

COMPARATIVE ANATOMICAL INVESTIGATIONS ON SIX ENDEMIC *TANACETUM* (ASTERACEAE) TAXA FROM TURKEY

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Abstract

Tanacetum is one of the large genera, belonging to the *Anthemideae* tribe of *Asteraceae* family and has numerous medicinal plants and widely usage in folk medicine. In this study, anatomical features of six endemic species to Turkey viz. *Tanacetum albipannosum*, *T. argenteum* subsp. *argenteum*, *T. cappadocicum*, *T. densum* subsp. *sivasicum*, *T. haussknechtii* and *T. heterotomum*, were investigated for the first time. The specimens were collected from their natural habitats in Sivas province (Turkey). Transverse sections of root, stem, petiole and leaflet were observed under light microscope for various anatomical features. The results showed that, root included periderm in the outer. There were parenchymatous cortex, endodermis and pericycle under the periderm respectively. Primary xylem ridges were triarch in *T. albipannosum*, *T. densum* subsp. *sivasicum*, *T. haussknechtii* and *T. heterotomum*, pentarch in *T. cappadocicum* and hexarch in *T. argenteum* subsp. *argenteum*, and pith was filled with xylem elements. Stem was made up epidermis, parenchymatous cortex, endodermis, vascular bundles and parenchymatous pith from exterior to interior. *T. heterotomum* had a cavity formed by the disintegration of the cells in the center. The amphistomatic leaflets had a single layered epidermis with usually silvery or whitish tomentose indumentum and equifacial mesophyll. Stomata are anomocytic. There were significant difference among examined taxa in respect to contour of petiole, structure of cortex parenchyma and organization of vascular bundles. The anatomical characteristic features of petiole proved to be a useful tool for the taxonomic discrimination of the six studied taxa.

Key words: Anatomy; Asteraceae; Endemic; *Tanacetum*; Turkey.

Introduction

The Asteraceae family has 23.600 species, 1620 genera and 12 subfamilies, which are distributed naturally in temperate, sub-tropical and tropical climates (Stevens, 2001). The family represents the largest number of species in the flora of Turkey, with a total of 1209 recorded species. From these species, 447 are endemic, with an endemism ratio of 37% for Turkey (Doğan *et al.*, 2009). This family have species of great importance in the fields of nutrition, cosmetics and pharmacy due to the production of essential oils (Milan *et al.*, 2006). The genus *Tanacetum* L. has about 160 species which are native to Northern Hemisphere (Oberprieler *et al.*, 2007). *Tanacetum* is represented by 45 species and 60 taxa in Turkey, 27 of which are endemic (Özmen *et al.*, 2009). The taxa of the genus *Tanacetum* are reputed to have excellent medicinal value. So, many taxa of *Tanacetum* genus have wide range of pharmaceutical and ethnobotanical usage throughout the world. The taxa of *Tanacetum* secrete some secondary metabolites such as, essential oils, the large number of sesquiterpenoids and sesquiterpene lactones and they are used for their anti-inflammatory, antihistaminic and insecticidal effects. (Abad *et al.*, 1995; Başer *et al.*, 2001). The essential oils of most common and much studied species *T. vulgare* when rubbed on skin, repel insects and have antibacterial and anti-yeast activity (Grieve, 1971; Mikulašova & Vaverkova, 2009). The roots and rhizomes of *T. parthenium* (L.) Schulz. Bip. have been used in the Iranian traditional medicine as digestive and stomachic tonic (Amin, 2005). In addition, aerial parts, especially the leaflets of *T. parthenium* are eaten or used as infusions against arthritis, migraine and asthma (Bohlmann &

Zdero, 1982; Berry, 1984; Knight, 1995). The species dealt with in the present paper, *T. argenteum* (Lam.) Willd. subsp. *flabellifolium* (Boiss. et Heldr.) Grierson has been examined by Tabanca *et al.* (2007), *T. argenteum* subsp. *argenteum* and *T. densum* subsp. *amani* Heywood were investigated by Polatoglu *et al.* (2010) for antimicrobial activity. *T. densum* subsp. *sivasicum* Hub.-Mor. et Grierson, *T. densum* subsp. *eginense* Heywood and *T. densum* subsp. *amani* which are endemic to Turkish flora have been screened by Tepe & Sökmen (2007) for antimicrobial activities and antioxidant activities. *T. albipannosum* Hub.-Mor. et Grierson which is studied species in this paper, although endemic to Turkey flora, seeds and rhizomes have been exported abroad and this is species grown as ornamental plant for commercial purposes (Anon., 2013).

There are few studies on the morphology and anatomy of the some aromatic *Tanacetum* species. The widespread species of *Tanacetum* genus, *T. vulgare* L. has been investigated for its floral morphological and anatomical diagnostics by Kurkina (2013) and for its environmental impact on the morphological and anatomical structure of vegetative organs by Stevovic *et al.* (2010). Pollen morphology of our studied species *T. haussknechtii* and *T. corymbosum* (DC.) Schultz. subsp. *corymbosum*, *T. armenum* (DC.) Schultz and *T. nitens* (Boiss. & Noë) Grierson have been examined by Özmen *et al.* (2009). In addition, similar to the present study, there are some studies on anatomy of the other Turkish endemics which located different families (Akyol *et al.*, 2014; Binzet & Teke, 2014; Yetişen & Özdemir, 2015).

In this study, all examined taxa are endemic for Turkey flora. Ekim *et al.* (2000) are reported under the threat category. *T. albipannosum* Hub.-Mor. & Grierson,

T. argenteum subsp. *argenteum* and *T. cappadocicum* (DC.) Schultz Bip. is classified as lower risk (LR) and the threat category of *T. densum* (Lab.) Schultz Bip. subsp. *sivasicum* Hub.-Mor. & Grierson and *T. haussknechtii* (Bornm.) Grierson *T. heterotomum* (Bornm.) Grierson is vulnerable (VU).

In the present study, we aimed to examine the anatomy of root, stem, petiole and leaflet anatomy of all the 6 *T. albipannosum*, *T. argenteum* subsp. *argenteum*, *T. cappadocicum*, *T. densum* subsp. *sivasicum*, *T. haussknechtii*, *T. heterotomum*, which were not examined previously. In to find out whether the species could be distinguish anatomically or not.

Materials and Methods

The specimens of *T. albipannosum*, *T. argenteum* subsp. *argenteum*, *T. cappadocicum*, *T. densum* subsp.

sivasicum, *T. haussknechtii* *T. heterotomum* were collected from their natural populations which were identified by using the Flora of Turkey (Davis, 1975) and were fixed and conserved in 70% ethyl alcohol until used. Their localities are given in Table 1. Voucher specimens were deposited in the Cumhuriyet University, Faculty of Science Herbarium (CUFH).

For anatomical studies, specimens preserved in ethyl alcohol, were used. Hand sections were taken with a razor blade from roots, stems, petioles and leaflets. The sections were stained with Safranin, Alcian blue and Sudan III (Davis & Barnett, 1997), and then, the stained sections were mounted in glycerin-gelatin to make permanent preparations (Jensen, 1962). The cuticle measurements were carried out on the sections stained with Sudan III. The slides were examined by using an Olympus BX51 optical microscope and microphotographs were taken with an Olympus DP 70 digital camera.

Table 1. Collection data of investigated *Tanacetum* taxa.

Taxon	Locality	Collector and plant number of collector	Date
<i>T. albipannosum</i>	A7 Sivas: Suşehri to Refahiye, 54. km, roadside, 1550 m, 40° 00' 00.7" N ; 38° 38' 19.7" E	M. Tekin, 1632	06.07.2014
<i>T. argenteum</i> subsp. <i>argenteum</i>	B6 Sivas: Sivas to Gürün, Böğrüdelik village, 1845 m, 38° 57' 21.2" N; 37° 16' 35.7" E	M. Tekin, 1255	21.06.2012
<i>T. cappadocicum</i>	B6 Sivas: Sivas to Gürün, Böğrüdelik village, 1966 m, 38° 57' 26.2" N; 37° 16' 14.6" E	M. Tekin, 1260	21.06.2012
<i>T. densum</i> subsp. <i>sivasicum</i>	B6 Sivas: Sivas to Gürün, Böğrüdelik village, 1966 m, 38° 57' 26.2" N; 37° 16' 14.6" E	M. Tekin, 1257	21.06.2012
<i>T. haussknechtii</i>	B6 Sivas: Sivas-Kangal-Gürün road intersection, roadside, 1545 m, 39° 07' 52.7" N; 37° 14' 32.6" E	M. Tekin, 1462	18.06.2013
<i>T. heterotomum</i>	B6 Sivas: Ulaş town, Ziyarettepe, 1411 m, 39° 33' 08.1" N; 37° 01' 12.5" E	M. Tekin, 1425	11.05.2013

Results

Tanacetum albipannosum

Root: Cross sections taken from the root of *T. albipannosum* have revealed that the periderm layer on the outermost surface of the root consists of phelloderm (1 layered), phellogen (1 layered) and phellem (3–5 layered) which are distinct. There is 13–15 layered parenchymatic cortex under the periderm. Endodermis with casparian strip is one rowed. Parenchymatous pericycle is uniseriate and distinguishable under of the endodermis. The phloem is located in between the three radially arranged ridges of the xylem, under pericycle. There is sclerenchyma fiber cap over the phloem. The xylem is composed of vessels and tracheids. Xylem arms are triarc. Cambium cells are distinct between phloem and xylem. Pith is completely filled with metaxylem elements (Fig. 1 A, B; Table 2).

Stem: In the cross section of the stem, the epidermal cells are uniseriate and oval or square shaped. There are white simple hairs and a cuticle layer on the epidermis. The lamellar collenchyma groups alternate with parenchymatous cortex

which consists of 6–7 cell layers under the epidermis. The cortex includes secretory ducts just over the endodermis. The uniseriate endodermis is the innermost layer of the cortex, and is very distinct. The stem has 15–17 collateral type vascular bundles completely surrounded by sclerenchyma fibers. The vascular cambium is indistinguishable between phloem and xylem. The xylem contains vessels and tracheids. The pith is occupied with large, cylindrical and thick-walled parenchyma cells (Fig. 1 C, D; Table 2).

Petiole: In the cross section of the petiole shows that, while the adaxial surface is deeply grooved, the abaxial surface is convex and the middle-part is slightly grooved. There is uniseriate epidermis which has dense white simple hairs in the outer. The cortex consists of 6–7 rows parenchyma cells with chloroplasts under the epidermis. The lamellar collenchyma groups, which are placed on the vascular bundles, are alternated with parenchyma cells. There are 5 open collateral vascular bundles which are arranged as semicircle. Phloem and xylem are surrounded by sclerenchyma fibers. The cambium is distinguishable between phloem and xylem. The pith of the petiole consists of parenchyma cells and sclerenchyma fibers (Fig. 1 E, F; Table 3).

Leaflet: In cross section of the leaflet, adaxial and abaxial epidermises are uniseriate and contain dense white simple hairs. The stomata are present on both epidermises. The stoma type is anomocytic, and the stoma cells are located on the same level with the epidermal cells. The mesophyll is equifacial. The palisade parenchyma cells are 2 layered and present at

the both sides of the leaflet. 3–4 cell layered spongy parenchyma fills area of beneath the upper and lower palisade parenchymas. The collateral vascular bundles are surrounded by a parenchymatous bundle sheath. The cambium is indistinguishable between phloem and xylem. The leaflet includes secretory ducts near the xylem (Fig. 1 G, H; Table 3).

Table 2. Anatomical measurements of the root and stem of investigated *Tanacetum* taxa. Length (L), maximum (Max), minimum (Min), standart deviation (SD), width (W).

		<i>T. albipannosum</i>	<i>T. rgenteum</i>	<i>T. cappadocicum</i>	<i>T. densum</i> subsp. <i>sivasicum</i>	<i>T. haussknechtii</i>	<i>T. heterotomum</i>	
Root								
Cortex cell	L	Min – Max	12.35 – 49.54	16.47 – 51.06	10.52 – 41.14	12.49 – 44.21	12.01 – 38.66	15.17 – 50.51
		Mean ± SD	26.70 ± 9.04	31.05 ± 9.94	26.34 ± 6.50	25.42 ± 8.93	24.58 ± 7.20	32.94 ± 9.22
	W	Min – Max	9.28 – 34.82	9.50 – 27.58	7.50 – 29.91	7.15 – 33.17	7.87 – 23.41	10.37 – 37.92
		Mean ± SD	19.78 ± 7.58	18.34 ± 5.73	19.55 ± 4.71	19.15 ± 6.30	15.68 ± 4.57	21.36 ± 7.06
Endodermis cell	L	Min – Max	10.70 – 28.96	9.17 – 26.88	10.41 – 25.07	7.42 – 27.66	11.97 – 29.88	13.47 – 29.66
		Mean ± SD	20.95 ± 5.02	16.84 ± 4.60	16.98 ± 4.31	15.98 ± 4.63	20.63 ± 5.44	21.41 ± 4.54
	W	Min – Max	7.57 – 15.93	5.40 – 13.71	5.04 – 16.27	6.90 – 13.11	3.54 – 11.85	7.73 – 23.45
		Mean ± SD	11.02 ± 2.06	10.12 ± 1.87	9.58 ± 2.70	9.72 ± 1.49	7.79 ± 2.68	13.68 ± 3.73
Perisicle cell	L	Min – Max	7.25 – 20.77	8.53 – 32.09	9.76 – 34.22	11.70 – 26.72	14.46 – 28.54	13.65 – 36.53
		Mean ± SD	11.78 ± 2.91	19.56 ± 6.51	17.69 ± 4.95	18.15 ± 3.96	21.13 ± 3.77	21.62 ± 5.16
	W	Min – Max	2.62 – 12.26	7.25 – 14.91	5.04 – 10.90	6.18 – 13.82	4.60 – 12.03	6.04 – 17.43
		Mean ± SD	5.68 ± 2.10	9.81 ± 1.99	7.45 ± 1.17	8.78 ± 1.95	8.41 ± 2.24	11.44 ± 2.22
Cambium cell	L	Min – Max	6.55 – 11.36	9.34 – 16.81	6.04 – 13.24	5.59 – 10.58	7.35 – 20.30	8.28 – 17.75
		Mean ± SD	9.42 ± 1.19	12.46 ± 1.66	9.12 ± 1.79	8.48 ± 1.34	12.16 ± 2.61	11.16 ± 2.18
	W	Min – Max	2.32 – 5.94	2.08 – 9.82	2.03 – 7.20	2.07 – 6.94	2.93 – 8.25	3.53 – 9.14
		Mean ± SD	4.07 ± 0.94	5.13 ± 1.94	4.12 ± 1.39	3.77 ± 0.98	4.81 ± 1.42	6.72 ± 1.67
Trachea	W	Min – Max	8.82 – 36.05	10.79 – 47.81	7.44 – 21.06	7.25 – 27.28	9.38 – 34.80	9.80 – 29.05
		Mean ± SD	17.85 ± 5.72	21.56 ± 10.01	13.69 ± 3.35	14.89 ± 4.41	20.16 ± 6.38	20.93 ± 4.91
Stem								
Cuticle	W	Min – Max	0.60 – 1.24	0.77 – 2.15	0.58 – 1.12	0.77 – 1.42	0.71 – 1.66	0.91 – 1.38
		Mean ± SD	0.91 ± 0.15	1.32 ± 0.38	0.82 ± 0.14	1.02 ± 0.15	1.15 ± 0.25	1.07 ± 0.11
Epidermis cell	L	Min – Max	12.92 – 20.67	10.21 – 21.53	12.60 – 29.87	11.27 – 25.38	15.43 – 26.75	12.09 – 26.54
		Mean ± SD	17.21 ± 2.01	14.63 ± 3.45	19.66 ± 3.98	15.36 ± 2.73	20.91 ± 2.97	19.06 ± 4.00
	W	Min – Max	5.29 – 19.82	4.90 – 18.52	6.78 – 22.51	6.29 – 21.58	7.39 – 25.06	9.02 – 25.56
		Mean ± SD	12.53 ± 3.71	11.68 ± 3.48	15.11 ± 3.80	11.60 ± 3.71	16.49 ± 4.66	16.61 ± 3.75
Cortex cell	L	Min – Max	8.45 – 34.19	11.58 – 36.61	8.71 – 44.23	7.76 – 33.91	10.94 – 49.95	11.11 – 36.85
		Mean ± SD	18.95 ± 6.23	22.69 ± 6.72	22.50 ± 8.07	20.13 ± 7.30	28.81 ± 11.46	23.05 ± 7.13
	W	Min – Max	6.66 – 24.01	9.52 – 29.29	9.37 – 34.88	6.81 – 23.87	8.94 – 29.46	8.92 – 29.38
		Mean ± SD	13.61 ± 4.37	16.67 ± 4.82	18.19 ± 6.09	14.25 ± 4.48	18.64 ± 6.61	18.16 ± 6.17
Endodermis cell	L	Min – Max	13.34 – 31.65	10.09 – 34.05	11.25 – 42.09	11.61 – 29.76	13.81 – 31.92	12.62 – 40.63
		Mean ± SD	23.24 ± 5.49	24.84 ± 6.00	25.02 ± 7.03	21.38 ± 4.84	23.48 ± 5.12	27.52 ± 7.56
	W	Min – Max	9.06 – 23.05	6.45 – 26.53	8.20 – 31.48	7.38 – 22.84	7.93 – 21.80	11.51 – 35.63
		Mean ± SD	15.35 ± 3.42	13.09 ± 4.36	18.03 ± 5.28	13.84 ± 4.15	13.96 ± 3.70	21.58 ± 6.01
Pith cell	L	Min – Max	15.91 – 55.51	16.57 – 71.08	17.35 – 52.97	21.89 – 84.82	16.68 – 49.70	18.79 – 61.55
		Mean ± SD	32.01 ± 11.55	46.80 ± 17.99	34.47 ± 12.26	50.93 ± 18.04	32.21 ± 9.46	39.53 ± 11.96
	W	Min – Max	12.10 – 52.20	11.11 – 61.91	15.20 – 47.76	16.87 – 78.56	12.52 – 45.10	15.93 – 50.20
		Mean ± SD	30.48 ± 11.39	38.12 ± 14.41	29.74 ± 10.24	44.33 ± 17.85	26.65 ± 9.08	30.91 ± 9.52
Trachea	W	Min – Max	7.63 – 18.89	10.37 – 23.35	8.65 – 24.94	7.87 – 20.59	9.71 – 20.84	8.29 – 18.75
		Mean ± SD	13.50 ± 2.94	17.23 ± 3.29	15.35 ± 4.27	14.03 ± 3.41	14.92 ± 2.93	14.44 ± 2.71

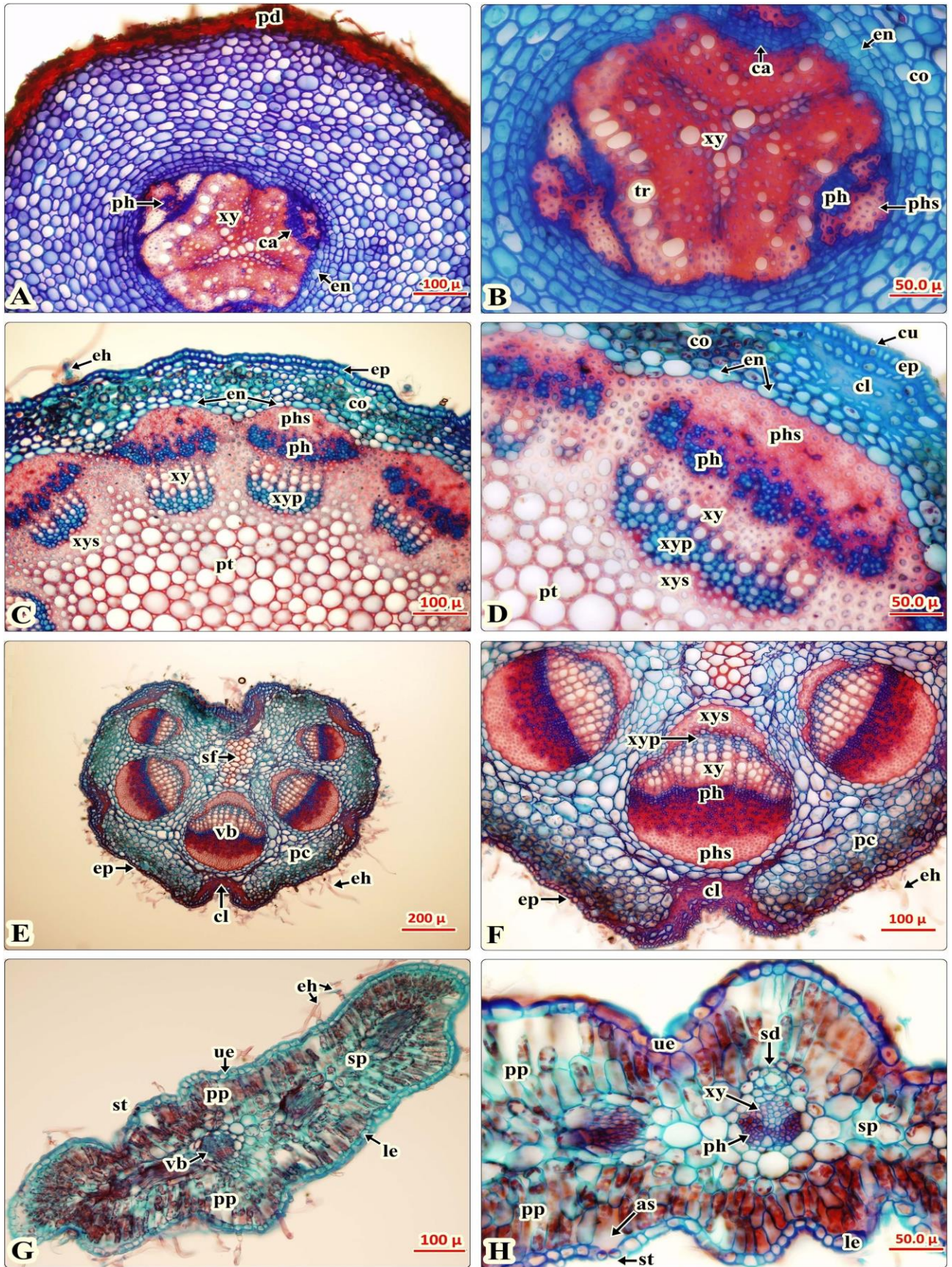


Fig. 1. Anatomical cross sections of *T. albipannosum*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). air space (as), cambium (ca), collenchyma (cl), cortex parenchyma (co), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phs), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

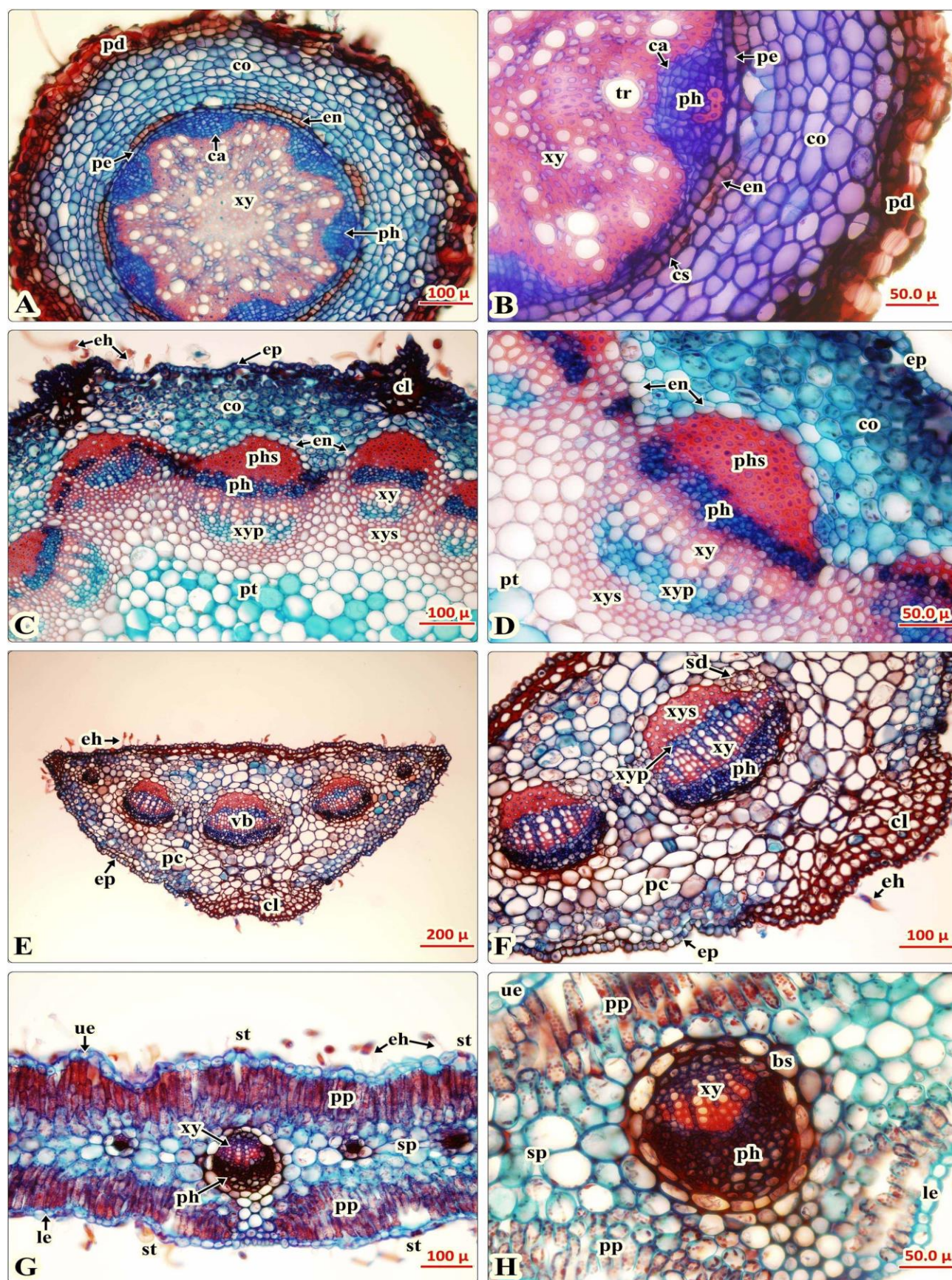


Fig. 2. Anatomical cross sections of *T. argenteum* subsp. *argenteum*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). bundle sheath (bs), cambium (ca), collenchyma (cl), cortex parenchyma (co), casparian strip (cs), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phs), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

Tanacetum argenteum* subsp. *argenteum

Root: Cross sections taken from the root, observed that the periderm develops just below the epidermis broken down. It consists of phellem (3–5 layered), phellogen (1 layered) and phelloderm (1 layered), from exterior to interior. There is 8–10 layered parenchymatous cortex that composed of ovoid cells beneath the periderm. The endodermis with casparian strip is uniseriate and its cell walls suberized and/or lignified at the sites opposite to xylem rays. The pericycle is single-layered, and consists of thin-walled parenchymatous cells. Protoxylem ridges are hexarch in structure and the phloem elements are located between of them. There are almost no sclerenchyma fiber caps on the phloem. The cambium is 2–3 layered and clearly distinguishable between xylem and phloem. The pith is occupied by the xylem elements. (Fig. 2 A, B; Table 2).

Stem: In the cross section of the stem, observed that the epidermis is the outermost layer, uniseriate and covered with thin cuticle. It has dense greyish-white simple hairs. There are 6–8 layered parenchymatous cortex which has the chloroplast and discontinuous lamellar collenchyma under the epidermis. The cortex includes secretory ducts just over the endodermis. Endodermis is a distinctly visible layer and make up inner boundary of the cortex. The central cylinder contains of 26–30 open collateral type vascular bundles completely surrounded by sclerenchyma fibers. The vascular cambium is indistinguishable between phloem and xylem. The pith is filled with large, cylindrical and thin-walled parenchyma cells (Fig. 2 C, D; Table 2).

Petiole: The cross section of petiole is seen almost triangular. Uniseriate epidermis has dense greyish-white simple hairs. The cortex consists of spherical and thin-walled parenchyma cells which have a few chloroplasts. The lamellar collenchyma is located on the corners (4–5 layered), and just beneath the both of adaxial (1 layered) and abaxial (3–4 layered) epidermises. The petiole consists of 5 open collateral vascular bundles of which 3 large bundles are located in the center and 2 small bundles in the corners. While the xylem is surrounded by sclerenchyma fibers, the phloem is surrounded above by uniseriate lacunar collenchyma. The cambium is distinguishable between phloem and xylem. The petiole has secretory duct near the xylem. The parenchyma cells that lack of chloroplast are filled the pith of the petiole (Fig. 2 E, F; Table 3).

Leaflet: In cross section of the leaflet, adaxial and abaxial epidermises are uniseriate and contain dense greyish or whitish simple hairs. The stomata are present on both epidermises. The stoma type is anomocytic, and the stoma cells are located slightly above the level of the epidermal cells. The mesophyll is equifacial, and consists of 2 layers of palisade parenchyma below both epidermises and 3–4 layers of spongy parenchyma between of them. The midrib is obviously larger than the other bundles. The

collateral vascular bundles are surrounded by a distinct bundle sheath. The cambium is distinguishable between phloem and xylem. The leaflet does not include secretory duct (Fig. 2 G, H; Table 3).

Tanacetum cappadocicum

Root: Periderm, the outermost layer of the root, is formed to replace the broken epidermal layer. The cortex consists of 13–16 layered, cylindrical and elliptical parenchymatous cells. The endodermis with casparian strip is distinguishable as innermost layer of the cortex. The pericycle is made up parenchymatous cells under the endodermis. The xylem arms are pentarch in structures and the phloem elements are located between of them. There is almost no sclerenchyma fiber cap on the phloem. The cambium is distinct between xylem and phloem. The pith is occupied by the xylem elements (Fig. 3 A, B; Table 2).

Stem: In the cross section of the stem, the epidermis is single layered and cells have thin-cuticle. There are greyish simple hairs on the epidermis. The collenchyma is 6–7 layered and discontinuously under the epidermis. The parenchymatous cortex with chloroplast is made up of 6–7 layers and placed between the collenchyma groups. There are secretory ducts just above the endodermis and between the vascular bundles. The endodermis, innermost layer of the cortex, is very distinct. The stem has 14–16 open collateral type vascular bundles surrounded by sclerenchyma fibers. The vascular cambium is hardly detected between xylem and phloem. The xylem contains vessels and tracheids. The pith is occupied by large, cylindrical and thick-walled parenchyma cells (Fig. 3 C, D; Table 2).

Petiole: Petiole is flattened and surrounded by uniseriate epidermis. The greyish-white simple hairs are present on the epidermis. There is lamellar collenchyma discontinuously under the epidermis. The midrib is distinctly larger than the other bundles which are different sized and with a number 5–7. The xylem and phloem have a large sclerenchyma fibers cap. The cambium is distinguishable between phloem and xylem. The secretory ducts are situated near the vascular bundles. The parenchyma cells that lack of chloroplast are filled between both of epidermises (Fig. 3 E, F; Table 3).

Leaflet: In cross section of the leaflet, adaxial and abaxial epidermises are uniseriate and contain greyish-white simple hairs. The stomata are present on both epidermises. The stoma type is anomocytic, and the stoma cells are located on the same level with the epidermal cells. The mesophyll is equifacial, and has 1–2 layers of palisade parenchyma below both epidermises and 3–4 layers of spongy parenchyma between of them. The midrib is obviously larger than the other bundles. The collateral vascular bundles are surrounded by a parenchymatous bundle sheath. The cambium is indistinguishable between phloem and xylem. The leaflet does not include secretory duct (Fig. 3 G, H; Table 3).

Table 3. Anatomical measurements of the petiole and leaflet of investigated *Tanacetum* taxa. Diameter (D), length (L), maximum (Max), minimum (Min) standard deviation (SD), thickness (T), width (W).

			<i>T. albipannosum</i>	<i>T. argenteum</i>	<i>T. cappadocicum</i>	<i>T. densum</i> subsp. <i>sivasicum</i>	<i>T. haussknechtii</i>	<i>T. heterotomum</i>	
Petiole									
Cuticle	T	Min – Max	0.52 – 1.18	0.72 – 1.39	0.63 – 1.09	0.60 – 1.26	0.69 – 1.30	0.86 – 11.97	
		Mean ± SD	0.80 ±0.20	0.96 ±0.16	0.85 ±0.12	0.97 ±0.15	1.05 ±0.14	5.14 ±4.44	
Epidermis cell	L	Min – Max	9.26 – 19.51	11.92 – 27.49	12.51 – 31.50	10.83 – 22.90	17.07 – 43.63	14.31 – 33.11	
		Mean ± SD	14.56 ±2.91	20.98 ±3.74	21.78 ±4.47	16.75 ±3.39	30.11 ±7.14	24.14 ±4.80	
	W	Min – Max	3.66 – 16.87	5.19 – 21.95	8.32 – 28.34	4.97 – 19.70	9.92 – 39.66	9.19 – 33.86	
		Mean ± SD	10.51 ±3.63	14.02 ±4.06	18.06 ±5.13	13.20 ±3.56	23.93 ±7.19	21.78 ±5.66	
Parenchyma cell	L	Min – Max	10.66 – 69.30	10.78 – 88.64	11.86 – 72.70	12.16 – 78.03	12.01 – 71.93	17.92 – 64.81	
		Mean ± SD	29.90 ±15.72	35.75 ±18.41	35.05 ±17.72	35.74 ±19.88	42.07 ±17.96	41.52 ±12.73	
	W	Min – Max	10.25 – 53.57	9.83 – 63.17	12.05 – 61.96	9.37 – 49.62	9.49 – 62.28	15.15 – 48.63	
		Mean ± SD	20.45 ±10.66	27.78 ±13.57	26.14 ±12.63	22.10 ±10.18	34.57 ±15.94	23.87 ±8.53	
Trachae	D	Min – Max	8.66 – 26.91	8.97 – 24.29	8.56 – 26.21	7.75 – 19.25	9.49 – 22.55	12.84 – 33.43	
		Mean ± SD	15.73 ±5.50	15.38 ±4.65	17.65 ±4.10	13.05 ±3.02	15.08 ±4.12	21.07 ±6.24	
Leaflet									
Upper cuticle	T	Min – Max	0.17 – 1.12	0.15 – 0.57	0.55 – 1.11	0.63 – 1.21	0.74 – 1.36	0.48 – 1.11	
		Mean ± SD	0.47 ±0.27	0.27 ±0.08	0.80 ±0.13	0.91 ±0.16	1.02 ±0.17	0.76 ±0.19	
Lower cuticle	T	Min – Max	0.51 – 1.12	0.25 – 0.86	0.44 – 1.27	0.60 – 1.47	0.81 – 1.97	0.60 – 1.18	
		Mean ± SD	0.78 ±0.15	0.49 ±0.18	0.86 ±0.24	1.04 ±0.18	1.28 ±0.30	0.93 ±0.14	
Upper cell	epidermis	L	Min – Max	14.08 – 26.93	11.61 – 29.65	16.80 – 50.08	11.48 – 32.09	22.74 – 40.89	23.15 – 40.98
			Mean ± SD	18.27 ±2.89	22.04 ±4.48	28.94 ±9.01	23.51 ±4.66	28.66 ±4.37	31.32 ±4.86
	W	Min – Max	0.65 – 22.69	11.04 – 28.77	9.64 – 43.35	9.92 – 28.30	12.07 – 33.35	7.91 – 37.70	
		Mean ± SD	14.23 ±4.55	18.99 ±4.27	25.23 ±8.89	19.02 ±4.76	24.19 ±6.21	22.41 ±5.89	
Lower cell	epidermis	L	Min – Max	9.83 – 27.36	12.77 – 25.32	13.12 – 37.94	13.82 – 29.14	22.90 – 39.39	18.71 – 38.72
			Mean ± SD	17.48 ±4.01	18.90 ±3.49	23.04 ±6.90	21.26 ±4.22	28.87 ±3.71	26.72 ±5.21
	W	Min – Max	4.54 – 21.95	6.78 – 26.80	6.86 – 35.35	6.02 – 26.23	9.95 – 41.81	10.02 – 37.10	
		Mean ± SD	13.09 ±4.18	17.06 ±4.22	19.97 ±7.10	16.78 ±4.96	25.39 ±7.47	21.00 ±7.39	
Upper parenchyma cell	palisade	L	Min – Max	14.39 – 47.45	27.82 – 72.62	48.56 – 92.69	29.02 – 89.63	62.14 – 160.22	43.83 – 111.24
			Mean ± SD	35.34 ±7.53	53.92 ±10.09	70.39 ±12.13	55.85 ±14.18	99.90 ±20.78	81.62 ±15.02
	W	Min – Max	8.58 – 19.69	12.13 – 20.53	14.13 – 25.27	15.96 – 27.57	22.86 – 38.39	12.97 – 31.57	
		Mean ± SD	13.32 ±2.67	15.91 ±2.03	19.23 ±2.93	21.24 ±3.08	28.34 ±4.18	19.42 ±3.83	
Lower parenchyma cell	palisade	L	Min – Max	27.75 – 59.58	22.53 – 65.82	42.17 – 92.18	35.19 – 94.23	50.12 – 135.52	60.98 – 125.15
			Mean ± SD	42.38 ±9.06	44.76 ±11.68	65.80 ±13.36	55.42 ±15.11	94.47 ±20.52	82.46 ±15.04
	W	Min – Max	10.65 – 21.55	12.81 – 20.30	10.45 – 26.21	13.50 – 27.09	17.38 – 44.33	14.96 – 32.41	
		Mean ± SD	14.76 ±2.55	15.60 ±1.78	17.30 ±3.12	18.94 ±2.98	29.56 ±5.63	21.75 ±4.63	
Spongy parenchyma cell	L	Min – Max	9.34 – 42.97	12.45 – 54.01	15.29 – 80.53	25.66 – 61.47	29.26 – 102.19	18.13 – 84.49	
		Mean ± SD	27.29 ±9.14	34.94 ±10.97	37.73 ±13.55	44.11 ±10.22	53.17 ±16.32	41.16 ±15.12	
	W	Min – Max	6.24 – 30.44	11.72 – 40.71	10.05 – 44.00	19.01 – 51.61	24.10 – 56.62	14.76 – 50.11	
		Mean ± SD	19.48 ±6.78	27.83 ±9.53	27.74 ±7.46	32.76 ±7.90	38.23 ±8.66	31.12 ±10.96	
Upper parenchyma	palisade	T	Min – Max	27.05 – 96.32	71.27 – 129.5	57.80 – 94.84	63.71 – 128.5	107.40 – 222.2	56.92 – 138.0
			Mean ± SD	67.00 ±20.15	96.30 ±15.80	76.81 ±9.45	95.14 ±18.80	153.03 ±28.94	97.88 ±23.80
Lower parenchyma	palisade	T	Min – Max	37.20 – 109.5	59.24 – 115.8	58.17 – 117.6	58.58 – 131.2	58.97 – 272.4	55.09 – 197.3
			Mean ± SD	79.01 ±17.01	81.05 ±13.83	78.32 ±15.38	91.84 ±19.34	172.58 ±59.33	127.35 ±39.37
Spongy parenchyma	T	Min – Max	34.45 – 112.8	97.52 – 175.3	53.54 – 112.2	96.73 – 212.0	95.71 – 309.6	51.80 – 215.3	
		Mean ± SD	66.61 ±21.82	126.03 ±17.76	87.41 ±14.70	142.49 ±34.15	196.50 ±53.81	123.26 ±40.35	
Mesophyll	T	Min – Max	128.8 – 282.0	243.0 – 351.8	208.42 – 276.5	277.23 – 418.9	302.5 – 673.5	162.1 – 580.9	
		Mean ± SD	206.9 ±30.96	304.7 ±24.89	246.84 ±19.45	339.40 ±29.65	508.97 ±92.76	373.77 ±112.5	
Leaflet	T	Min – Max	158.5 – 303.8	276.8 – 385.3	266.1 – 353.9	353.1 – 462.4	412.9 – 762.1	266.1 – 650.3	
		Mean ± SD	230.1 ±36.92	345.3 ±23.97	299.2 ±19.68	392.5 ±27.28	578.7 ±95.30	449.0 ±111.2	

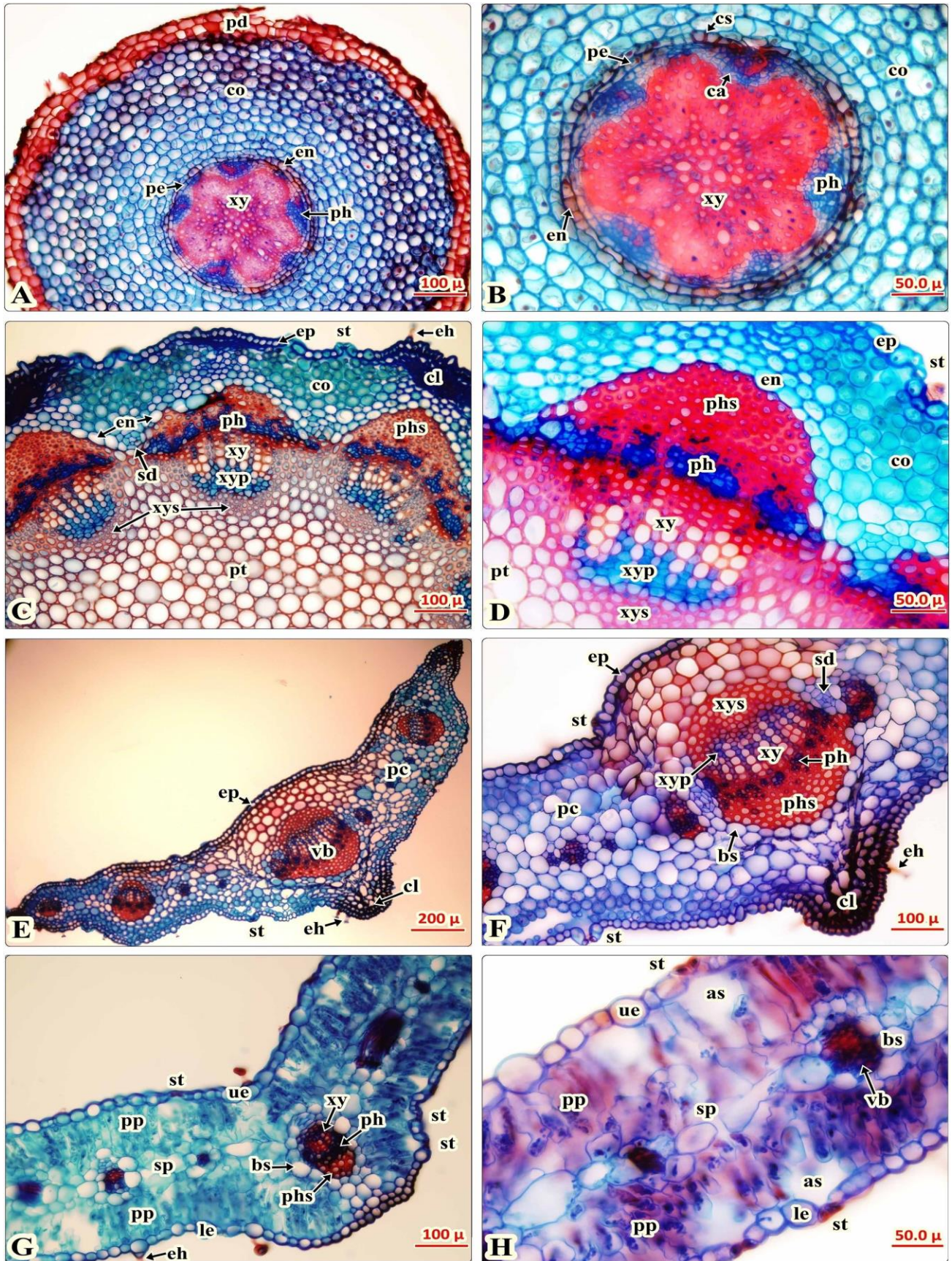


Fig. 3. Anatomical cross sections of *T. cappadocicum*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). air space (as), bundle sheath (bs), cambium (ca), collenchyma (cl), cortex parenchyma (co), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phts), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

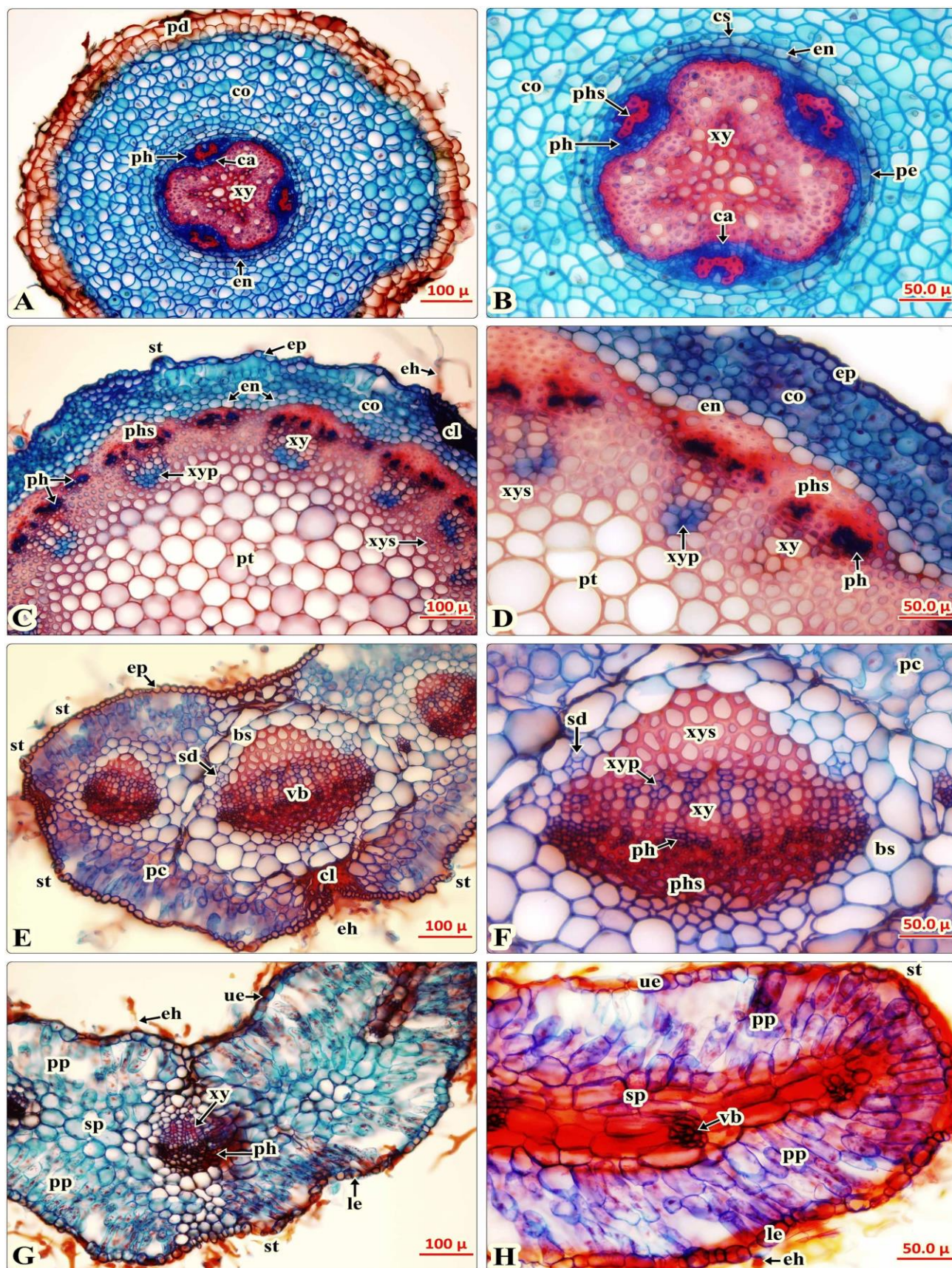


Fig. 4. Anatomical cross sections of *T. densum* subsp. *sivasicum*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). bundle sheath (bs), cambium (ca), collenchyma (cl), cortex parenchyma (co), casparian strip (cs), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phs), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

Tanacetum densum subsp. *sivasicum*

Root: In the root cross sections, the periderm which consists of phellem, phellogen and phelloderm, is formed to replace the broken epidermis. The parenchymatous cortex is composed of 10–13 cell layers under the periderm. The endodermis with a casparian strip is distinct inside of the cortex. A single-row pericycle is present under the endodermis. The three protoxylem ridges are located opposite to the phloem. The phloem lies narrowly between the xylem ridges. The sclerenchyma fibers are present above the phloem. The cambium consists of 2–3 cell layers and is very clear. The center of the root is occupied by metaxylem elements (Fig. 4 A, B; Table 2).

Stem: In the cross section of the stem, epidermis is uniseriate and cells are oval or square under the cuticle. There are silvery-white simple hairs on the epidermis. The lamellar collenchyma consists of 4–5 cell layers that are alternated with 5–6 cell layered parenchymatous cortex under the epidermis. The cortex includes secretory ducts just over the endodermis. The endodermis is very distinct. The stem has 15–18 vascular bundles surrounded by sclerenchymatic fibers. The vascular cambium is indistinguishable. The xylem contains vessels and tracheids. The pith is occupied by large, cylindrical and thick-walled parenchymatous cells (Fig. 4 C, D; Table 2).

Petiole: In the cross section of petiole shows that, the adaxial surface is slightly concave and the abaxial surface is convex. There is single-row epidermis which has silvery-white simple hairs in the outer. The palisade parenchyma is 1-2 layered under the epidermis. There is a large collateral vascular bundle on the median region and 2 of the smaller bundles on both sides of the petiole. Phloem and xylem are surrounded by sclerenchymatic fibers. The 3–4 layered lamellar collenchyma groups are located close to vascular bundles. The cambium is distinguishable between phloem and xylem. The secretory ducts are situated near the vascular bundles. The parenchyma cells that lack of chloroplast are 3–4 layered between the outer palisade parenchyma layers (Fig. 4 E, F; Table 3).

Leaflet: There is a uniseriate epidermis on the adaxial and abaxial surfaces of the leaflet. There are stomata and dense silvery-white simple hairs on the both epidermises. The stoma type is anomocytic, and the stoma cells are located on the same level with the epidermal cells. The mesophyll is equifacial. The palisade parenchyma is 2 layered under both of the epidermises. The spongy parenchyma is 3–4 layered between the upper and lower palisade parenchyma cells. The vascular bundles are located among the spongy parenchyma in one row. The collateral vascular bundles are surrounded by a parenchymatous bundle sheath. The cambium is indistinguishable between phloem and xylem. The leaflet does not include secretory duct (Fig. 4 G, H; Table 3).

Tanacetum haussknechtii

Root: The periderm develops just below the epidermis broken down. The cortex consists of 8-10 layered parenchymatous cells. The endodermis with a casparian strip is distinct inside the cortex. The parenchymatic

pericycle is present under the endodermis. The three protoxylem ridges are located opposite to the phloem. There is no sclerenchyma fiber cap on the phloem. The cambium is distinct between xylem and phloem. The pith is occupied by xylem elements (Fig. 5 A, B; Table 2).

Stem: The epidermis is uniseriate and cells are with a striated cuticle. The outer tangential walls of the epidermal cells are more thickened than the others. There are greyish simple hairs on the epidermis. The collenchyma is 3–4 layered and discontinuously under the epidermis. The cortex parenchyma with chloroplast is 6–7 cell layered and cells are oval shaped, beneath the epidermis. The cortex includes secretory ducts just over the endodermis. The endodermis is very distinct. The stem has 10–12 vascular bundles and they are surrounded by sclerenchyma fibers. The cambium is not clear between xylem and phloem. The pith is occupied by large, cylindrical and thick-walled parenchyma cells (Fig. 5 C, D; Table 2).

Petiole: The cross section of petiole is seen triangular. There is uniseriate epidermis which has a striated thick cuticle and greyish or whitish simple hairs in the outer. These hairs are sparsely distributed. The outer tangential walls of the epidermal cells are more thickened than the others. There is a larger collateral vascular bundle on the median region than the other bundles which are different sizes. Although there are few sclerenchyma fibers above the xylem, the phloem no includes fibers. The cambium is very distinct between xylem and phloem. The secretory ducts are situated near the vascular bundles. The round parenchyma cells are filled between both epidermises (Fig. 5 E, F; Table 3).

Leaflet: In cross section of the leaflet, adaxial and abaxial epidermises are uniseriate and contain dense greyish-white simple hairs on the surface. The outer tangential walls of the epidermal cells are more thickened than the others. The stomata are present on both epidermises. The stoma type is anomocytic, and the stoma cells are located on the same level with the epidermal cells. The mesophyll is equifacial, with 2 layers of palisade parenchyma below both epidermises and 4–5 layers of spongy parenchyma between upper and lower palisade parenchyma. The collateral vascular bundles are located among the spongy parenchyma in one row. The vascular bundles are enclosed by a bundle sheath of parenchyma cells. The cambium is indistinguishable between phloem and xylem. The leaflet includes secretory ducts near the xylem (Fig. 5 G, H; Table 3).

Tanacetum heterotomum

Root: In the root cross sections, the periderm, which consists of phellem, phellogen and phelloderm, is formed to replace the broken epidermis. There is 9–12 cell layered parenchymatous cortex beneath the periderm. The endodermis with casparian strip is single-layered and its cell walls are suberized and/or lignified except for thin-walled passage cells. The pericycle consists of parenchymatous cells. The three protoxylem ridges are located opposite to the phloem. A few sclerenchyma fibers are present over the phloem. The xylem is composed of vessels and tracheids. Cambium cells are distinguishable between phloem and xylem. Pith is completely filled with metaxylem elements (Fig. 6 A, B; Table 2).

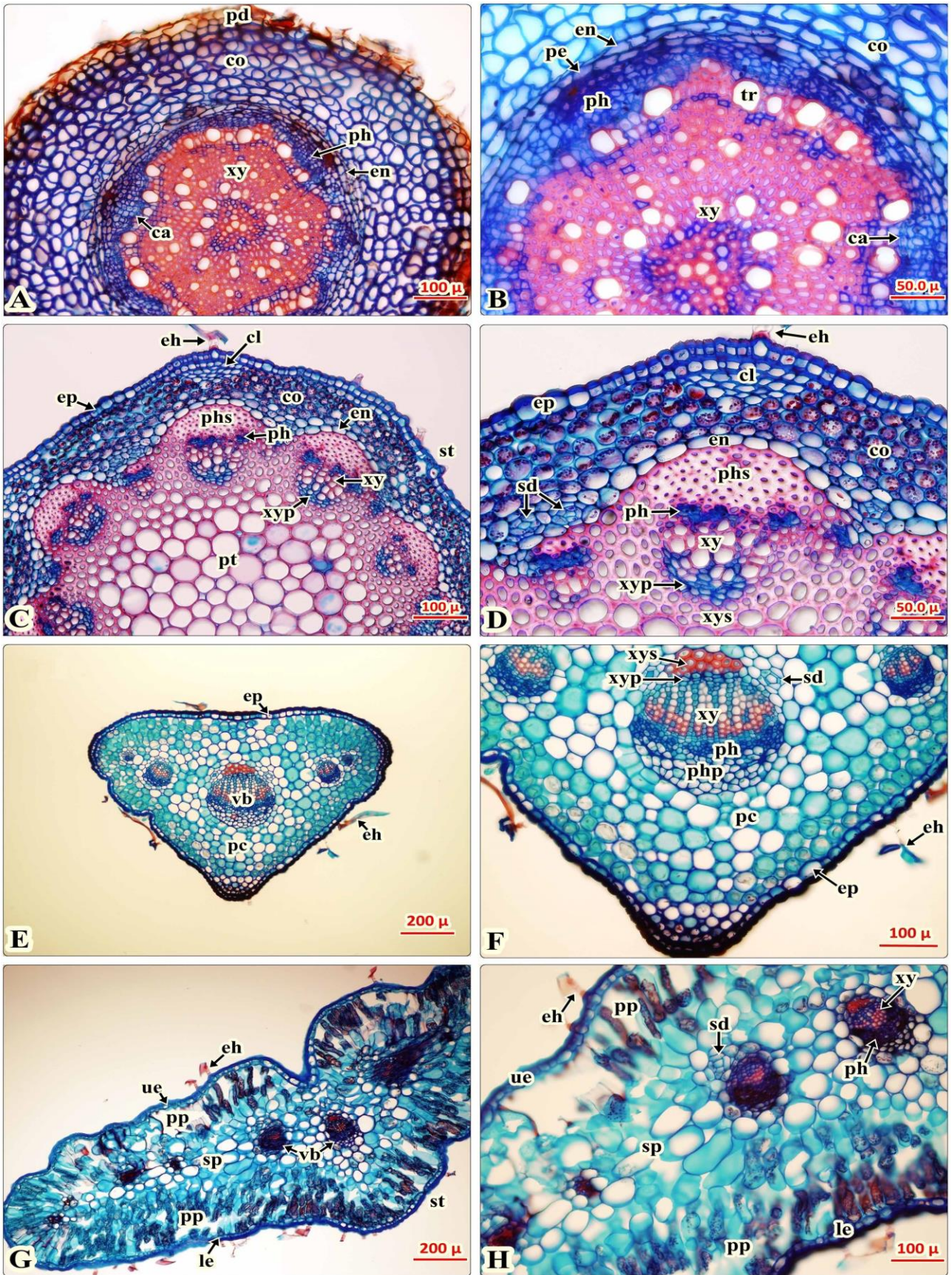


Fig. 5. Anatomical cross sections of *T. haussknechtii*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). bundle sheath (bs), cambium (ca), collenchyma (cl), cortex parenchyma (co), casparian strip (cs), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phs), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

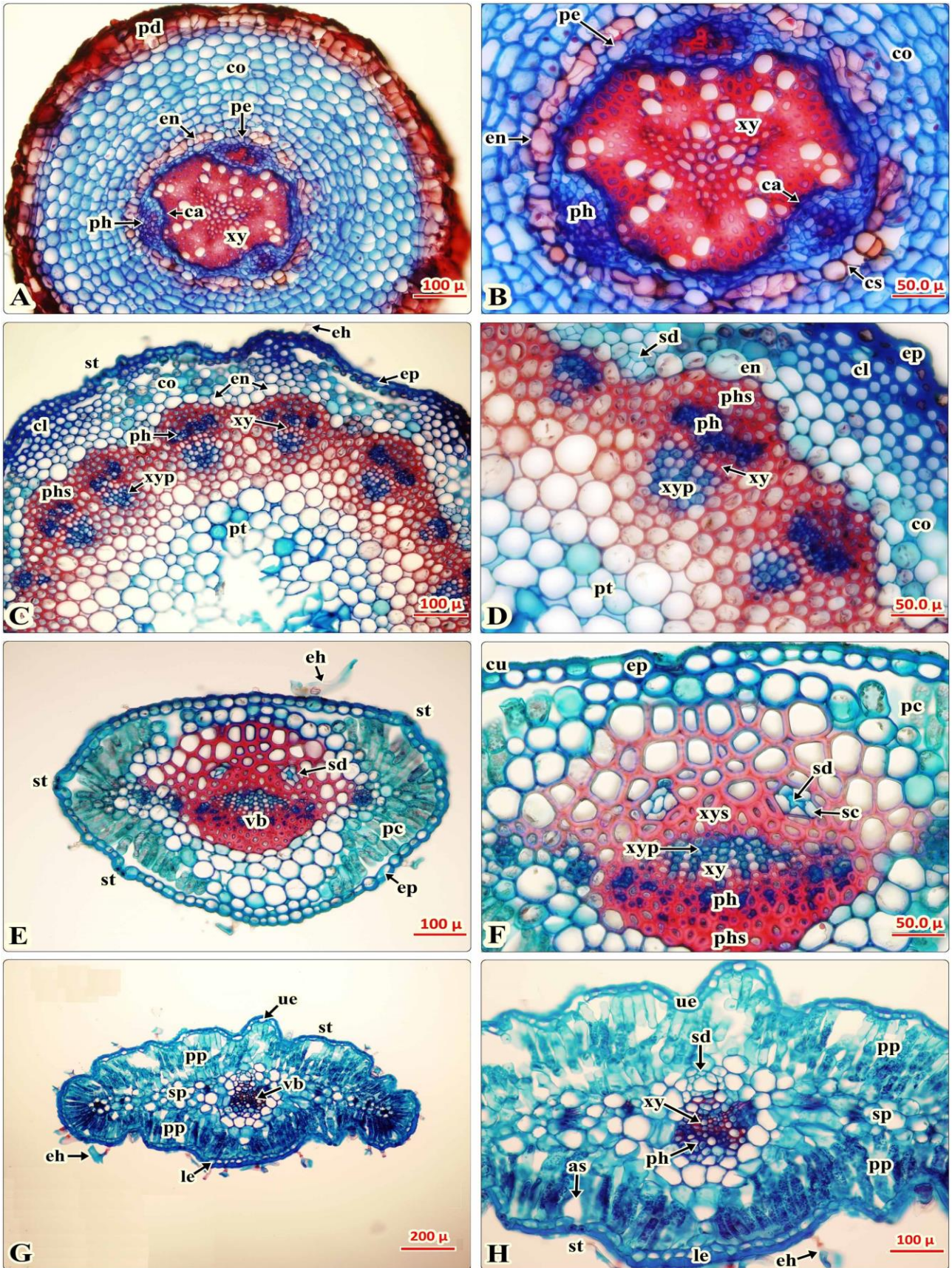


Fig. 6. Anatomical cross sections of *T. heterotomum*; root (A-B), stem (C-D), petiole (E-F) and leaflet (G-H). air space (as), cambium (ca), collenchyma (cl), cortex parenchyma (co), casparian strip (cs), epidermal hair (eh), endodermis (en), epidermis (ep), lower epidermis (le), parenchymatic cell (pc), periderm (pd), pericycle (pe), phloem (ph), phloem sclerenchyma (phs), palisade parenchyma (pp), pith (pt), secretory duct (sd), sclerenchyma fibers (sf), spongy parenchyma (sp), stoma (st), trachea (tr), upper epidermis (ue), vascular bundle (vb), xylem (xy), xylem parenchyma (xyp), xylem sclerenchyma (xys).

Stem: The epidermis is uniseriate and cells are with a striated cuticle. There are silvery simple hairs on the epidermis. The collenchyma is 4–5 layered and discontinuously under the epidermis. The cortex parenchyma with chloroplast beneath the epidermis is oval celled, 6–7 layered and it is located between the collenchyma groups. There are secretory ducts just above the endodermis and between the vascular bundles. The endodermis is very distinct. The stem has 16–20 vascular bundles and they are surrounded by sclerenchymatic fibers. The cambium is indistinguishable between xylem and phloem. The pith comprises thin-walled parenchyma cells and a cavity formed by the disintegration of the cells in the center (Fig. 6 C, D; Table 2).

Petiole: In cross section, the petiole is nearly oval shaped, with slightly convex adaxial side and markedly convex abaxial side. There is single-row epidermis which has silvery-white simple hairs and a striated thick cuticle in the outer. The outer tangential walls of the epidermal cells are markedly thickened than the others. The palisade parenchyma is 2 layered under the epidermis except for the part between the vascular bundle and both the epidermises. This part is filled with round parenchyma cells that lack of chloroplast. There is a large collateral vascular bundle surrounded by sclerenchyma fibers on the median region. The cambium is unclear between xylem and phloem. The petiole contains secretory ducts in the xylem fibers (Fig. 6 E, F; Table 3).

Leaflet: In cross section of the leaflet, adaxial and abaxial epidermises are uniseriate and have dense greyish-white simple hairs and a striated thick cuticle. The outer tangential walls of the epidermal cells are markedly thickened than the others. The stomata are present on both epidermises. The stoma type is anomocytic, and the stoma cells are located on the same level with the epidermal cells. The mesophyll is equifacial, and consists of 1–2 layers of palisade parenchyma below both epidermises and 2–3 layers of spongy parenchyma between of them. The midrib is obviously larger than the other bundles. The collateral vascular bundles are surrounded by a parenchymatous bundle sheath. The cambium is indistinguishable between phloem and xylem. The leaflet includes secretory duct near the xylem (Fig. 6 G, H; Table 3).

Discussion

Despite of being huge genus in Asteraceae and having importance in folk medicine, anatomical studies on the genus *Tanacetum* are very limited. In literature review, Kurkina (2013) has only investigated the floral morphological and anatomical diagnostics of *T. vulgare*. Stevovic *et al.*, (2010) have observed the environmental impact on the morphological and anatomical structure of the vegetative organs of *T. vulgare*.

When evaluated the roots of the species investigated, they display generally similar features with respect to anatomical characters. In roots, from outside to inside, the presence of periderm, cortex, endodermis, pericycle, and

vascular elements are identical. The pith region is filled with xylem elements in all taxa. One of the remarkable differences is the number of xylem arcs, so that, it is triarch in *T. albipannosum*, *T. densum* subsp. *sivasicum*, *T. haussknechtii* and *T. heterotomum*, pentarch in *T. cappadocicum* and hexarch in *T. argenteum* subsp. *argenteum*. In Asteraceae family, secretory structures have great taxonomical interest, and their restricted distribution has an important diagnosis value (Metcalfe & Chalk, 1950; Fahn, 1979). In addition, according to Solereder (1908), secretory structures occupy distinct positions in different organs of the plant. In all examined *Tanacetum* taxa, we could not observe secretory duct in the roots. Similar to our results, Stevovic *et al.*, (2010) have not been found secretory duct in the root of *T. vulgare*, but absence of secretory ducts in root is not common result for *Tanacetum* genus. Schweingruber *et al.*, (2013) studied the anatomy of *T. parthenium*, and they reported the presence of secretory ducts in root cross section.

The stem of the investigated taxa had very similar features. The stem has epidermis with greyish or whitish hairs, discontinuous collenchyma, parenchymatous cortex, endodermis, vascular bundles with sclerenchymatous sheet and parenchymatous pith except for *T. heterotomum*, which has a cavity formed by the disintegration of the cells in the center. All species had secretory ducts just over the endodermis, in cortex. In stem anatomy, the presence of collenchyma under epidermis and presence of endodermis with phloem sclerenchyma which are the same in all examined *Tanacetum* taxa, are suggested as frequent characteristics for Asteraceae members (Metcalfe & Chalk, 1950)

Metcalfe & Chalk (1950) have been suggested that, in Asteraceae, the petiole anatomy of some genus might also have taxonomic significance. Additionally, Akinnubi *et al.*, (2013) have reported that the shapes of the petioles, the layers of their collenchyma, and parenchyma cells and arrangements of vascular bundles usually have variations between the species, and these characteristics are important in the classification and delimitation of the species in Asteraceae. Similar to the reported these findings, we determined some significant differences among six *Tanacetum* taxa with respect to contour of petiole, structure of cortex parenchyma, and organization of vascular bundles of petioles. In the cross section, contour of petiole is triangle-shaped in *T. argenteum* subsp. *argenteum* and *T. haussknechtii*, it is almost biconvex in *T. heterotomum* and is boat-shaped (adaxial side concave and abaxial side convex) in *T. densum* subsp. *sivasicum*. While the cross section of petiole is dorsiventrally flattened in *T. cappadocicum*, it is nearly circular shaped with adaxial surface has deeply grooved in the middle-part in *T. albipannosum*. One of the other obvious differences for petiole anatomy is the presence and organization of parenchymatous bundle sheath. In *T. densum* subsp. *sivasicum*, vascular bundle is surrounded by 2-3 layered wide parenchymatous bundle sheath, which occupy great place around vascular bundle in center of petiole, while in *T. cappadocicum*, parenchymatous bundle sheath consists of single smaller

cell layer. There is no bundle sheath around of main petiole bundles of *T. albipannosum*, *T. argenteum*, *T. haussknechtii* and *T. heteretomum*. However, one of different circumstances for *T. heteretomum*, is the presence of lignified parenchymatous cells between main vascular bundle and adaxial epidermis. In petiole cross section, except for *T. albipannosum*, all other examined five taxa have secretory ducts which are located near xylem, towards adaxial surface. While, secretory ducts of *T. heteretomum* are surrounded by lignified parenchymatous cells, in all other taxa have no lignified parenchymatous cells around the secretory ducts. Ekeke & Mensah (2015) have studied petiole midrib anatomy of 17 species belonging to 14 different genera of Asteraceae family, and they have observed significant differences between the species. One of their results, between three species within the same genus, is that *Vernonia biafrae* Oliv. & Hiern and *Vernonia cinerea* (L.) Less. had secretory ducts near midrib, while secretory ducts were absent in other species of the same genus, *Vernonia amygdalina* Delile. Additionally, they have observed secretory ducts within the same genus, in *Emilia coccinea* G. Don and *Emilia praetermissa* Milne-Redh. as well as in other species belong to different genera. In addition, Ekeke & Mensah (2015) reported that hydrocentric and bicollateral type vascular bundles in all examined species belong to other genera except *Tanacetum* of Asteraceae family. Unlike their study, here we observed that vascular bundles are in the same type as collateral arrangement, and that the secretory ducts are present close to the xylem tissue, in all examined *Tanacetum* taxa.

In leaflet anatomy, all examined taxa have equifacial, anomocytic leaflets, and vascular bundles are surrounded by a parenchymatous bundle sheath. Additionally, leaflets of all examined taxa have a uniseriate epidermises with tomentose indumentum which composed of greyish or whitish simple hairs on both adaxial and abaxial sides. According to Metcalfe & Chalk (1950), the leaves are generally dorsiventral and stomata are anomocytic. In the present study, all examined *Tanacetum* taxa have equifacial leaves which are different of mentioned literature and anomocytic stomata. Metcalfe & Chalk (1950) have been suggested that anatomical diversity is commonly observed in the structure of leaflets of species belonging to the family Asteraceae. Similar to this finding, we determined some anatomical differences among examined taxa, such as the palisade parenchyma which consists of 1–2 cell layers in *T. cappadocicum* and *T. heterotomum* while in all other examined taxa palisade parenchyma consists of 2 cell layers above adaxial and abaxial epidermises. Spongy parenchyma composed of 4–5 cell layers in *T. haussknechtii*, 2–3 cell layers in *T. heterotomum* and 3–4 cell layers in all other examined taxa. The cambium is indistinguishable in leaflet midrib of all examined taxa. In leaflet anatomy, we observed secretory ducts near xylem of main bundles of *T. albipannosum*, *T. haussknechtii* and *T. heteretomum* while no secretory ducts in *T. argenteum* subsp. *argenteum*, *T. cappadocicum* and *T. densum* subsp. *sivasicum*.

Conclusion

The present study is the first and comprehensive report on the anatomy of six Turkish endemic *Tanacetum* taxa. This study is important for the taxonomy of *Tanacetum* genus, because of significant differences such as number of xylem arcs in root, shape of petiole cross section, and presence of secretory ducts in leaflets. Through them, the major convenient anatomical characteristic is acceptable as the shape of petiole cross section. This characteristics and other observations, and given findings of this study might be useful tools for the taxonomic discrimination for examined *Tanacetum* taxa, and provide a useful data for further studies.

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