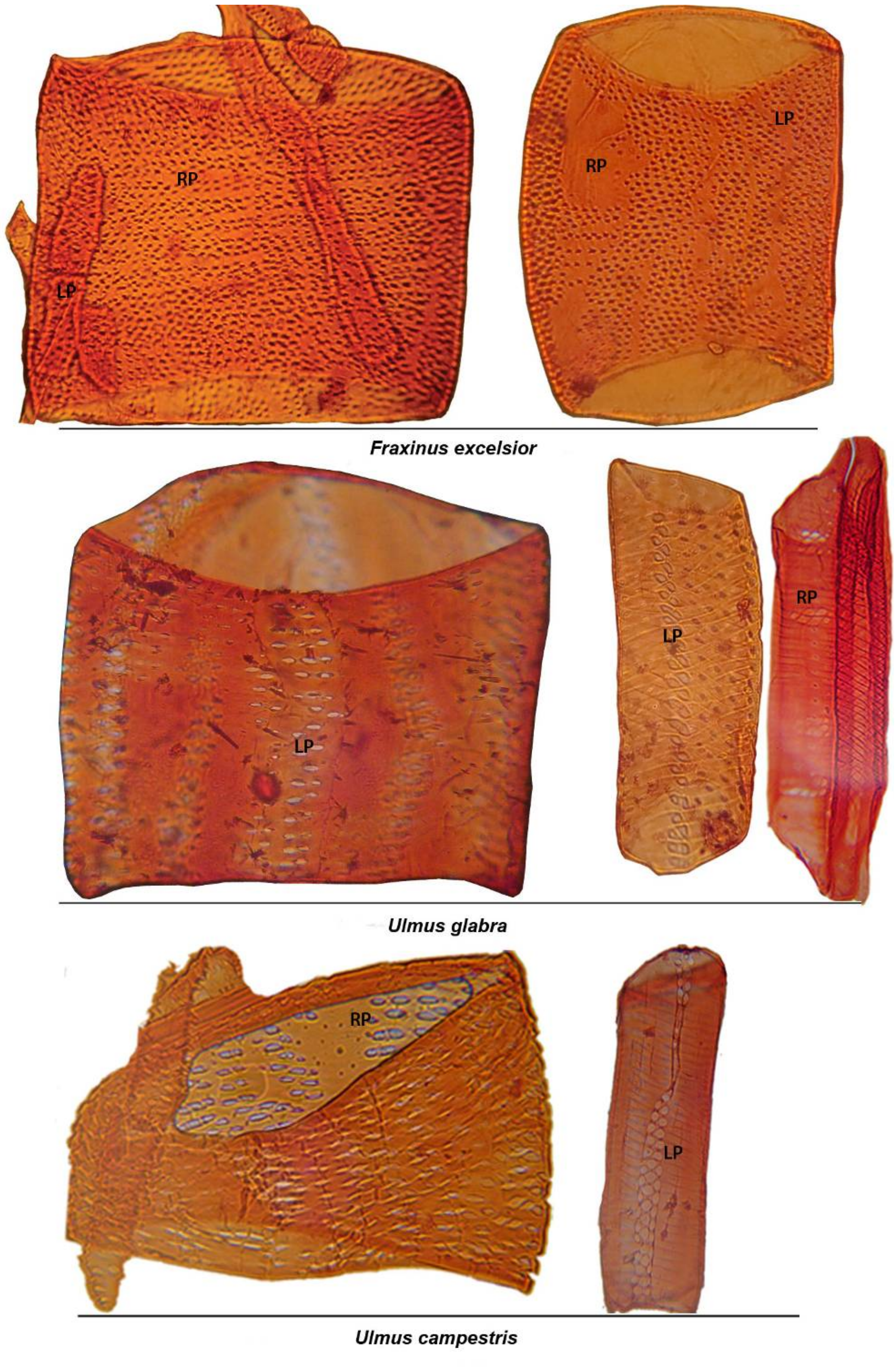

Figure 4. Vessels of ring - porous hardwoods (see table 3). RP stands for vessel-ray pits and LP for longitudinal parenchyma.

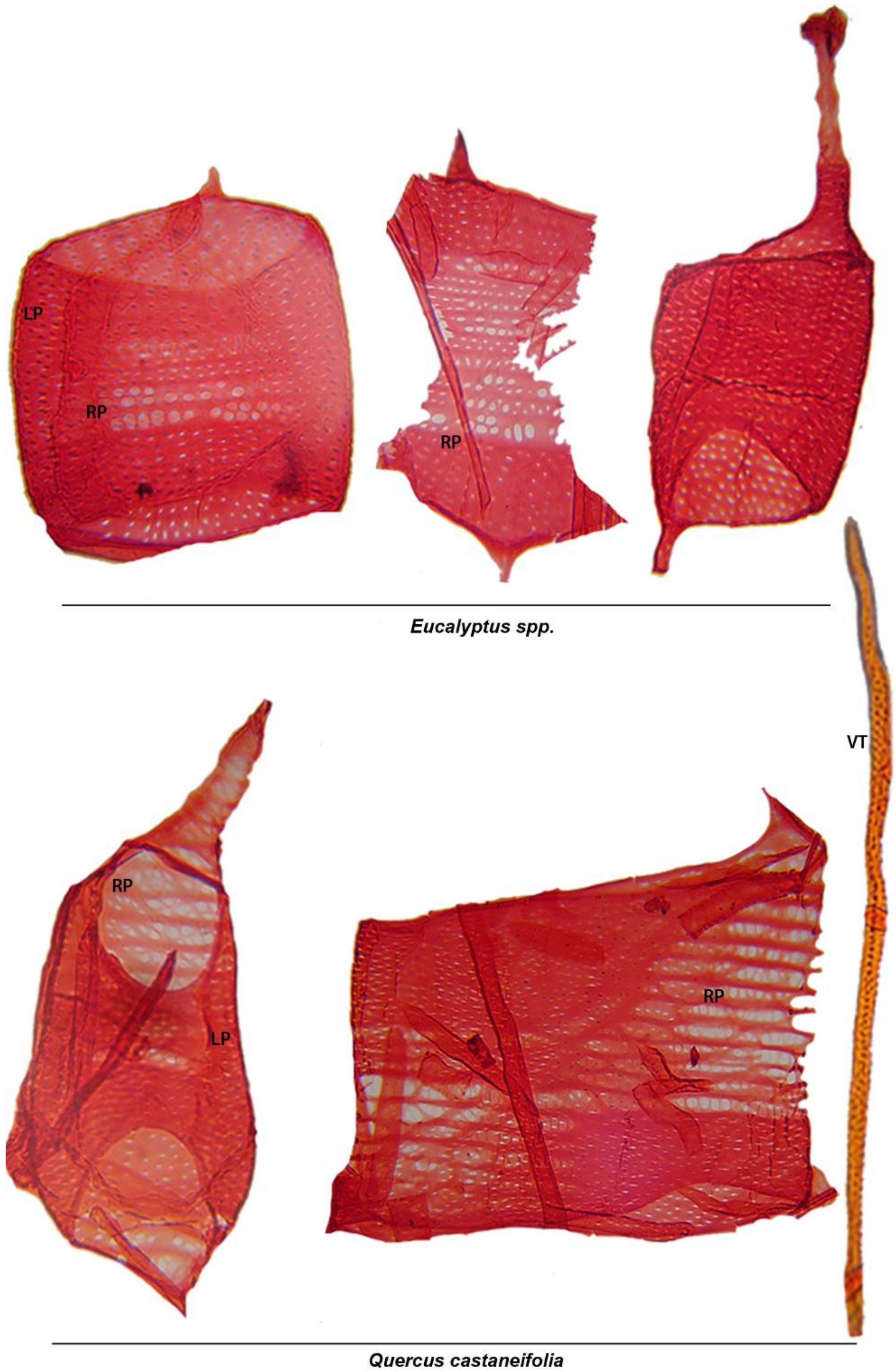

Figure 5. Vessels of ring-porous hardwoods (see table 3). RP stands for vessel-ray pits; LP for longitudinal parenchyma and Vt: vasicentric tracheids.

Figure 6. Vessels of other important Iranian hardwoods (see table 4). RP stands for vessel-ray pits and LP for longitudinal parenchyma.

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