Wood Anatomy of Some Turkish Plants with Special Reference to Perforated Ray Cells

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Abstract: This study is a further contribution to a series describing perforated ray cells and the wood anatomy of some Dicotyledons families and their taxa indigenous to Turkey: *Berberis vulgaris* L. (*Berberidaceae*), *Colutea armena* Boiss & Huet (*Fabaceae*), *Coronilla emerus* L. (*Fabaceae*), *Chamaecytisus hirsutus* (L.) Link. (*Fabaceae*), *Cytisus villosus* Pourr. (*Fabaceae*), *Hedera helix* L. (*Araliaceae*), *Paliurus spina-christii* Mill. (*Rhamnaceae*), *Pistacia lentiscus* L. (*Anacardiaceae*), *Salix triandra* L. subsp. *triandra* L. (*Saliaceae*), *Sambucus nigra* L. (*Caprifoliaceae*), *Staphylea pinnata* L. (*Staphyleaceae*), *Tamarix smyrnensis* Bunge (*Tamaricaceae*), *Vitis silvestris* Gmelin. and *V. vinifera* L. (*Vitaceae*). Perforated ray cells were found either isolated or together in groups, localised at the end of uniseriate and multiseriate rays and in the body of multiseriate rays according to taxa. Perforation types of perforated ray cells usually coincide with perforation plates of vessel, and are larger than adjacent ray cells.

Key Words: Wood Anatomy, Perforated Ray Cells, Turkey

Perforasyonlu Özışını Hücreli Bazı Türkiye Bitkilerinin Odun Anatomisi

Özet: Bu çalışma daha ziyade, Türkiye'de doğal olarak yetişen bazı dikotil familya taksonlarının perforasyonlu özışını hücrelerini ve odun anatomisi özelliklerini sırası ile tanımlayan bir makaledir: *Berberis vulgaris* L. (*Berberidaceae*), *Colutea armena* Boiss & Huet (*Fabaceae*), *Coronilla emerus* L. (*Fabaceae*), *Chamaecytisus hirsutus* (L.) Link. (*Fabaceae*), *Cytisus villosus* Pourr. (*Fabaceae*), *Hedera helix* L. (*Araliaceae*), *Paliurus spina-christii* Mill. (*Rhamnaceae*), *Pistacia lentiscus* L. (*Anacardiaceae*), *Saix triandra* L. subsp. *triandra* L. (*Salicaceae*), *Sambucus nigra* L. (*Caprifoliaceae*), *Staphylea pinnata* L. (*Staphyleaceae*), *Tamarix smyrnensis* Bunge. (*Tamaricaceae*), *Vitis silvestris* Gmelin. ve *V. vinifera* L. (*Vitaceae*). Perforasyonlu özışını hücreleri, taksonlara göre, tek veya grup halinde, üniseri ve mültiseri özışınlarının uç kısımlarında, ve mültiseri özışınlarının gövde kısımında bulunmaktadır. Perforasyonlu özışını hücrelerinin perforasyon tipleri genellikle trahe hücrelerinin perforasyon tablasına benzemektedir, komşu hücrelere göre daha büyük boyutludurlar.

Anahtar Sözcükler: Odun Anatomisi, Perforasyonlu Özışını Hücreleri, Türkiye

Introduction

The first monographic treatment of perforated ray cells was by Chalk and Chattaway (1933) in the wood of several genera and species belonging to widely unrelated families, and different habits (trees and shrubs) and geographic distributions. Subsequently many workers, i.e. Stern (1967), Koek-Noorman (1970), Nazma et al. (1981), Botosso et al. (1982), Rao et al. (1984), Dayal et al. (1984), Rudall (1985), Norverto (1993), Nagai et al. (1994), Otegui (1994), Eom & Chung (1996), Merev

(1998), Lindorf (1999), Ceccantini et al. (2000), Terrazas (2000) and Serdar et al. (2004), have reported these features in several taxa.

Perforated ray cells are secondary xylem cells derived from ray initials but with perforation plates and lateral pitting like those of vessels. The type of perforation in a perforated ray cell may be simple, scalariform, reticulate, or foraminate, and does not necessarily coincide with the type of perforation plate occurring in the vessel elements of the same wood. The aim of this study was to report the first record of some woody taxa with perforated ray cells in Turkey.

Materials and Methods

All wood specimens were available as dried samples in the KATO herbarium. Wood samples were sectioned on a sliding microtome after they were boiled. Sections were stained with a safranin O-alcian blue combination. Macerations were prepared by Schultze's method. The places from which the wood samples were collected, were as follows: Berberis vulgaris L., Trabzon, Macka 700 m; Chamaecytisus hirsutus (L.) Link. Artvin 350 m; Coronilla emerus L. Aydın, Dilek Peninsula 560 m; Cytisus villosus Pourr. Aydın, Dilek Peninsula 270 m; Hedera helix L., Paliurus spina-christii Mill. and Pistacia lentiscus L. Aydın, Dilek Peninsula 8-10 m; Platanus orientalis L. Giresun, Bulancak 50 m; Salix triandra L. subsp. triandra Bayburt 1500 m; Sambucus nigra L. Artvin, 1000 m; Staphylea pinnata L. Trabzon, Macka 1000 m; Tamarix smyrnensis Bunge. Artvin, Hatila Valley 200 m; Vitis silvestris Gmelin. Giresun Island 20 m; and V. vinifera L. Trabzon, Zafanoz 200 m. The terminology follows that of the IAWA Committee on Nomenclature (1989).

Results and Discussion

Wood Anatomical Descriptions

Berberis vulgaris L.

Type of the perforation in ray cells of *Berberis* is simple like those of vessel elements; single and not abundant. They occur in the body of multiseriate rays among procumbent cells; larger ($30 \times 30 \mu m$ in horizontal x vertical diameter) than adjacent ray cells ($14 \times 26 \mu m$ in horizontal x vertical diameter) (Figure 1, Table 1).

Growth ring distinct and wood ring porous; latewood pores in diagonal aggregation pattern. Pores $208-864/\text{mm}^2$; vessel groups more abundant in latewood (3-13) than earlywood (2-5); tangential diameter $30-97 \,\mu\text{m}$ and $11-43 \,\mu\text{m}$ in earlywood and latewood, respectively. Vessel elements $125-288 \,\mu\text{m}$ long; perforation plate simple; intervessel pits alternate; helical thickenings only in narrow vessels. Libriform fibres 240-552 $\,\mu\text{m}$ long; vasicentric tracheids with helical thickening observed. Axial parenchyma absent. Rays only multiseriate (3-14), homocellular, 1-4/mm, 240-2400

μm high; composed of entirely procumbent cells. Prismatic crystals abundant in ray cells.

Chamaecytisus hirsutus (L) Link.

The type of perforation in ray cells is simple like those of vessel elements, single and in group in horizontal direction; rather abundant. They occur among procumbent cells in the body of multiseriate rays; usually larger (40 x 52 μ m) than adjacent ray cells (19 x 40 μ m), sometimes the same in diameter. They are surrounded with helical thickening (Figures 6 & 7).

Wood ring or semi-ring porous; growth rings distinct. Pores 144/mm²; 21-58 μ m in tangential diameter; vessel elements 84-328 μ m long with conspicuous helical thickening; perforation plates simple. Libriform fibres 405-764 μ m long; vascular tracheids abundant with conspicuous helical thickening. Axial parenchyma apotracheal (diffuse-in-aggregate) and scanty paratracheal. Rays uniseriate and multiseriate (1-4), heterocellular or heterogeneous, Kribs's type II B. Prismatic crystals observed (Table 1).

Colutea armena Boiss. & Huet

Type of perforation is simple like those of vessel elements; single; not abundant. They occur in the body of multiseriate rays among procumbent cells; larger (56 x 41 μ m) than adjacent ray cells (19 x 34 μ m) (Figure 2).

Wood semi-ring porous. Pores 24/mm², rather small (28-65 μ m in tangential diameter); vessel elements 92-199 μ m long with thin and closely spaced helical thickening (sometimes in fingerprint shape); perforation plates simple; intervessel pits alternate. Libriform fibres 535-1039 μ m long; vascular tracheids abundant with helical thickening. Axial parenchyma apotracheal-diffuse, paratracheal-vasicentric, sometimes confluent. Rays uniseriate and multiseriate (1-5), heterocellular, Kribs's type II B. Prismatic crystals observed (Table 1).

Coronilla emerus L.

Type of the perforation in ray cells is simple like those of vessel elements, single and in horizontally orientated groups, rather abundant. They occur with both procumbent and square cells in the body of multiseriate rays; usually larger $(37 \times 51 \ \mu\text{m})$ than adjacent ray cells (19 x 38 μm) but sometimes the same in diameter. Surrounded with helical thickening (Figures 3-5, Table 2).

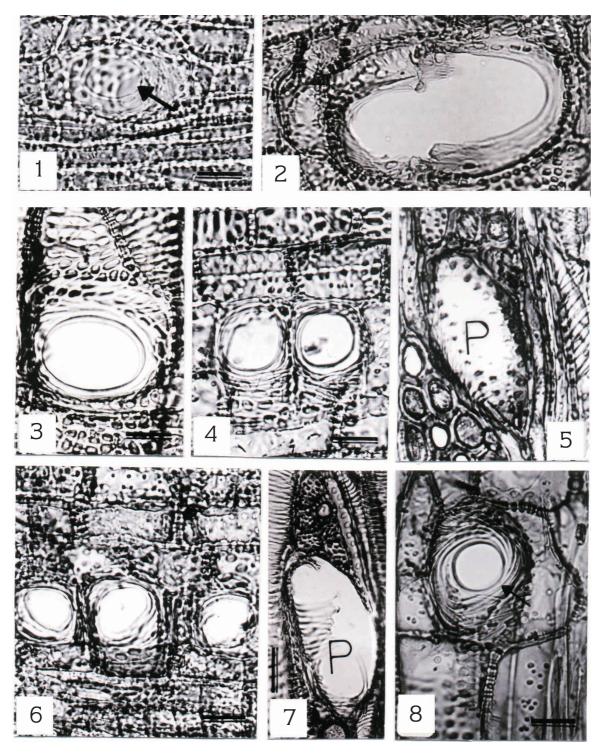


Figure 1. Perforated ray cells. —1: RS (radial section), *Berberis vulgaris* simple perforated ray cell (PRC) in the body of multiseriate ray (arrow). — 2: RS, *Colutea armena*, simple PRC among procumbent cells. —3-5: *Coronilla emerus*, simple PRC; —3: RS, Single PRC; —4: RS, 2 PRCs in horizontal direction; —5: TS (tangential section), PRC (P) in the body of multiseriate ray on tangential walls. —6 & 7: *Chamaecytisus hirsutus*, —6: TS, 3 simple PRCs in horizontal direction in the body of multiseriate ray; —7: TS, Simple PRC (P) in the body of multiseriate ray on tangential walls. —8: RS, *Cytisus villosus*, simple PRC with surrounding helical thickening (arrow) among upright cells. Scale bars in figure 7 = 50 µm, in the other figures = 25 µm.

Table 1. Wood anatomical characters of taxa

P: Pores/1 mm², TD: Tangential diameter of pores, PTV: Perforation plates of vessel elements (S = simple, S^c = scalariform), VL: Vessel element length, LL: Libriform fibre length, TL: Fibre-tracheid length, V: Vascular or vasicentric tracheids, present (+), absent (-), HT: Helical thickening in vessels, presence (+), absent (-), C: Crystals, PC: Prismatic crystals, R: Raphide, present (+), absent (-), KATO: Herbarium of Karadeniz Technical University Faculty of Forestry Department of Forest Botany.

SAMPLES	KATO	P (mm ²)	TD (μm)	PTV	VL (µm)	LL (µm)	TL (μm)	V	HT	С
Berberis vulgaris	-	502	24-63	S	218	401	-	+	+	PC
Chamaecytisus	8425	144	32	S	144	612	-	+	+	PC
Colutea armena	8690	24	44	S	127	753	-	+	+	-
Coronilla emerus	8202	92	34	S	161	651	-	+	+	-
Cytisus villosus	8207	96	38	S	153	729	-	-	+	-
Hedera helix	-	150	35	S	580	750	-	+	+	-
Paliurus spina-chr.	8321	40	50	S	369	699	-	+	-	PC
Pistacia lentiscus	8330	217	58	S	307	648	-	+	+	PC
Salix triandra	15,833	261	36	S	355	591	-	-	-	-
Sambucus nigra	9981	187	46-61	S>S ^c	329	1060	-	+	-	-
Staphylea pinnata	-	119	38-47	S ^c	746	-	1048	-	+	-
Tamarix smyrnensis	8006	56	37-78	S	102	600	-	-	-	PC
Vitis silvestris	-	32	30-306	S ^c >S	626	1001	-	+	+	-
Vitis vinifera	-	80	60-220	S ^c >S	590	870	-	+	+	R

Table 2. Characters of rays and perforated ray cells in taxa.

U: Uniseriate rays, present (+), absent (-), M: Multiseriate rays, present (+), absent (-), U+M: Uniseriate and multiseriate rays, present (+), absent (-), RT: Type of the rays, HO: Homogeneous, HT: Heterogeneous rays, RH: Rays height, MRW: Multiseriate ray width, PRCD: Dimension of perforated ray cells, ARCD: Adjacent ray cell dimensions, HD: Horizontal diameter, VD: Vertical diameter.

SAMPLES	U	М	U+M	RT	RH μm	MRW Cell	PRCD (µm HD :	ARCD x VD μm)
Berberis vulgaris	-	+	-	HO	1009	2-4	30 x 30	14 x 26
Chamaecytisus	-	-	+	HT	-	2-4	40 x 52	19 x 40
Colutea armena	-	-	+	HT	-	2-5	56 x 41	19 x 34
Coronilla emerus	-	-	+	HT	552	2-8	37 x 51	19 x 38
Cytisus villosus	-	-	+	HT	350	2-5	40 x 38	28 x 60
Hedera helix	-	-	+	HT	6000	1-14	125 x 84	63 x 35
Paliurus spina-chri.	+	-	-	HO	699	1	73 x 58	14 x 34
Pistacia lentiscus	-	-	+	HT	203	3-4	37 x 33	22 x 28
Salix triandra	+	-	-	HT	257	1	63 x 46	24 x 32
Sambucus nigra	-	-	+	HT	479	2-5	76 x 77	19 x 100
Staphylea pinnata	-	-	+	HT	705	2-7	121 x 56	18 x 102
Tamarix smyrnensis	-	+	-	HO	1078	2-11	59 x 43	57 x 14
Vitis silvestris	-	+	-	HO	≈15,000	7-10	175 x 150	25 x 125
Vitis vinifera	-	+	-	НО	≈20,000	7-13	119 x 87	34 x 23

Wood ring porous; growth rings distinct. Pores arranged in dendritic pattern; 38-121 pores/mm²; small (17-73 μ m in tangential diameter); vessel elements 84-206 μ m long; perforation plates simple; intervessel pits alternate; vessel elements storied in latewood; helical thickening present in all vessel walls. Libriform fibres 512-848 μ m long; vascular tracheids abundant with helical thickening. Axial parenchyma paratracheal. Rays 5-7/mm, 1–6 cells wide, 483-621 μ m high in multiseriate; heterogeneous type II B (Table 1).

Cytisus villosus Pourr.

The perforations in ray cells are simple like those of vessel elements; single and not abundant. They occur in the body of multiseriate rays among upright cells, usually larger (40 x 38 μ m) than adjacent ray cells (28 x 60 μ m). Surrounded with helical thickening (Figure 8, Table 2).

Wood diffuse-porous; growth rings marked by marginal parenchyma and distended rays. Pores $69-116/\text{mm}^2$, arranged in diagonal to dendritic pattern or tangential bands; $21-54 \ \mu\text{m}$ in tangential diameter; mostly grouped (98%) in radial multiples, oblique and in clusters. Vessel elements $84-199 \ \mu\text{m}$ long; perforation plates simple; intervessel pits alternate; helical thickening throughout body of vessel element; vessel element storied with axial parenchyma. Libriform fibres $535-978 \ \mu\text{m}$ long; vascular tracheids abundant. Axial parenchyma scanty paratracheal and storied. Rays 8 (mean)/mm, 1-4 cells wide, $350 \ (\text{mean}) \ \mu\text{m}$ high in multiseriate; heterogeneous type II B; sheath cells observed (Table 1).

Hedera helix L.

The perforations in ray cells are simple like those of vessel elements, single and horizontally orientated group, sometimes clusters; abundant. They usually occur in the body of multiseriate rays among procumbent cells, sometimes in marginal cells; larger (125 x 84 μ m) than adjacent ray cells (63 x 35 μ m); their walls are very thick (Figures 9 & 10, Table 2).

Evergreen climbing shrub. Wood diffuse porous with indistinct growth rings. Pores 200–250/mm²; mainly in clusters, sometimes in tangential or radial multiples of 2-4, often forming together with vasicentric tracheids a pattern of tangential bands; tangential diameter of vessels 20–65 μ m. Vessel element 300–830 μ m long; perforation plates simple; intervessel pits alternate to diffuse; vessel walls sometimes with spiral thickenings. Libriform fibres 400–1050 μ m long. Axial parenchyma scanty

paratracheal. Rays 6–8/mm, 1-14 seriate, 1500–6000 µm high in multiseriate; homocellular to heterocellular, composed of procumbent central cells and slightly square, sometimes upright marginal cells (Table 1).

Paliurus spina-christii Mill.

The perforations in ray cells are simple like those of vessel elements; single and rather abundant. They occur in the body of ray tissues among upright or square cells; larger (73 x 58 μ m) than adjacent ray cells (14 x 34 μ m); their walls thicker than those of adjacent cells; surrounded by minute bordered pits (Figures 11 & 12, Table 2).

Wood semi-ring or diffuse porous, growth rings distinct with thick-walled latewood fibres. Pores $28-55/\text{mm}^2$, mostly solitary, remainder 2-3 radial multiples, rarely in small clusters; $13-80 \,\mu\text{m}$ in tangential diameter with thick walls (4–7 μm); perforation plates simple; intervessel pits alternate. Vessel elements 235–558 μm long. Libriform fibres 470–942 μm long; vasicentric tracheids observed, but not abundant. Axial parenchyma paratracheal-vasicentric and scanty paratracheal. Rays 16–27/mm, 48–960 (2064) μm high, homocellular to heterocellular uniseriate, mostly composed of square, sometimes upright cells, remainder procumbent cells; some cells crystalliferous (prismatic) (Table 1).

Pistacia lentiscus L.

Type of the perforation in ray cells is simple like those of vessel elements, single; rather abundant. They occur in the body of rays among procumbent cells, larger (37 x 33 μ m) than adjacent ray cells (22 x 28 μ m). Surrounded with helical thickenings connected with small bordered pits (Figure 13, Table 2).

Wood diffuse to semi-ring porous; growth rings distinct. Pores $151-272/\text{mm}^2$; at the beginning of the growth rings in radial multiples of 2-12 or in clusters; $17-123 \ \mu\text{m}$ in tangential diameter with thick walls; perforation plates simple; intervessel pits alternate. Vessel elements $237-420 \ \mu\text{m}$ long; helical thickening observed only in narrowest vessels. Libriform fibres $535-764 \ \mu\text{m}$ long; vascular tracheids abundant with helical thickenings. Parenchyma scanty paratracheal and apotracheal-diffuse. Rays 6 (mean)/mm; 1-4 cells wide, 203 $\ \mu\text{m}$ high; heterocellular, Kribs's type II B. Intercellular radial canal abundant in multiseriate rays (Table 1).

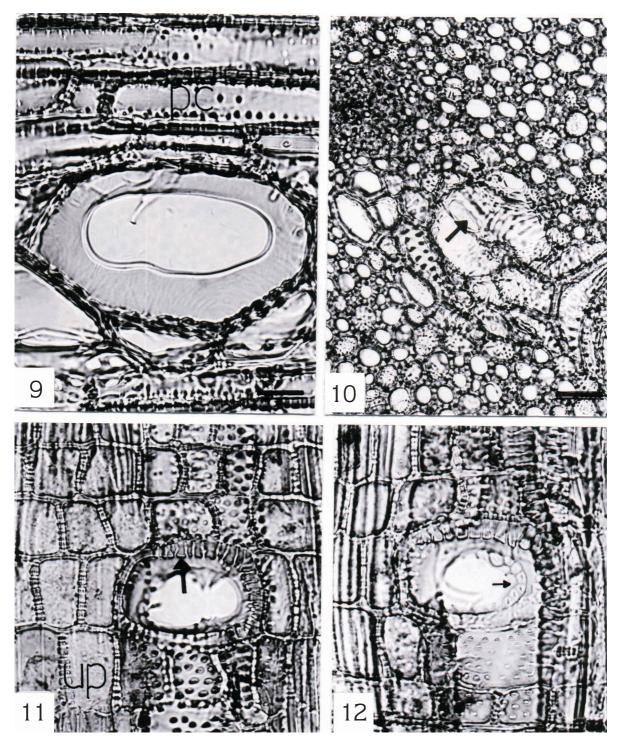


Figure 2. Perforated ray cells. —9 & 10: Hedera helix; —9: RS, Simple PRC with thick walled among procumbent cells (PC) in the body of multiseriate ray; —10: TS, Several simple PRCs in the body of multiseriate ray (arrow) on tangential walls. —11 & 12: RS, Paliurus spina-christii, PRC with thick walled (large arrow) among upright cells (UCs), and PRCs with surrounding bordered pits (small arrow). Scale bars in figure 10 = 50 µm, in the other figures = 25 µm.

Salix triandra L. subsp. triandra L.

The perforated ray cells were found either isolated or together in pairs in the uniseriate ray bodies, sometimes in marginal cells of ray tissues; abundant. Simple like those of vessel elements; larger ($63 \times 46 \mu m$) than adjacent ray cells ($24 \times 32 \mu m$). Surrounded with several bordered pits of perforated ray cells conspicuous on *Salix rizeensis* photograph (Figures 14 & 15), *S. triandra* subsp. *triandra* (Figure 16).

Wood semi-ring porous; earlywood pores mostly solitary, remainder in radial small groups; latewood pores mostly grouped more than earlywood ones (2–6); numerous (168–288/mm²); 19-77 μ m in tangential diameter; vessel elements 230–467 μ m long; perforation plates simple; intervessel pits alternate; vessel-ray pits with much reduced borders and rounded to angular outline. Libriform fibres 499–1000 μ m long. Axial parenchyma in narrow and discontinuous terminal band. Ray uniseriate, heterogeneous type III; 153–499 μ m high (Table 1).

Sambucus nigra L.

The perforations in ray cells are simple like those of most vessel elements; single and in groups in vertical and horizontal direction; abundant. They occur in the body or marginal cells of ray tissues in both upright and procumbent cells; larger (76 x 77 μ m) than adjacent ray cells (19 x 100 μ m) (Figures 17-21, Table 2).

Wood diffuse porous, growth rings marked by vascular tracheids and very narrow pores. Pores mostly grouped, 2-7 in tangential and radial, 3-27 in clusters; numerous ($141-278/mm^2$), small to large ($19-108 \mu m$ in tangential diameter); vessel elements $110-494 \mu m$ long; perforation plates mostly simple, sometimes scalariform and reticulate; intervessel pits alternate. Libriform fibres 588-1559 µm long; vascular tracheids abundant; septate fibre present. Axial parenchyma scanty paratracheal sometimes apotracheal-diffuse, strands of 2–5 cells and fusiform. Rays 7–14/mm, 1-5 cells, 120–1080 µm high in multiseriate; heterogeneous type II A (Table 1).

Staphylea pinnata L.

Type of the perforation in ray cells is scalariform like those of vessel elements, bars are rather numerous (up to 10); single and abundant. They occur in uniseriate and multiseriate marginal ray cells, sometimes in the body of multiseriate rays, where connected to 2 ray tissues among upright cells; larger ($121 \times 56 \mu m$) than adjacent

ray cells (18 x 102 μm) (Figures 22-25, Table 2).

Wood diffuse-porous; growth rings marked by thick walled fibres. Pores evenly distributed without any tendency to form a specific pattern, 93-140/mm², 19-69 μ m in tangential diameter; mostly solitary (98%); vessel element 470-1029 μ m long; perforation plates scalariform with 7–32 bars per perforation plate; intervessel pits sparse, opposite to scalariform; spiral thickenings distinct and related to intervessel pits. Fibre-tracheids, 617–1570 μ m long. Axial parenchyma restricted to some paratracheal or diffuse, fusiform or 2–5 cells. Rays 10–19/mm, 1-7 cells wide, 240-1776 μ m high in multiseriate rays; heterogeneous type I (Table 1).

Tamarix smyrnensis Bunge.

Type of the perforation in ray cells is simple, like those of vessel elements; single and rather abundant. They occur in the body of multiseriate rays among procumbent cells; dimensions of perforated ray cells vary within ray tissue (Figure 26, Table 2).

Wood ring porous, growth rings marked differences. Pores 35-79/mm², mostly solitary, remainder 2–4 tangential multiples; tangential diameter large in earlywood (46-115 μ m), small (6-73 μ m) in latewood; vessel elements 72–134 μ m long; perforation plates simple; intervessel pits alternate; often coalescent apertures; vessel-parenchyma and vessel-ray pits similar but half-bordered. Vessel elements storied together with parenchyma cells. Libriform fibres 353–823 μ m long. Axial parenchyma scanty paratracheal, fusiform. Rays homocellular and only multiseriate (2–11), Kribs's type II, storied; 147–2500 μ m in height (Table 1).

Vitis silvestris Gmelin.

Type of the perforation in ray cells is simple like those of some vessel elements and surrounded by thick walls and numerous thin radiate bars; single and rather abundant. They occur in the multiseriate ray body, among procumbent cells; larger (175 x 150 μ m) than other ray cells (25 x 125 μ m) (Figure 27, Table 2).

Climber and deciduous plant. Growth rings distinct with marked differences in vessel diameter, but wood not ring porous. Vines often have vessels of 2 distinct diameter classes. Pores $20-52/mm^2$, mostly in radial multiples of 2-10 and clusters of 3-10 in the small vessels; large vessels $222-306 \mu m$ in tangential diameter, often associated with very narrow ones. Vessel elements $267-840 \mu m$ long, perforation plates simple in large

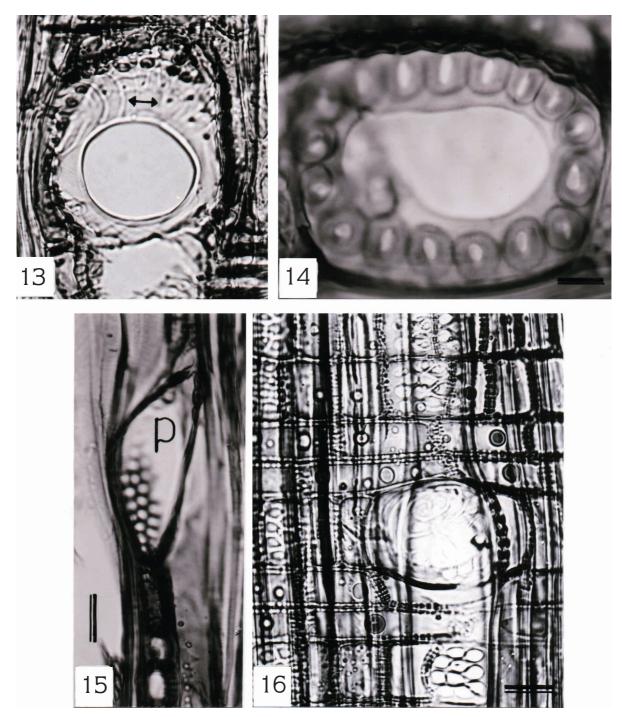


Figure 3. Perforated ray cells. —13: RS, *Pistacia lentiscus*, simple PRC with bordered pits (arrow) related to helical thickening. —14 & 15: RS, *Salix rizeensis*, simple PRC surrounded with bordered pits; —15: TS, PRC (P) in uniseriate marginal ray cell and bordered pits on tangential wall. —16: RS, *Salix triandra* subsp. *triandra*, heterocellular ray tissues, and simple PRC in the among upright cells. Scale bars in figure 14 = 50 μ m, in the other figures = 25 μ m.

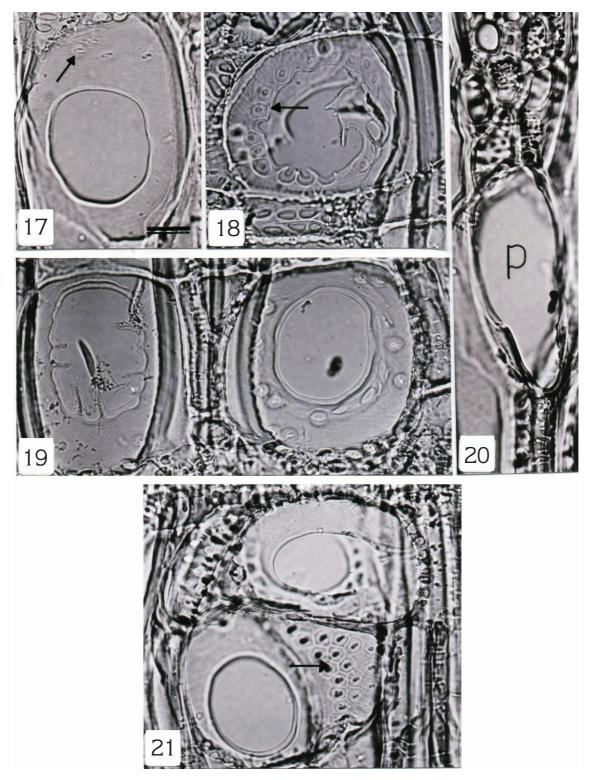


Figure 4. *Sambucus nigra*, simple perforated ray cells. —17 & 18: RS, Single PRC in ray tissues on radial wall; —17: RS, Long PRC in vertical direction, minute bordered pits (arrow); —18: RS, Wide PRC in horizontally direction and bordered pits; —19: RS, Two PRCs in horizontally direction; —20: TS, PRC (P) in the marginal cell of multiseriate ray: —21: RS, 2 PRCs in vertical direction and bordered pits (arrow). Scale bars in figures = 25 µm.

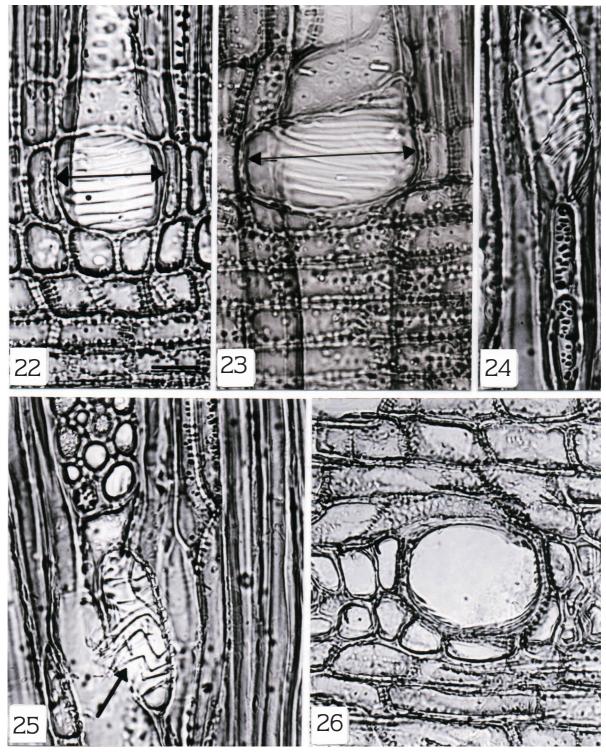


Figure 5. Perforated ray cells. —22-25. *Staphylea pinnata*, scalariform perforated ray cells. —22 & 23: RS, Scalariform PRC on radial wall. —22: RS, Scalariform PRC with 8 bars (arrow) among upright cells; upright cells (next and upper side of PRC), square cells (lower side of PRC), procumbent cells (lower side of picture) in ray tissues. —23: RS, PRC with 6 bars upper side of procumbent cells (arrow). —24: TS, Upper side of picture scalariform PRC with approximately 10 bars in marginal cell (upright cell) of uniseriate ray. —25: TS, PRC in marginal cell of multiseriate ray (arrow). —26: RS, *Tamarix smyrnensis*, simple PRC surrounded with different type cells, procumbent ray cells in lower and upper side of picture on radial wall. Scale bars in figures = 25 µm.

vessels and scalariform in narrow vessels; intervessel pits mostly scalariform; narrow vessel elements with spiral thickening. Libriform fibre 706-1412 μ m long and septate. Vascular tracheids observed. Axial parenchyma scanty paratracheal. Rays 2–5/mm, 5-9 cells wide, very high (over 10 mm); homocellular, composed of procumbent cells; homogeneous type II (Table 1).

Vitis vinifera L.

The type of perforation in ray cells is simple, like those of most vessel elements; single and in groups; rather abundant. They occur in the body of ray tissues among procumbent cells; dimensions of perforated ray cells vary within ray tissue (Figures 28-30, Table 2).

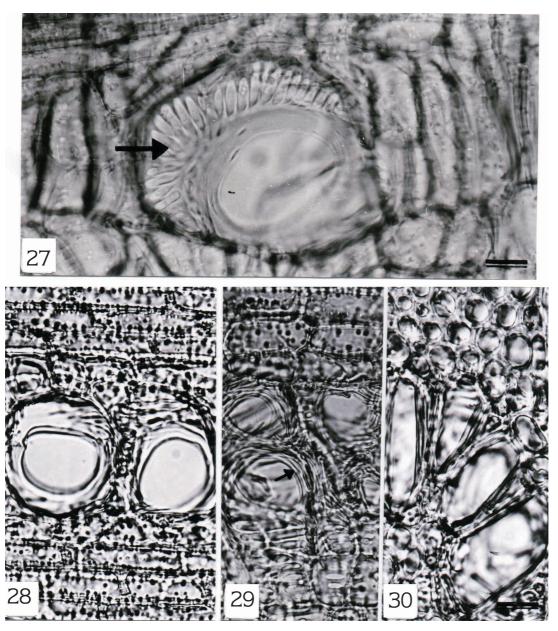


Figure 6. Perforated ray cells. —27: RS, *Vitis silvestris*, simple PRC surrounded with thick wall (inside of radiate bars) and numerous thin radiate bars (arrow) on RS. —28-30: *Vitis vinifera*, simple PRC on radial wall. —28 & 29: RS, Horizontal arrangement of PRCs (figure 28); clusters arrangement of PRC with helical thickening (arrow). —30: TS, Several PRCs (2-5) in the body of multiseriate ray on tangential walls. Scale bars in figures = 25 µm.

Pores 60–100/mm², mostly in radial multiples (2-15) and clusters, rarely solitary (small vessel); large vessels 60–220 μ m in tangential diameter; often associated with very narrow ones. Vessel elements 240–750 μ m long; perforation plates simple in large vessels, scalariform in narrow vessels; intervessel pits mostly scalariform, spiral thickening restricted with narrow vessel elements. Libriform fibres (septate) 580–1250 μ m long. Vascular tracheids observed. Parenchyma scanty paratracheal. Rays 2–4/mm, 7-15 cells wide, very high (over 20 mm); heterocellular, composed mostly of procumbent cells and some square or upright cells. Crystals observed in some enlarged ray cells as raphides (Table 1).

The type of perforation in perforated ray cells is mostly simple with a few scalariform (*Staphylea*). It usually coincides with the type of perforation plate occurring in the vessel elements of the same species.

Perforated ray cells in Turkish taxa have perforation plates in their radial walls (*Berberis, Colutea, Cytisus, Paliurus, Tamarix* and *Vitis silvestris*), but perforations also occur in the tangential walls of the other taxa. However, perforated ray cells could be seen more clearly in the radial walls than in the tangential walls. According to Eom & Chung (1993), perforated ray cells in radial and tangential walls are connected to 2 longitudinal vessel elements in tangential and radial directions.

In some taxa (e.g., *Quercus cerris*), the radial vascular or imperforate tracheary elements are also a group of vessels and fibres that run radially and cross rays in a tangential direction. They are somewhat different from the perforated ray cells described above.

So far, observations on perforated ray cells in *Salix* species have not been found in the literature, but were

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recently described in *Salicaceae* by Serdar et al. (2004) for the first time. Although all the wood species of *Salicaceae* in Turkey have been studied in an ongoing project, perforated ray cells were observed abundantly in only *Salix rizeensis* (Serdar, 2004) and *S. triandra* subsp. *triandra*. Perforated ray cells were generally observed in the upright cells of uniseriate rays. This taxa of *Salix* may be distinguished taxonomically, especially from the other shrubby taxa. A difference was also found between perforated ray cells of *Vitis vinifera* and *V. silvestris*.

In the present study, the presence of perforated ray cells in the ray tissues is also described for the first time in some species of *Berberis, Colutea, Coronilla, Chamaecytisus, Cytisus, Paliurus, Pistacia, Tamarix, Vitis* and *Salix triandra* subsp. *triandra*. The first record of perforated ray cells in *Sambucus latipinna* and *S. williamsii* was reported by Eom and Chung (1996). The type of perforations in these taxa is similar to that of *Sambucus nigra* in Turkey, and also, similar to the Turkish taxon. Carlquist (1985) recorded perforated ray cells in *Staphylea bumalda* in the study of the wood anatomy of *Staphyleaceae*.

The diagnostic value of perforated ray cells has been discussed by several authors. Chalk and Chattaway (1933), Dayal et al. (1984), Rudall (1985) and Carlquist (1988) considered that since the development of this cell type is due to variable cambial activity, it is not a constant anatomical feature and therefore of limited taxonomic value.

Wood anatomical descriptions of the investigated taxa are in full agreement with those documented by Fahn et al. (1986), Schweingruber (1990), and many others.

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