ABANT IZZET BAYSAL UNIVERSITY

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ANATOMICAL PROPERTIES OF THE GENUS *TULIPA* L. (LILIACEAE) IN TURKEY

MASTER OF SCIENCE

EZGİ TANIŞ

BOLU, APRIL 2016

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APPROVAL OF THE THESIS

ANATOMICAL PROPERTIES OF THE GENUS *TULIPA* L. (LILIACEAE) IN TURKEY submitted by **Ezgi TANIŞ** in partial fulfillment of the requirements for the degree of Master of Science in Department of Biology, Abant Izzet Baysal University by,

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April 25, 2016

Prof. Dr. Duran KARAKAS ....D. Karakas

Director, **Graduate School of Natural and Applied Sciences**

To my family

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

EZGİ TANIŞ

ABSTRACT

ANATOMICAL PROPERTIES OF THE GENUS *TULIPA* L. (LILIACEAE) IN TURKEY
MSC THESIS
EZGİ TANIŞ
ABANT IZZET BAYSAL UNIVERSITY GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF BIOLOGY
(SUPERVISOR: DOÇ DR. İSMAİL EKER)

BOLU, APRIL 2016

In this study, the anatomical features of the genus *Tulipa* L. (Liliaceae) in Turkey were investigated. All anatomical structures including transverse sections of the root, stem and leaf, and surface sections of the leaves were illustrated. 420 specimens belonging to 42 populations were examined. Numbers of stomata and ratio of stomatal index in the leaf surfaces per 1 mm^2 were calculated. Some important differences among *Tulipa* taxa have been found with regard to comprehensive and comparative anatomical study for the first time. In the statistical analyses, cluster and principal component analysis (PCA) was used and compared. Adopting the classification of Zonneveld, the genus *Tulipa* in Turkey are divided into three subgenera according to anatomical results: *Eriostemones, Tulipa* and *Clusianae*. Subgenus *Clusianae* included only one species, *T. clusiana*. Subgenus *Eriostemones* is also divided into two sections following Baker and Eker et al.'s studies: *Sylvestres* and *Saxatiles*. Other subgenus *Tulipa* included one section: *Tulipa*.

KEYWORDS: *Tulipa*, Liliaceae, Anatomy, Taxonomy, Turkey

ÖZET

TÜRKİYE' DEKİ *TULIPA* L. (LILIACEAE) CİNSİNİN ANATOMİK ÖZELLİKLERİ
YÜKSEK LISANS TEZİ
EZGİ TANIŞ
ABANT İZZET BAYSAL ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ
BİYOLOJİ ANABILIM DALI
(TEZ DANIŞMANI: DOÇ DR. İSMAİL EKER)

BOLU, NİSAN - 2016

Bu çalışmada, Türkiye'deki *Tulipa* L. (Liliaceae) cinsinin anatomik özellikleri incelenmiştir. Kök, gövde ve yaprak enine kesitleri ve yaprak yüzeysel kesitlerini içeren tüm anatomik yapılar resimlendirilmiştir. 42 popülasyona ait 420 örnek incelenmiştir. Yaprak yüzeylerinde 1 mm^2 deki stoma sayıları ve stoma indeks oranları hesaplanmıştır. İlk kez kapsamlı ve karşılaştırmalı anatomi çalışması ile *Tulipa* taksonları arasında önemli bazı farklılıklar bulunmuştur. İstatistik analizlerde, kümeleme ve temel bileşen analizleri kullanılmış ve karşılaştırılmıştır. Zonneveld'in sınıflandırmasını benimseyerek anatomik özelliklerine göre *Tulipa* cinsi üç altcinse ayrılmaktadır: *Eriostemones, Tulipa* ve *Clusianae.* Altcins *Clusianae* sadece *T. clusiana*'yı içerir. Baker ve Eker vd.'ni takip ederek altcins *Eriostemones* ise iki seksiyona ayrılmaktadır: *Sylvestres* ve *Saxatiles.* Diğer altcins *Tulipa* bir seksiyon içermektedir: *Tulipa*.

ANAHTAR KELİMELER: *Tulipa*, Liliaceae, Anatomi, Taksonomi, Türkiye

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LIST OF ABBREVIATIONS AND SYMBOLS

AIBU **:** Herbarium of Abant İzzet Baysal University

Abb **:** Abbreviations

App **:** Appendix

Eker **:** İsmail EKER

et al. **:** And others

HCL **:** Hydrochloric acid

IPNI **:** International Plant Names Index

PCA **:** Principal component analysis

SL **:** Similarity level

s.l. : Sensu lato

s.s. : Sensu stricto

subsp. **:** Subspecies

µm **:** Micrometer

var. **:** Variety

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1. INTRODUCTION

Anatolia is one of the most important biodiversity centers of the world due to varied climatic and topographic structures, water resources, elevation and habitat differences. Besides, Anatolia is located at the intersection of three major floristic regions: the Euro-Siberian, the Irano-Turanian and the Mediterranean (Davis et al., 1988). As a result of this diversity, there are 11.707 different plant taxa and 1/3 of them is endemic to Turkey (Güner et al., 2012).

Most of the ornamental geophytes are cultivated in temperate-climate regions of the world. It is important to note that although ornamental geophytes exist in over 800 different genera (Bryan, 1995), the industry is dominated by seven genera: *Tulipa*, *Lilium* L., *Narcissus* L., *Gladiolus* L., *Hyacinthus* Tourn. ex L., *Crocus* L., and *Iris* L. (Kamenetsky and Okubo, 2013). In Turkey, there are more than 1000 native petaloid monocotyledonous geophytes belonging mainly to the Liliaceae *s.s.*, Asparagaceae, Amaryllidaceae, Iridaceae, Araceae and Orchidaceae families. Many of these geophytes have good potential in terms of ornamental features (Demir and Eker, 2015).

The Liliaceae was formerly treated as a large family. According to Cronquist (1981), Liliaceae *s.l.* consisted of about 280 genera and nearly 4000 species. They are naturally distributed in the tropical and temperate regions.

1.1 The Genus *Tulipa* L.

The genus *Tulipa* L. is one of the members of Liliaceae. The centre of diversity of the genus is in the Pamir Alai, Tien Shan and Hindu Kush mountains, and the steppes of Kazakhstan (Botschantzeva, 1982; Christenhusz et al., 2013; Eker et al., 2014). They grow naturally in Central Asia, Caucasus, Anatolia, Iran, the Middle East, North Africa, and South Europe and is widely used as an ornamental plant because of its very attractive flowers (Eker et al., 2014).

The Tulip was first cultivated by the Turks as early as 1000 AD. Starting from 12th century, the tulip entered into decorative art in stilized form during Seljuk

Empire (Ünver, 1969). The history of tulips that were known in Persia as early as in the 12th century (Lodewijk, 1979; Lythberg, 2010) and were praised by the poet Omar Khayyam in the twelfth century (Segal, 1992) and, in the fifteenth century, tulips were used in city gardens and those of the Sultans of Turkey. Lodewijk (1979), Segal (1992), and Pavord (1999) have traced the introduction of the tulip from Anatolia to European countries. In the 18th century Sultan Ahmed III of Ottoman Empire imported tulips from the Netherlands and regained popularity. Tulips were widely grown commercially or extensively studied and explored in that period. After Sultan Ahmed III (Tulip Era/1718-1730), they lost this popularity.

Nowadays, tulips are popular plants as cut flower and potted plant and also in landscaping. About 85% of the world bulb production is grown in the Netherlands (Le Nard and De Hertogh, 1993). Another important tulip producer is France. In 1995, the annual turnover for bulb production was about 600 million Dutch guilders and for cut flower production about 274 million Dutch guilders (Anonymous, 1996).

Although the Latin name of most tulip cultivars is referred to as *Tulipa gesneriana* L., the wild type of this species has not been found. It seems that tulips (later *T. gesneriana*) were already hybrids when introduced into Europe. The epithet name "*gesneriana*" is at present applied also to "Darwin hybrid cultivars", which are known to be hybrids with *T. fosteriana* W.Irving (Kamenetsky and Okubo, 2013).

Most species of *Tulipa* are diploid, 2n=24 (x=12). However, polyploidy is common, e.g. triploidy (2n=3x=36) in *T. aleppensis, T. raddii* and *T. orphanidea,* tetraploidy (2n=4x=48) in *T. sylvestris* subsp. *sylvestris,* pentaploidy (2n=5x=60) in *T. clusiana* were reported by Eker et al., 2014.

Palynologically, the genus *Tulipa* was divided into two main subgenera; *Eriostemones* and *Tulipa*. The species of the subgenus *Eriostemones* were characterized by monosulcate pollen grains with microreticulate-striate exine surface. Most of the species of the subgenus *Tulipa* posses distal-lateral-three-sulcate pollen grains with microreticulate-striate exine surface (Kosenko, 1991, 1992). Similar results were seen in Eker's palynological studies about tulips, pollen grains in the subgenus *Eriostemones* were homogenously monosulcate while those in the subgenus *Tulipa* were predominantly trisulcate (Eker, 2010).

According to Eker et al.'s (2014), the total number of tulip species, native and naturalised distribution in the world are given Table 1.

Table 1. Native and naturalised distribution and number of species of *Tulipa* in the world (Eker et al., 2014).

Turkey	18 species (19 taxa)
Flora of the USSR (including Russia, Central Asia and Caucasus)	65 species
Kazakhstan	32 species
Tajikistan	25 species
Uzbekistan	21 species
Russia	6 species
Armenia	7 species
Flora Iranica (including Iran, Afghanistan, western Pakistan, northern Iraq, Azerbaijan, Turkmenistan)	36 species (38 taxa)
Iraq	3 species (4 taxa)
Syria, Palastine and Sinai	10 species (13 taxa)
Palaestine	3 species (4 taxa)
Israel	4 species
Jordan	3 species
Saudi Arabia	1 species
Pakistan	6 species
Afghanistan	8 species
India	2 species (6 taxa)
Balkans	8 species
Greece	6 species
Bulgaria	4 species (7 taxa)
Croatia	2 species
Romania	6 species (7 taxa)
Serbia	5 species
Switzerland	2 species (3 taxa)
Malta	2 species
Flora Europea	11 species (12 taxa)
Italy	9 species
France	13 species
Iberian Peninsula	5 species (6 taxa)
Cyprus	2 species
Crete	4 species
Chios	4 species
Corsica	2 species
Morocco	1 species (2 taxa)
Egypt	2 species
Algeria	1 species
Libya	1 species
North Africa	4 species (9 taxa)
China	13 species
Hungary	1 species
Mongolia	1 species

Despite the existence of a large body of literature on *Tulipa*, its taxonomy is generally considered to be difficult. The main reason is that there are many

overlapping characters that are variable even within a species. The other problem in tulip taxonomy in the world is that, previous studies have been mainly performed with many herbarium specimens and commercial stocks. This situation can cause some confusions in colour, shape and size (Eker et al., 2014).

In Turkey, Eker et al. (2014) revised the genus *Tulipa*. Despite putting forward solutions to a large extent, drew attention to some problems. That is, many populations of subgenus *Tulipa* formed complex groups, especially contained populations of *T. armena* var. *armena*, *T. armena* var. *galatica*, *T. julia* and *T. aleppensis*. This group showed high levels of variation between and within populations.

1.2 Classification History of the Genus *Tulipa*

The genus *Tulipa* has historically been subdivided into two subgenera: '*Eutulipa'* (=*Tulipa*) with rudimentary styles and subgenus *Orithyia* (D.Don) Baker with long styles (Baker, 1874). Then, Boissier (1882) divided *Tulipa* into two main sections: *Leiostemones* Boiss. and *Eriostemones* Boiss., but he also added four sections: *Tulipanum* Reboul, *Spiranthera* Vved., *Lophophyllon* Vved., *Orithyia* (D. Don) Vved.

Traditionally genus *Tulipa* is divided into two sections: *Tulipa* and *Eriostemones* Boiss. until the publications of two papers by van Raamsdonk and de Vries. Van Raamsdonk and de Vries (1992, 1995) used principal component and canonical variate analyses to investigate the variation of 35 morphological characters, and they substantially clarified systematic relationships within *Tulipa*. They raised these sections to subgenera. The genus has been subdivided into two subgenera: *Tulipa* and *Eriostemones* Boiss. and divided the subgenus *Tulipa* into five sections and the subgenus *Eriostemones* into three sections (Table 2).

Table 2. Classification on the genus *Tulipa* at level of subgenera and sections according to the studies of Raamsdonk and Vries (1992, 1995).

Subgenus *Tulipa*
Section *Tulipa*
Section *Tulipanum* Reboul
Section *Eichleres* (A.D. Hall) Raamsd.
Section *Kolpakowskianae* (A.D. Hall) Raamsd.
Section *Clusianae* Baker
Subgenus *Eriostemones* (Boiss.) Raamsd.
Section *Australes* sensu A.D. Hall
Section *Saxatiles* Baker
Section *Biflores* sensu A.D. Hall

Veldkamp and Zonneveld (2012) classified tulips into four subgenera, subgenus *Eriostemones* was divided into three sections while subgenus *Tulipa* was divided into six sections (Table 3).

Table 3. Veldkamp and Zonneveld's classification on the genus *Tulipa*.

Subgenus *Clusianae* (Baker) Zonn.
Subgenus *Eriostemones* (Boiss.) Van Raamsd.
Section *Biflores* A.D. Hall
Section *Saxatiles* (Baker) Baker
Section *Sylvestres* (Baker) Baker
Subgenus *Orithyia* (D. Don) Baker
Subgenus *Tulipa*
Section *Tulipa*
Section *Tulipanum* Reboul
Section *Lanatae* (Van Raamsd.) Zonn.
Section *Spiranthera* Vved. ex Zonn. & Veldk.
Section *Multiflorae* (Van Raamsd.) Zonn.
Section *Kolpakowskianae* Van Raamsd. ex Zonn. & Veldk.

Recently, Christenhusz et al. (2013) explained historical overview of classification in *Tulipa* under the light of phylogenetic findings and divided tulips into four subgenera: *Clusianae* (Baker) Zonn. & Veldkamp, *Eriostemones* (Boiss.) Hall, *Orithyia* (D.Don) Baker and *Tulipa*. However, they did not place sections and subsections (Table 6).

In Turkey, the oldest significant study relating to the genus *Tulipa* was performed by Marais (1984) who published 15 taxa (14 species and 1 variety). In that study, all tulips are attributed into two sections: *Eriostemones* Boiss. and *Tulipa* (Table 4).

Table 4. Marais's classification on the genus *Tulipa* in Turkey.

Section *Eriostemones* Boiss.
T. biflora Pallas
T. humilis Herbert
T. saxatilis Sieber ex Sprengel
T. sylvestris L.
T. orphanidea Boiss. ex Heldr.
Section *Tulipa*
T. armena Boiss. var. *armena*
T. julia C. Koch
T. armena Boiss. var. *lycica* (Baker) Marais
T. agenensis DC.
T. sintenesii Baker
T. praecox Ten.
T. aleppensis Boiss. ex Regel
T. sprengeri Baker
T. undulatifolia Boiss.
T. clusiana DC.

The latest study about tulip taxonomy has been published by Eker et al. (2014). According to detailed morphologic, geographic and cytotaxonomic studies of the taxa, they represented 17 species, two subspecies and two varieties (in total 19 taxa). The genus *Tulipa* was divided into two subgenera: *Eriostemones* (Boiss.) Raamsd. and *Tulipa*. Subgenus *Eriostemones* (Boiss.) Raamsd. was divided into two sections while they placed subsections under these sections. Also, subgenus *Tulipa* was divided into two sections (Table 5).

Table 5. Eker et al.'s classification on the genus *Tulipa* in Turkey.

Subgenus *Eriostemones* (Boiss.) Raamsd.
Section *Sylvestres* (Baker) Baker
Subsection *Sylvestres*
Tulipa sylvestris L. subsp. *sylvestris*
Tulipa sylvestris L. subsp. *australis* (Link) Pamp.
Subsection *Biflores* (A.D.Hall ex Zonn. & Veldk.) Eker
Tulipa biflora Pall.
Tulipa koyuncui Eker & Babaç
Section *Saxatiles* (Baker) Baker
Subsection *Saxatiles* (Baker) Baker
Tulipa saxatilis Sieber ex Spreng.
Tulipa humilis Herb.
Tulipa pulchella (Regel) Baker
Subsection *Orphanidetes* Eker & Babaç

Table 5. Eker et al. 's classification on the genus Tulipa in Turkey (continued).

	Tulipa orphanidea Boiss. ex Heldr.
	Tulipa sprengeri Baker
	Tulipa cinnabarina K.Perss.
Subgenus *Tulipa*	
Section *Tulipa*	
	Tulipa armena Boiss. var. *armena*
	Tulipa armena Boiss. var. *galatica* (Freyn) Eker
	Tulipa sintenisii Baker
	Tulipa julia C.Koch
	Tulipa aleppensis Boiss. ex Regel
	Tulipa agenensis DC.
	Tulipa raddii Reboul
	Tulipa undulatifolia Boiss.
Section *Clusianae* Baker	
	Tulipa clusiana DC.

Table 6. Historical overview of classification in *Tulipa*.

Marais (1984)	**Van Raamsdonk and De Vries (1992, 1995)**	**Veldkamp and Zonneveld (2012)**	**Christenhusz et al. (2013)**	**Eker et al. (2014)**
Section *Tulipa*	**Subgenus** *Tulipa*	**Subgenus** *Tulipa*	**Subgenus** *Tulipa*	**Subgenus** *Tulipa*
	Section *Tulipa*	**Section** *Tulipa*		**Section** *Tulipa*
	Section *Tulipanum* Reboul	**Section** *Tulipanum* Reboul		
	Section *Eichleres* (A.D. Hall) Raamsd.	**Section** *Lanatae* (Van Raamsd.) Zonn.		
		Section *Spiranthera* Vved. ex Zonn. & Veldk.		
		Section *Multiflorae* (Van Raamsd.) Zonn.		
	Section *Kolpakowskianae* (A.D. Hall) Raamsd.	**Section** *Kolpakowskianae* Van Raamsd. ex Zonn. & Veldk.		
	Section *Clusianae* Baker	**Subgenus** *Clusianae* (Baker) Zonn.	**Subgenus** *Clusianae* (Baker) Zonn. & Veldkamp	**Section** *Clusianae*
Section *Eriostemones* Boiss.	**Subgenus** *Eriostemones* (Boiss.) Raamsd.	**Subgenus** *Eriostemones* (Boiss.) Van Raamsd.	**Subgenus** *Eriostemones* (Boiss.) Hall	**Subgenus** *Eriostemones* (Boiss.) Raamsd.
	Section *Saxatiles* Baker	**Section** *Saxatiles* (Baker) Baker		**Section** *Saxatiles* (Baker) Baker
				Subsection *Saxatiles* (Baker) Baker
				Subsection *Humiles* Eker & Babaç
				Subsection *Orphanidetes* Eker & Babaç
	Section *Australes* sensu A.D. Hall	**Section** *Sylvestres* (Baker) Baker		**Section** *Sylvestres* (Baker) Baker
				Subsection *Sylvestres*
	Section *Biflores* sensu A.D. Hall	**Section** *Biflores* A.D. Hall		**Subsection** *Biflores* (A.D.Hall ex Zonn. & Veldk.) Eker
(not included)	(not included)	**Subgenus** *Orithyia* (D. Don) Baker	**Subgenus** *Orithyia*	(not included)

1.3 Anatomical Studies of the Genus *Tulipa* in Turkey

There are no any comprehensive and comparative anatomical studies relating to the genus *Tulipa* except of a few studies including in species in Turkey. These studies have been initiated after 2000s. The morphological and anatomical properties of *Tulipa armena* var. *lycica* (currently synonym of *T. armena* var. *armena*) have been presented by Kandemir and Özkan (2000) and Ocak et al. (2004). In these studies, most of the anatomical properties of *Tulipa armena* var. *lycica* was found similar with the general characteristics of monocotyledons. Moreover, they mentioned the thickening of endodermis and number of xylem in root sections and the presence of sclerenchyma in stem sections. *Tulipa aleppensis* was investigated by Satıl and Akan (2006) and compared with *Scilla mesopotamica* Speta and *Asphodeline damascena* (Boiss.) Baker subsp. *gigantea* E. Tuzlacı. It was found some similarities and dissimilarities among taxa, and the thickening of endodermis in *T. aleppensis* was found as remarkable in root sections. A comparative study on two closely relative taxa, *Tulipa gumusanica* (currently synonym of *T. armena* var. *galatica*) and *T. armena* var. *armena,* has been presented by Coşkunçelebi et al. (2008). In this study, general anatomical traits of both examined taxa were found similar, in having isolateral leaves with distinct hypodermis and a stem with distinct monolayer collenchyma close to the epidermis. However, some anatomical characters such as mesophyll width, average number of stomata on lower epidermis, and epidermal cells on upper epidermis were found to be important in delimiting these taxa. There was an obvious thick cuticle in the leaves of both taxa, However, the cuticle is distinctly undulate in *T. gumusanica*, but not in *T. armena* var. *armena*. Among the most important anatomical features of stems of both taxa was the presence of monolayer sclerenchyma beneath the epidermis. The anatomical properties of *Tulipa orphanidea* was investigated by Meriç and Soykan (2012). The leaf and stem features of *T. orphanidea* were found similar to above mentioned *Tulipa* species. It is reported that the mesophyll was not differentiated into a palisade and a spongy parenchyma, and the stem contained monolayer collenchyma close to the epidermis.

2. AIM AND SCOPE OF THE STUDY

This thesis represents an anatomical study of the genus *Tulipa* in Turkey. The main goals of the study that introduce the anatomical properties of the root, stem and leaf of the genus *Tulipa* and emphasize the taxonomic significances of all these anatomical characters. The anatomical and statistical analyses of the taxa were studied for the solution of taxonomic problems. Our country has a significant potential in terms of wild plant species and in rich floristic diversity some of *Tulipa* species distribute in Turkey naturally. *Tulipa* species grown as ornamental plants due to their attractive flowers are among the world's most valuable plants. The genus *Tulipa* has some of taxonomic problems and for the solution of these problems different systematic methods were tested.

Transverse sections of root, stem (scape), leaf, and the surface sections of leaf derived from different populations of the same species and different individuals of the same population will be examined using dying techniques. Of taxa belonging to the genus *Tulipa* in our country will be performed a comprehensive and comparative anatomical study for the first time. This thesis that was established by some anatomical samples and examination of their anatomical structures.

3. MATERIALS AND METHODS

3.1 Materials

This thesis represents an anatomical study of genus *Tulipa* (Liliaceae) based on 18 taxa were sampled in the same developmental stage (flowering time) from 42 various populations in Turkey (Table 7). Field trips in collecting of taxa were performed by Eker between March and June in the years of 2006 and 2009 and the taxonomic revision of Eker et al. (2014) were initially followed for aim of plant identification. Authors' names were aceppted those of in accordance with Brummitt and Powell (1992) and IPNI (2016). Plant samples were stored in 70% ethyl alcohol for anatomic studies and both anatomic and voucher specimens were also deposited in the herbarium of Abant İzzet Baysal University (AIBU).

Table 7. Plant materials used in anatomical analyses and their localities.

No	Abb.	Voucher	Locality	No	Abb.	Voucher	Locality
1	AG1	Eker 2001	Hatay-Şenköy	22	JU5	Eker 2141	Bayburt-Kop
2	AG2	Eker 2270	Adana-Kozan	23	KO1	Eker 1853	Van-Güzeldere
3	AL1	Eker 1533	Şanlıurfa-Siverek	24	OR1	Eker 2062	Muğla-Gülağzı
4	AL2	Eker 1814	Şanlıurfa-Halfeti	25	OR2	Eker 2075	Aydın-Köşk
5	AL3	Eker 2287	Elazığ-Harput	26	OR3	Eker 2078	Manisa-Spil
6	AR1	Eker 1580	Hakkari-Yüksekova	27	PU1	Eker 2042	Karaman-Sarıveliler
7	AR2	Eker 1755	Hatay-Arsuz	28	RA1	Eker 2146	Amasya-Alptekin Gazi
8	AR3	Eker 1858	Van-Başkale	29	RA2	Eker 2243	Amasya-Derbent
9	AR4	Eker 2130	Bitlis-Adilcevaz	30	SA1	Eker 2064	Muğla-Bozburun
10	AR5	Eker 2165	Amasya-Ferhat	31	SI1	Eker 1515	Gaziantep-Üçgöze
11	AR6	Eker 2288	Elazığ-Gözeli	32	SI2	Eker 1546	Muş-Tigem
12	AR7	Eker 3836	Ankara-Kızılcahamam	33	SI3	Eker 1864	Muş-Muş ovası
13	GA1	Eker 2341	Gümüşhane-Zigana	34	SI4	Eker 1998	Gaziantep-Sof Dağı
14	BI1	Eker 2098	Van-Çatak	35	SI5	Eker 2139	Ağrı-Tutak
15	CI1	Eker 2030	Karaman-Sarıveliler	36	AU1	Eker 2050	Antalya-Elmalı
16	CL1	Eker 3854	Aydın-Gözpınar	37	AU2	Eker 2166	Ankara-Kızılcahamam
17	HU1	Eker 1563	Van-Güzeldere	38	SY1	Eker 1842	Van-Yörük evleri
18	JU1	Eker 1557	Van-Gürpınar	39	UN1	Eker 2085	Çanakkale-Dümrek
19	JU2	Eker 1593	Van-Muradiye	40	UN2	Eker 2086	Tekirdağ-Şarköy
20	JU3	Eker 1862	Hakkari-Çukurca	41	UN3	Eker 2248	İzmir-Urla
21	JU4	Eker 2096	Van-Özalp	42	UN4	Eker 2336	Ankara-Şereflikoçhisar

3.2 Methods

3.2.1 Anatomical Analyses

The anatomical structure of transverse sections of root, stem (scape), leaf, and the surface sections of leaf were investigated. The transverse sections of root, stem and leaf, which were taken from middle part, were dissected with a razor blade. Lugol solution was used for starch identification. To decide the best staining procedure for the anatomical sections, various staining methods were applied by the use of different dyes. The used dyes were fast green, crystal violet, orange G, safranine-alcian blue and phloroglucinol-HCL. However, the best visualization of the cellular differences within plant sections was achieved by staining the sections with safranine-alcian blue method. Thus, all anatomical samples were stained in the solutions of safranine and alcian blue dyes. Sections were waited in 25% glycerin for 2 hours for safranine-alcian blue staining. The Safranine and Alcian blue solutions were prepared. Safranine solution was obtained with 1g safranine and 100 ml distilled water while alcian blue solution was obtained with 1g Alcian blue, 3% asetik asit, 100 ml distilled water and 1 thymol crystal. Firstly, sections were waited in safranine solution for 1 min. Secondly, sections were waited in alcian blue solution for 30 seconds. After, sections were washed twice in 70% alcohol, put into 25% glycerin and then mounted on slides.

Glycerin-gelatine method (Jensen 1962) was used in order to make permanent preparations. In preparation of glycerin-gelatine mixture, 8 g of gelatine were dissolved in 52 ml distilled water and 1 gr phenol and 50 ml glycerin were added (phenol added as a preservative to prevent the growth of microorganisms). The mixture was heated in the water bath for 10−15 min under 75 C° until it is homogeneous. Then, it was cooled and stored in a refrigerator. When ever, this mixture was required, it was melted.

The slides of root, stem, and leaf sections were examined with 10×, 40× magnifications under an Olympus BX21 microscope and the selected images were photographed by a connected DP71 digital camera. Micrometric ocular was used for anatomical measurements for the sizes of root, stem and leaf cells of the species.

The leaf surface preparations of specimens were also employed in order to compute the average number of stomata and epidermis cells per unit leaf. These cells were counted on both leaf epidermis surfaces with ocular micrometer in 1 mm^2. The stomatal index and its rate were calculated according to the method described by Meidner and Mansfield (1968). This calculation is as formula:

stomatal index = (number of stoma in per unit of area / number of stoma in per unit area+ number of epidermal cells in per unit area) × 100

ratio of stomatal index = [upper stomatal index / lower stomatal index]

3.2.2 Statistical Analyses

Anatomical characters were measured in 10 anatomical preparations obtained from 2−4 individuals randomly taken from each population. In total, 420 preperations belonging to 42 populations were examined. 44 quantitative and 15 qualitative characters were measured/observed. The significance of quantitave characters were analyzed by one-way ANOVA in Excel 12.0 for windows (Millar, 2001) and 24 quantitative characters were found statistically significant (p-value<0.05) while 20 quantitative characters were not significant (p-value>0.05) (Table 11). Thus, only 24 quantitative and 7 qualitative characters were used. The significant quantitative (yellow colour symbols) and non-significant quantitative (red colour symbols) characters are also represented in the figures 1−3. Besides, The significant and non-significant qualitative characters used in the anatomical descriptions and statistical analyses are listed in Table 8 and Table 9, respectively.

Table 8. Qualitative characters used in numerical analyses.

No	List of characters	Abb.	Character states coding
1	Presence of sclerenchymatic cells at stem (scape) section	PSC	absent (0)/present (1)
2	Presence of starch granules at stem (scape) section	PSS	absent (0)/rare (1)/normal density (2)/intense (3)
3	Presence of starch granules at leaf section	PSL	absent (0)/present (1)
4	Presence of hairness at leaf section	PHL	absent (0)/present (1)
5	Presence of hypodermis cells at leaf section	PHY	absent (0)/present (1)
6	Thickening of endodermal cells at root section	TEC	thin (0)/thick (1)/over thickened (2)
7	The presence of cuticle bulge at leaf section	PCB	absent (0)/present (1)

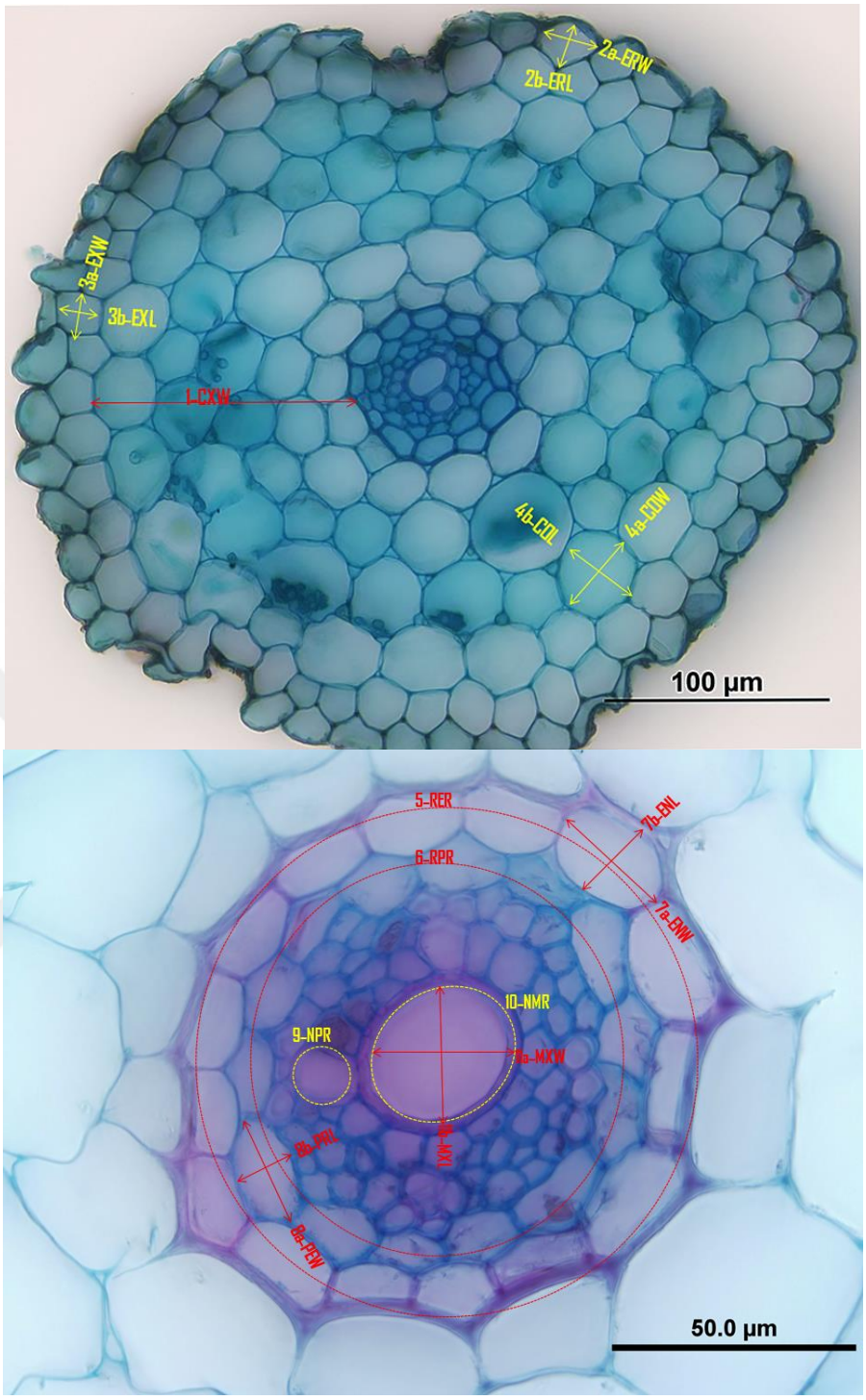

Figure 1. Measurements of quantitavive characters related to root; 1-CXW: Width of cortex region at root section, 2a-ERW: Width of epidermal cells at root section, 2b-ERL: Length of epidermal cells at root section, 3a-EXW: Width of exodermal cells at root section, 3b-EXL: Length of exodermal cells at root section, 4a-COW: Width of cortex parenchymatous cells at root section, 4b-COL: Length of cortex parenchymatous cells at root section, 5-RER: Row number of endodermal cells at root section, 6-RPR: Row number of pericycle cells at root section, 7a-ENW: Width of endodermal cells at root section, 7b-ENL: Length of endodermal cells at root section, 8a-PEW: Width of pericycle cells at root section, 8b-PRL: Length of pericycle cells at root section, 9-NPR: Number of protoxylem at root section, 10-NMR: Number of metaxylem elements at root section, 11a-MXW: Width of metaxylem elements at root section, 11b-MXL: Length of metaxylem elements at root section.

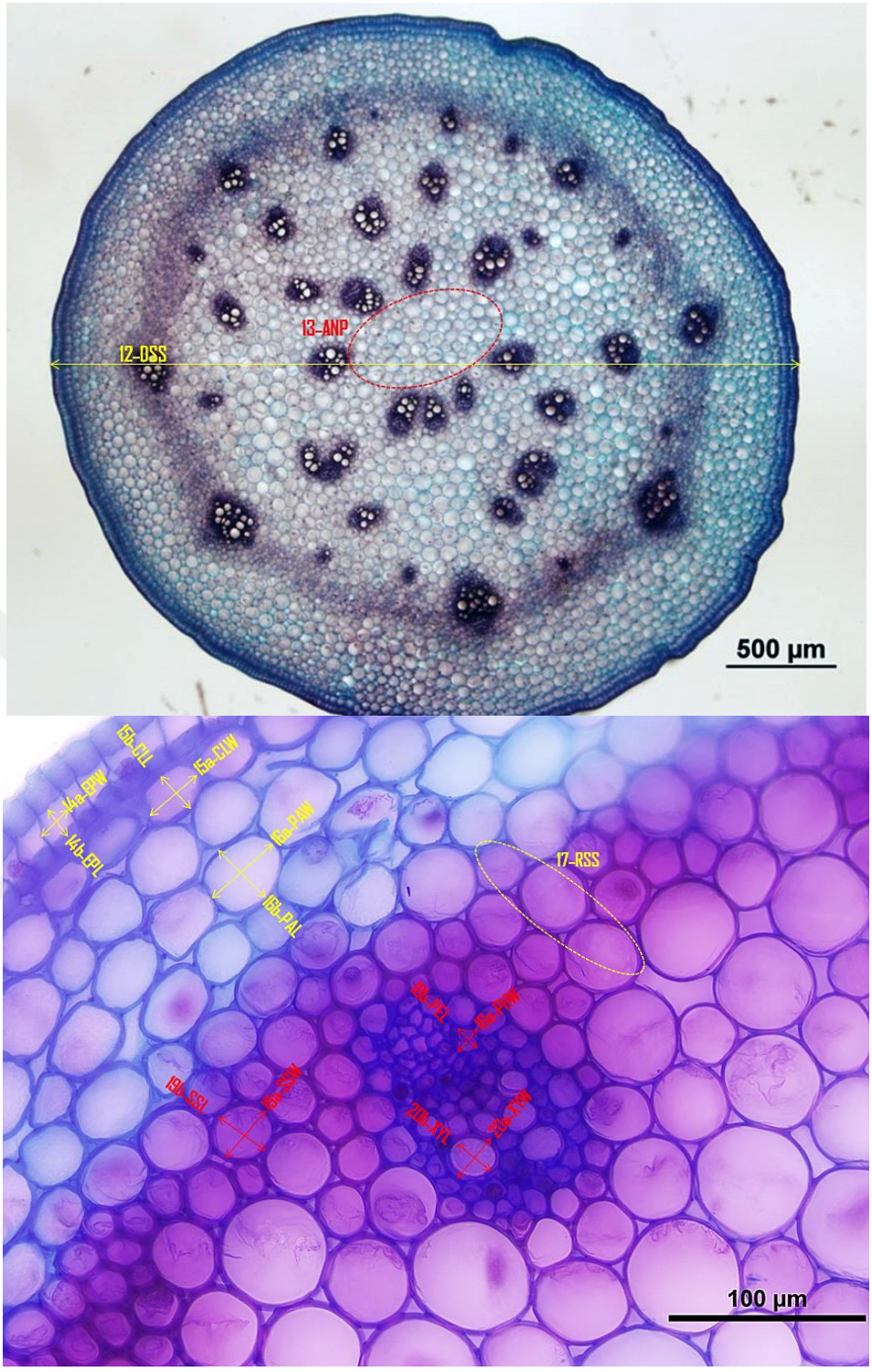

Figure 2. Measurements of quantitavive characters related to stem (scape); 12-DSS: Diameter of stem section, 13-ANP: The average number of cell in pith at stem section, 14a-EPW: Width of epidermal cells at stem section, 14b-EPL: Length of epidermal cells at stem section, 15a-CLW: Width of collenchyma cells at stem section, 15b-CLL: Length of collenchyma cells at stem section, 16a-PAW: Width of parenchymatous cells at stem section, 16b-PAL: Length of parenchymatous cells at stem section, 17-RSS: Row number of sclerenchyma cells at stem section, 18a-PHW: Width of phloem elements at stem section, 18b-PEL: Length of phloem elements at stem section, 19a-SSW: Width of sclerenchyma cells at stem section, 19b-SSL: Length of sclerenchyma cells at stem section, 20a-XYW: Width of xylem elements at stem section, 20b-XYL: Length of xylem elements at stem section.

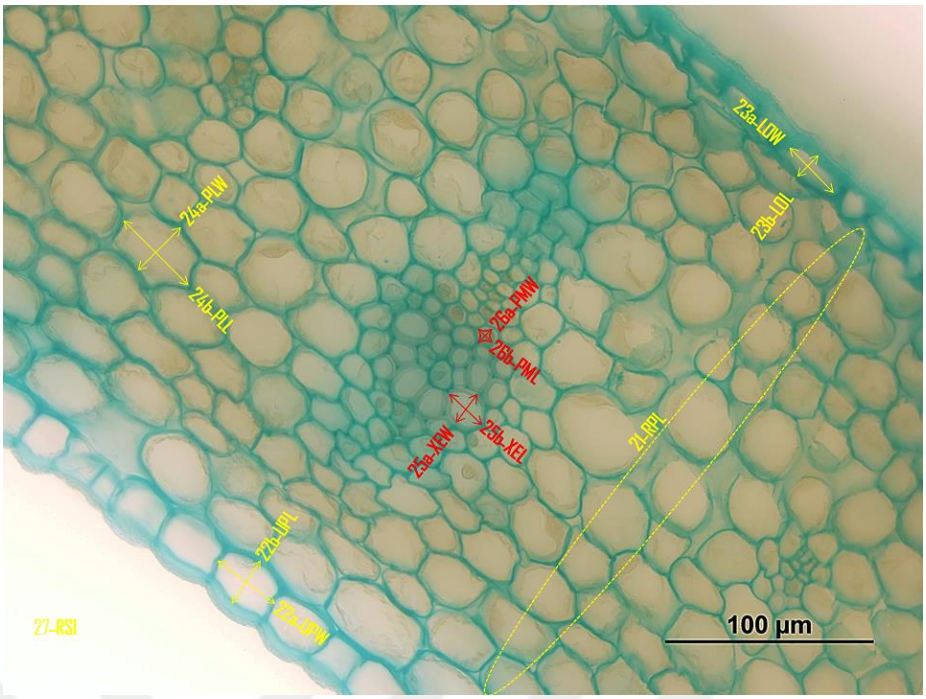

Figure 3. Measurements of quantitavive characters related to leaf; 21-RPL: Row number of parenchymatous cells at leaf section, 22a-UPW: Width of upper epidermal cells at leaf section, 22b-UPL: Length of upper epidermal cells at leaf section, 23a-LOW: Width of lower epidermal cells at leaf section, 23b-LOL: Length of lower epidermal cells at leaf section, 24a-PLW: Width of parenchymatous cells at leaf section, 24b-PLL: Length of parenchymatous cells at leaf section, 25a-XEW: Width of xylem elements at leaf section, 25b-XEL: Length of xylem elements at leaf section, 26a-PMW: Width of phloem elements at leaf section, 26b-PML: Length of phloem elements at leaf section, 27-RSI: Ratio of stoma index.

Table 9. Qualitative characters not used in numerical analyses.

No	List of characters	Abb.
1	The shape of cortex cells at stem (scape) section	GKS
2	The shape of sclerenchyma cells at stem (scape) section	GSS
3	The shape of epidermis cells at leaf section	YHS
4	The shape of parenchyma cells at leaf section	YPS
5	The presence of cuticle bulge at leaf section	YKV
6	The shape of exodermis cells at root section	KES
7	The shape of epidermis cells at root section	KEH
8	The shape of cortex cells at root section	KKS

The mean values of each character were calculated. The raw measurements of each character were obtained from ten preparations belonging to each population. Then, mean values of the raw measurements were calculated for every character from each population. Afterwards, according to the modified Whisker's graph (Massart et al. 2005), mean values of each character with their standard errors were plotted on one group graph by using the Graphpad programme (Figure 4). When means and standard error lines of each quantitative character belonging to different

populations overlap each other, they were grouped and coded as the same state of the character in ascending order (modified from Almeida and Bisby, 1984). After all quantitative characters were coded by using this technique, a data matrix was created using 24 quantitative characters showing good seperation. Qualitative characters with two-states were coded in binary forms, e.g., by scoring “0” and “1” while multi-state characters were coded in ordered series of discrete states, e.g., by scoring “0”, “1”, “2” etc. Minitab 16 for Windows package programme was used for cluster and principal component analysis (PCA). To decide the similarity of the populations and their distance from each other were also used principal component analysis (Figures 77−80). In the cluster analysis, for measuring the distance between populations, “average linkage between groups” was used. In analysis of clusters and establishing of dendrogram, the “Mannhattan’s City block method” was used because of high variation between and within populations (Figures 81−82).

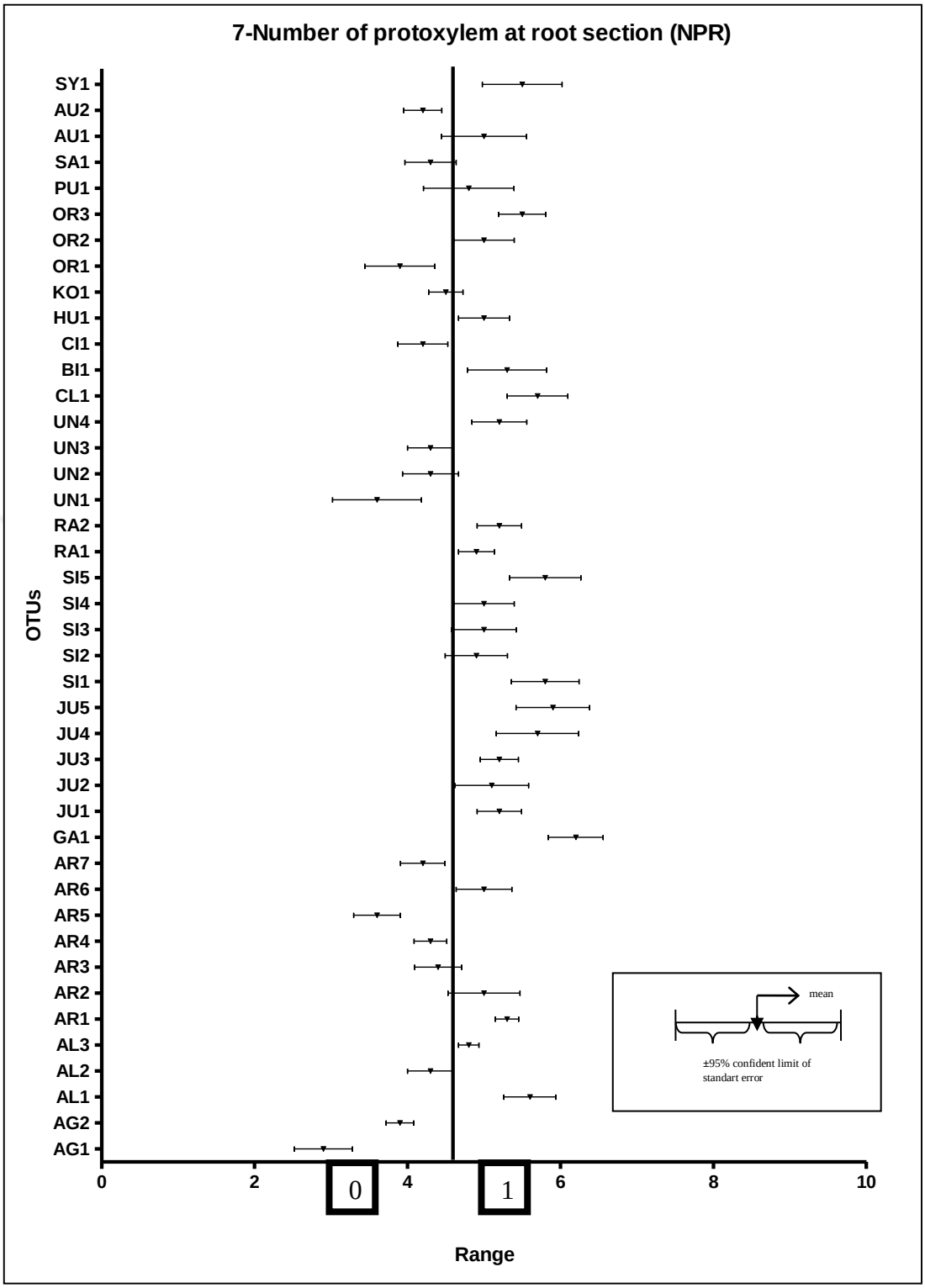

Figure 4. Grouping and coding the character states of a quantitative character on a modified Whisker's graph. The character states of this character were coded as follows: the mean values are less than 4.59 was scored by 0 and the mean values are more than 4.59 was scored by 1 (<4.59: 0 and 4.59<: 1).

4. RESULT

4.1 Anatomical Characteristics of the genus *Tulipa*

Transverse sections of the root consists of a single-layered epidermis on the outermost surface, while a single-layered exodermis is located under the epidermis. The cortex covers a large area with mainly spheroid parenchymatous cells. The single-layered endodermis comprised of regular and rectangular cells is present under the cortex layer. Single-row pericycle composed of ovoid or rectangular cells is appeared under the endodermis. Phloem components are located around protoxylem elements. The centre of the vascular cylinder is occupied by 1−3 metaxylem elements.

Transverse sections of the stem are composed by a single-layered epidermis which is covered by a thin cuticle on the outermost surface. The single-layered collenchyma is either lacking or found under the epidermis. The cortex comprises of parenchymatous cells under the epidermis. The sclerenchyma tissue is either lacking or multi-layered spheroid cells. Vascular bundles of varied sizes and numbers embedded irregularly in the parenchymatous tissue. The pith consists of parenchymatous cells.

Transverse section of leaf comprises a single-layered epidermis which is covered by a not-thickened cuticle on both sides. Hypodermis consisting of large and flat cells is located under the upper epidermis expect *T. clusiana*. Mesophyll is not differentiated into palisade and spongy parenchyma (unifacial leaf type) and all cells include chloraplasts (chlorenchyma). Vascular bundles of varied sizes are arranged in a one-row. Anomocytic type stomata are placed on both surfaces (amphistomatic leaf) and are located at the same level with epidermal cells (mesomorphic type stoma).

4.1.1 *Tulipa agenensis* DC.

4.1.1.1 Root Anatomy of *T. agenensis*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and regular cells on the outermost surface. Epidermis cells are 14−28 × 14−29 µm. The single layered exodermis consisting of hexagon cells is found under the epidermis. Exodermis cells are 18−40 × 21−45 µm. The cortex is composed of 5−6 rows of spheroid parenchymatous cells under the exodermis. These cells are 36−49 × 28−50 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 2−6 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 5).

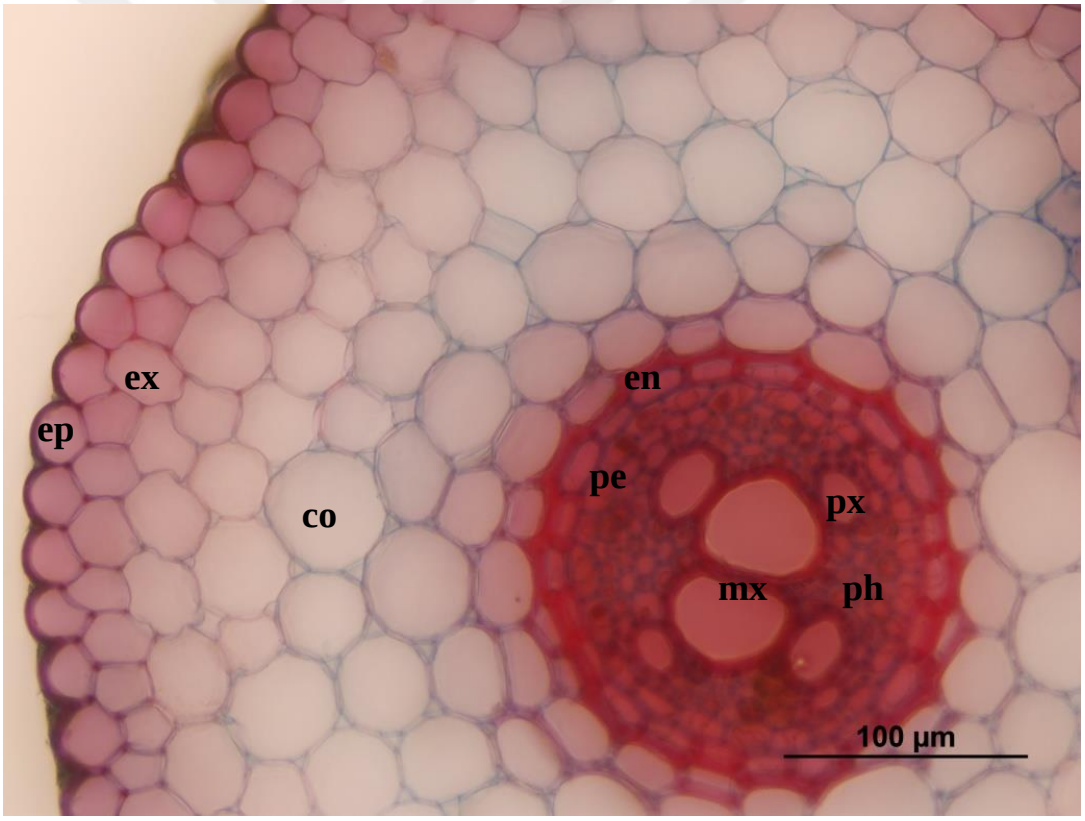

Figure 5. Root anatomy of *T. agenensis*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.1.2 Stem (Scape) Anatomy of *T. agenensis*

The epidermis is composed of hexagon cells which are 11−22 × 11−29 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of hexagon cells which are 13−30 × 22−40 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 5−6 layered spheroid cells which are 20−65 × 29−70 µm. The sclerenchyma tissue consists of 2−5 layered spheroid cells. The stem contains averagely 37 vascular bundles of various sizes in the vascular cylinder (Figure 6).

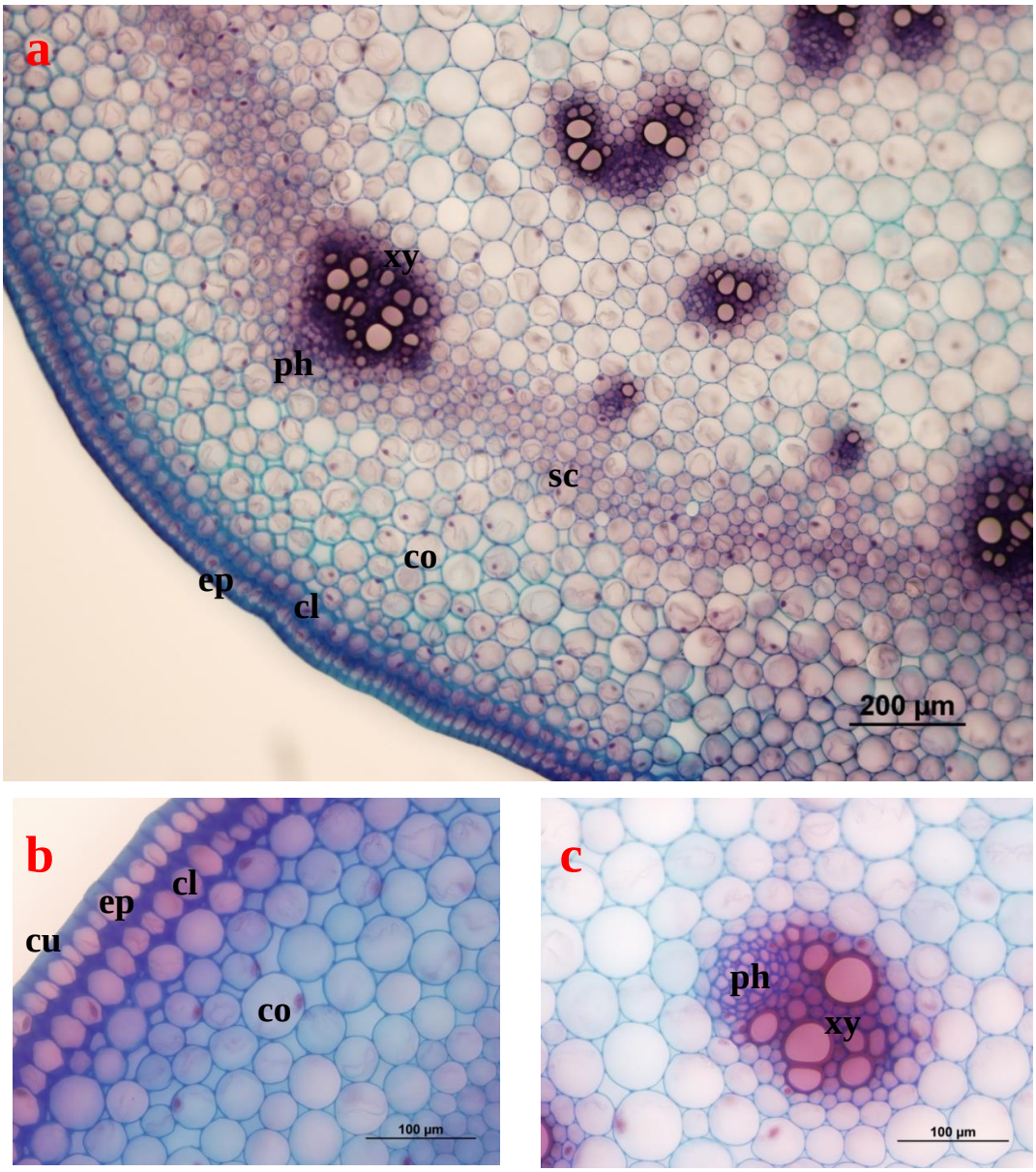

Figure 6. Stem anatomy of *T. agenensis*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.1.3 Leaf Anatomy of *T. agenensis*

Upper epidermis consists of rectangular cells while lower epidermis consists of square cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 15−39 × 19−34 and 10−20 × 16−25 µm, respectively. The parenchymatous cells composed of 5−11 layered spheroid cells are 20−60 × 22−56 µm (Figure 7).

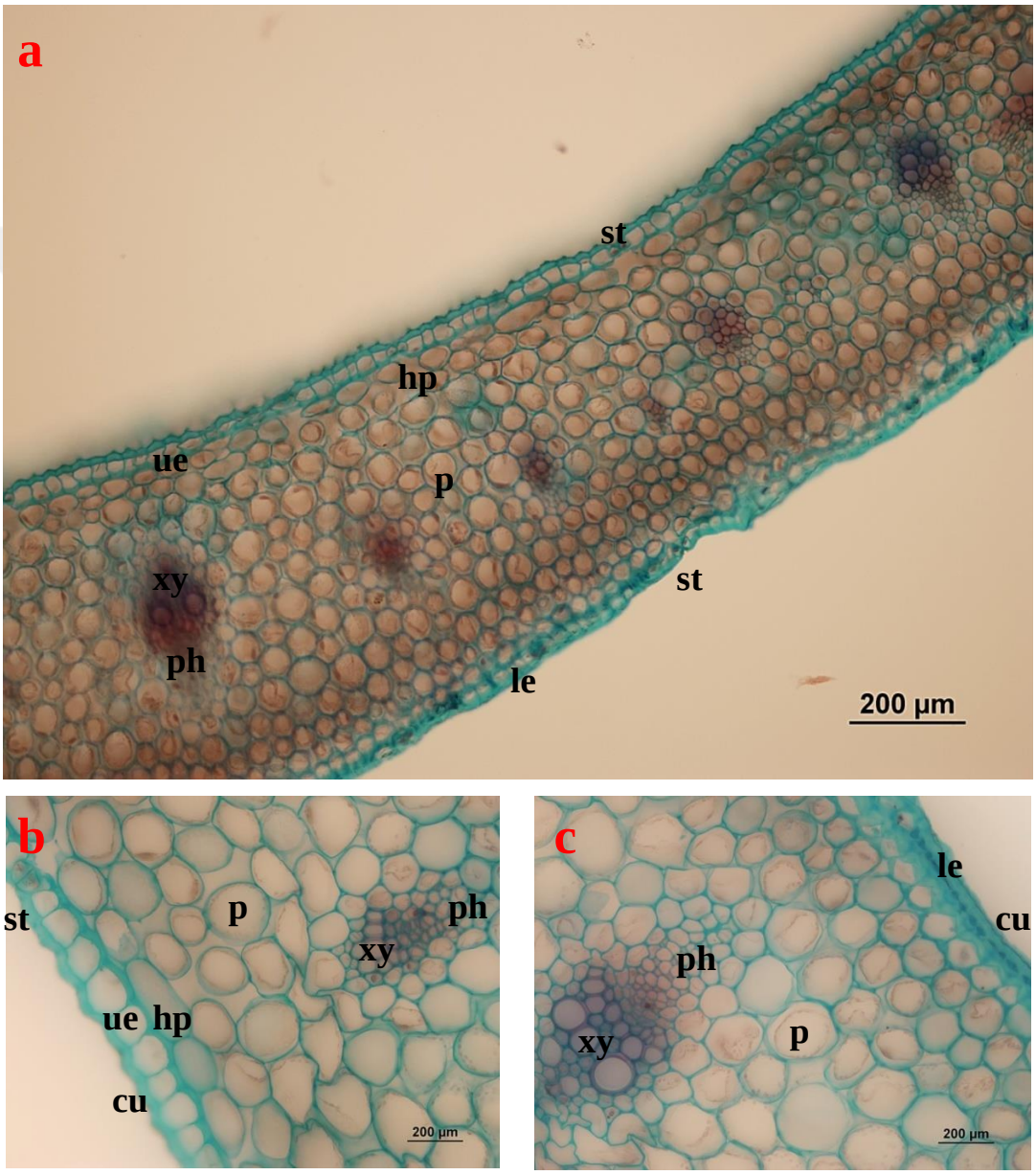

Figure 7. Leaf anatomy of *T. agenensis*; a) section of leaf (10x), b) upper epidermis in the leaf section (40x), c) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 84 and 224, respectively. Stomata index is 27,27 for the upper

epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 101 and 241, respectively. Stomata index is 29,83 for the lower epidermis. Stomata index ratio is found as 0,92 (Figure 8).

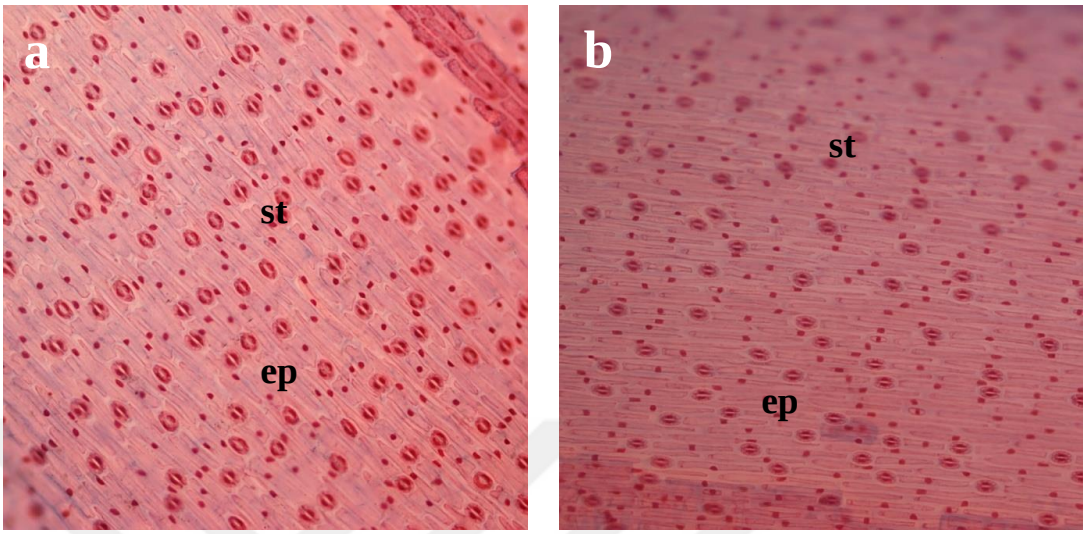

Figure 8. Leaf surface section of *T. agenensis*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.2 *Tulipa aleppensis* Boiss. ex Regel

4.1.2.1 Root Anatomy of *T. aleppensis*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 14−26 × 20−38 µm. The single layered exodermis consisting of irregular or hexagon cells is found under the epidermis. Exodermis cells are 12−32 × 16−38 µm. The cortex is composed of 5−6 rows of irregular parenchymatous cells under the exodermis. These cells are 29−60 × 30−65 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 3−7 protoxylem ridges. 1−3 metaxylem is present on the median part of vascular cylinder (Figure 9).

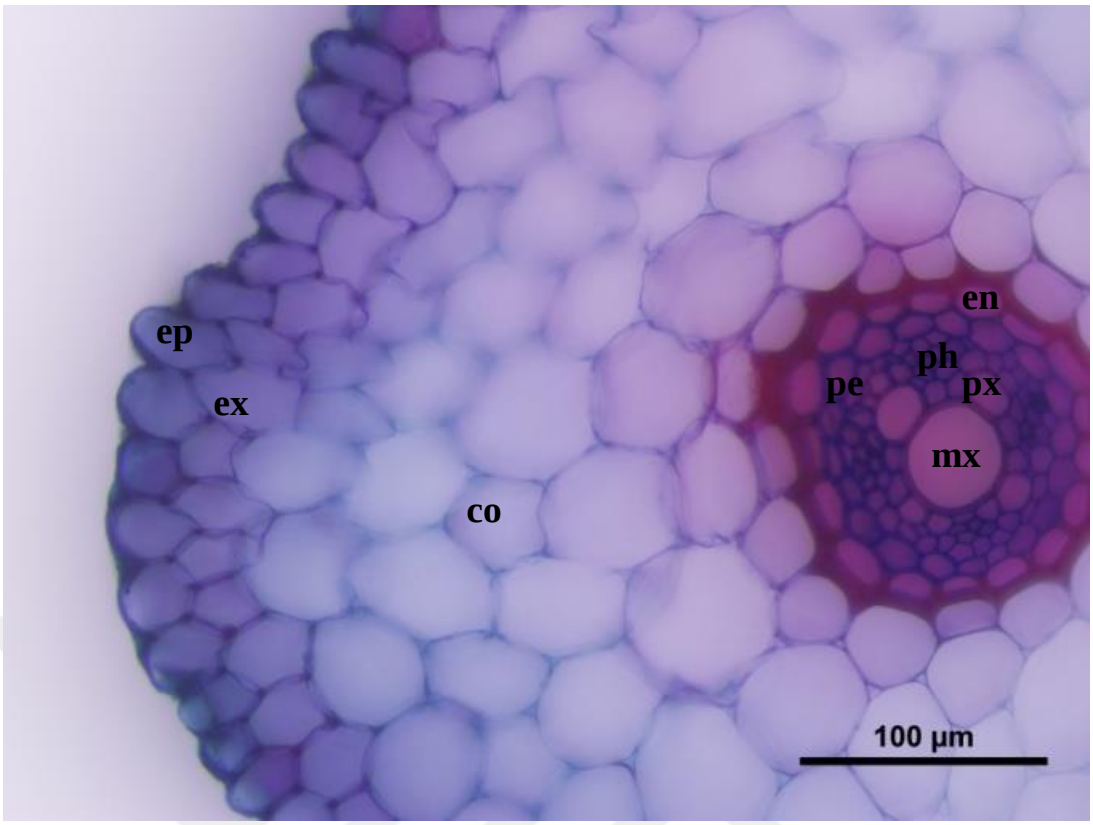

Figure 9. Root anatomy of *T. aleppensis*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.2.2 Stem (Scape) Anatomy of *T. aleppensis*

The epidermis is composed of square cells which are 8−27 × 8−24 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 10−36 × 10−12 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 6−7 layered spheroid cells which are 19−72 × 29−80 µm. The sclerenchyma tissue is either lacking or consists of 2−5 layered spheroid cells. The stem contains averagely 52 vascular bundles of various sizes in the vascular cylinder (Figure 10).

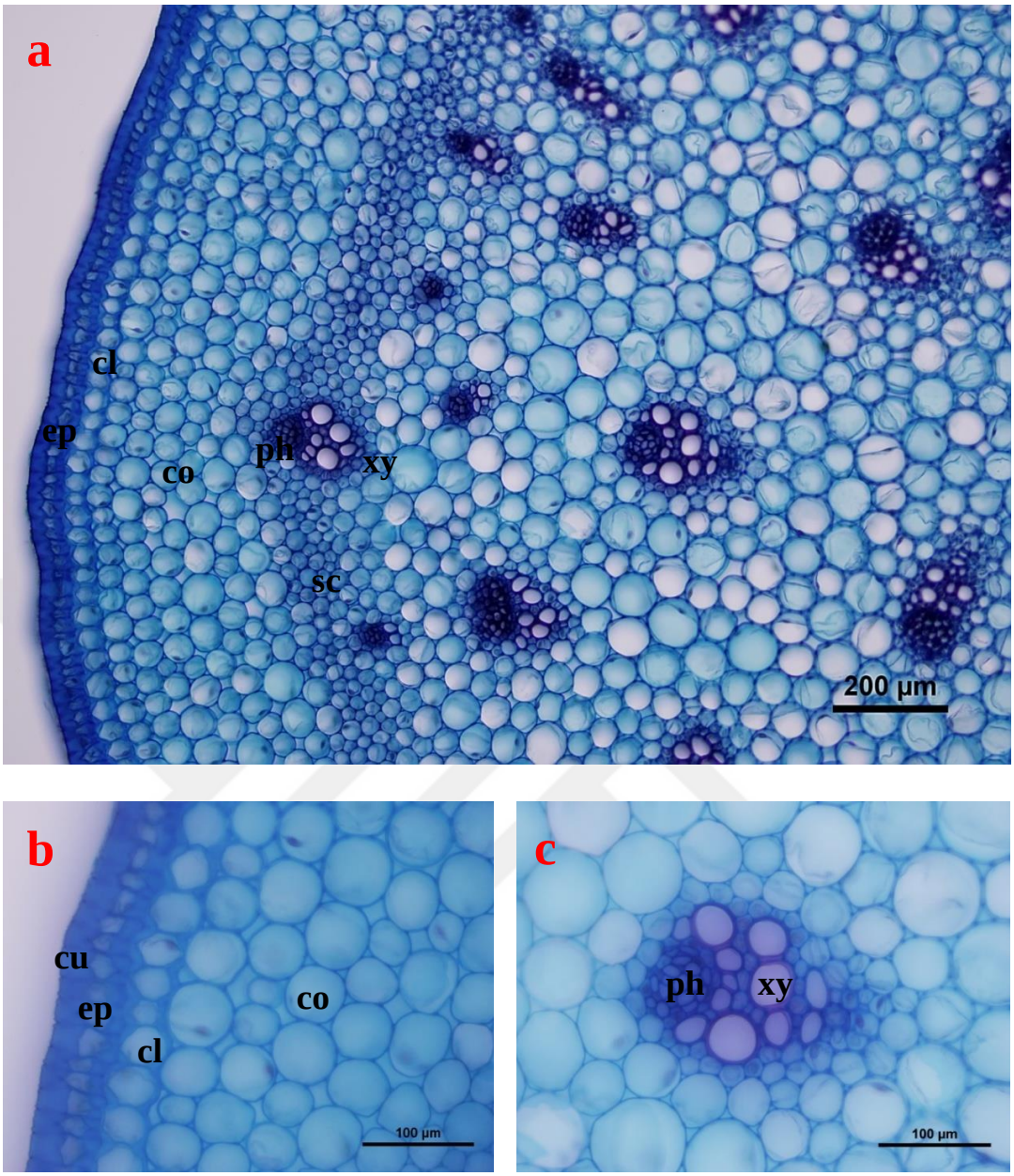

Figure 10. Stem anatomy of *T. aleppensis*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.2.3 Leaf Anatomy of *T. aleppensis*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 20−49 × 18−40 and 17−39 × 19−39 µm, respectively. The parenchymatous cells composed of 8−16 layered spheroid cells are 30−70 × 28−60 µm (Figure 11).

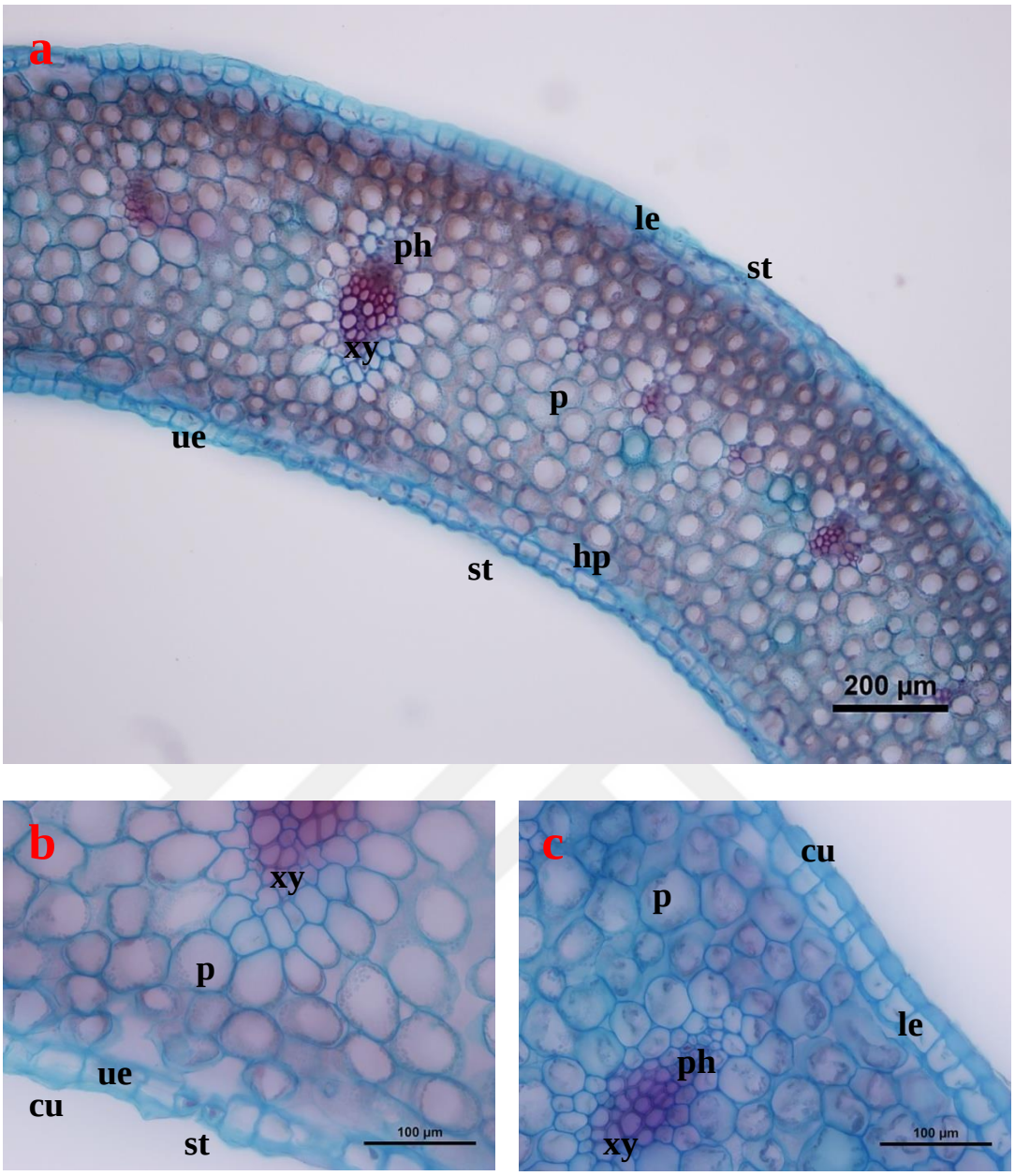

Figure 11. Leaf anatomy of *T. aleppensis* a) section of leaf (10x), b) upper epidermis in the leaf section (40x), c) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 54 and 115, respectively. Stomata index is 31,95 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 58 and 135, respectively. Stomata index is 30,05 for the lower epidermis. Stomata index ratio is found as 1,06 (Figure 12).

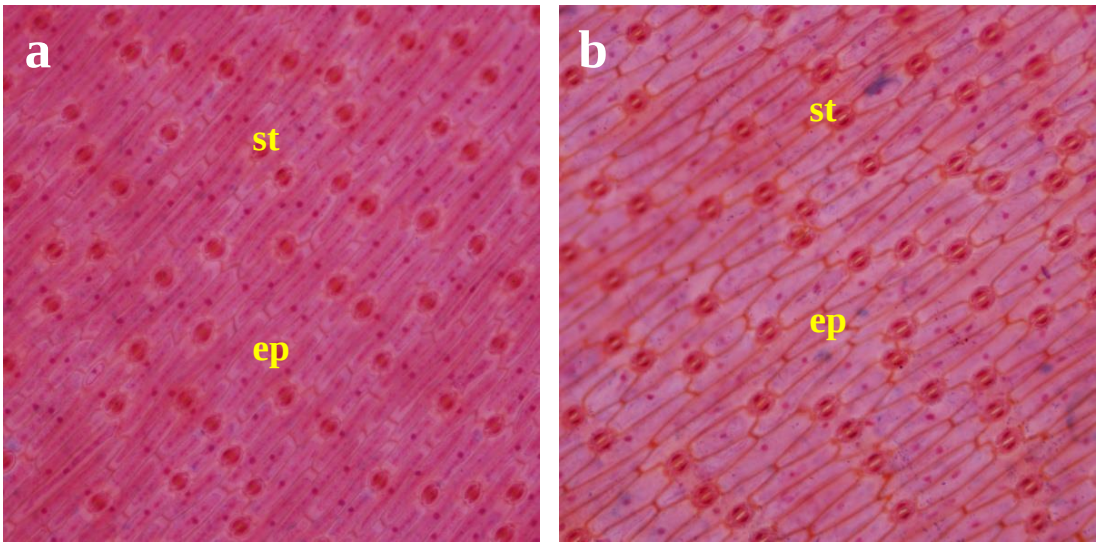

Figure 12. Leaf surface section of *T. aleppensis*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.3 *Tulipa armena* Boiss. var. *armena*

4.1.3.1 Root Anatomy of *T. armena* var. *armena*

Transverse section of the root includes a single-layered epidermis composed of small and irregular shapes on the outermost surface. Epidermis cells are 10−26 × 10−26 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 10−32 × 16−45 µm. The cortex is composed of 5−6 rows of irregular parenchymatous cells under the exodermis. These cells are 20−60 × 30−62 µm. The wall of the endodermis is thin. The phloem components are located around 2−7 protoxylem ridges. 1−3 metaxylem is present on the median part of vascular cylinder (Figure 13).

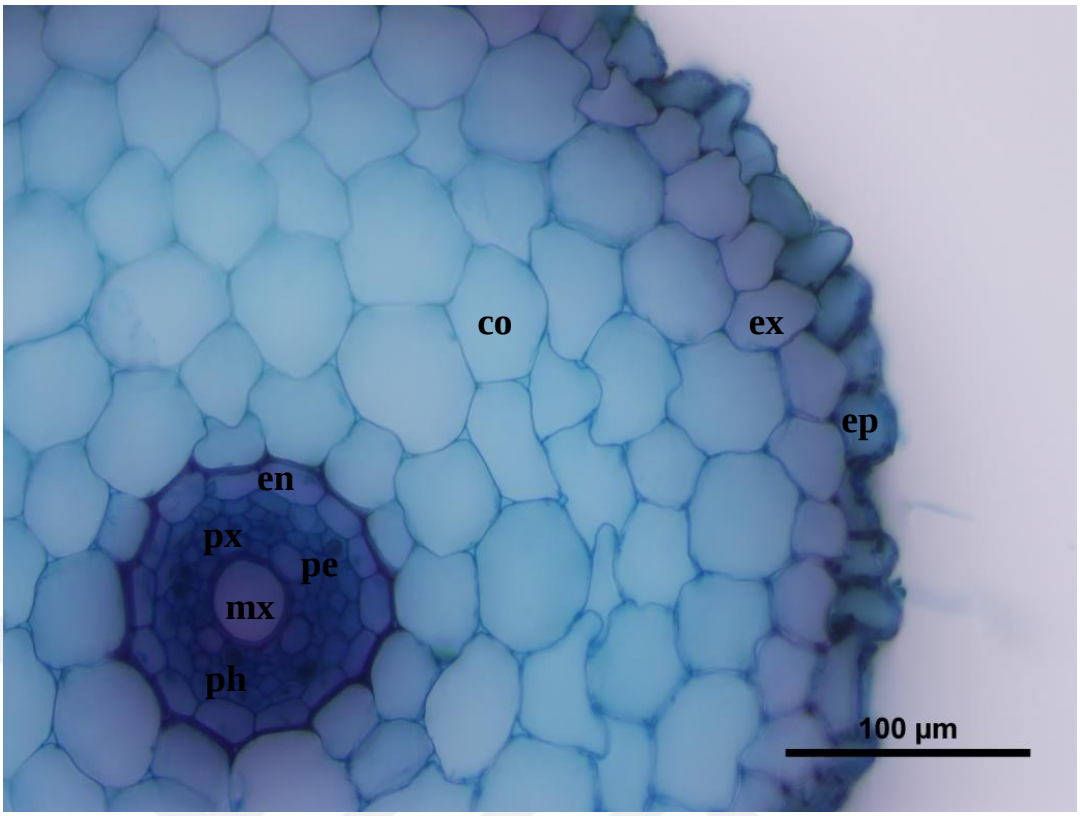

Figure 13. Root anatomy of *T. armena* var. *armena*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.3.2 Stem (Scape) Anatomy of *T. armena* var. *armena*

The epidermis is composed of rectangular cells which are 9−25 × 12−38 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of rectangular cells which are 15−35 × 12−32 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 6−7 layered spheroid cells which are 29−69 × 20−74 µm. The sclerenchyma tissue is either lacking or consists of 2−6 layered spheroid cells. The stem contains averagely 43 vascular bundles of various sizes in the vascular cylinder (Figure 14).

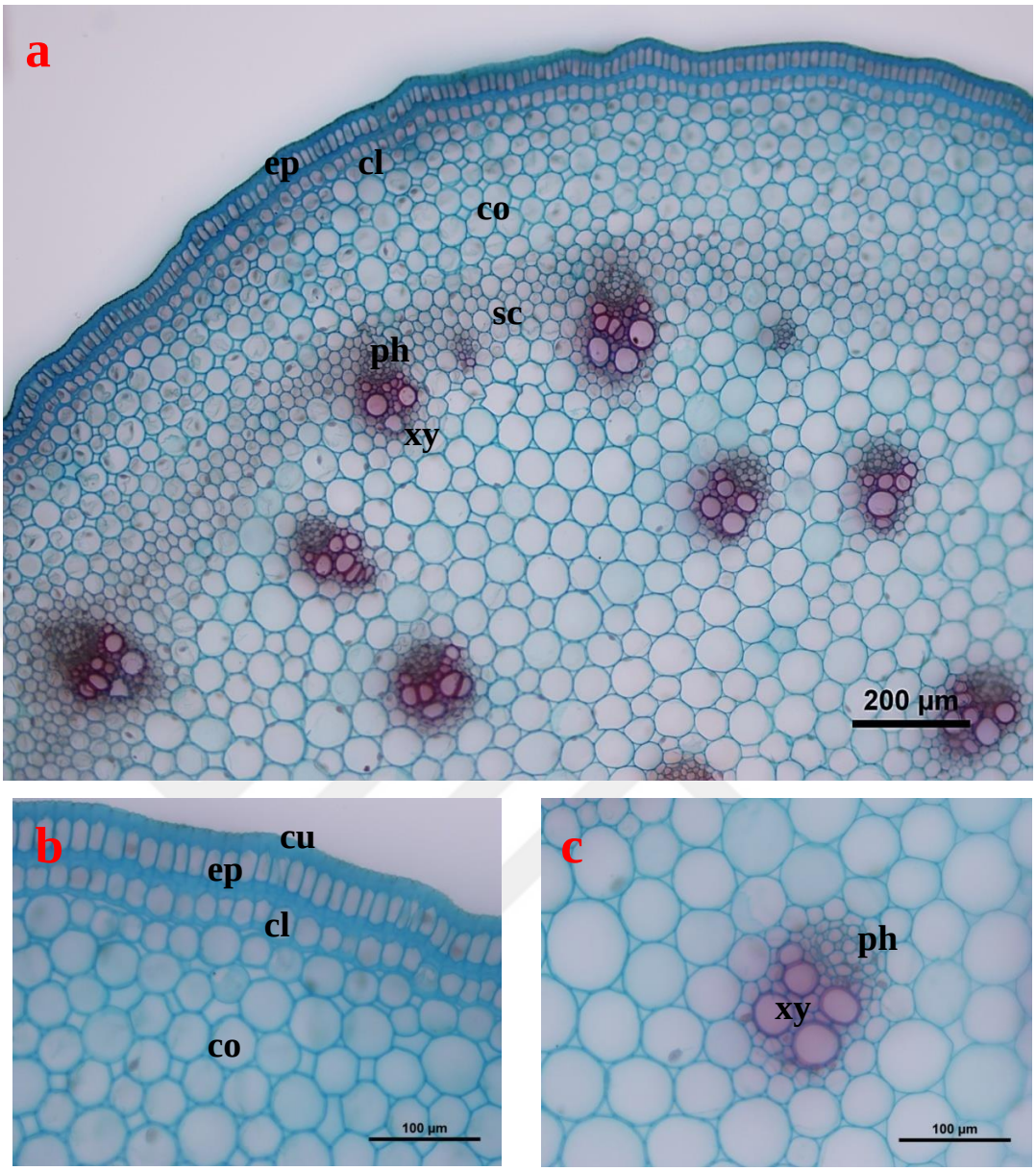

Figure 14. Stem anatomy of *T. armena* var. *armena*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.3.3 Leaf Anatomy of *T. armena* var. *armena*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 14−40 × 12−39 and 15−49 × 15−32 µm, respectively. The parenchymatous cells composed of 5−16 layered ovoid or spheroid cells are 20−60 × 20−68 µm (Figure 15).

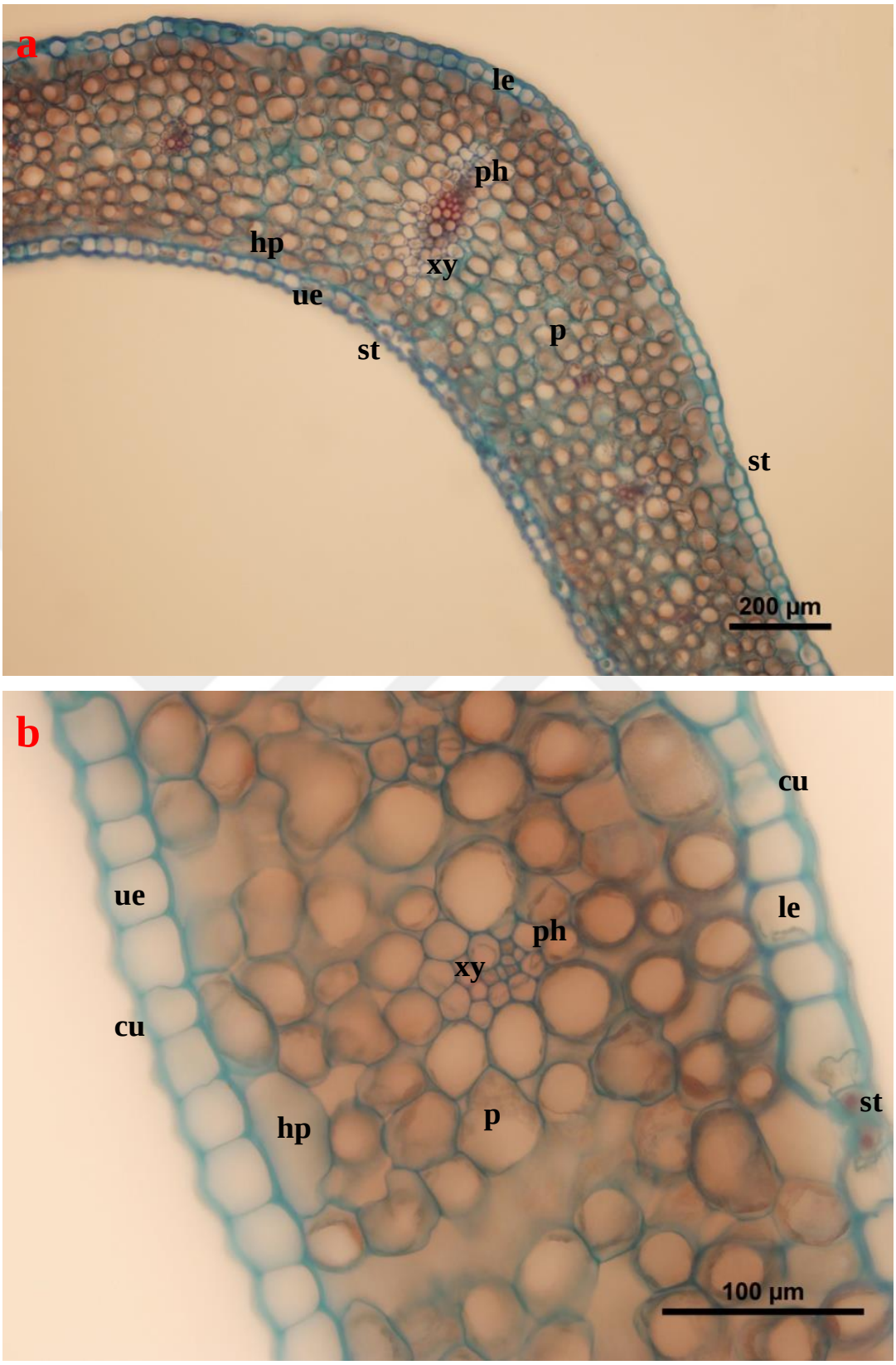

Figure 15. Leaf anatomy of *T. armena* var. *armena*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 50 and 126, respectively. Stomata index is 28,40 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 69 and 120, respectively. Stomata index is 36,50 for the lower epidermis. Stomata index ratio is found as 0,77 (Figure 16).

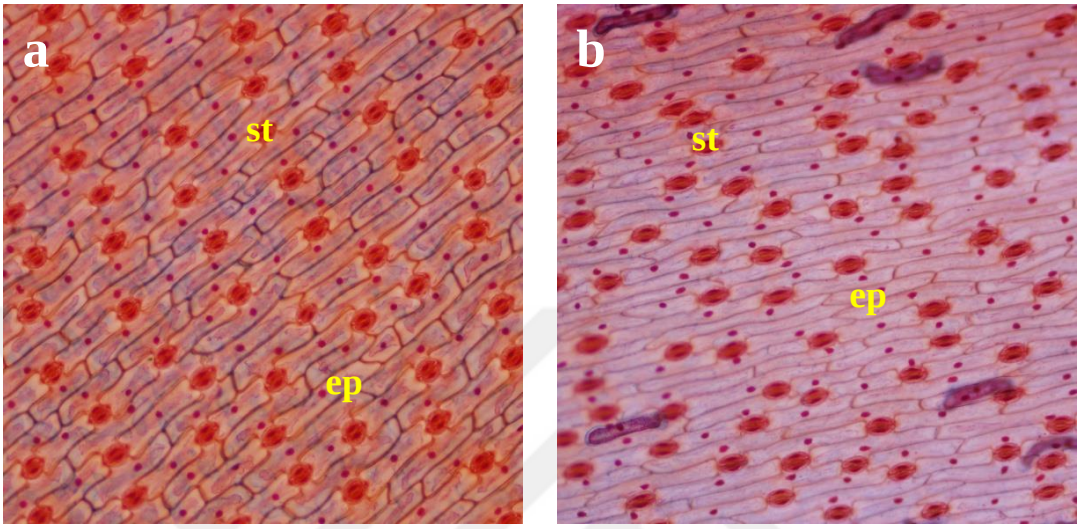

Figure 16. Leaf surface section of *T. armena* var. *armena*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.4 *Tulipa armena* Boiss. var. *galatica* (Freyn) Eker

4.1.4.1 Root Anatomy of *T. armena* var. *galatica*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and regular cells on the outermost surface. Epidermis cells are 21−31 × 21−32 µm. The single layered exodermis consisting of pentagon cells is found under the epidermis. Exodermis cells are 21−32 × 23−37 µm. The cortex is composed of 5−6 rows of spheroid parenchymatous cells under the exodermis. These cells are 40−51 × 42−60 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 4−8 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 17).

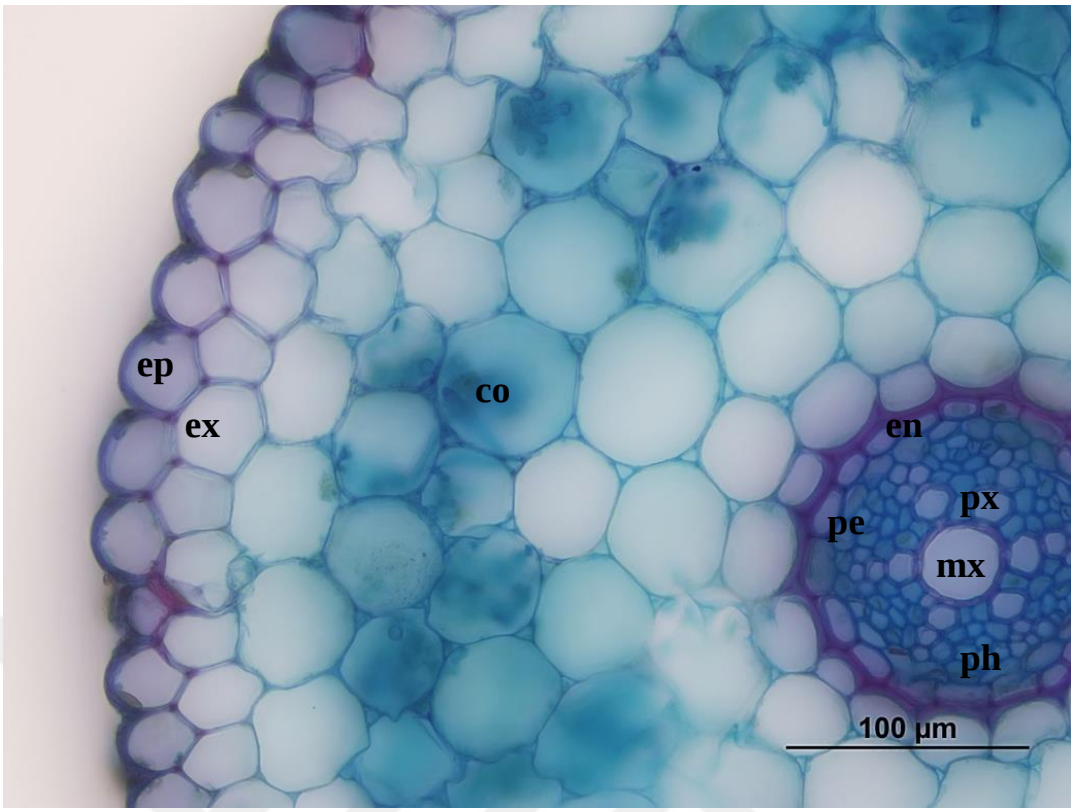

Figure 17. Root anatomy of *T. armena* var. *galatica*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.4.2 Stem (Scape) Anatomy of *T. armena* var. *galatica*

The epidermis is composed of rectangular cells which are 9−14 × 16−25 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 20−30 × 15−17. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 4−5 layered spheroid cells which are 20−30 × 25−39 µm. The sclerenchyma tissue is either lacking or consists of 3−5 layered spheroid cells. The stem contains averagely 40 vascular bundles of various sizes in the vascular cylinder (Figure 18).

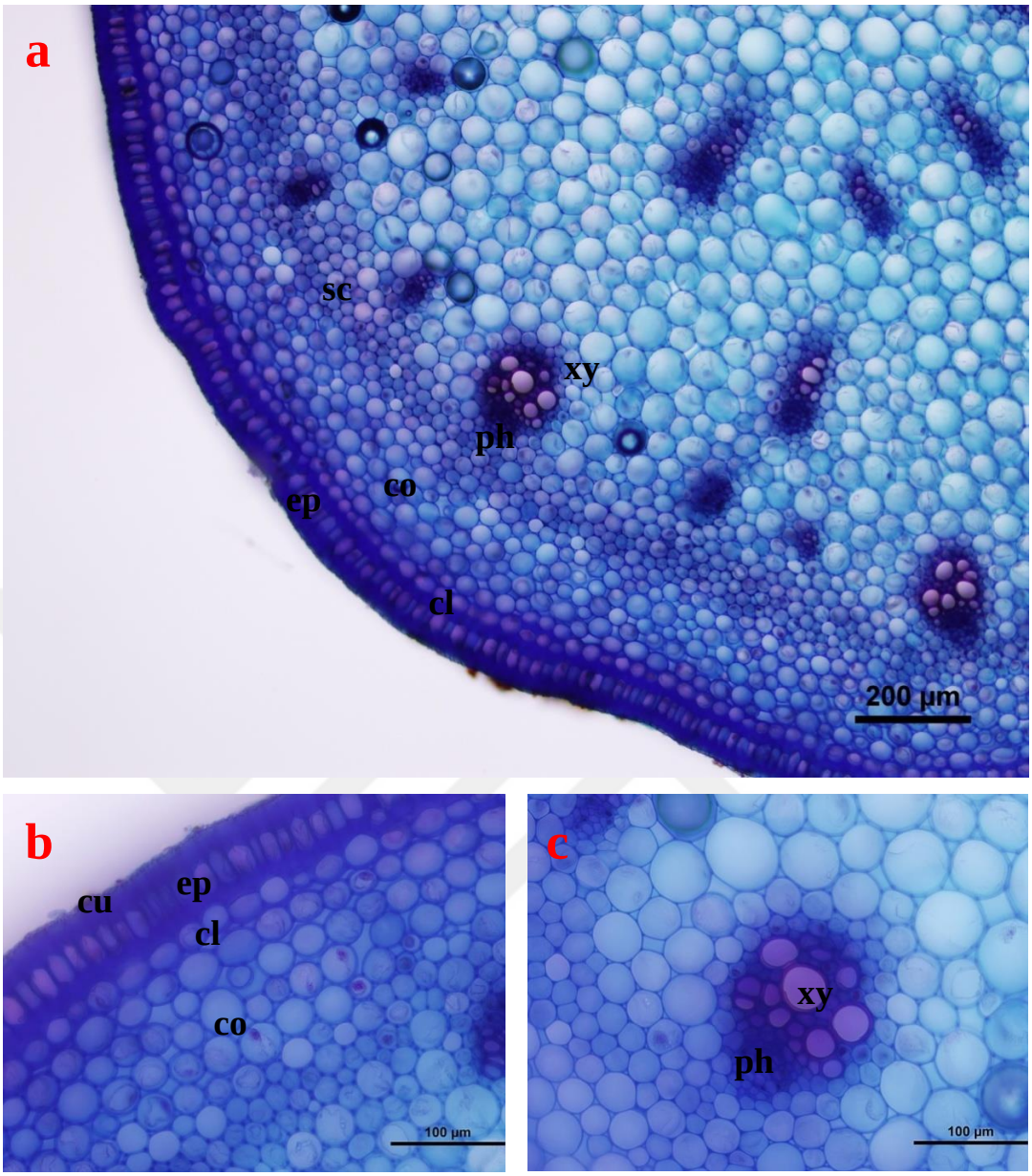

Figure 18. Stem anatomy of *T. armena* var. *galatica*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.4.3 Leaf Anatomy of *T. armena* var. *galatica*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 12−28 × 11−23 and 17−28 × 25−34 µm, respectively. The parenchymatous cells composed of 5−10 layered ovoid or spheroid cells are 25−37 × 21−41 µm (Figure 19).

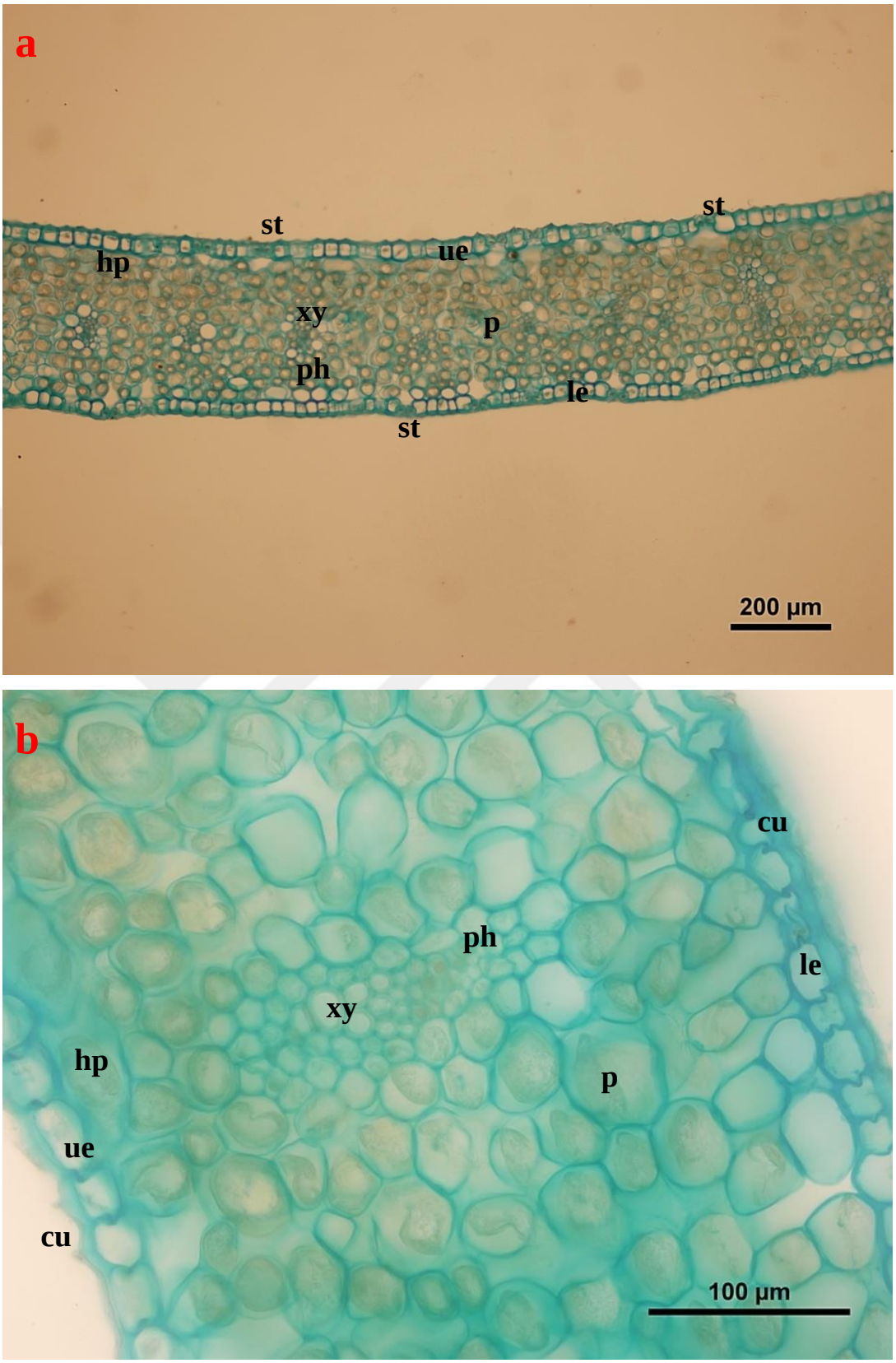

Figure 19. Leaf anatomy of *T. armena* var. *galatica;* a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 43 and 168, respectively. Stomata index is 20,37 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 59 and 166, respectively. Stomata index is 26,22 for the lower epidermis. Stomata index ratio is found as 0,77 (Figure 20).

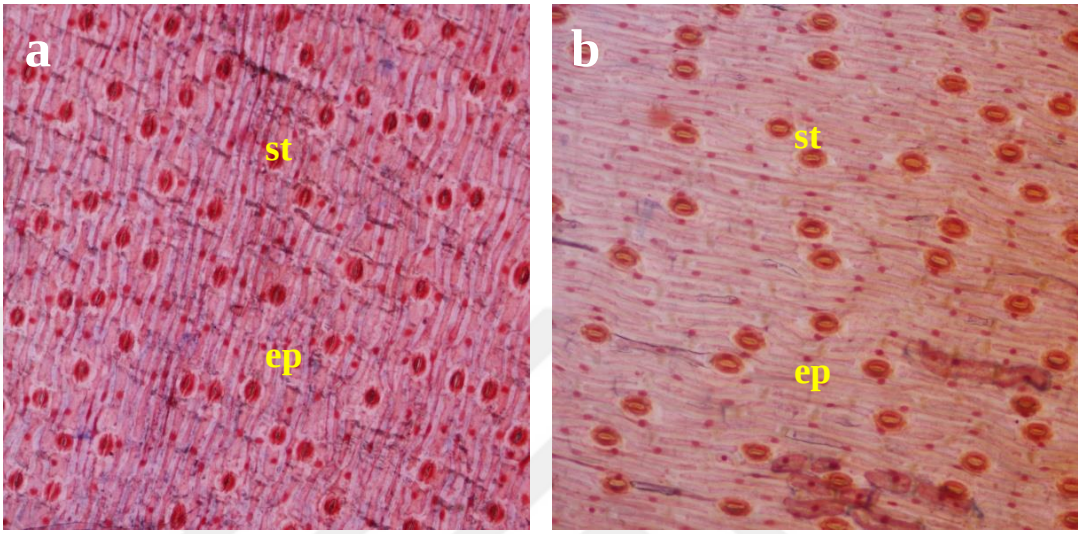

Figure 20. Leaf surface section of *Tulipa armena* var. *galatica*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.5 *Tulipa biflora* Pall.

4.1.5.1 Root Anatomy of *T. biflora*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 16−26 × 13−21 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 18−29 × 15−30 µm. The cortex is composed of 4−5 rows of ovoid or spheroid parenchymatous cells under the exodermis. These cells are 20−49 × 19−48 µm. The wall of the endodermis is thick and direction of thickning is towards cortex. The phloem components are located around 3−8 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 21).

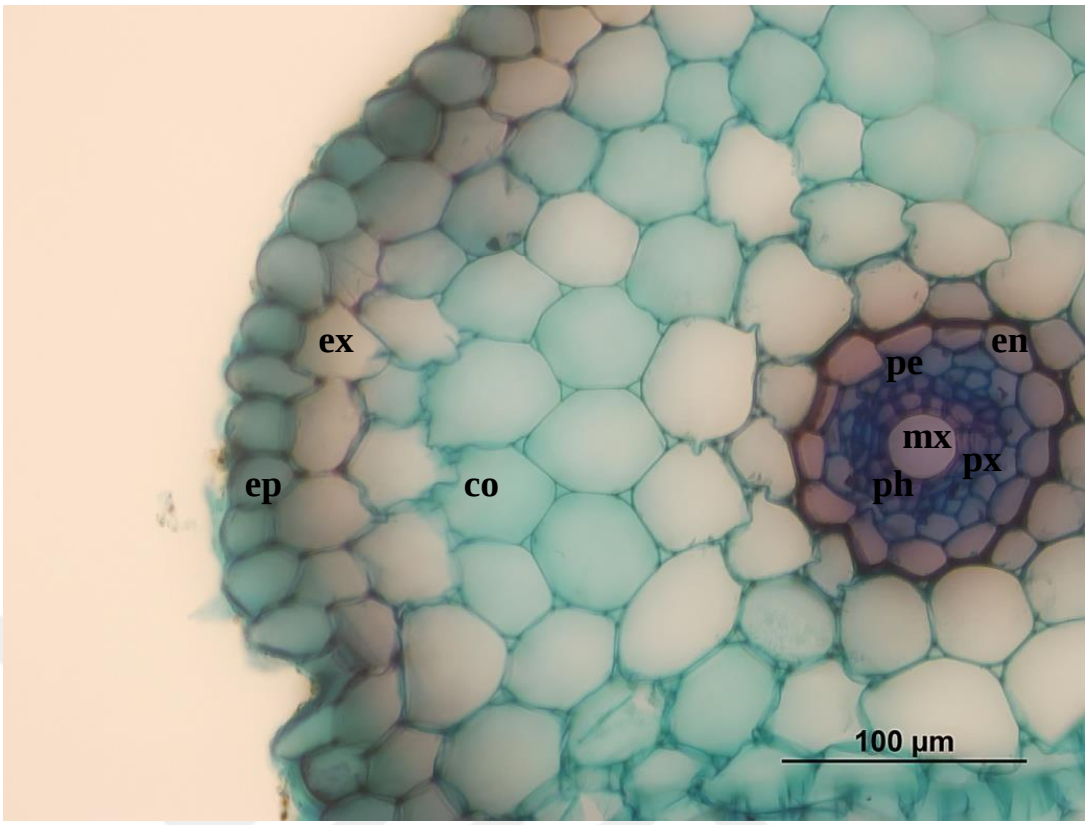

Figure 21. Root anatomy of *T. biflora*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.5.2 Stem (Scape) Anatomy of *T. biflora*

The epidermis is composed of rectangular cells which are 10−18 × 18−26 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 25−39 × 9−15 µm. The cortex comprises parenchymatous cells. The parenchyma consists of 4−5 layered ovoid cells which are 30−50 × 29−50 µm. The sclerenchyma tissue is either lacking or consists of 2−3 layered spheroid cells. The stem contains averagely 28 vascular bundles of various sizes in the vascular cylinder (Figure 22).

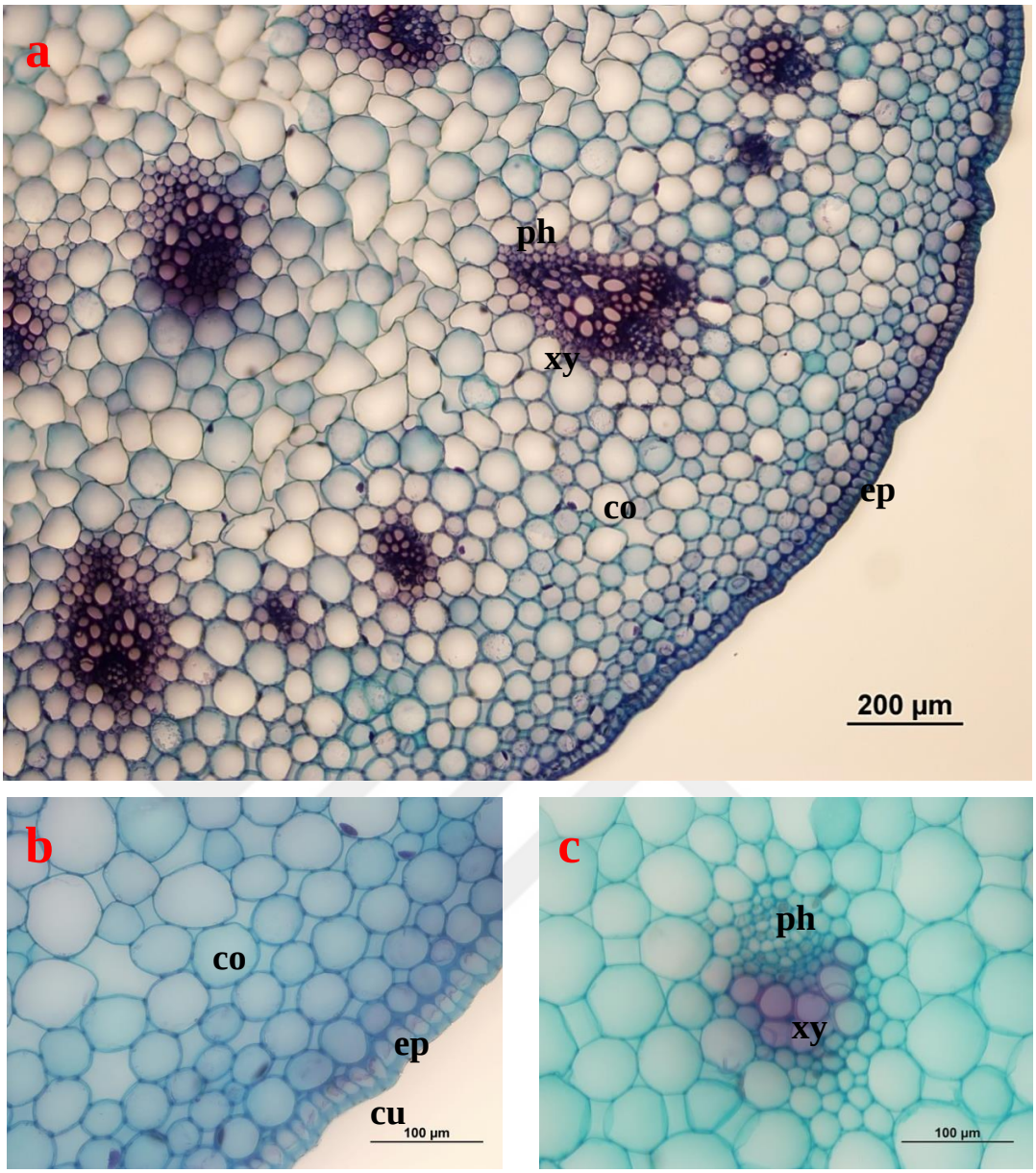

Figure 22. Stem anatomy of *T. biflora*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, ph: phloem, xy: xylem.

4.1.5.3 Leaf Anatomy of *T. biflora*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 8−25 × 12−39 µm and 13−21 × 14−21 µm, respectively. The parenchymatous cells composed of 7−14 layered ovoid or spheroid cells are 22−45 × 24−52 µm (Figure 23).

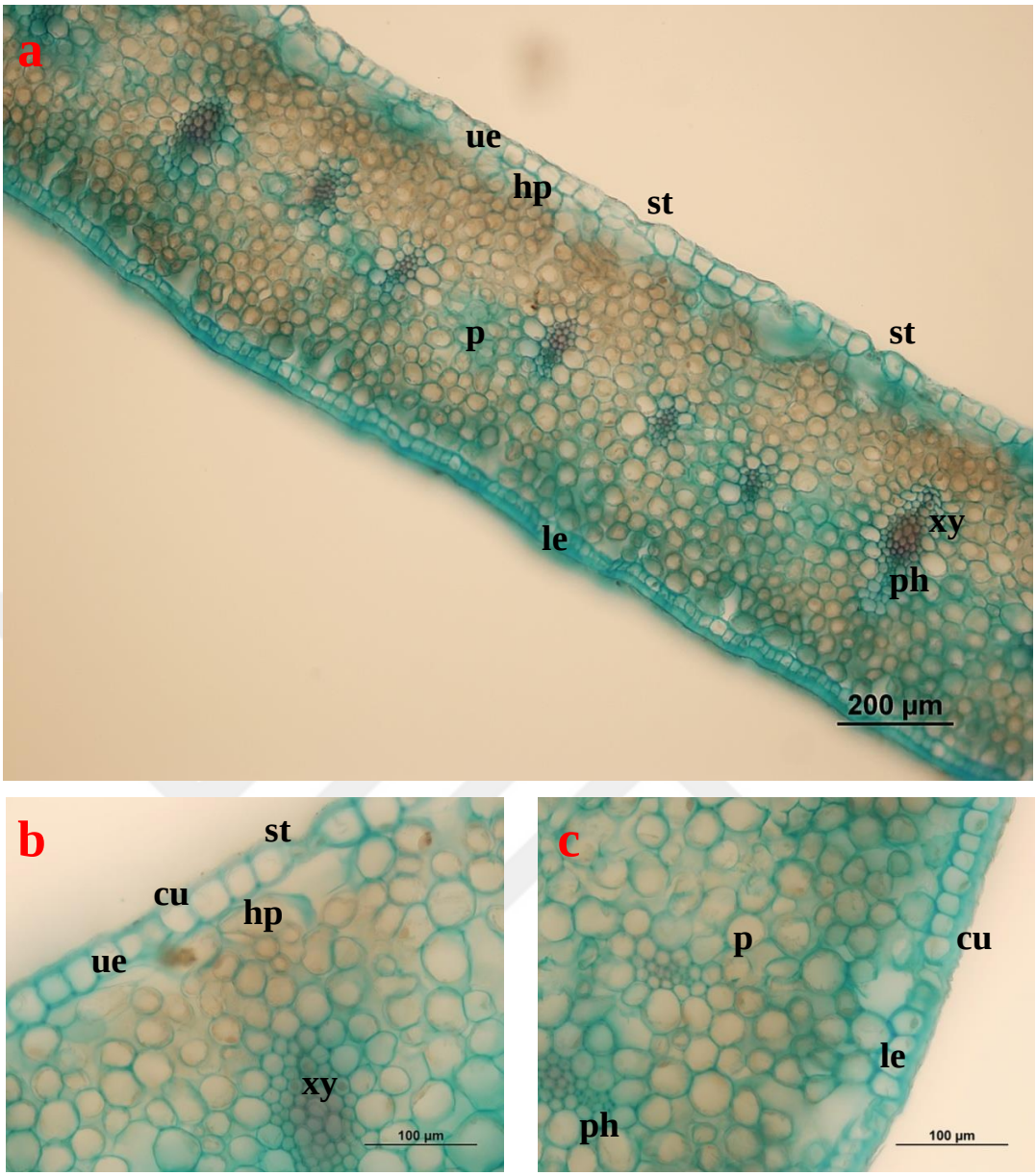

Figure 23. Leaf anatomy of *T. biflora*; a) section of leaf (10x), b) upper epidermis in the leaf section (40x), c) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 35 and 125, respectively. Stomata index is 21,87 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 61 and 141, respectively. Stomata index is 30,19 for the lower epidermis. Stomata index ratio is found as 0,72 (Figure 24).

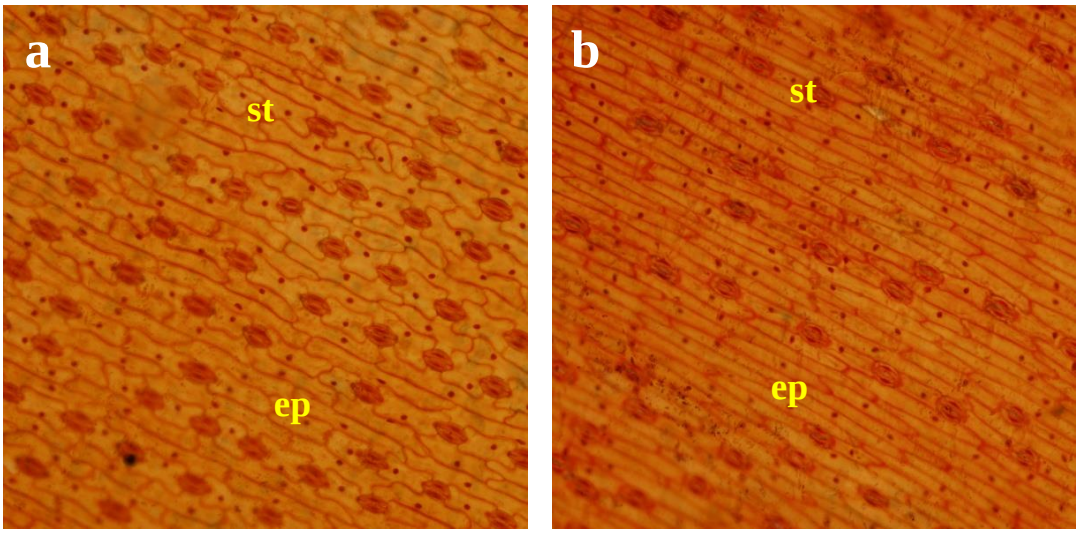

Figure 24. Leaf surface section of *T. biflora*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.6 *Tulipa cinnabarina* K.Perss.

4.1.6.1 Root Anatomy of *T. cinnabarina*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 21−30 × 19−29 µm. The single layered exodermis consisting of hexagon cells is found under the epidermis. Exodermis cells are 22−38 × 22−35 µm. The cortex is composed of 4−5 rows of ovoid parenchymatous cells under the exodermis. These cells are 35−56 × 30−59 µm. The wall of the endodermis is thin. The phloem components are located around 3−6 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 25).

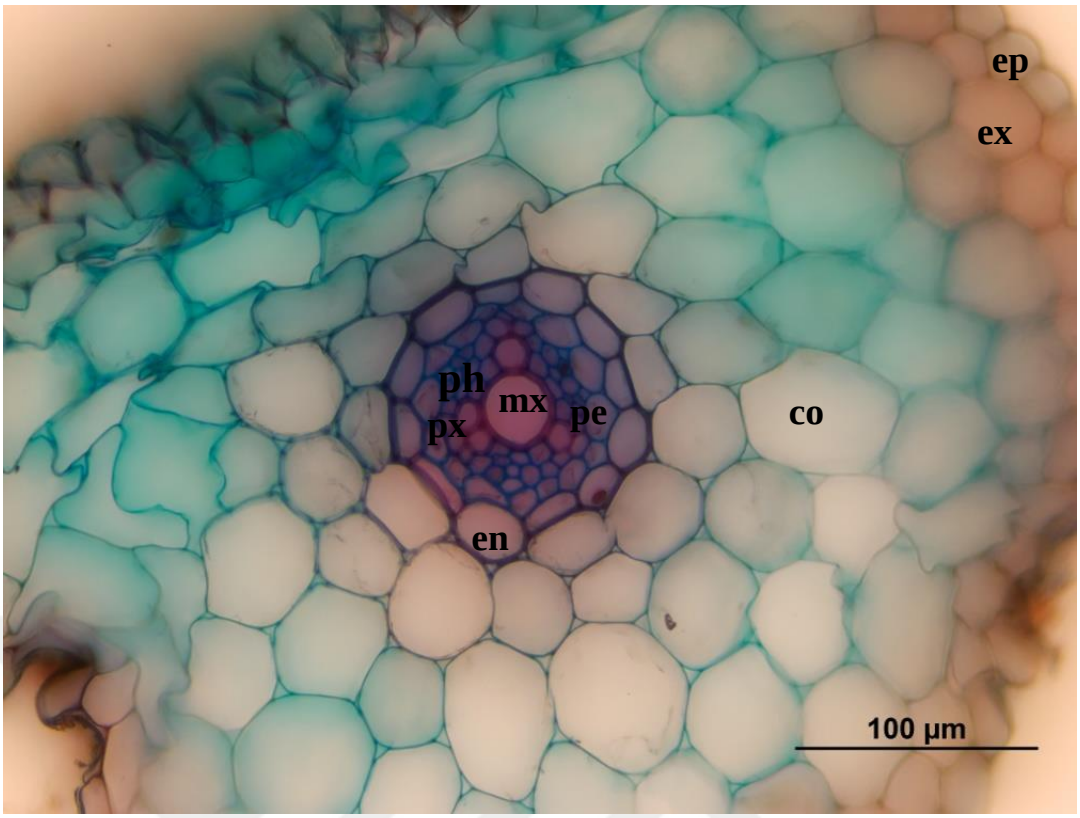

Figure 25. Root anatomy of *T. cinnabarina*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.6.2 Stem (Scape) Anatomy of *T. cinnabarina*

The epidermis is composed of rectangular cells which are 12−19 × 26−32 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 35−48 × 9−11 µm. The cortex comprises parenchymatous cells. The parenchyma consists of multilayered spheroid cells which are 30−60 × 39−55 µm. The sclerenchyma tissue is either lacking or consists of 3−4 layered spheroid cells. The stem contains averagely 36 vascular bundles of various sizes in the vascular cylinder (Figure 26).

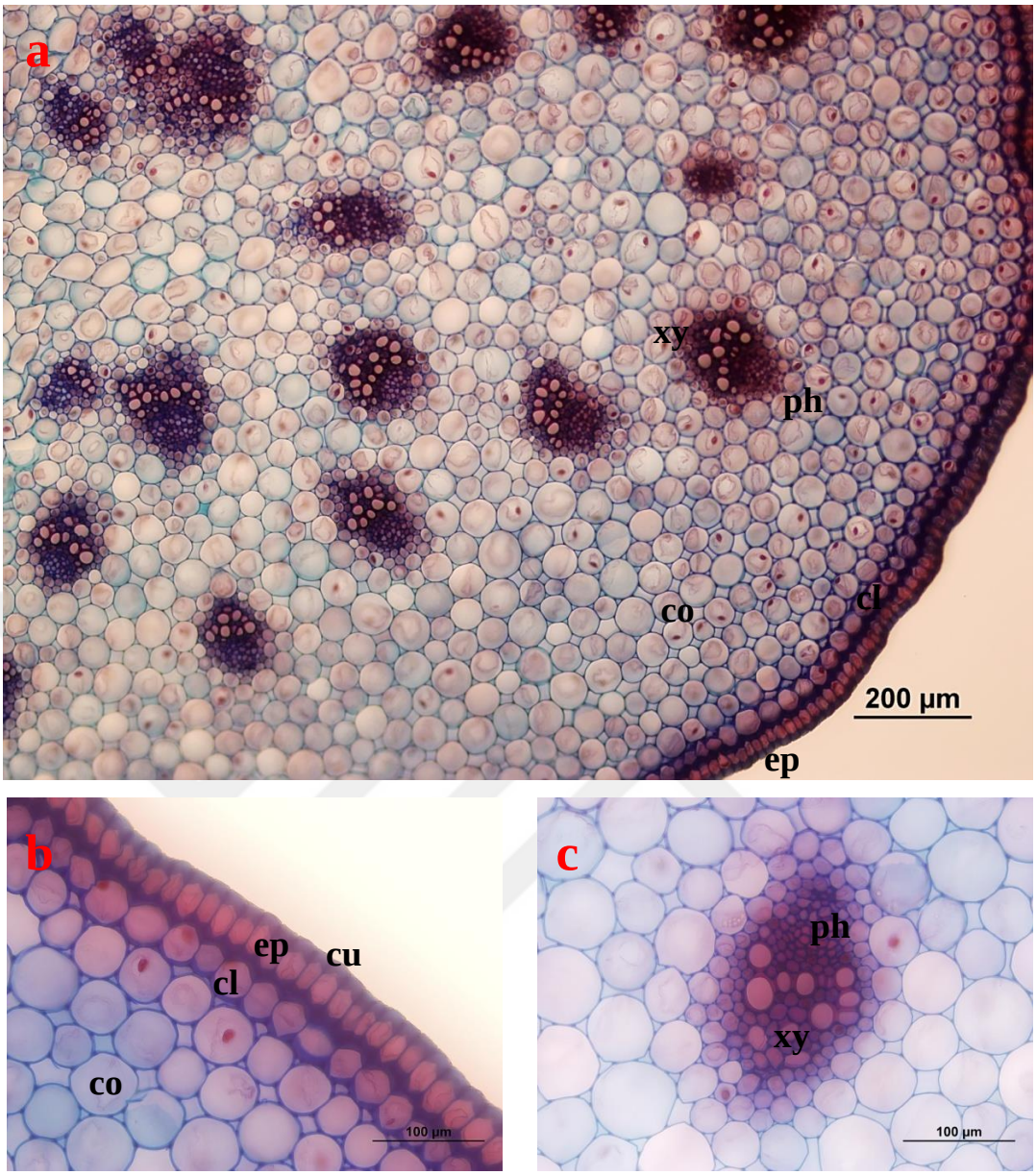

Figure 26. Stem anatomy of *T. cinnabarina*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, ph: phloem, xy: xylem.

4.1.6.3 Leaf Anatomy of *T. cinnabarina*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 10−29 × 20−30 and 14−20 × 15−19 µm, respectively. The parenchymatous cells composed of 6−15 layered spheroid cells are 20−32 × 20−59 µm (Figure 27).

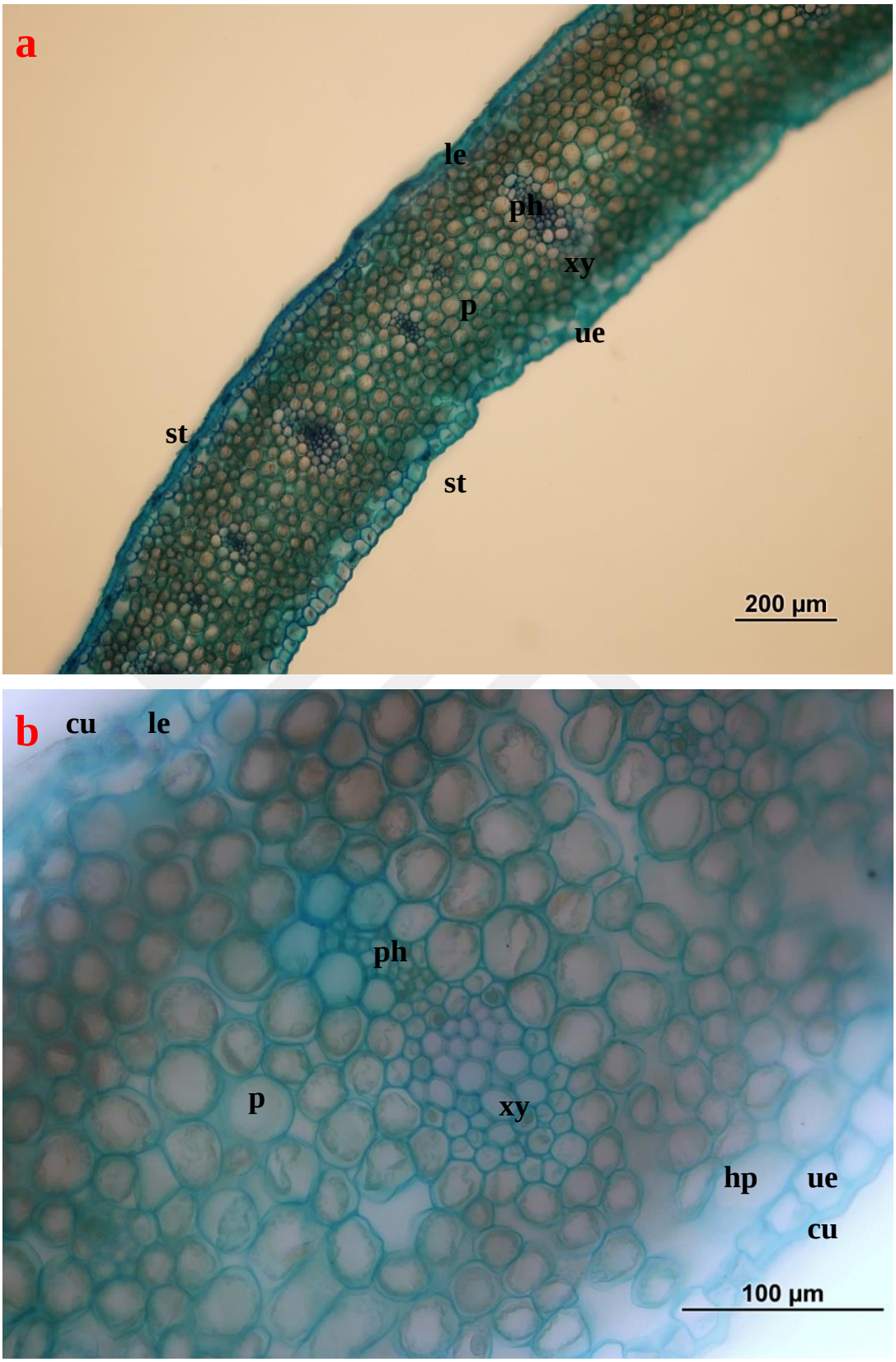

Figure 27. Leaf anatomy of *T. cinnabarina*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 28 and 139, respectively. Stomata index is 16,76 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 63 and 108, respectively. Stomata index is 36,84 for the lower epidermis. Stomata index ratio is found as 0,45 (Figure 28).

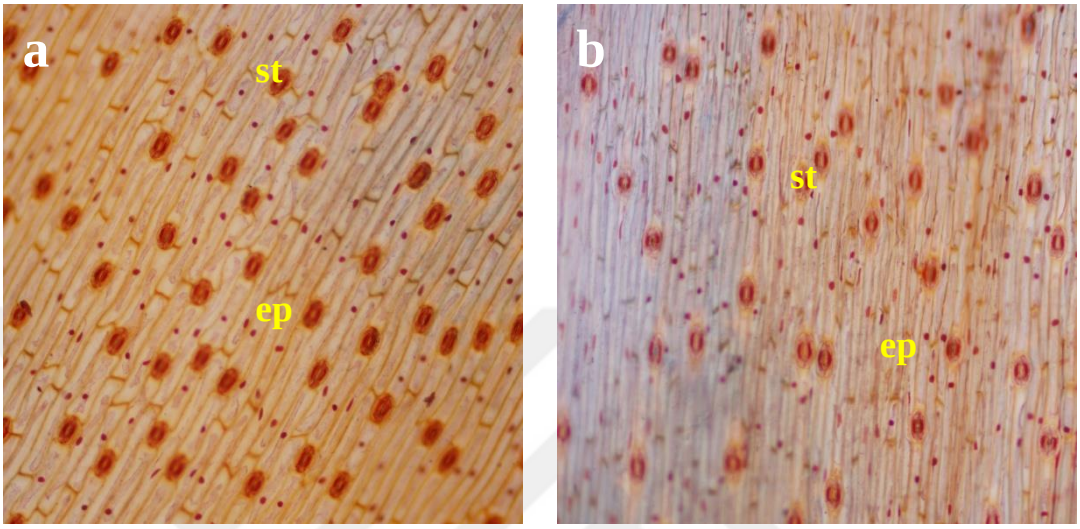

Figure 28. Leaf surface section of *T. cinnabarina* ; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.7 *Tulipa clusiana* DC.

4.1.7.1 Root Anatomy of *T. clusiana*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 10−20 × 10−19 µm. The single layered exodermis consisting of ovoid cells is found under the epidermis. Exodermis cells are 17−34 × 20−35 µm. The cortex is composed of multilayered of irregular parenchymatous cells under the exodermis. These cells are 30−37 × 20−36 µm. There isn't wall thickening of the endodermis. The phloem components are located around 4−8 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 29).

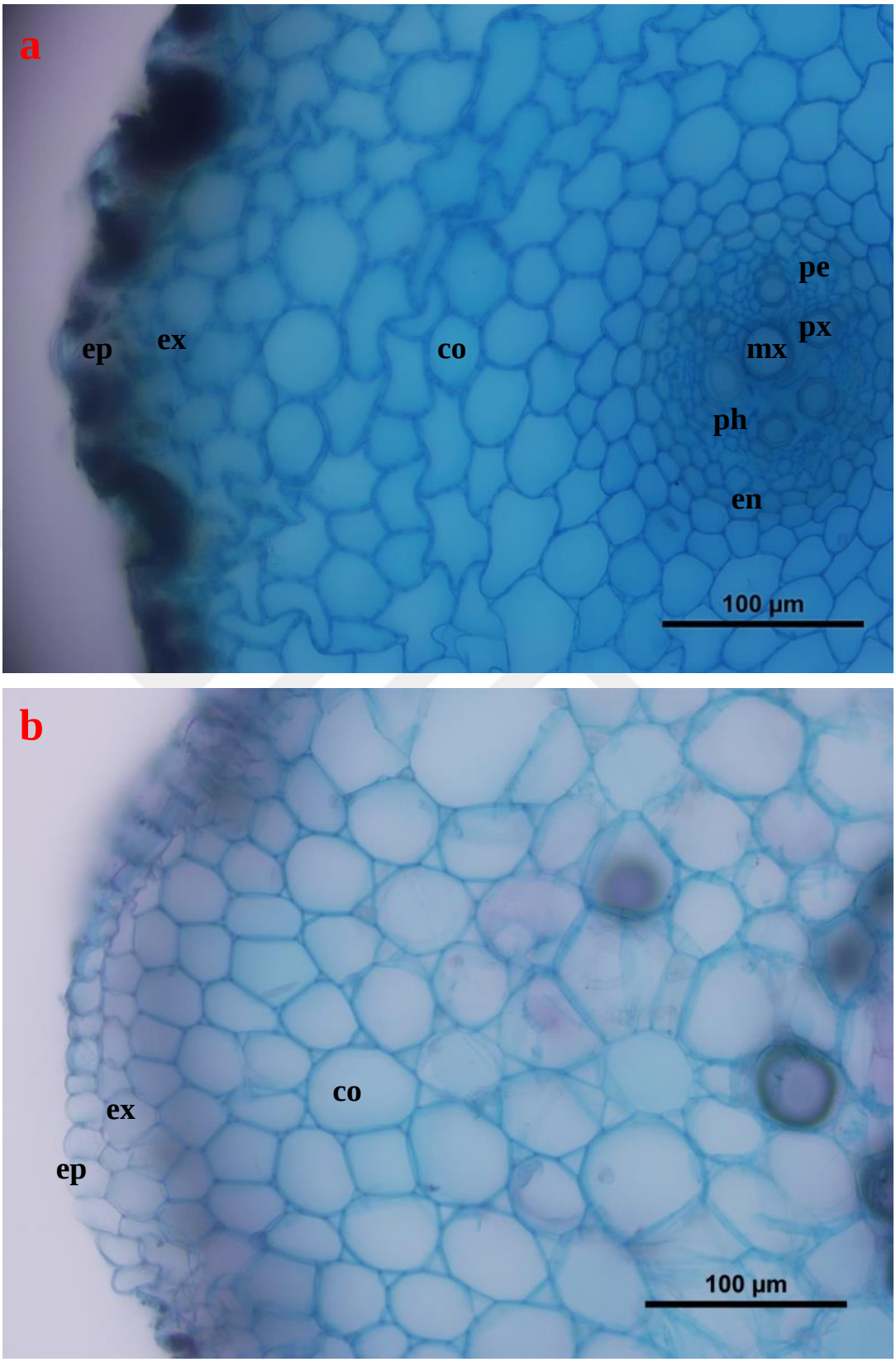

Figure 29. Root anatomy of *T. clusiana*; a) section of root (40x), b) epidermis, exodermis and cortex in the root section (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.7.2 Stem (Scape) Anatomy of *T. clusiana*

The epidermis is composed of rectangular cells which are 12−30 × 19−22 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 26−36 × 9−12 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 6−7 layered ovoid or spheroid cells which are 55−70 × 55−70 µm. The sclerenchyma tissue consists of 2−4 layered spheroid cells. The stem contains averagely 36 vascular bundles of various sizes in the vascular cylinder (Figure 30).

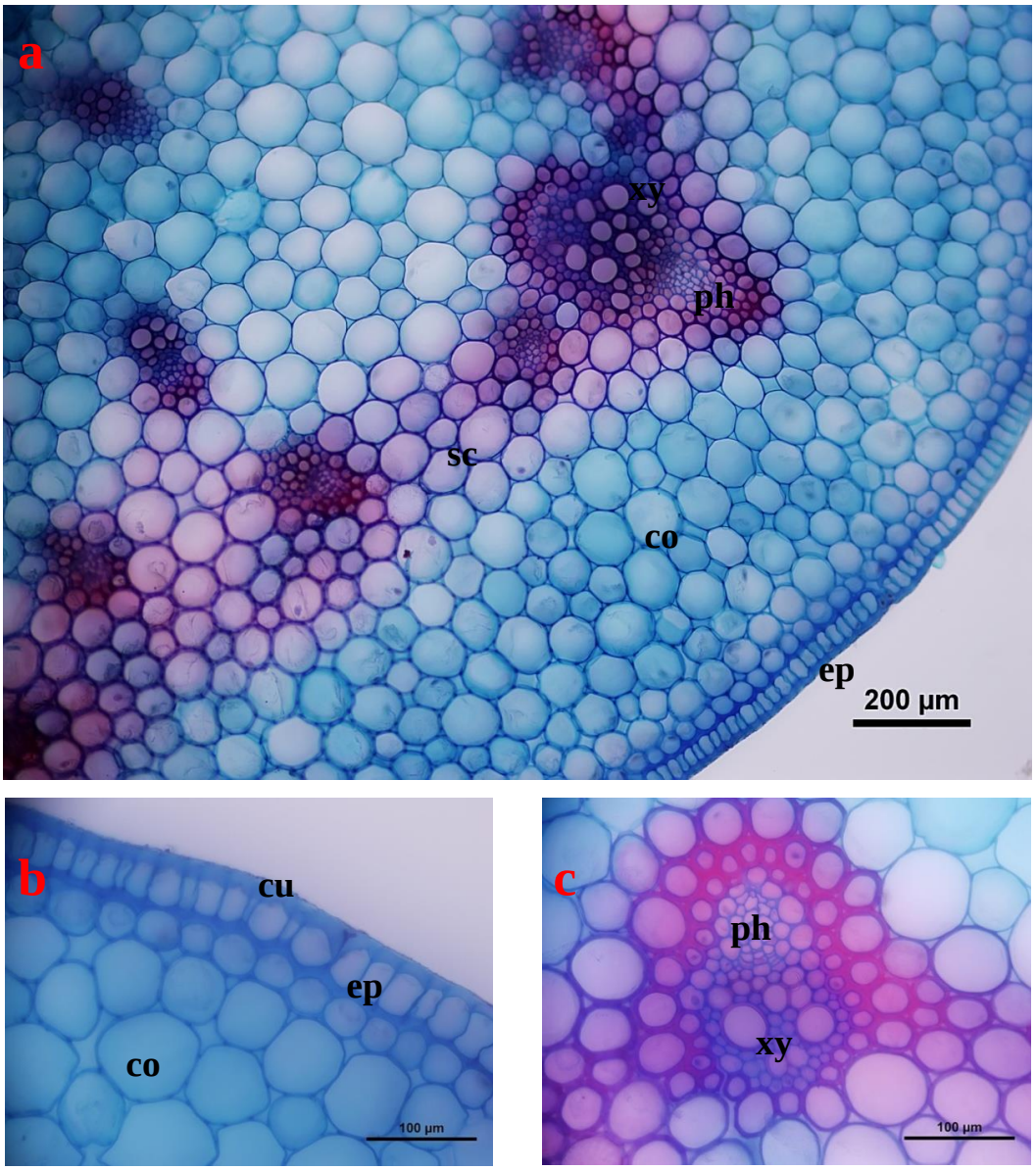

Figure 30. Stem anatomy of *T. clusiana*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.7.3 Leaf Anatomy of *T. clusiana*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 11−28 × 14−31 and 15−46 × 29−52 µm, respectively. The parenchymatous cells composed of 9−14 layered ovoid or spheroid cells are 35−61 × 32−59 µm (Figure 31).

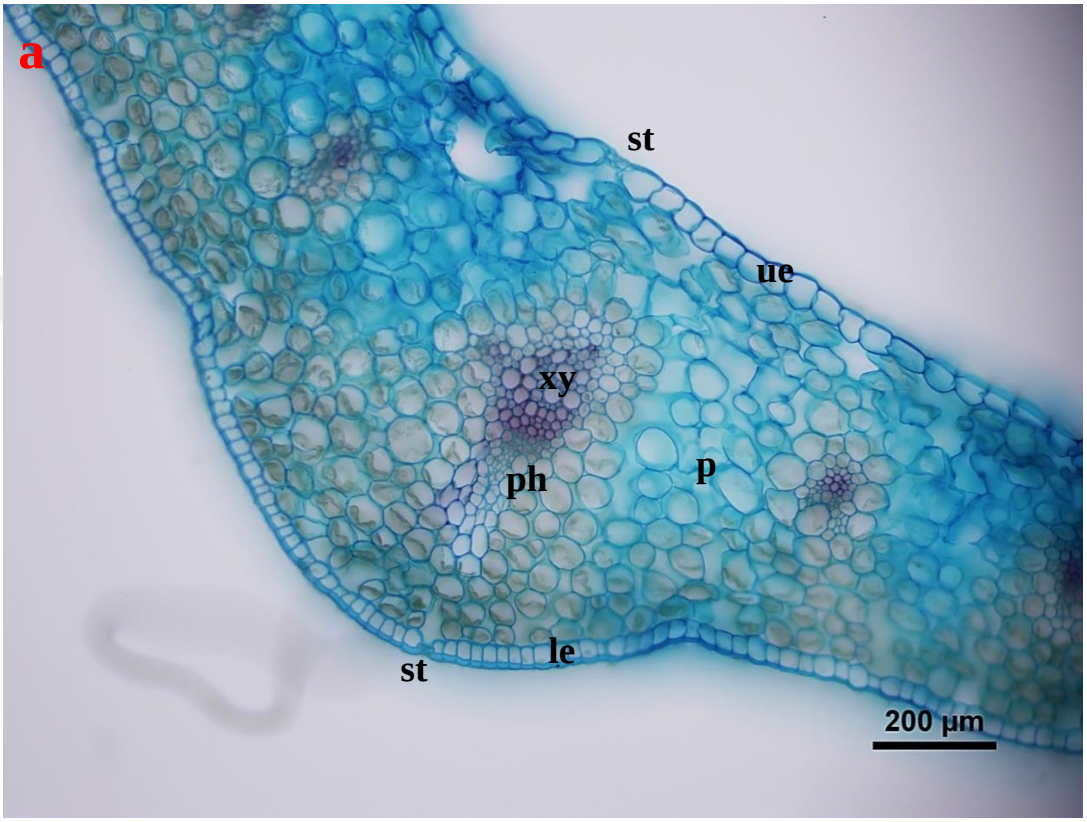

Figure 31. Leaf anatomy of *T. clusiana*; a) section of leaf (10x), b) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, xy: xylem, ph: phloem, st: stomata.

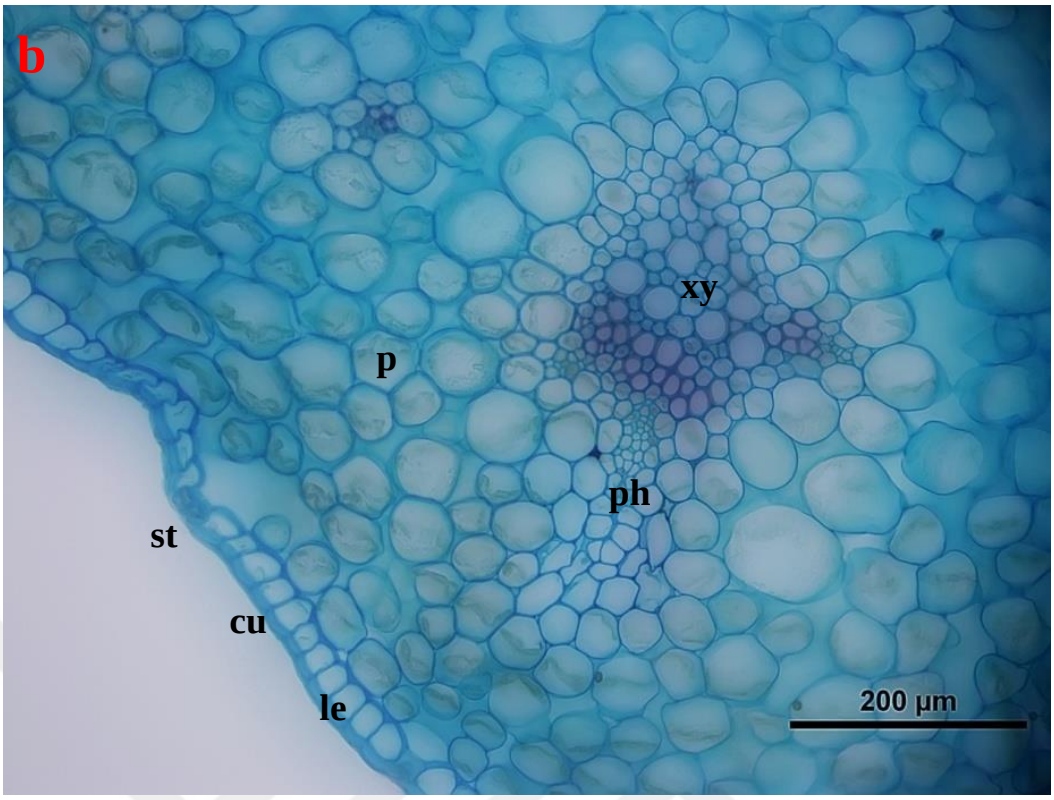

Figure 31. Leaf anatomy of *T. clusiana*; a) section of leaf (10x), b) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, xy: xylem, ph: phloem, st: stomata (continued).

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 54 and 115, respectively. Stomata index is 31,95 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 58 and 135, respectively. Stomata index is 30,05 for the lower epidermis. Stomata index ratio is found as 1,06 (Figure 32).

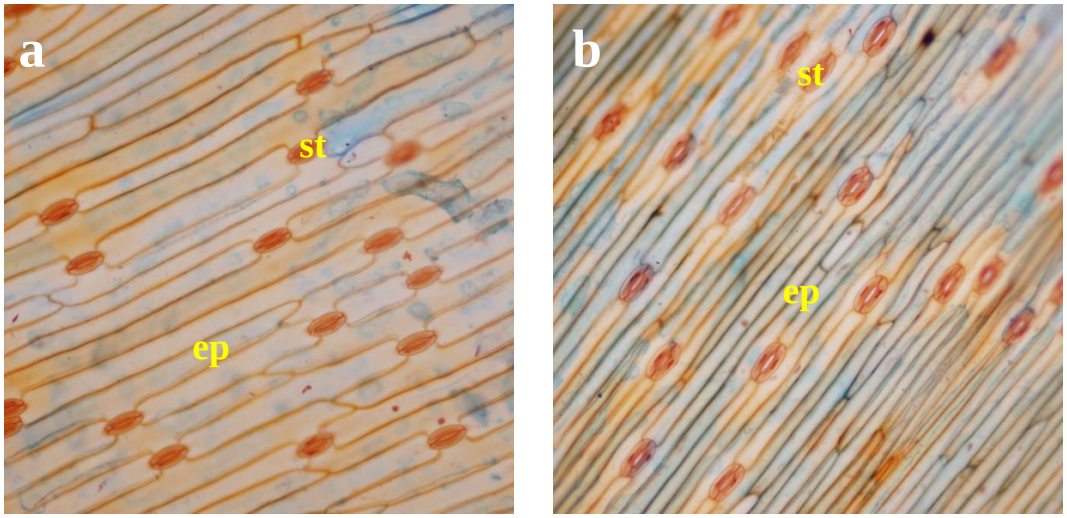

Figure 32. Leaf surface section of *T. clusiana*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.8. *Tulipa humilis* Herb.

4.1.8.1 Root Anatomy of *T. humilis*

Transverse section of the root includes a single-layered epidermis composed of small and irregular shapes on the outermost surface. Epidermis cells are 8−20 × 10−20 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 20−37 × 23−34 µm. The cortex is composed of 4−5 rows of ovoid parenchymatous cells under the exodermis. These cells are 37−60 × 33−59 µm. The wall of the endodermis is thin. The phloem components are located around 3−6 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 33).

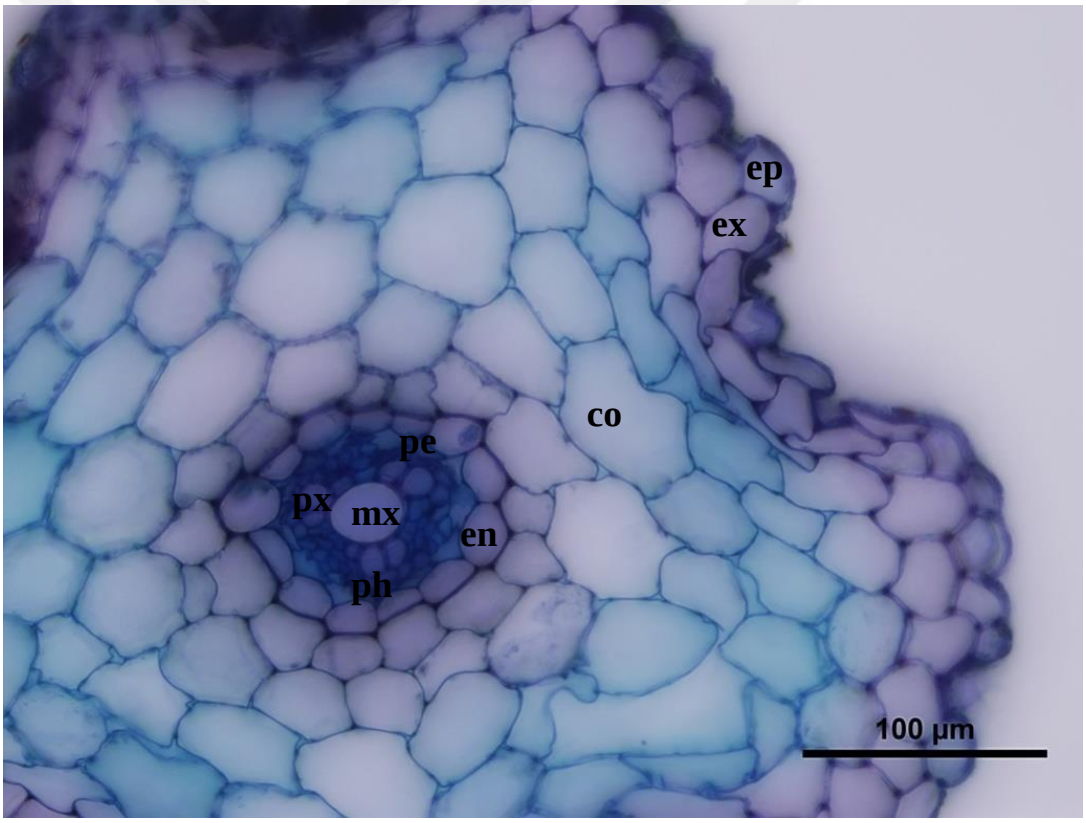

Figure 33. Root anatomy of *T. humilis*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.8.2 Stem (Scape) Anatomy of *T. humilis*

The epidermis is composed of rectangular cells which are 9−21 × 15−26 µm. The single-layered angular collenchyma is either lacking or found under the

epidermis. The collenchyma composes of ovoid cells which are 34−45 × 10−12 µm. The cortex comprises parenchymatous cells. The parenchyma consists of multilayered ovoid or spheroid cells which are 30−52 × 33−54 µm. The sclerenchyma tissue is either lacking or consists of 2−4 layered spheroid cells. The stem contains averagely 30 vascular bundles of various sizes in the vascular cylinder (Figure 34).

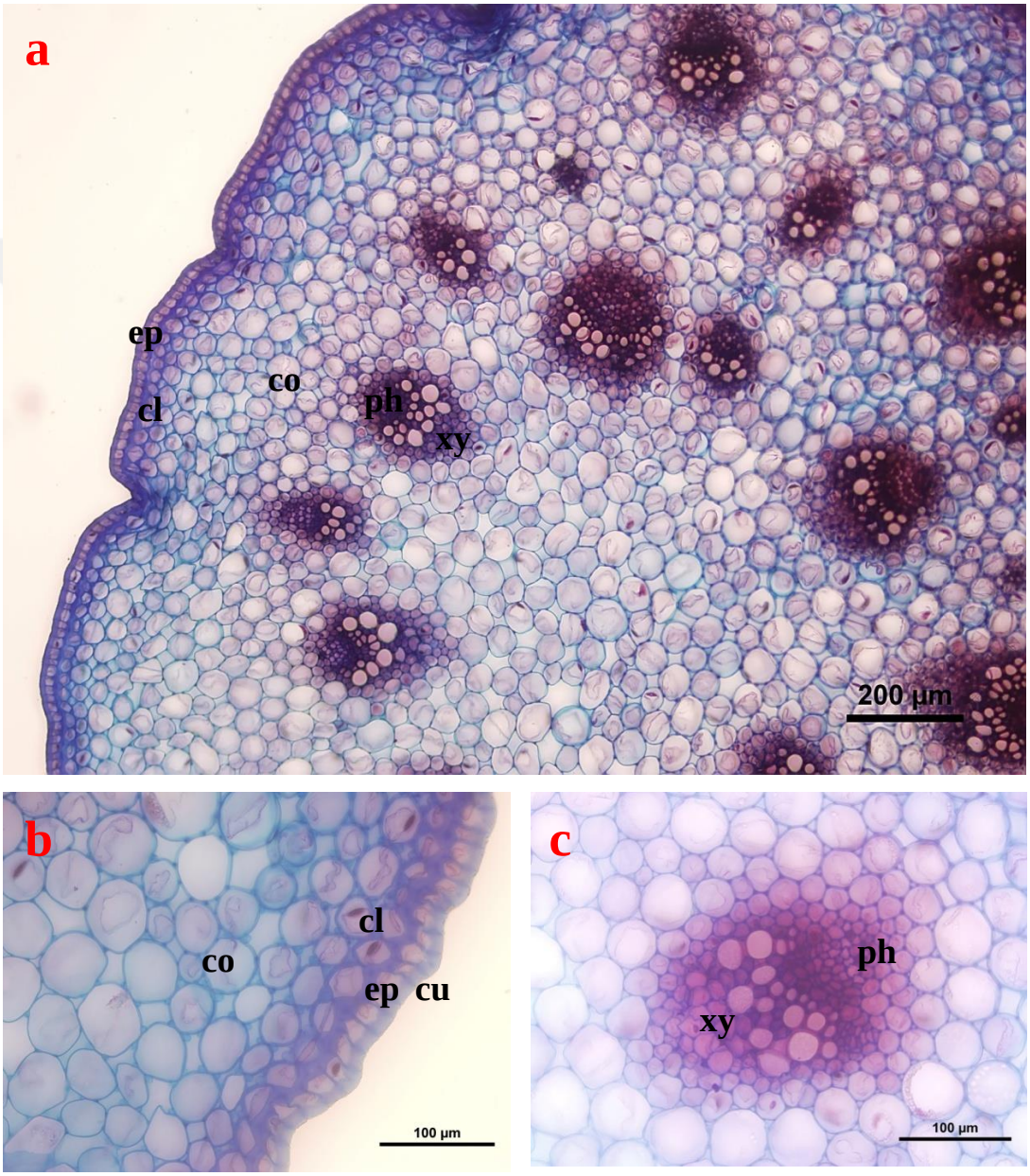

Figure 34. Stem anatomy of *T. humilis*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, ph: phloem, xy: xylem.

4.1.8.3 Leaf Anatomy of *T. humilis*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 20−40 × 21−41 and 19−49 × 30−42 µm, respectively. The parenchymatous cells composed of 7−11 layered ovoid or spheroid are 29−49 × 27−59 µm. 2−3 row of parenchymatous cells are small and flat cells under upper epidermis. The gaps under the stomata are more (Figure 35).

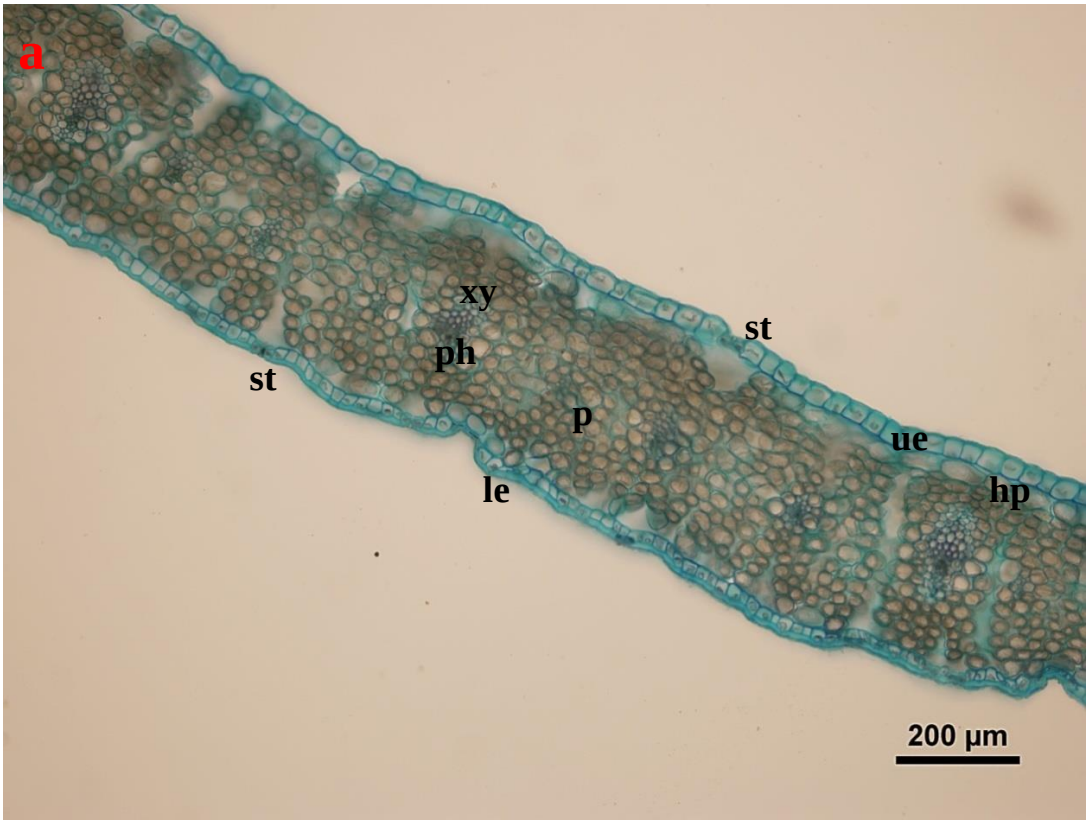

Figure 35. Leaf anatomy of *T. humilis*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

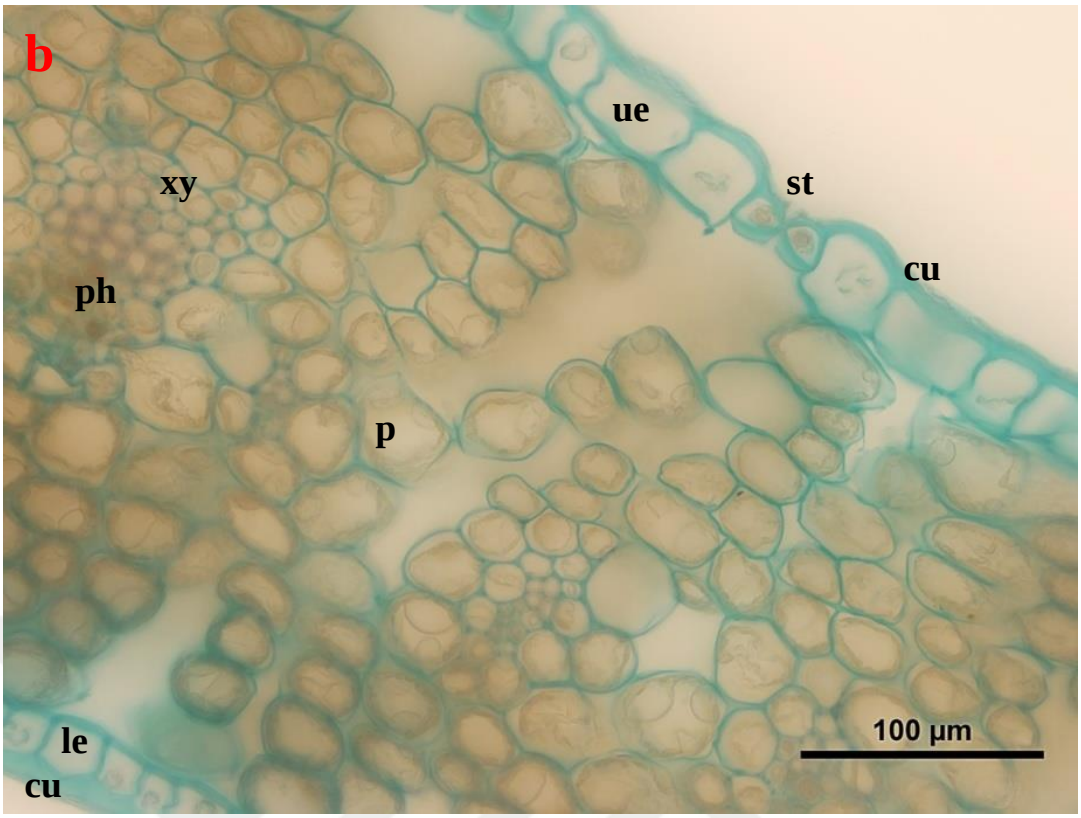

Figure 35. Leaf anatomy of *T. humilis*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata (continued).

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 49 and 109, respectively. Stomata index is 31,01 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 59 and 143, respectively. Stomata index is 29,20 for the lower epidermis. Stomata index ratio is found as 1,06 (Figure 36).

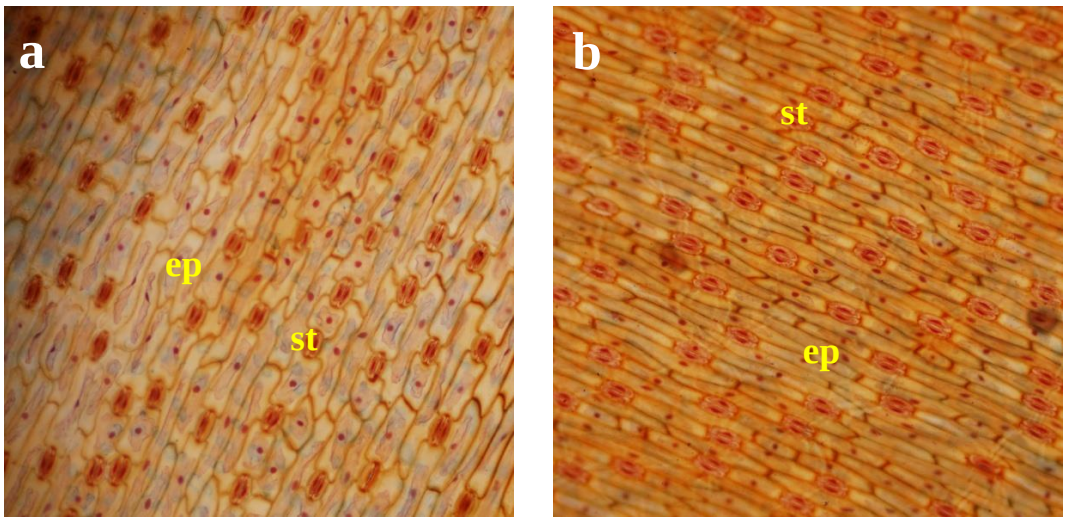

Figure 36. Leaf surface section of *T. humilis*; a) lower epidermis, b) upper epidermis, ep: epidermis, st**:** stomata

4.1.9 *Tulipa julia* C. Koch

4.1.9.1 Root Anatomy of *T. julia*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and regular cells on the outermost surface. Epidermis cells are 10−32 × 12−32 µm. The single layered exodermis consisting of ovoid or hexagon cells is found under the epidermis. Exodermis cells are 16−42 × 20−45 µm. The cortex is composed of 4−5 rows of ovoid or spheroid parenchymatous cells under the exodermis. These cells are 25−58 × 30−62 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 3−9 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 37).

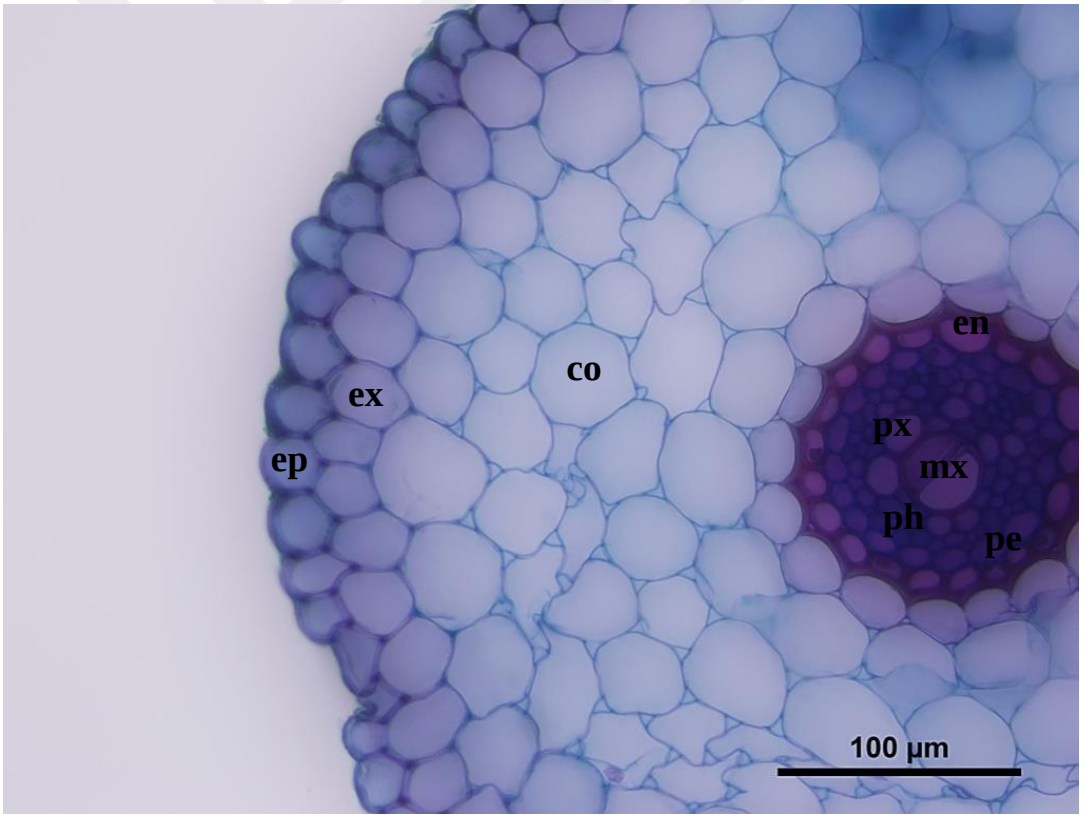

Figure 37. Root anatomy of *T. julia*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.9.2 Stem (Scape) Anatomy of *T. julia*

The epidermis is composed of rectangular cells which are 8−37 × 10−29 µm. The single-layered lamellar collenchyma is either lacking or found under the

epidermis. The collenchyma composes of ovoid cells which are 11−35 × 11−33 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 4−5 layered ovoid or spheroid cells which are 20−78 × 20−79 µm. The sclerenchyma tissue is either lacking or consists of 2−6 layered spheroid cells. The stem contains averagely 76 vascular bundles of various sizes in the vascular cylinder (Figure 38).

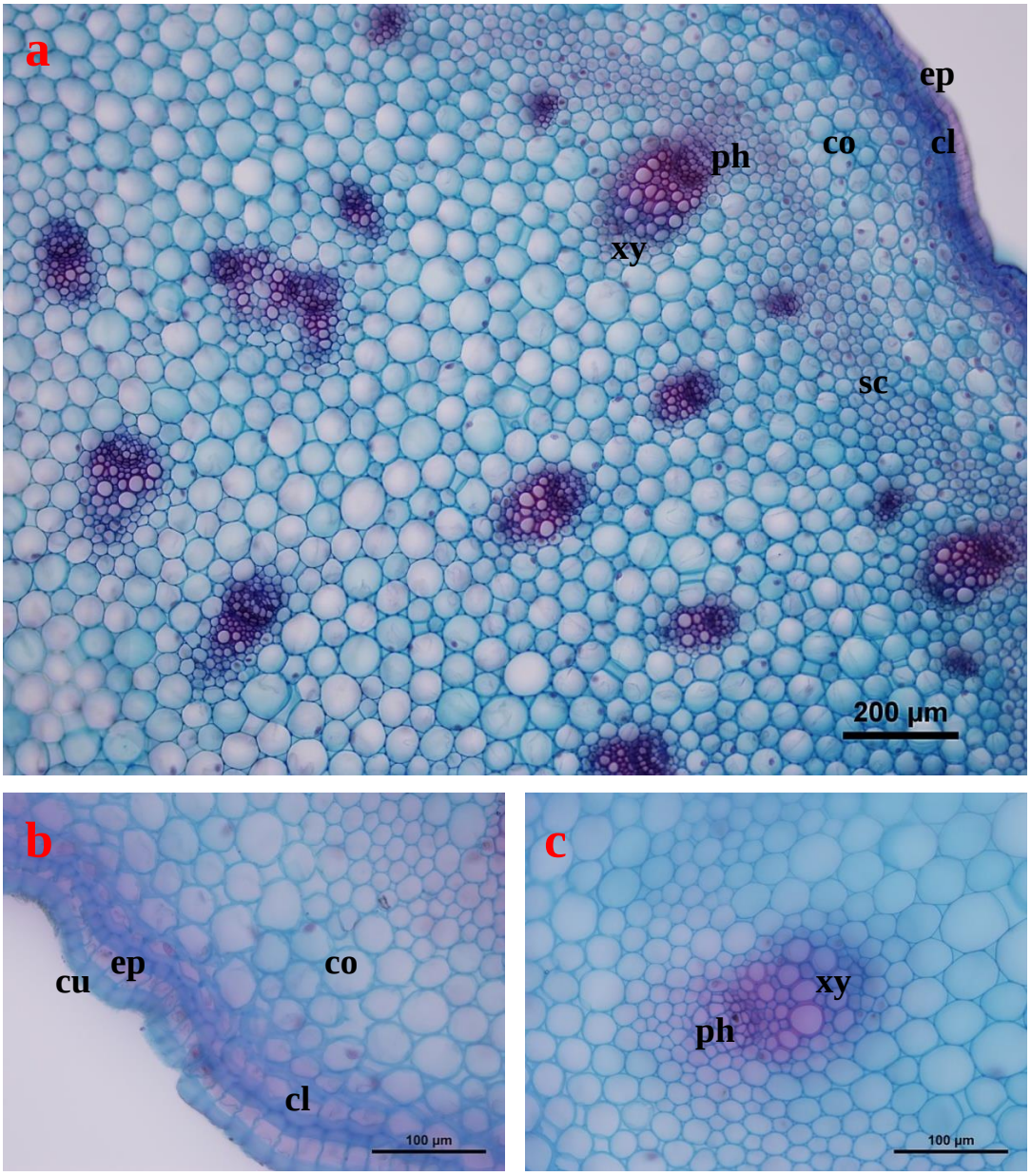

Figure 38. Stem anatomy of *T. julia*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.9.3 Leaf Anatomy of *T. julia*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 15−50 × 10−40 and 12−32 × 10−30 µm, respectively. The parenchymatous cells composed of 5−16 layered ovoid or spheroid cells are 19−57 × 20−50 µm (Figure 39).

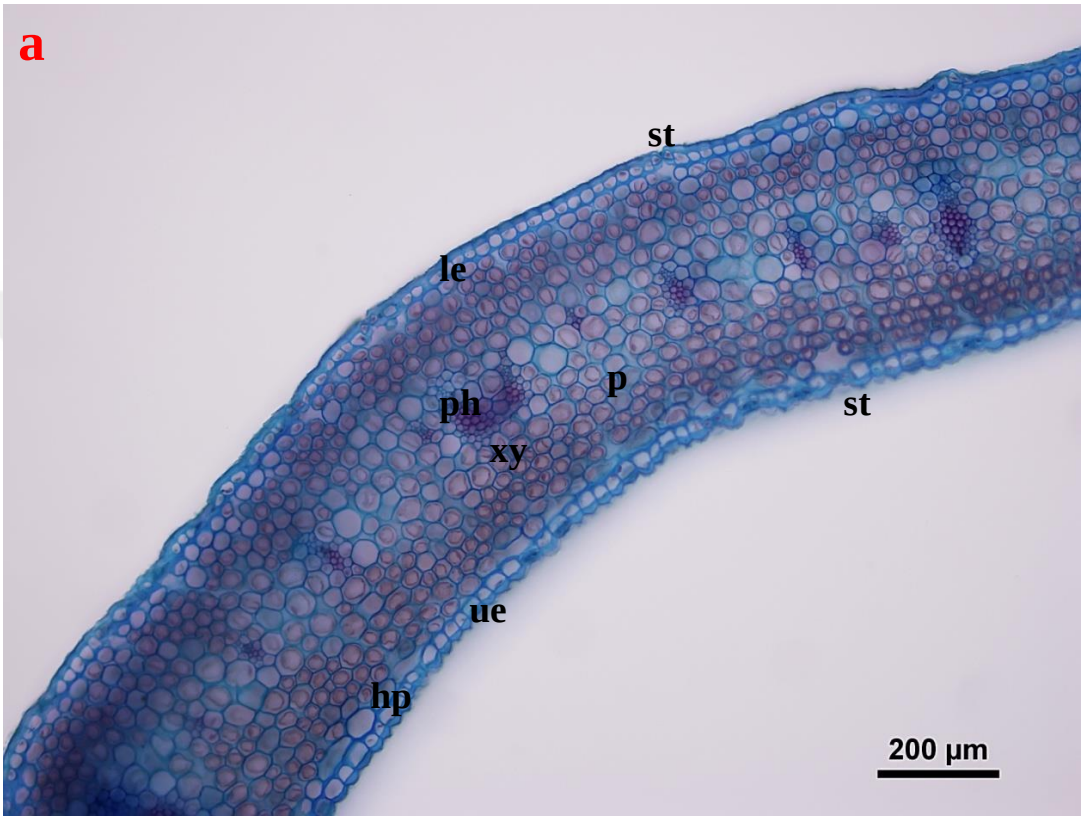

Figure 39. Leaf anatomy of *T. julia*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

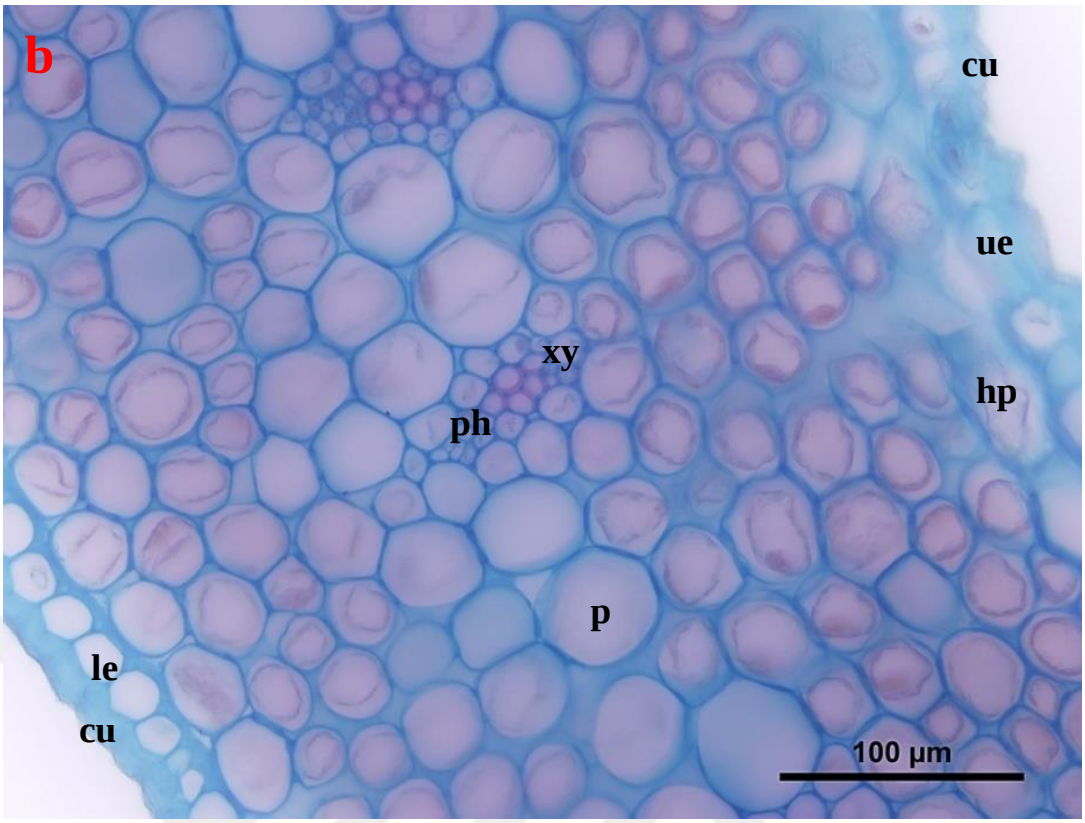

Figure 39. Leaf anatomy of *T. julia*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata (continued).

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 71 and 169, respectively. Stomata index is 29,58 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 77 and 174, respectively. Stomata index is 30,67 for the lower epidermis. Stomata index ratio is found as 0,96 (Figure 40).

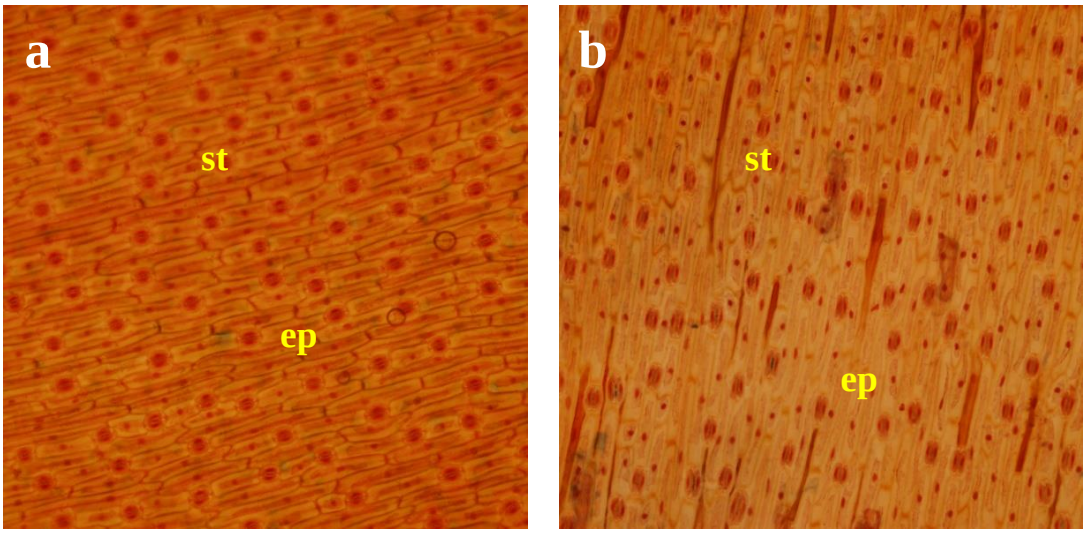

Figure 40. Leaf surface section of *T. julia*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.10 *Tulipa koyuncui* Eker & Babaç

4.1.10.1 Root Anatomy of *T. koyuncui*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and regular cells on the outermost surface. Epidermis cells are 16−26 × 11−25 µm. The single layered exodermis consisting of irregular or pentagon cells is found under the epidermis. Exodermis cells are 20−26 × 14−33 µm. The cortex is composed of 4−5 rows of spheroid parenchymatous cells under the exodermis. These cells are 30−40 × 30−40 µm. The wall of the endodermis is thin. The phloem components are located around 3−5 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 41).

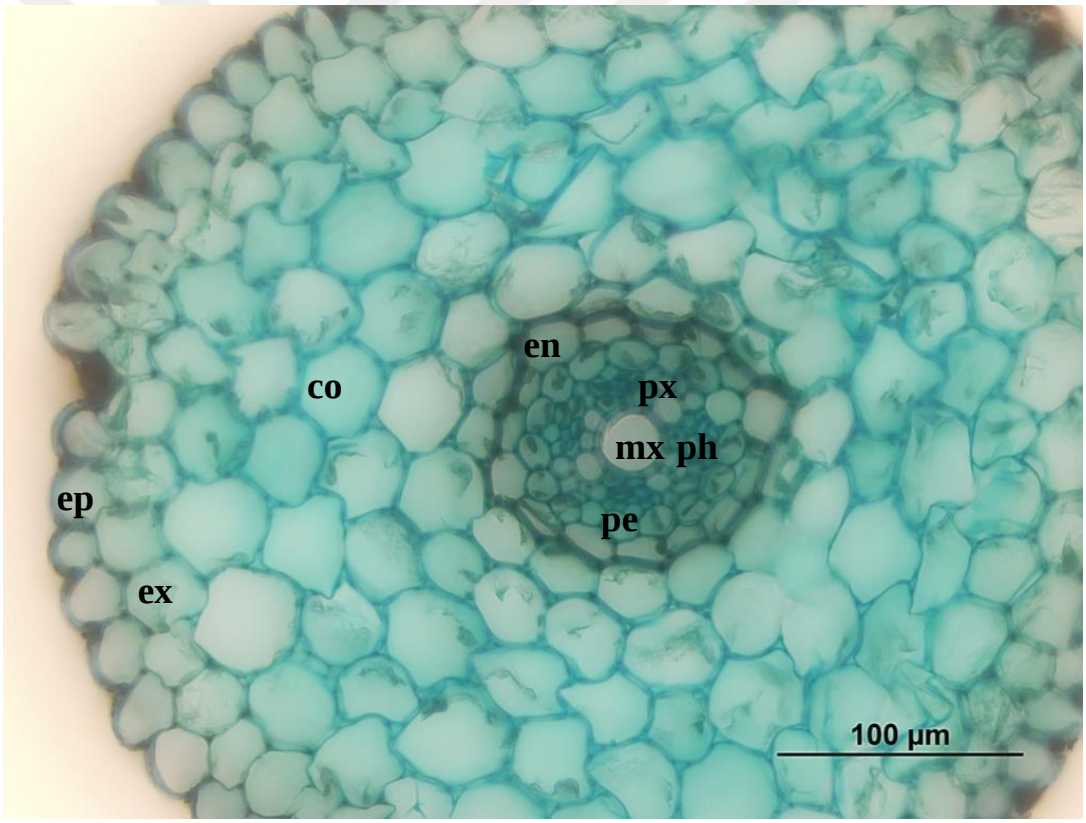

Figure 41. Root anatomy of *T. koyuncui*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.10.2 Stem (Scape) Anatomy of *T. koyuncui*

The epidermis is composed of rectangular cells which are 9−15 × 12−20 µm. The single-layered lamellar collenchyma is either lacking or found under the

epidermis. The collenchyma composes of ovoid cells which are 30−42 × 9−11 µm. The cortex comprises parenchymatous cells. The parenchyma consists of 5−6 layered spheroid cells which are 30−55 × 33−50 µm. The sclerenchyma tissue is either lacking or consists of 2−3 layered spheroid cells. The stem contains averagely 31 vascular bundles of various sizes in the vascular cylinder (Figure 42).

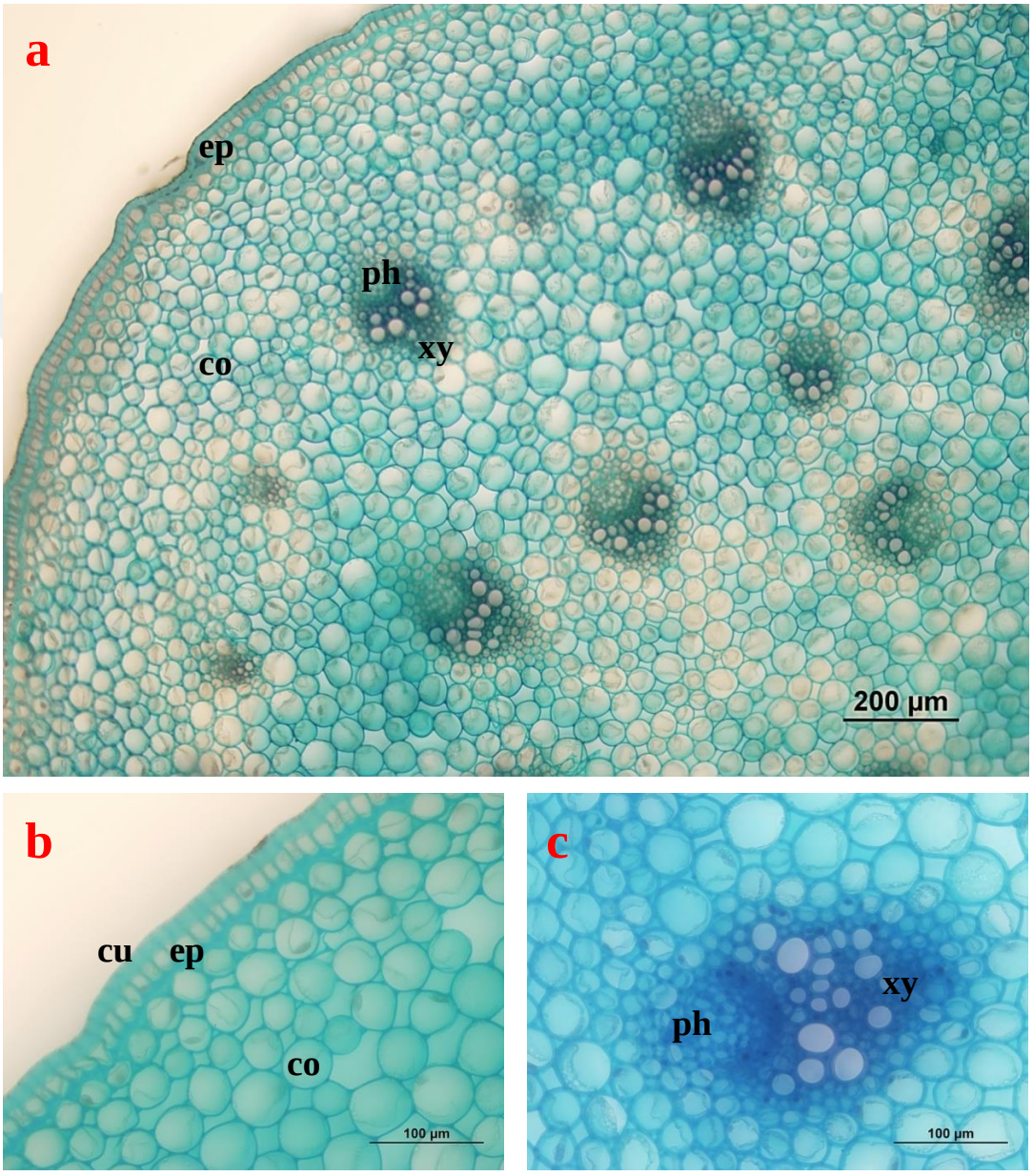

Figure 42. Stem anatomy of *T. koyuncui*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, ph: phloem, xy: xylem.

4.1.10.3 Leaf Anatomy of *T. koyuncui*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 28−40 × 20−30 and 10−20 × 9−16 µm, respectively. The parenchymatous cells composed of 8−14 layered ovoid or spheroid cells are 20−37 × 25−40 µm (Figure 43).

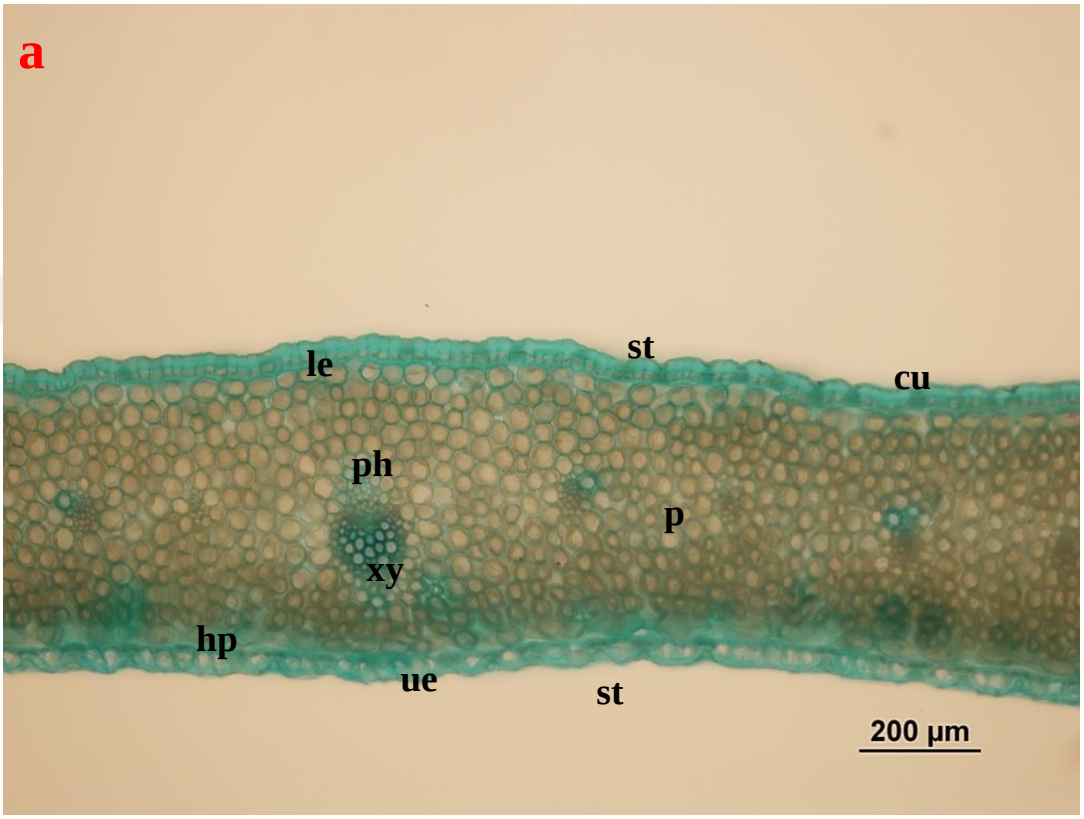

Figure 43. Leaf anatomy of *T. koyuncui*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

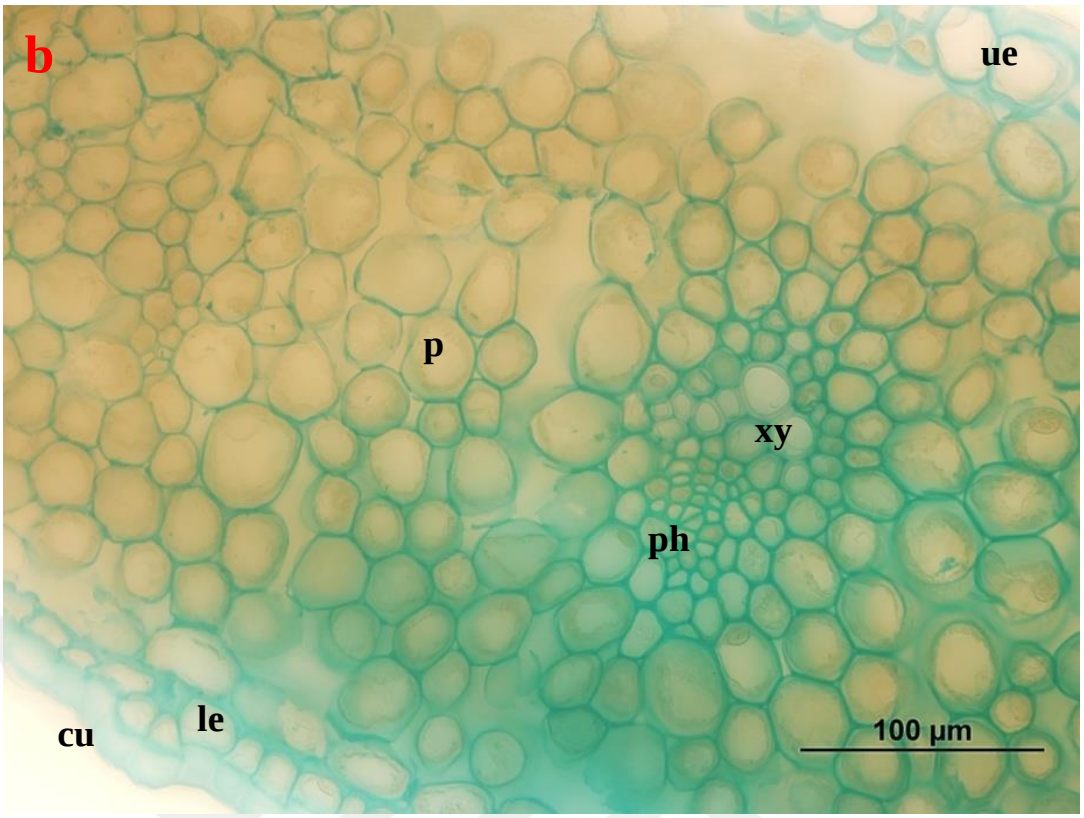

Figure 43. Leaf anatomy of *T. koyuncui*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata (continued).

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 79 and 177, respectively. Stomata index is 30,85 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 82 and 165, respectively. Stomata index is 33,19 for the lower epidermis. Stomata index ratio is found as 0,92 (Figure 44).

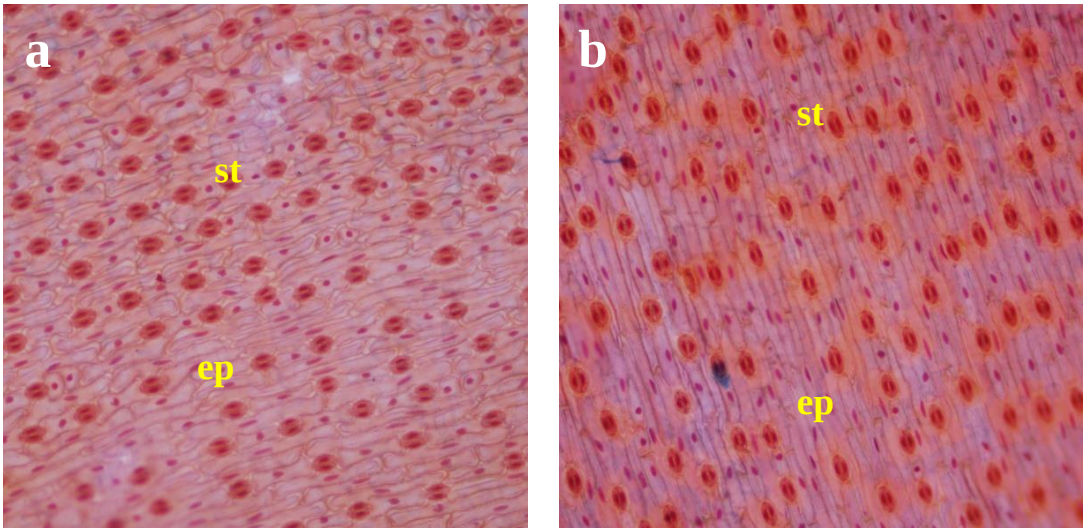

Figure 44. Leaf surface section of *T. koyuncui*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.11 *Tulipa orphanidea* Boiss. ex Heldr.

4.1.11.1 Root Anatomy of *T. orphanidea*

Transverse section of the root includes a single-layered epidermis composed of ovoid and regular cells on the outermost surface. Epidermis cells are 10−29 × 15−30 µm. The single layered exodermis consisting of pentagon cells is found under the epidermis. Exodermis cells are 18−41 × 20−40 µm. The cortex is composed of 5−6 rows of ovoid parenchymatous cells under the exodermis. These cells are 30−64 × 30−65 µm. The wall of the endodermis is thin. The phloem components are located around 3−8 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 45).

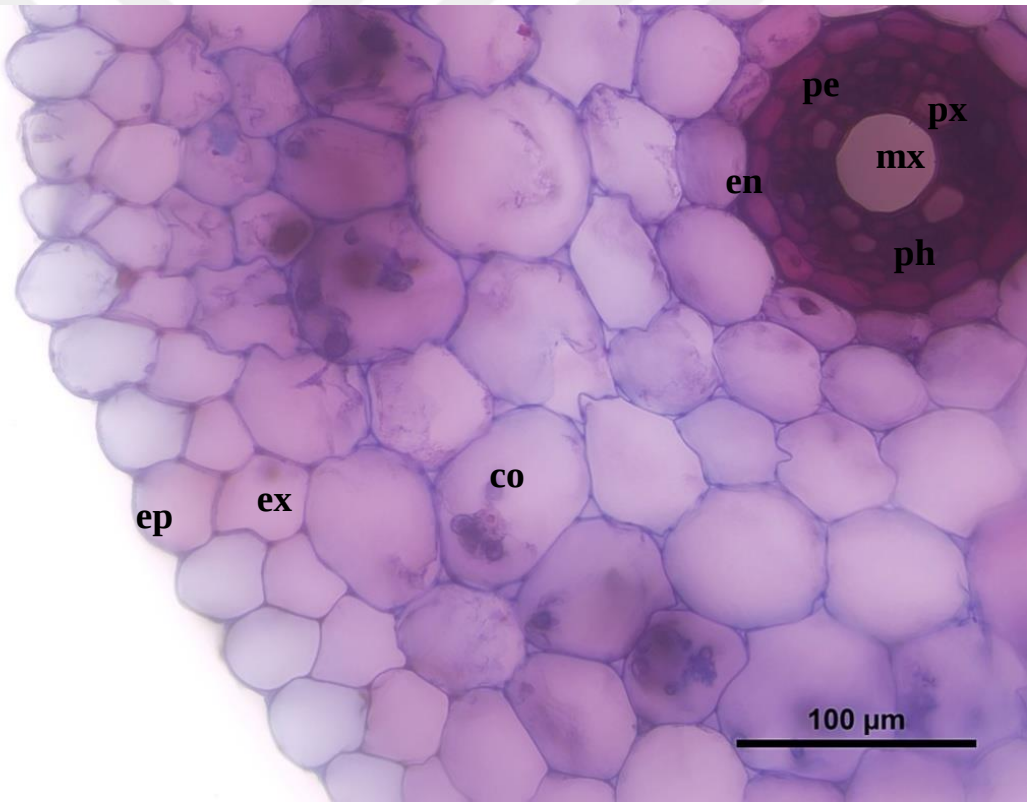

Figure 45. Root anatomy of *T. orphanidea*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.11.2 Stem (Scape) Anatomy of *T. orphanidea*

The epidermis is composed of rectangular cells which are 10−32 × 10−25 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 35−49 × 9−18 µm.

The cortex comprises parenchymatous cells. The parenchyma consists of multilayered ovoid or spheroid cells which are 30−60 × 20−62 µm. The sclerenchyma tissue is either lacking or consists of 2−5 layered spheroid cells. The stem contains averagely 31 vascular bundles of various sizes in the vascular cylinder (Figure 46).

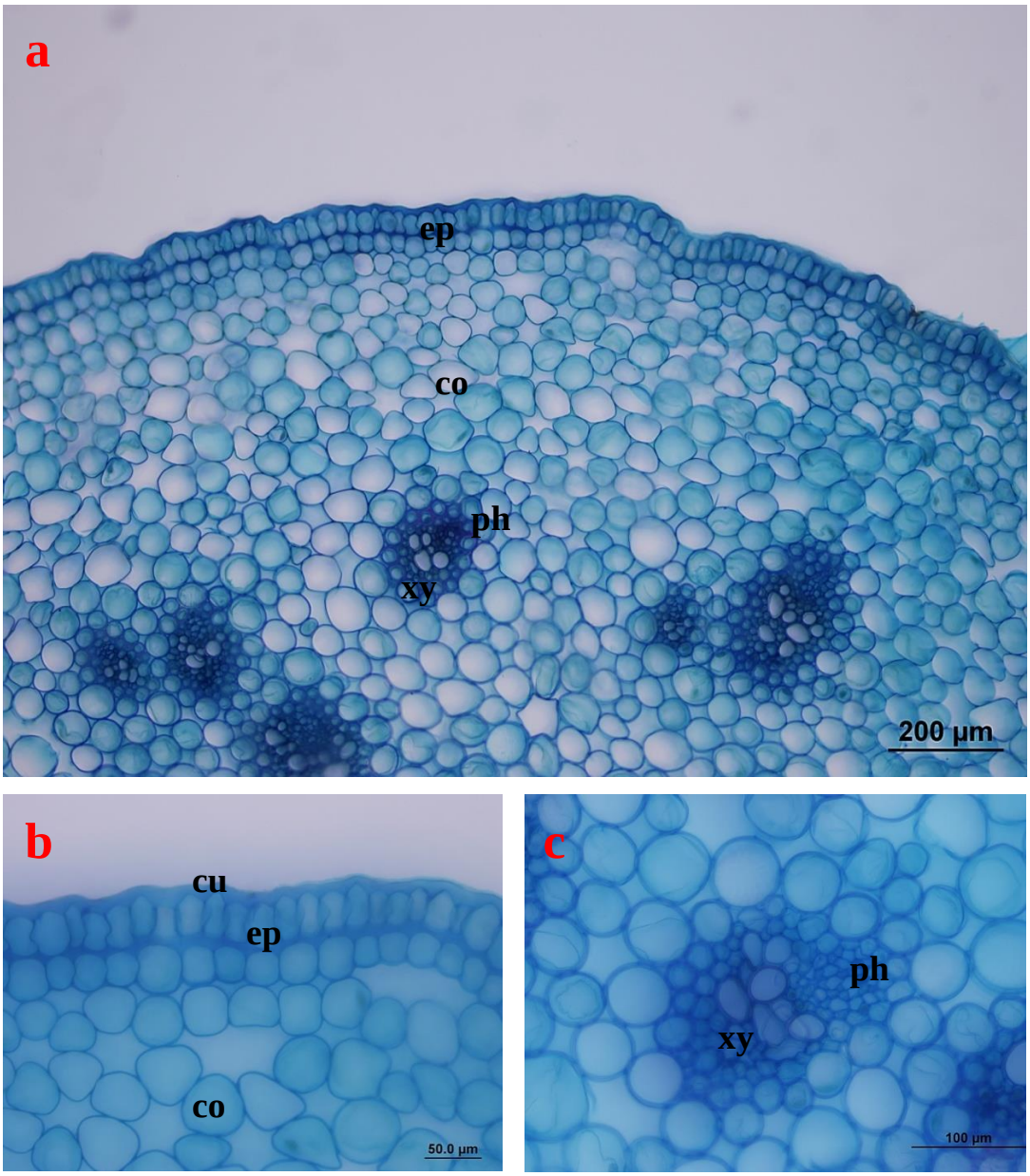

Figure 46. Stem anatomy of *T. orphanidea*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, ph: phloem, xy: xylem.

4.1.11.3 Leaf Anatomy of *T. orphanidea*

Upper epidermis consists of rectangular cells while lower epidermis consists of square cells. The size of the upper epidermis cells are larger than lower epidermis cells, which are 19−39 × 20−33 and 10−38 × 20−39 µm, respectively. The parenchymatous cells composed of 5−9 layered ovoid or spheroid cells are 25−53 × 32−59 µm (Figure 47).

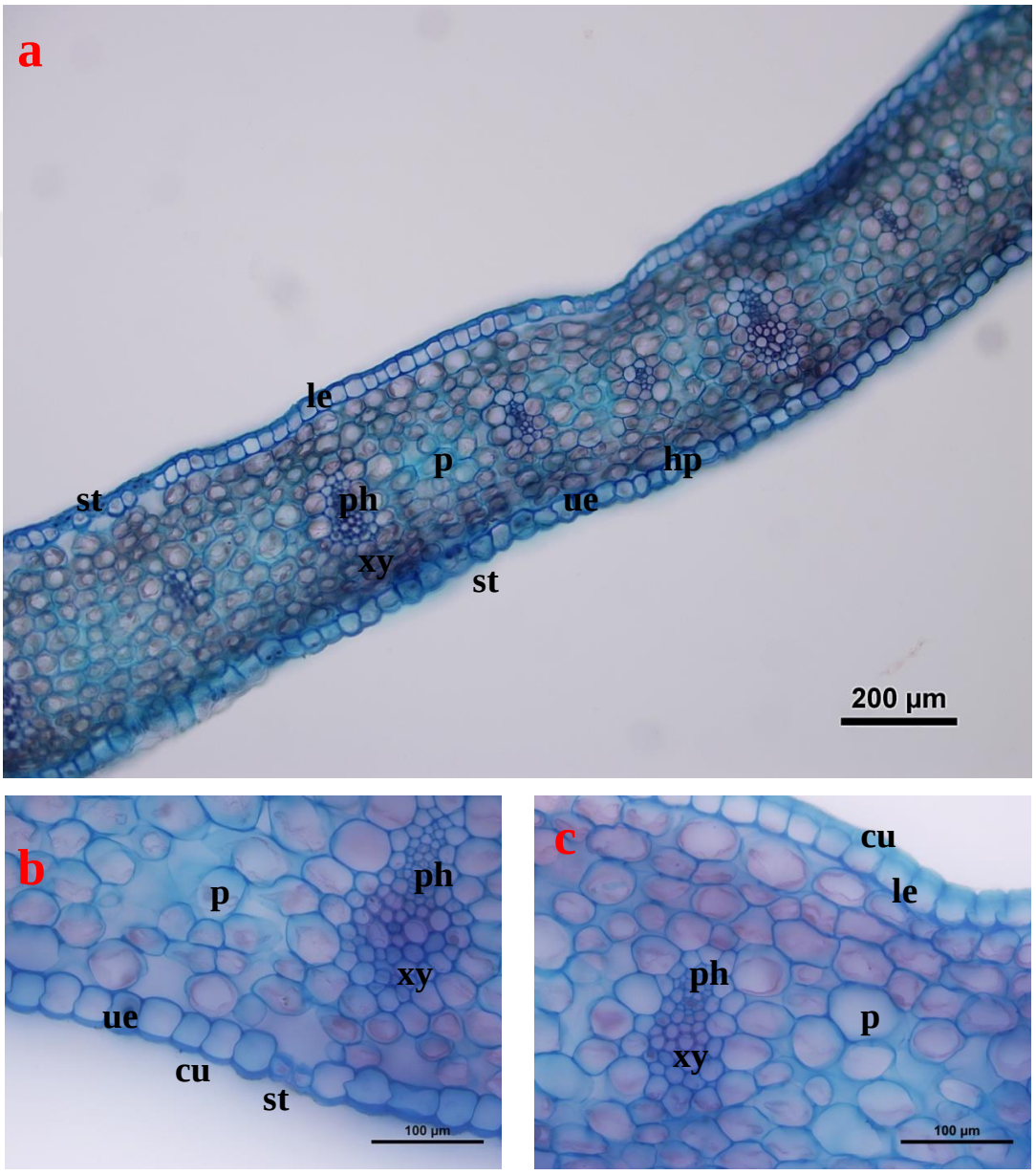

Figure 47. Leaf anatomy of *T. orphanidea*; a) section of leaf (10x), b) upper epidermis in the leaf section (40x), c) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 16 and 64, respectively. Stomata index is 20,00 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 42 and 73, respectively. Stomata index is 36,52 for the lower epidermis. Stomata index ratio is found as 0,54 (Figure 48).

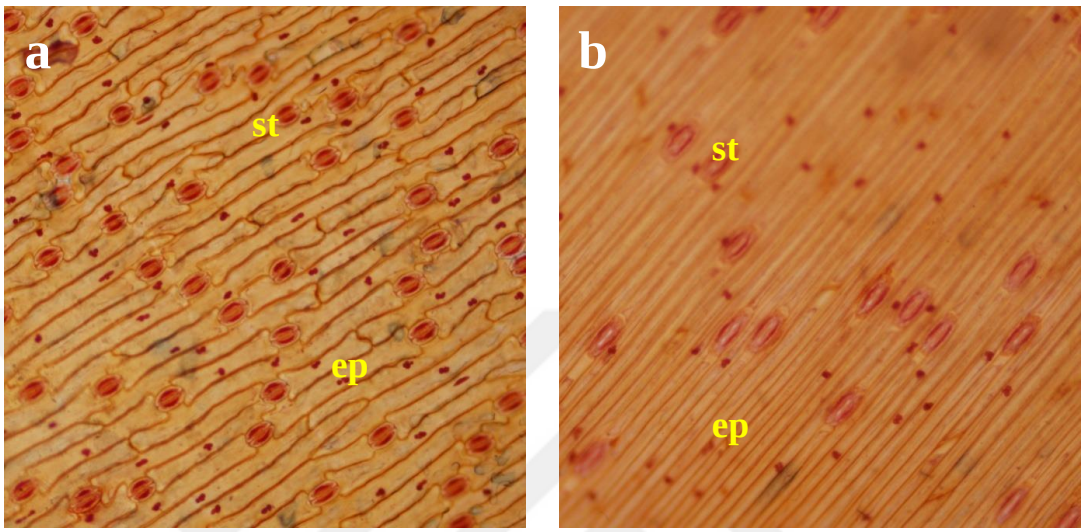

Figure 48. Leaf surface section of *T. orphanidea*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.12 *Tulipa pulchella* (Regel) Baker

4.1.12.1 Root Anatomy of *T. pulchella*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 15−21 × 13−19 µm. The single layered exodermis consisting of hexagon cells is found under the epidermis. Exodermis cells are 16−21 × 15−20 µm. The cortex is composed of 4−5 rows of ovoid or spheroid parenchymatous cells under the exodermis. These cells are 25−42 × 22−41 µm. The wall of the endodermis is thin. The phloem components are located around 2−7 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 49).

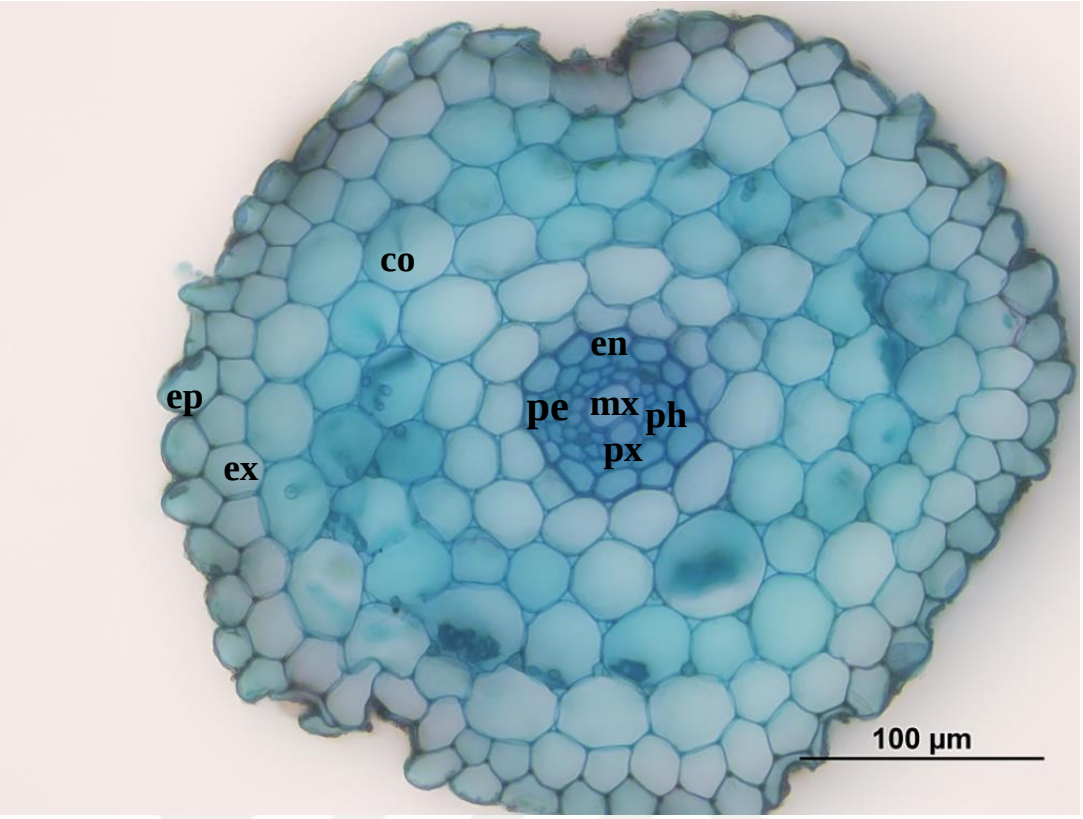

Figure 49. Root anatomy of *T. pulchella*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.12.2 Stem (Scape) Anatomy of *T. pulchella*

The epidermis is composed of rectangular cells which are 10−26 × 20−35 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 30−49 × 9−11 µm. The cortex comprises parenchymatous cells. The parenchyma consists of multilayered ovoid or spheroid cells which are 20−71 × 27−65 µm. The sclerenchyma tissue is either lacking or consists of 3−4 layered spheroid cells. The stem contains averagely 30 vascular bundles of various sizes in the vascular cylinder (Figure 50).

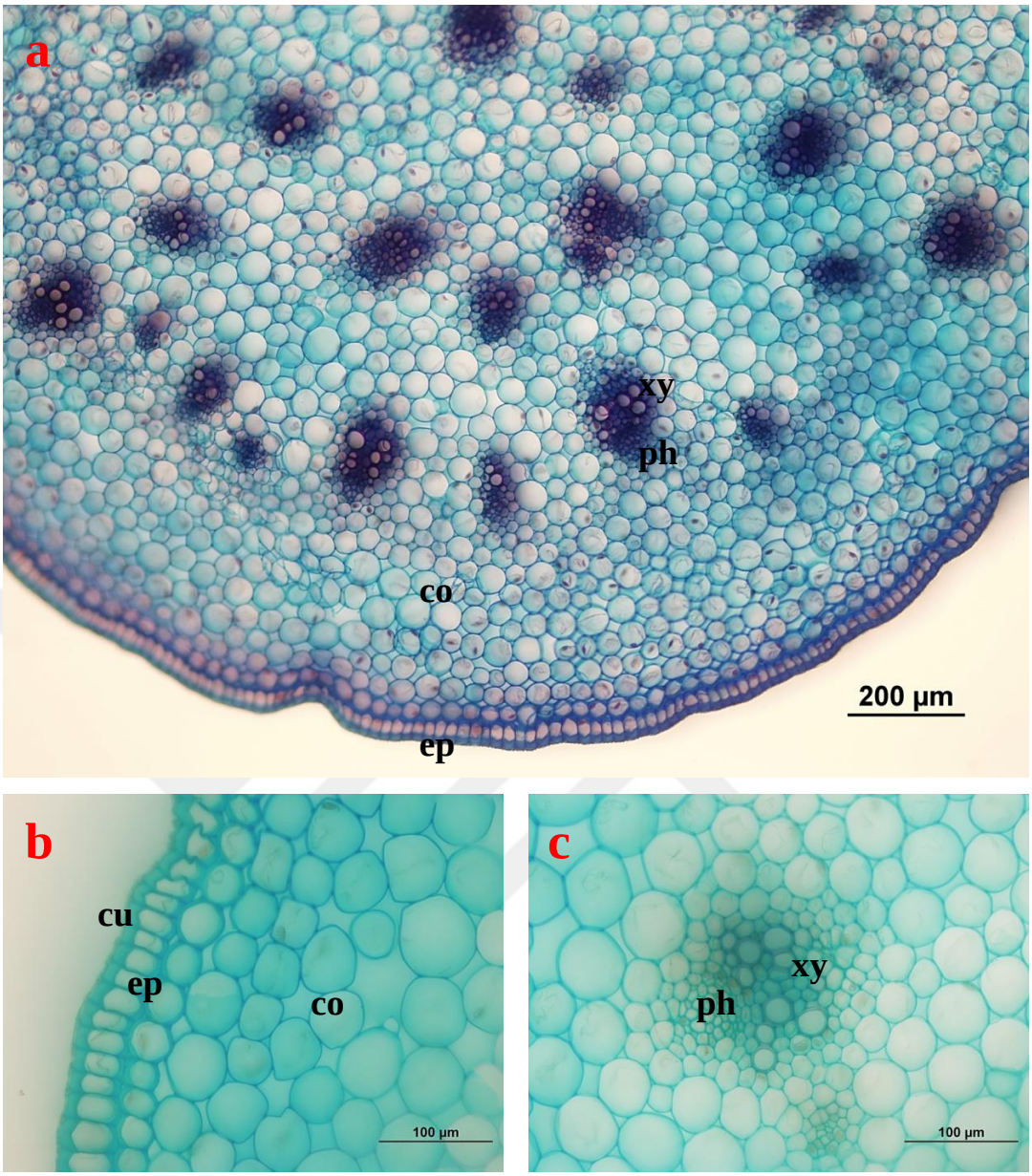

Figure 50. Stem anatomy of *T. pulchella*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.12.3 Leaf Anatomy of *T. pulchella*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 19−50 × 20−50 and 10−29 × 11−20 µm, respectively. The parenchymatous cells composed of 5−13 layered ovoid or spheroid cells are 55−79 × 50−80 µm. 2−3 row of parenchymatous cells are small and flat cells under upper epidermis (Figure 51).

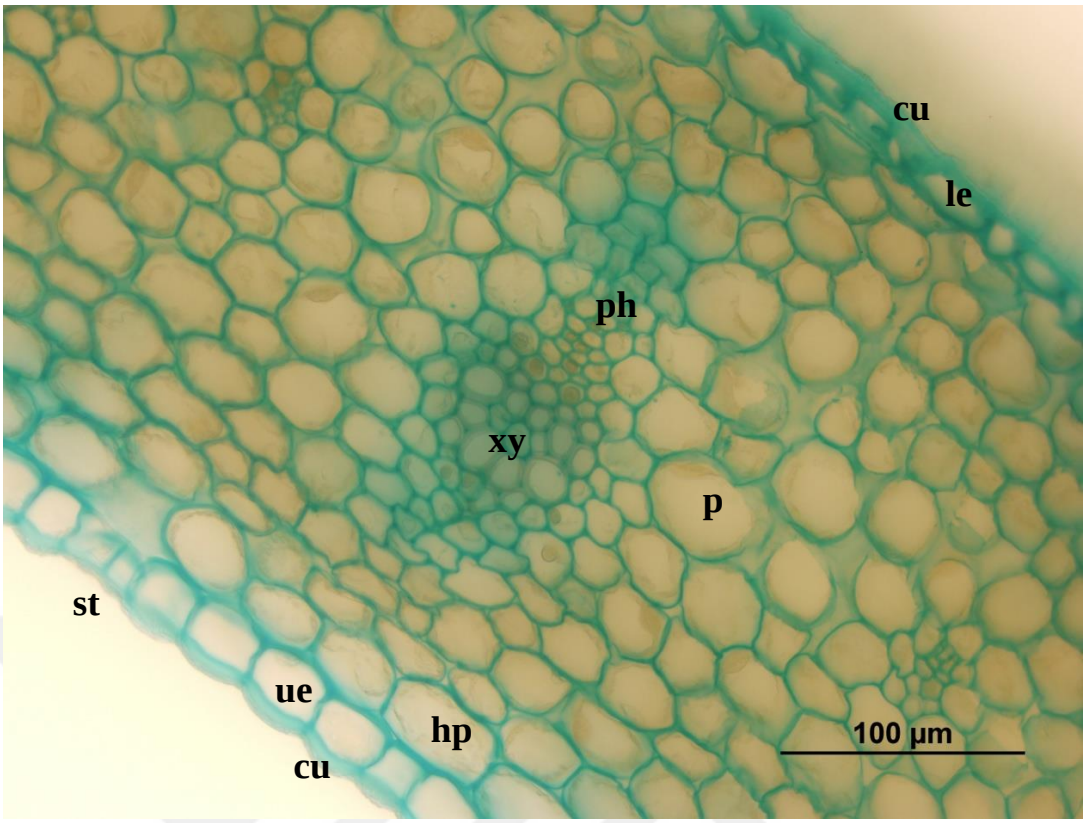

Figure 51. Leaf anatomy of *T. pulchella*; a) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 59 and 144, respectively. Stomata index is 29,06 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 68 and 171, respectively. Stomata index is 28,45 for the lower epidermis. Stomata index ratio is found as 1,02 (Figure 52).

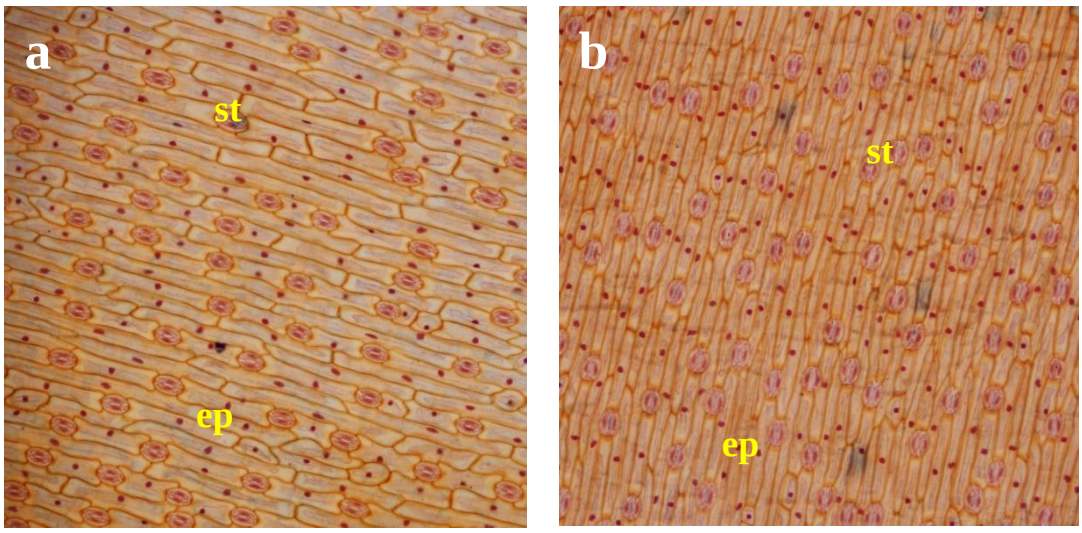

Figure 52. Leaf surface section of *T. pulchella*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.13 *Tulipa raddii* Reboul

4.1.13.1 Root Anatomy of *T. raddii*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and irregular cells on the outermost surface. Epidermis cells are 19−33 × 19−29 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 20−50 × 15−39 µm. The cortex is composed of 4−5 rows of irregular parenchymatous cells under the exodermis. These cells are 30−78 × 30−82 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 3−6 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 53).

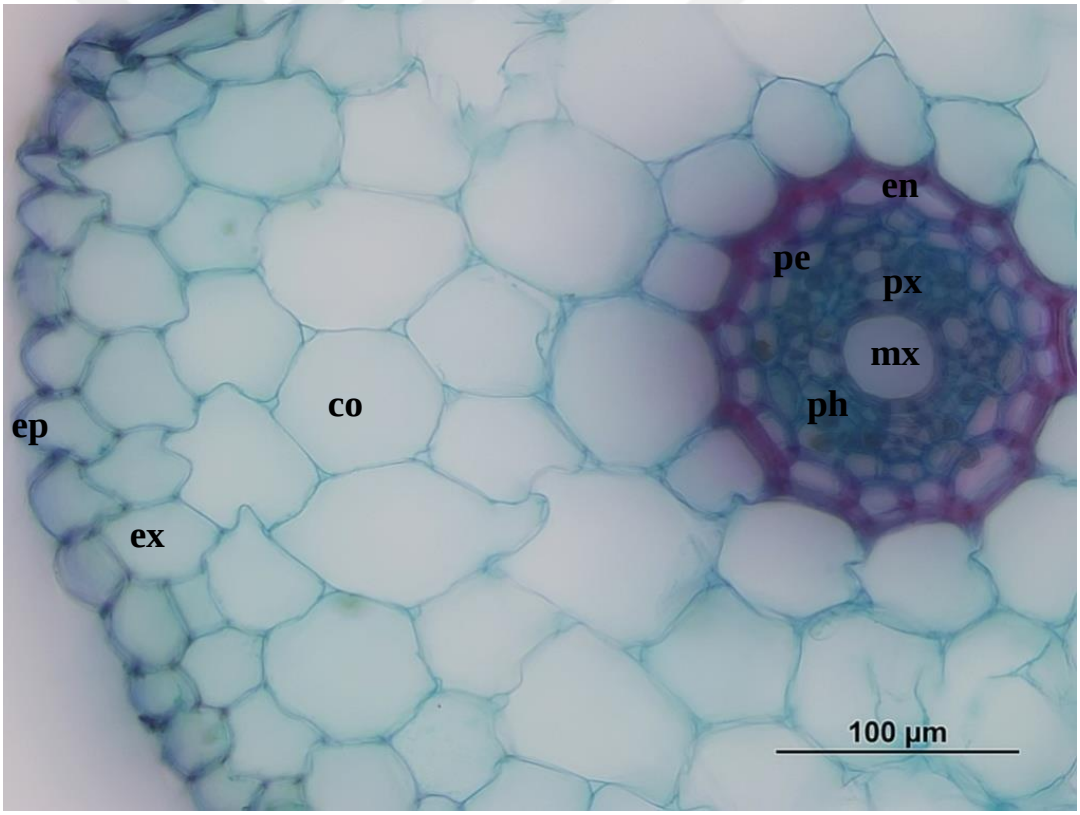

Figure 53. Root anatomy of *T. raddii*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.13.2 Stem (Scape) Anatomy of *T. raddii*

The epidermis is composed of rectangular cells which are 8−28 × 10−30 µm. The single-layered lamellar collenchyma is either lacking or found under the

epidermis. The collenchyma composes of ovoid cells which are 25−40 × 24−38 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 4−5 layered ovoid cells which are 30−63 × 30−60 µm. The sclerenchyma tissue consists of 3−5 layered spheroid cells. The stem contains averagely 36 vascular bundles of various sizes in the vascular cylinder (Figure 54).

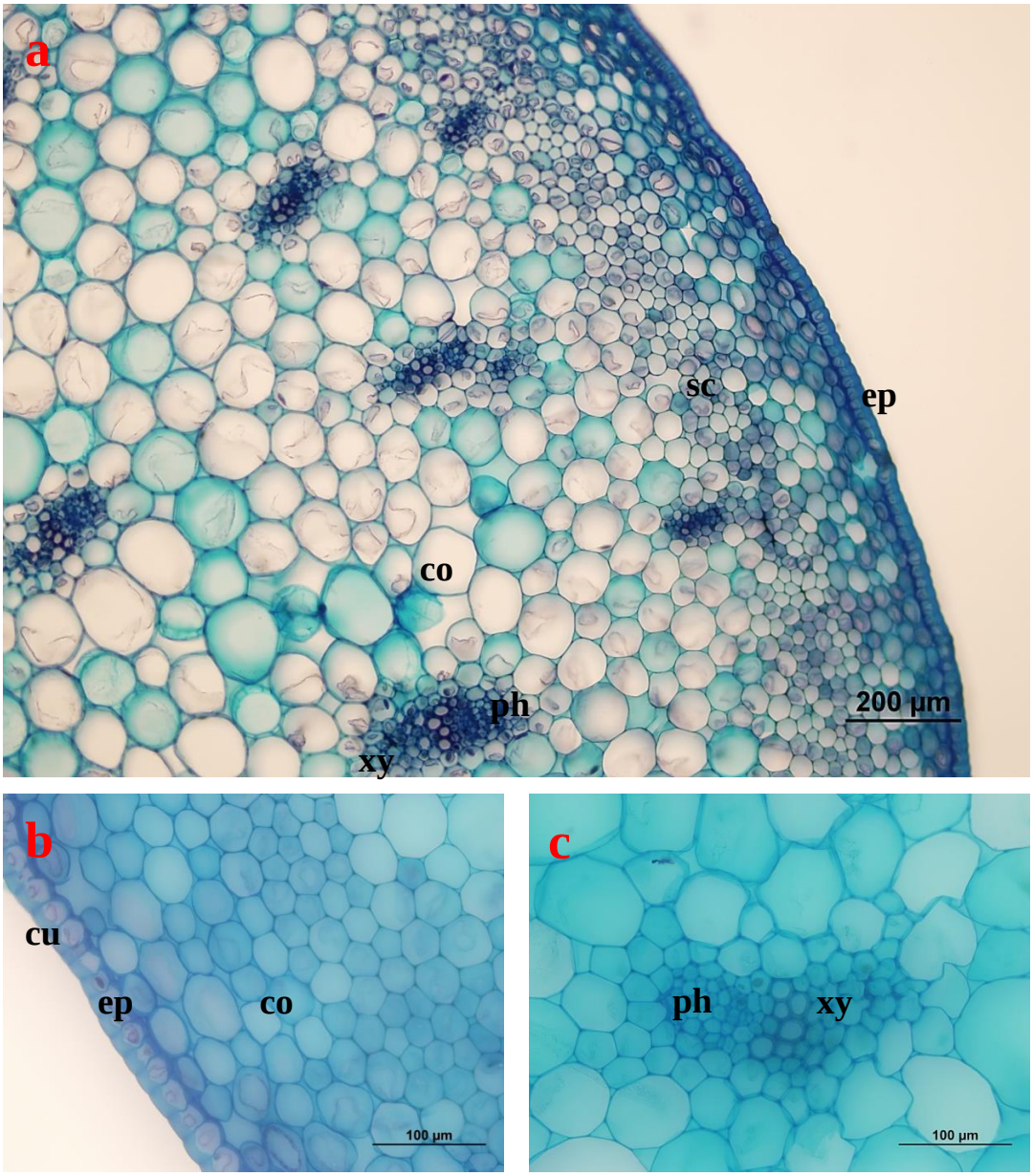

Figure 54. Stem anatomy of *T. raddii*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.13.3 Leaf Anatomy of *T. raddii*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 20−50 × 18−40 and 21−59 µm × 20−40 µm, respectively. The parenchymatous cells composed of 5−16 layered ovoid or spheroid cells are 18−53 × 23−70 µm (Figure 55).

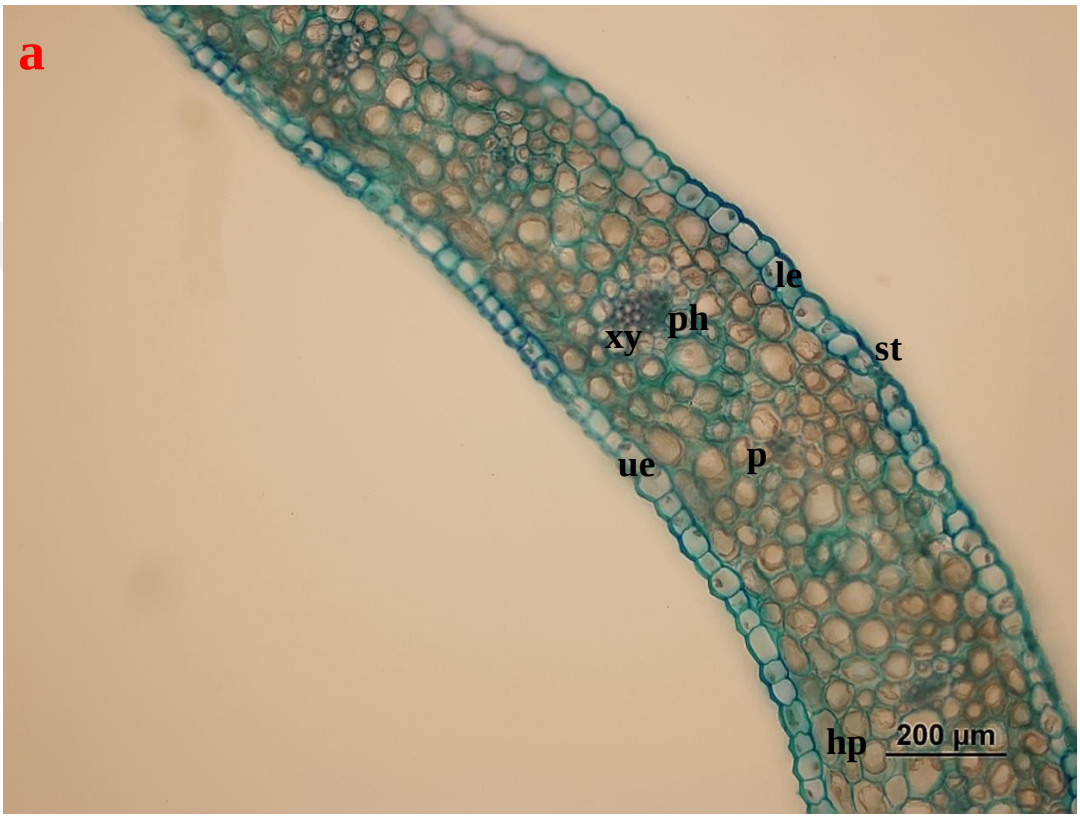

Figure 55. Leaf anatomy of *T. raddii*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

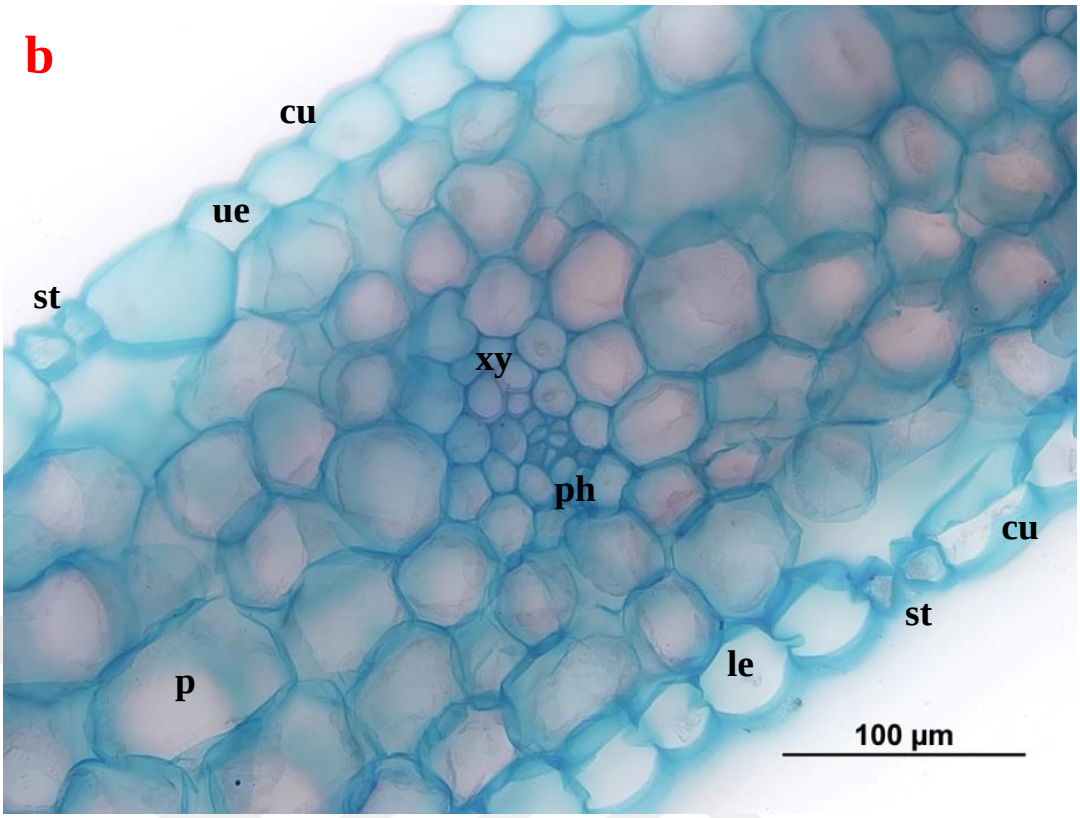

Figure 55. Leaf anatomy of *T. raddii*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata (continued).

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 28 and 55, respectively. Stomata index is 33,73 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 30 and 63, respectively. Stomata index is 32,25 for the lower epidermis. Stomata index ratio is found as 1,04 (Figure 56).

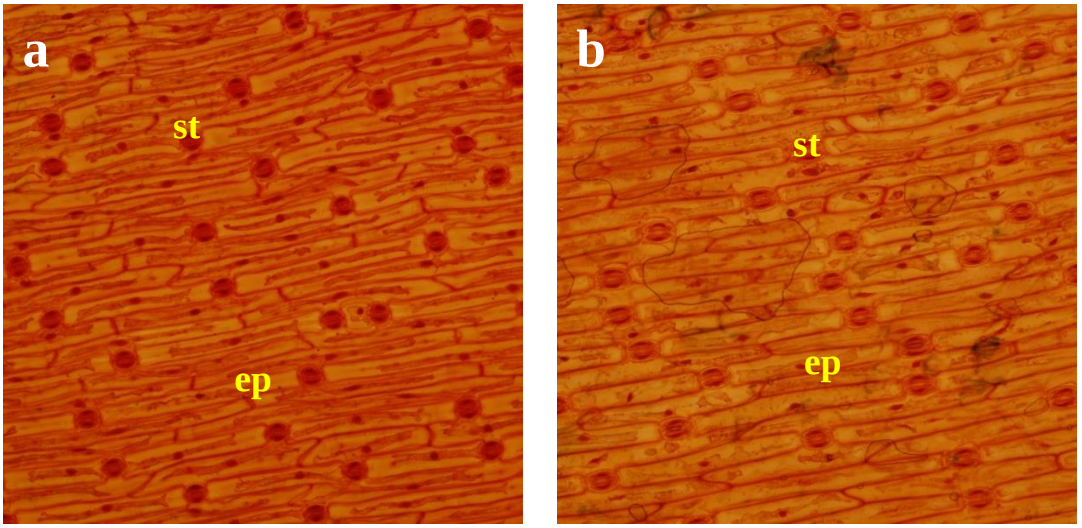

Figure 56. Leaf surface section of *T. raddii*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.14 *Tulipa saxatilis* Sieber ex Spreng.

4.1.14.1 Root Anatomy of *T. saxatilis*

Transverse section of the root includes a single-layered epidermis composed of small and irregular shapes on the outermost surface. Epidermis cells are 17−30 × 20−22 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 19−29 × 15−35 µm. The cortex is composed of 4−5 rows of irregular parenchymatous cells under the exodermis. These cells are 28−62 × 22−60 µm. The wall of the endodermis is thin. The phloem components are located around 3−6 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 57).

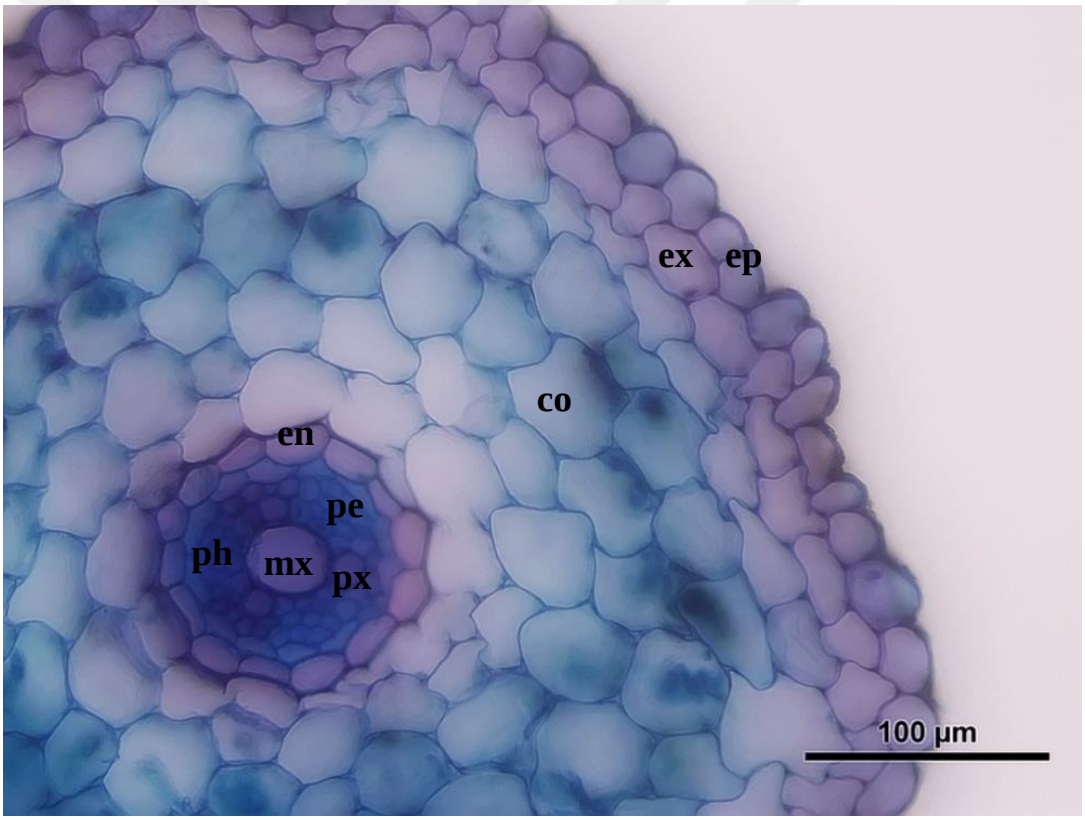

Figure 57. Root anatomy of *T. saxatilis*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.14.2 Stem (Scape) Anatomy of *T. saxatilis*

The epidermis is composed of rectangular cells which are 18−25 × 19−22 µm. The single-layered angular collenchyma is either lacking or found under the

epidermis. The collenchyma composes of ovoid cells which are 23−39 × 10−20 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of multilayered ovoid or spheroid cells which are 39−79 × 29−76 µm. The sclerenchyma tissue consists of 2−4 layered spheroid cells. The stem contains averagely 40 vascular bundles of various sizes in the vascular cylinder (Figure 58).

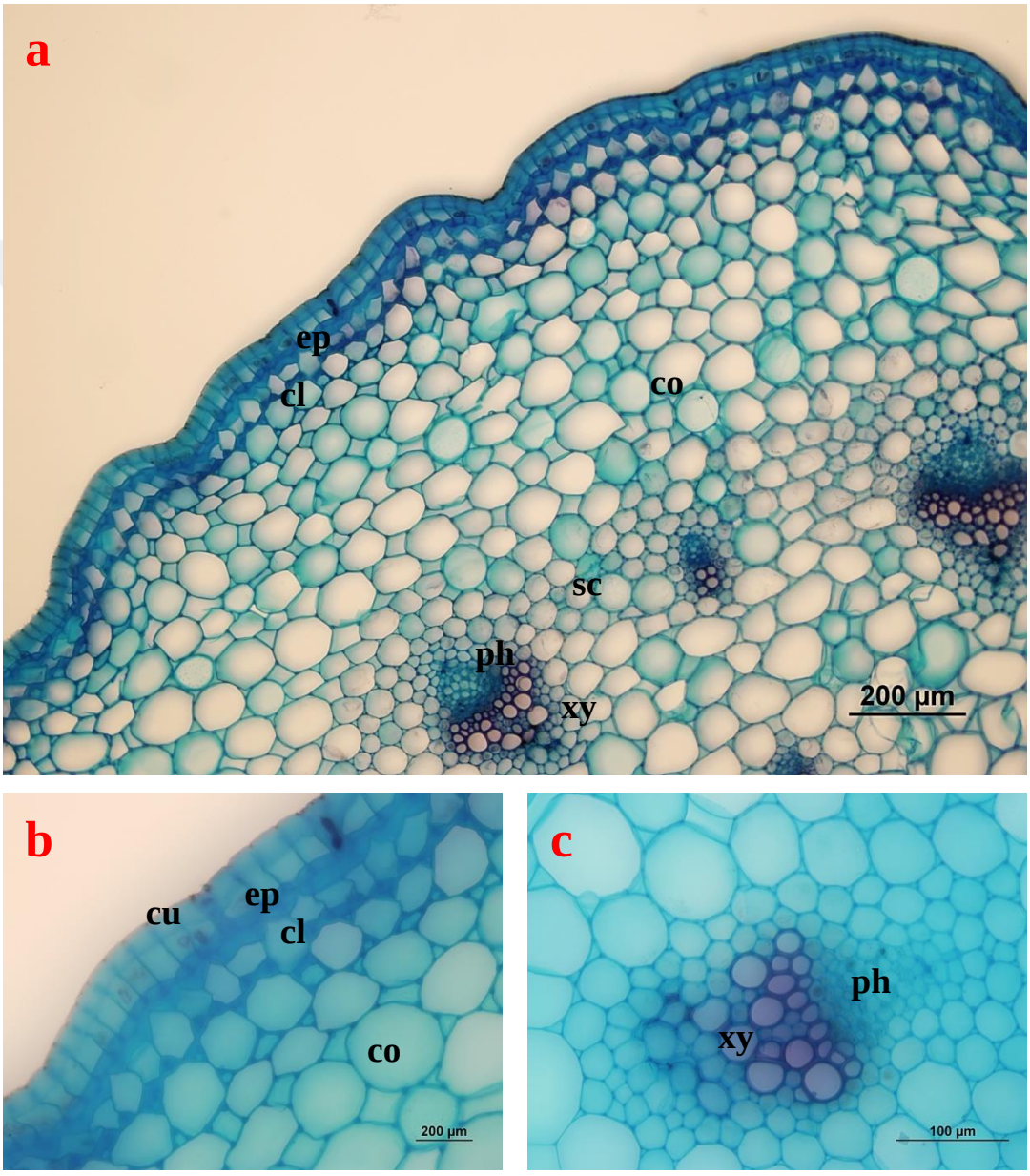

Figure 58. Stem anatomy of *T. saxatilis*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.14.3 Leaf Anatomy of *T. saxatilis*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 25−50 × 20−49 and 20−39 × 15−30 µm, respectively. The parenchymatous cells composed of 5−15 layered ovoid or spheroid cells are 40−59 × 40−60 µm (Figure 59).

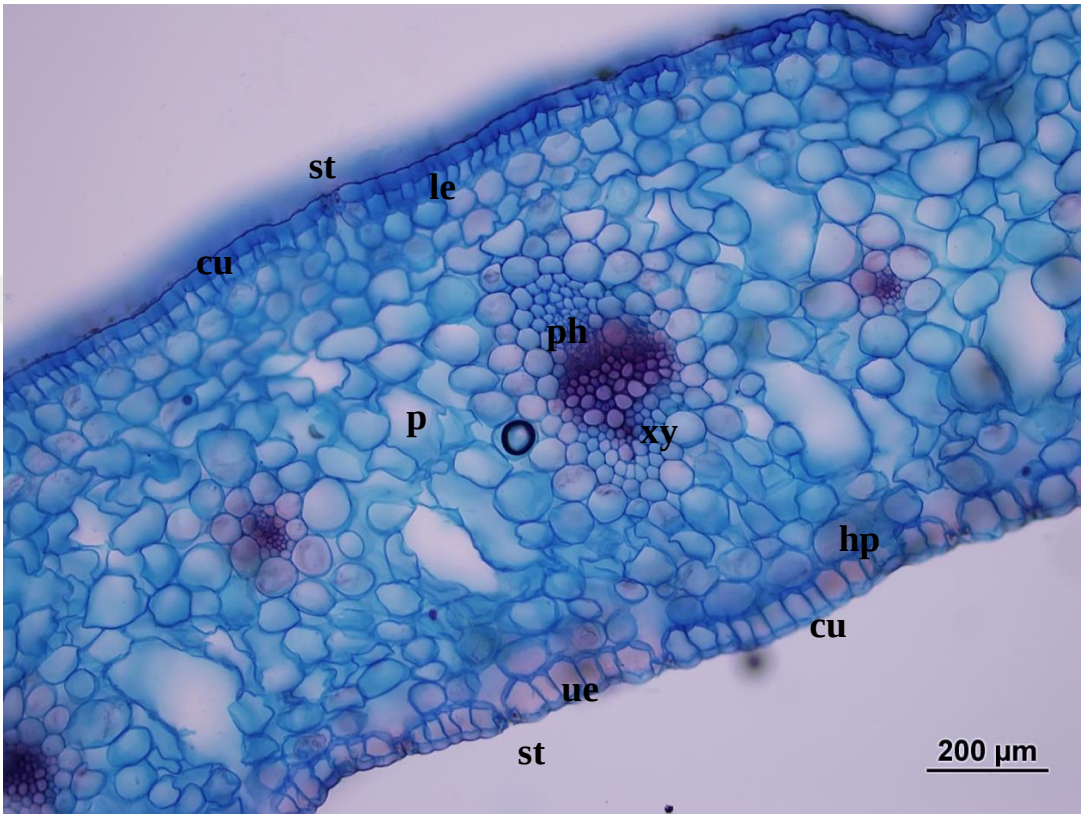

Figure 59. Leaf anatomy of *T. saxatilis*; a) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 19 and 78, respectively. Stomata index is 19,58 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 29 and 91, respectively. Stomata index is 24,16 for the lower epidermis. Stomata index ratio is found as 0,81 (Figure 60).

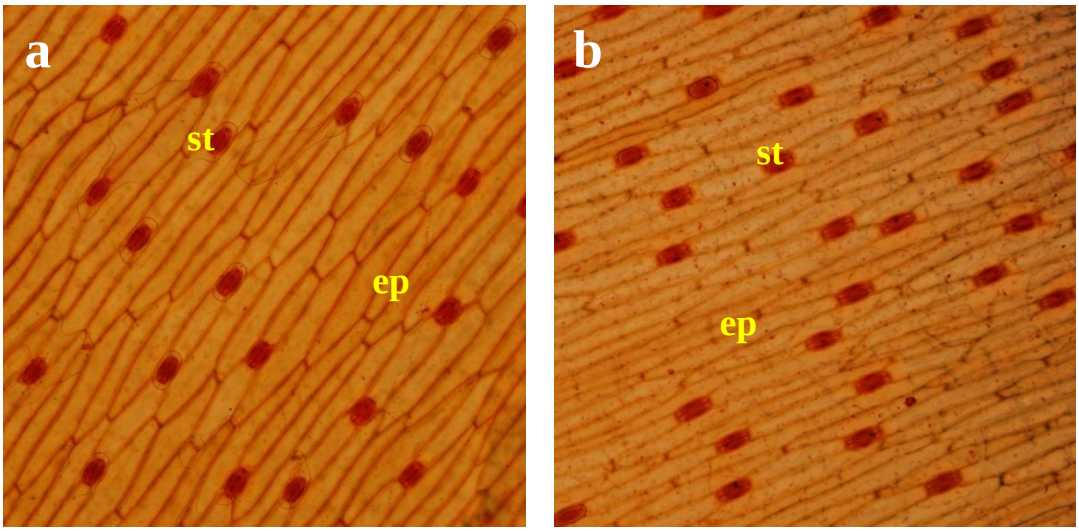

Figure 60. Leaf surface section of *T. saxatilis*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.15 *Tulipa sintenisii* Baker

4.1.15.1 Root Anatomy of *T. sintenisii*

Transverse section of the root includes a single-layered epidermis composed of small and irregular shapes on the outermost surface. Epidermis cells are 10−29 × 14−30 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 15−35 × 11−40 µm. The cortex is composed of 5−6 rows of ovoid or spheroid parenchymatous cells under the exodermis. These cells are 29−60 × 20−62 µm. The wall of the endodermis is thick and direction of thickning is towards cortex. The phloem components are located around 3−9 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 61).

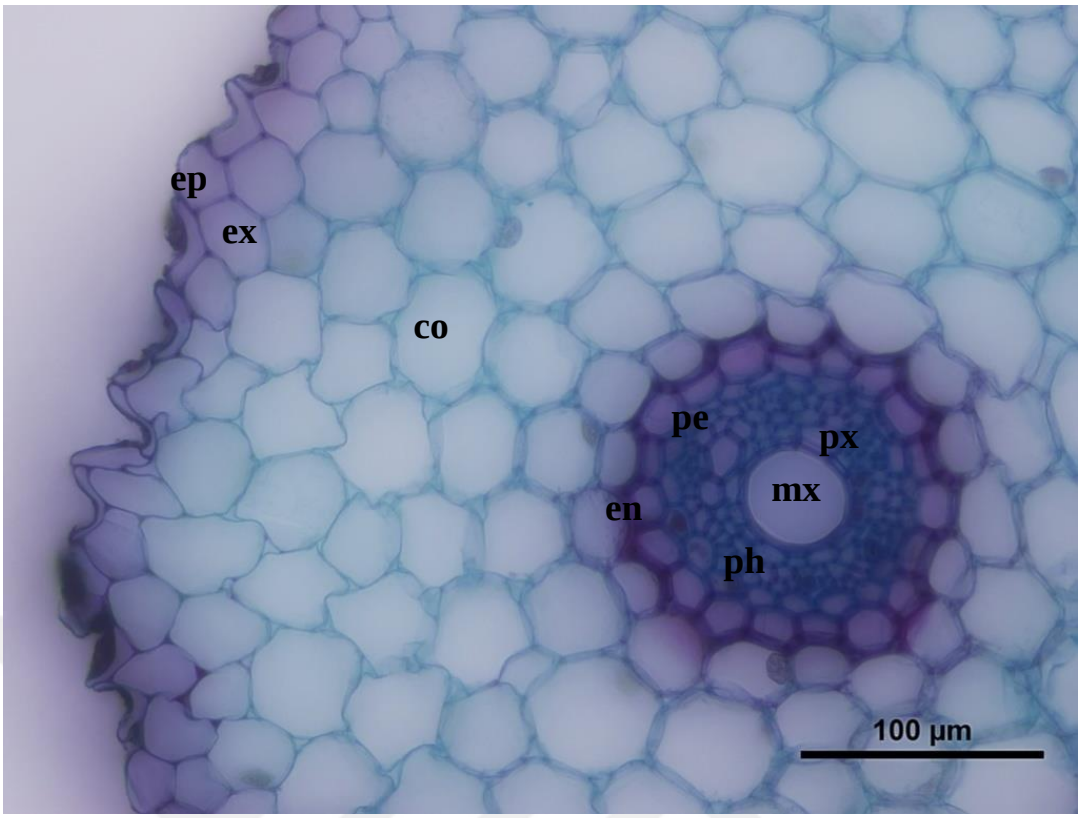

Figure 61. Root anatomy of *T. sintenisii*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.15.2 Stem (Scape) Anatomy of *T. sintenisii*

The epidermis is composed of rectangular cells which are 8−24 × 10−32 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 10−42 × 10−22 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 4−5 layered ovoid cells which are 20−70 × 22−66 µm. The sclerenchyma tissue is either lacking or consists of 2−5 layered spheroid cells. The stem contains averagely 37 vascular bundles of various sizes in the vascular cylinder (Figure 62).

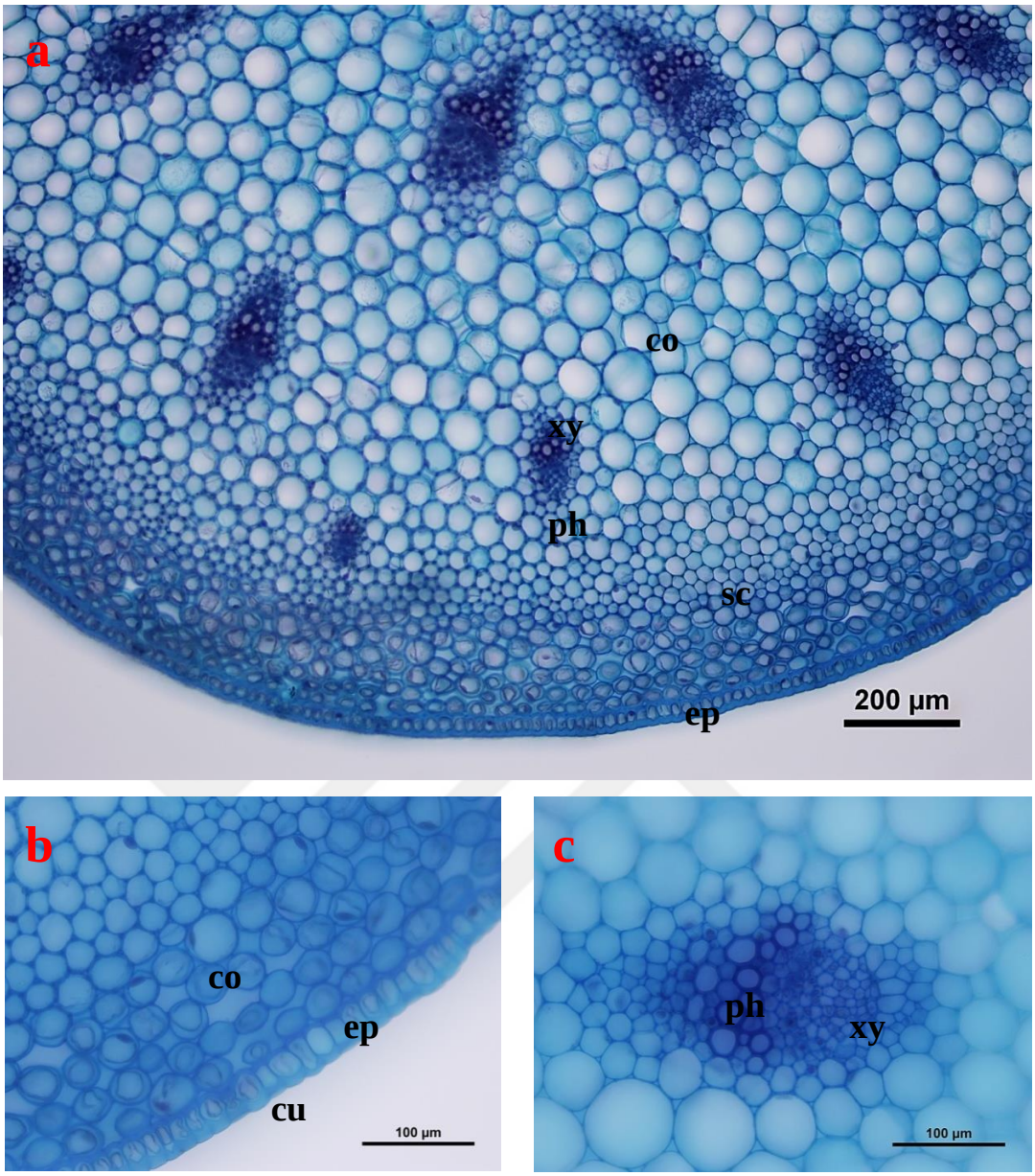

Figure 62. Stem anatomy of *T. sintenisii*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.15.3 Leaf Anatomy of *T. sintenisii*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 13−40 × 10−39 and 11−34 × 15−39 µm, respectively. The parenchymatous cells composed of 5−17 layered ovoid or spheroid cells are 20−56 × 26−82 µm (Figure 63).

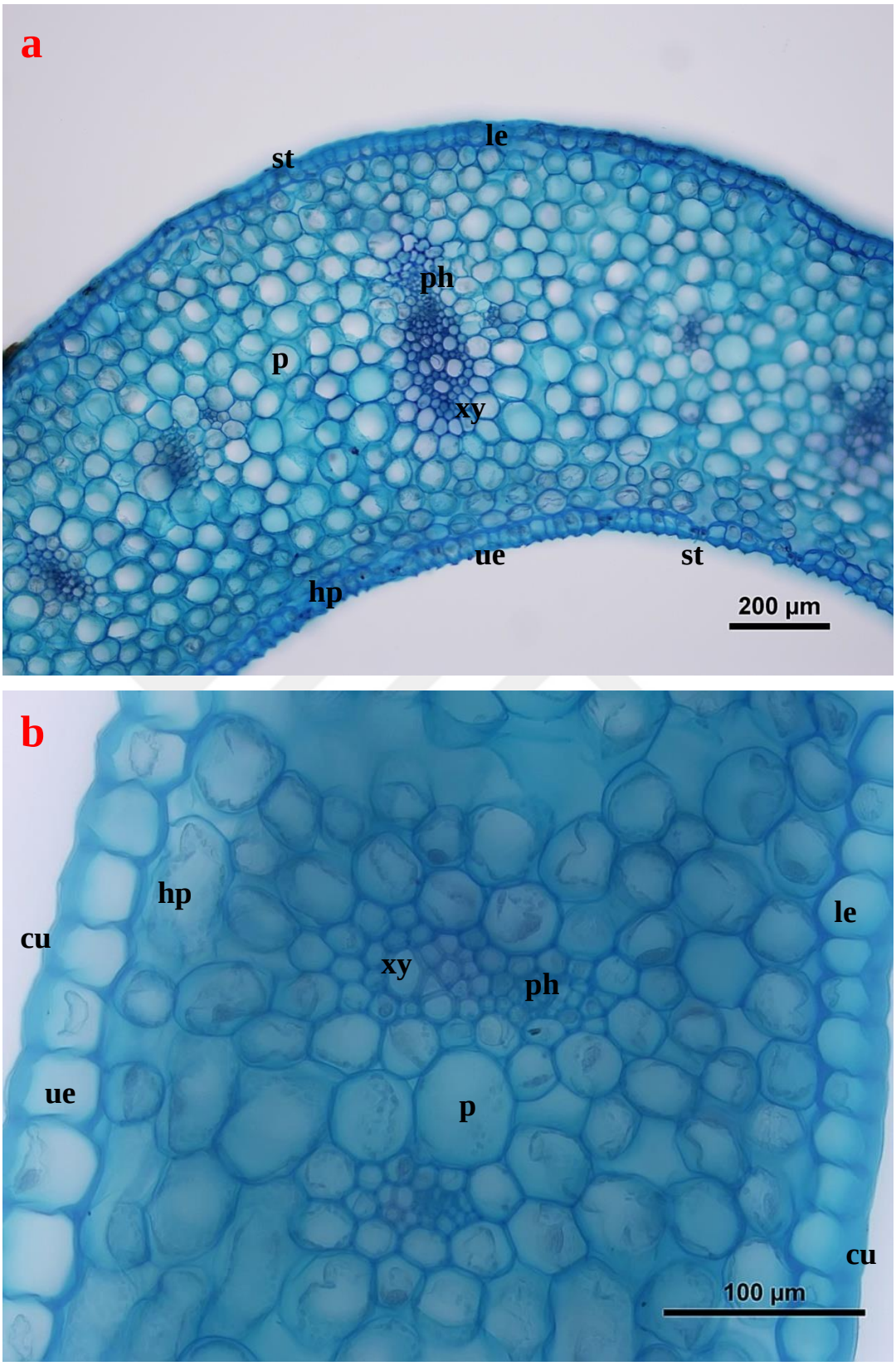

Figure 63. Leaf anatomy of *T. sintenisii*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 51 and 152, respectively. Stomata index is 25,12 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 53 and 137, respectively. Stomata index is 27,89 for the lower epidermis. Stomata index ratio is found as 0,90 (Figure 64).

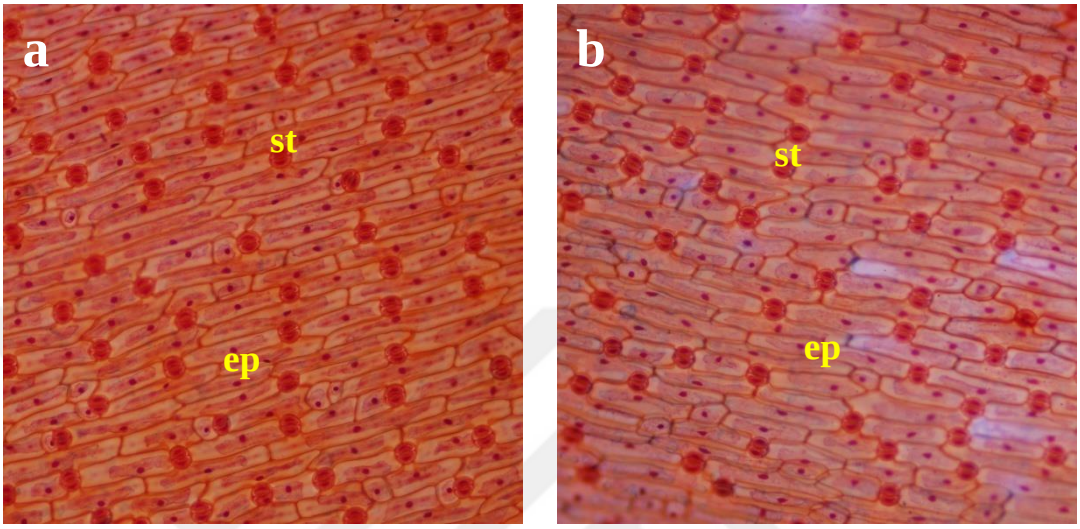

Figure 64. Leaf surface section of *T. sintenisii*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.16 *Tulipa sylvestris* subsp. L. *australis* (Link) Pamp.

4.1.16.1 Root Anatomy of *T. sylvestris* subsp. *australis*

Transverse section of the root includes a single-layered epidermis composed of small and irregular shapes on the outermost surface. Epidermis cells are 11−28 × 10−29 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 12−26 × 15−35 µm. The cortex is composed of 4−5 rows of irregular parenchymatous cells under the exodermis. These cells are 23−60 × 20−60 µm. The wall of the endodermis is thin. The phloem components are located around 2−7 protoxylem ridges. A single of metaxylem is present on the median part of vascular cylinder (Figure 65).

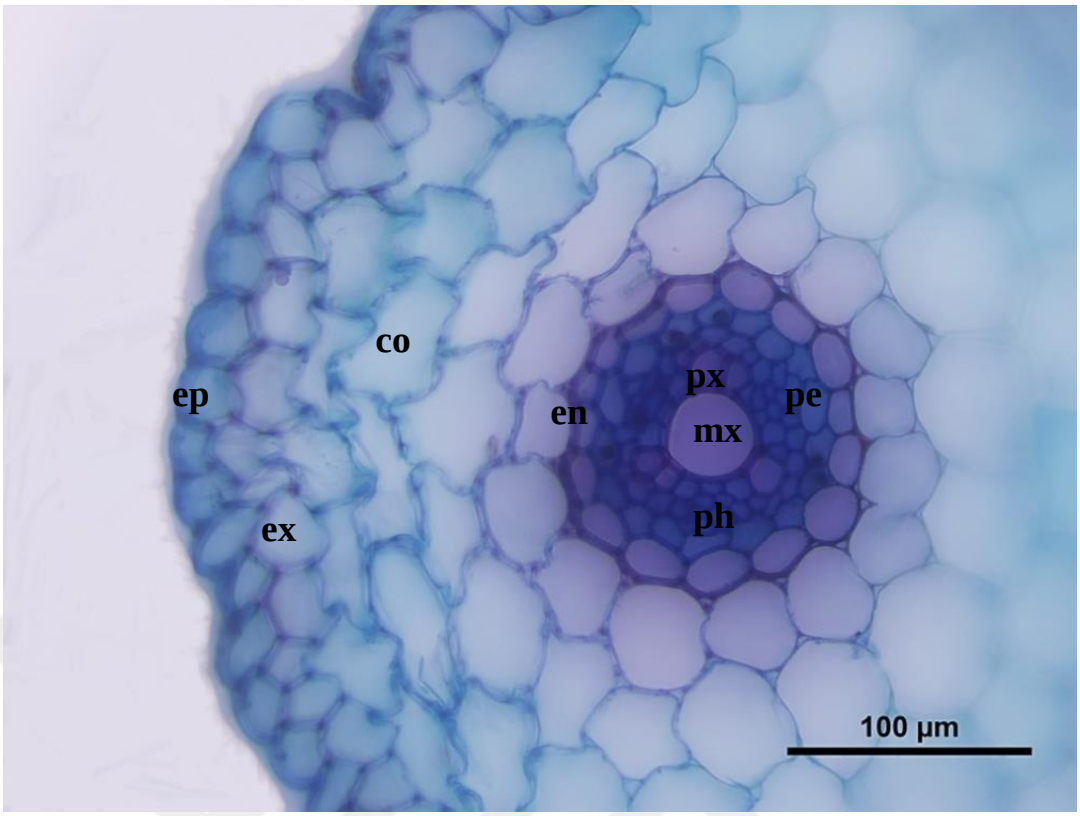

Figure 65. Root anatomy of *T. sylvestris* subsp. *australis*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.16.2 Stem (Scape) Anatomy of *T. sylvestris* subsp. *australis*

The epidermis is composed of rectangular cells which are 9−28 × 25−39 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 29−40 × 9−19 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 6−8 layered spheroid cells which are 28−61 × 29−62 µm. The sclerenchyma tissue consists of 2−6 layered spheroid cells. The stem contains averagely 28 vascular bundles of various sizes in the vascular cylinder (Figure 66).

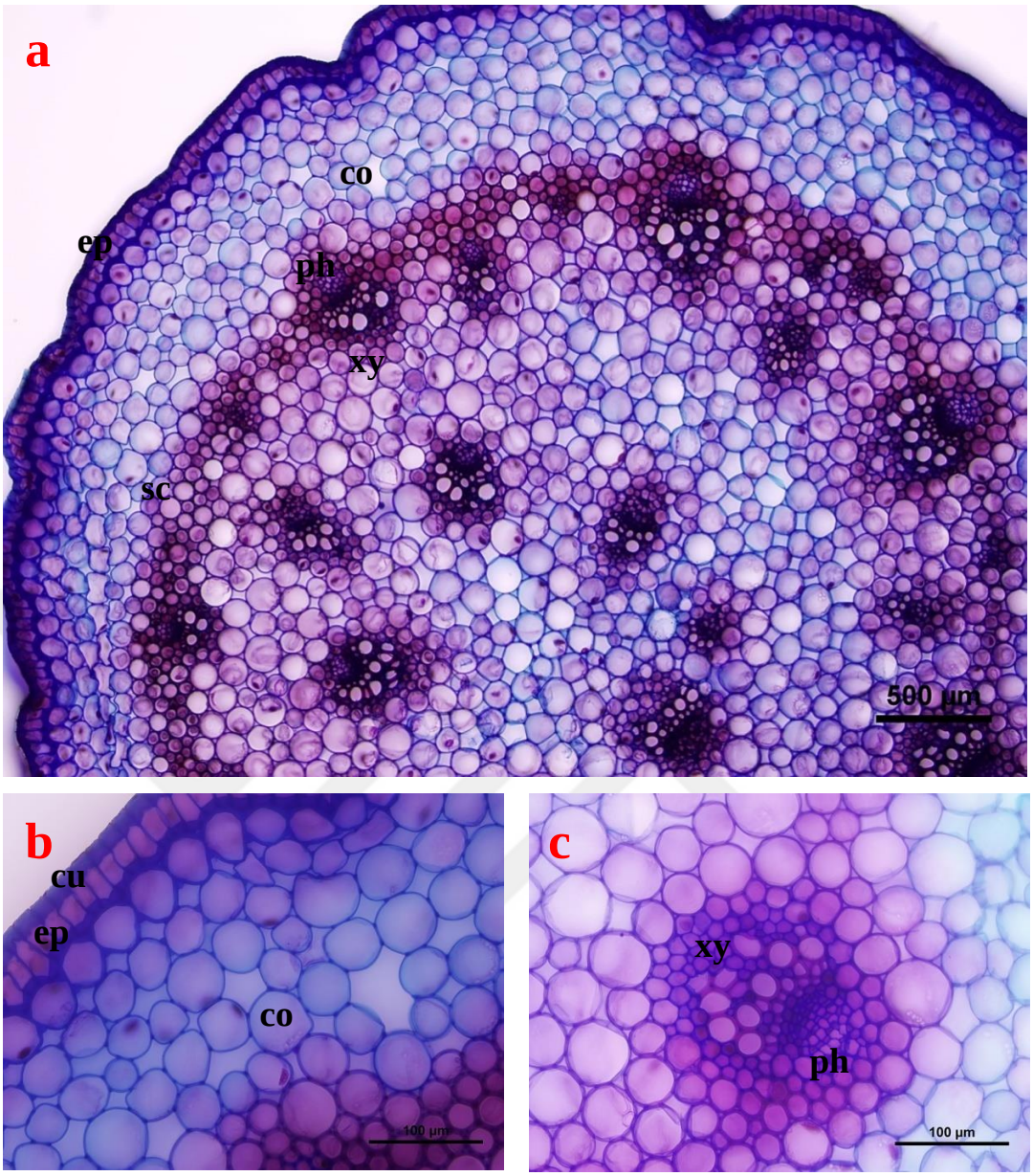

Figure 66. Stem anatomy of *T. sylvestris* subsp. *australis*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.16.3 Leaf Anatomy of *T. sylvestris* subsp. *australis*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similar to lower epidermis cells, which are 12−32 × 16−32 and 10−30 × 11−22 µm, respectively. The parenchymatous cells composed of 7−11 layered ovoid or spheroid cells are 21−69 × 20−63 µm (Figure 67).

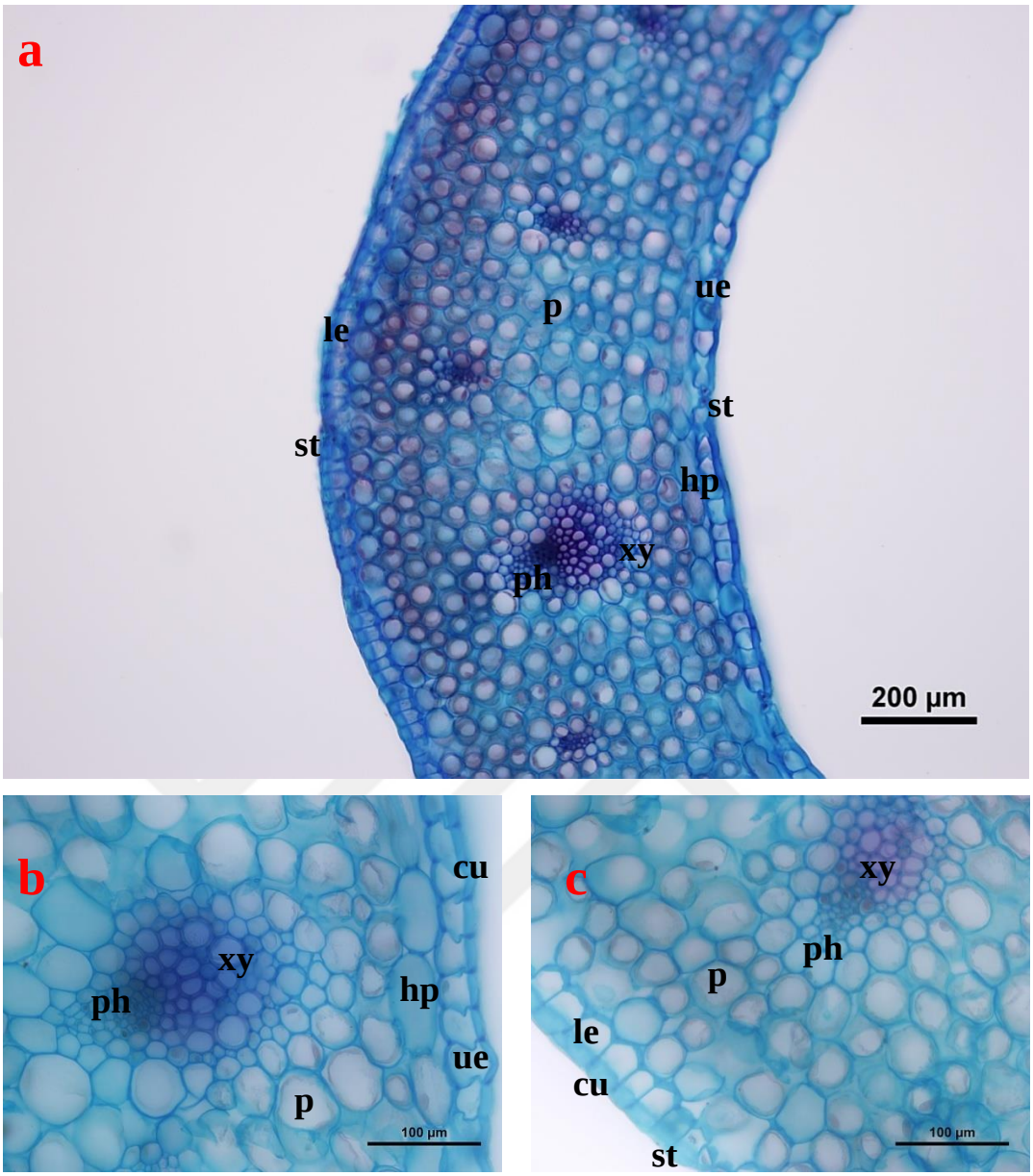

Figure 67. Leaf anatomy of *T. sylvestris* subsp. *australis*; a) section of leaf (10x), b) upper epidermis in the leaf section (40x), c) lower epidermis in the leaf section (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 66 and 96, respectively. Stomata index is 40,74 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 80 and 112, respectively. Stomata index is 41,66 for the lower epidermis. Stomata index ratio is found as 0,97 (Figure 68).

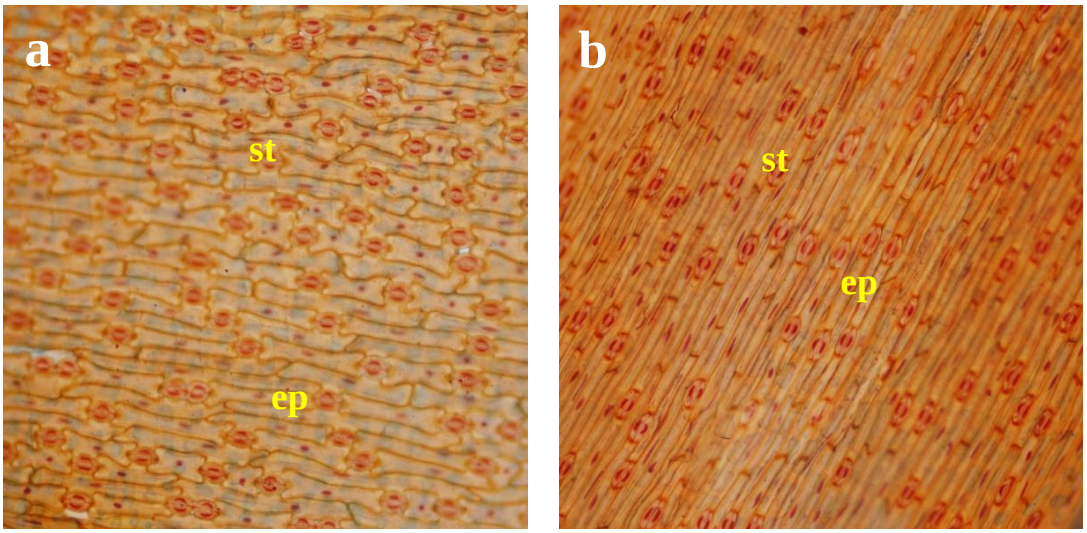

Figure 68. *T. sylvestris* subsp. *australis*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.17 *Tulipa sylvestris* subsp. L. *sylvestris*

4.1.17.1 Root Anatomy of *T. sylvestris* subsp. *sylvestris*

Transverse section of the root includes a single-layered epidermis composed of small, ovoid and regular cells on the outermost surface. Epidermis cells are 15−21 × 17−21 µm. The single layered exodermis consisting of pentagon cells is found under the epidermis. Exodermis cells are 10−22 × 17−25 µm. The cortex is composed of 4−5 rows of spheroid parenchymatous cells under the exodermis. These cells are 22−31 × 26−38 µm. The wall of the endodermis is thin. The phloem components are located around 3−8 protoxylem ridges. 1−3 metaxylem is present on the median part of vascular cylinder (Figure 69).

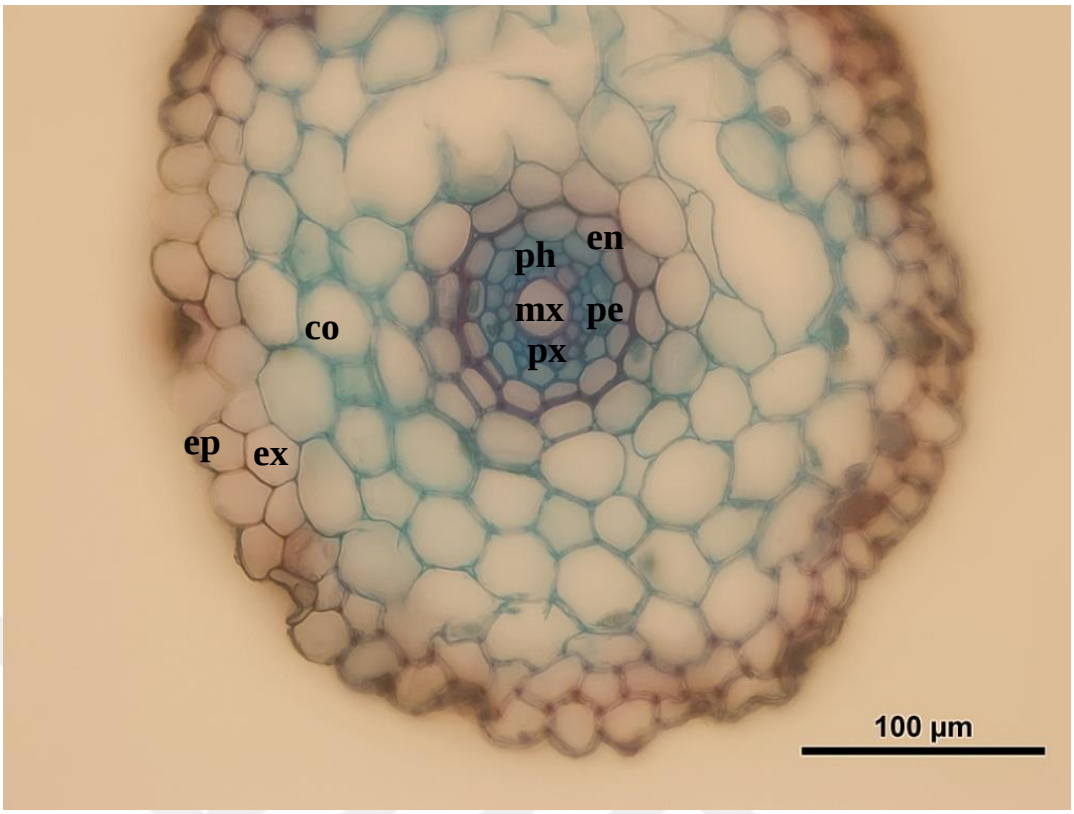

Figure 69. Root anatomy of *T. sylvestris* subsp. *sylvestris*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.17.2 Stem (Scape) Anatomy of *T. sylvestris* subsp. *sylvestris*

The epidermis is composed of rectangular cells which are 8−26 × 20−30 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 30−39 × 8−19 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 5−6 layered ovoid or spheroid cells which are 29−50 × 29−50 µm. The sclerenchyma tissue is either lacking or consists of 3−4 layered spheroid cells. The stem contains averagely 31 vascular bundles of various sizes in the vascular cylinder (Figure 70).

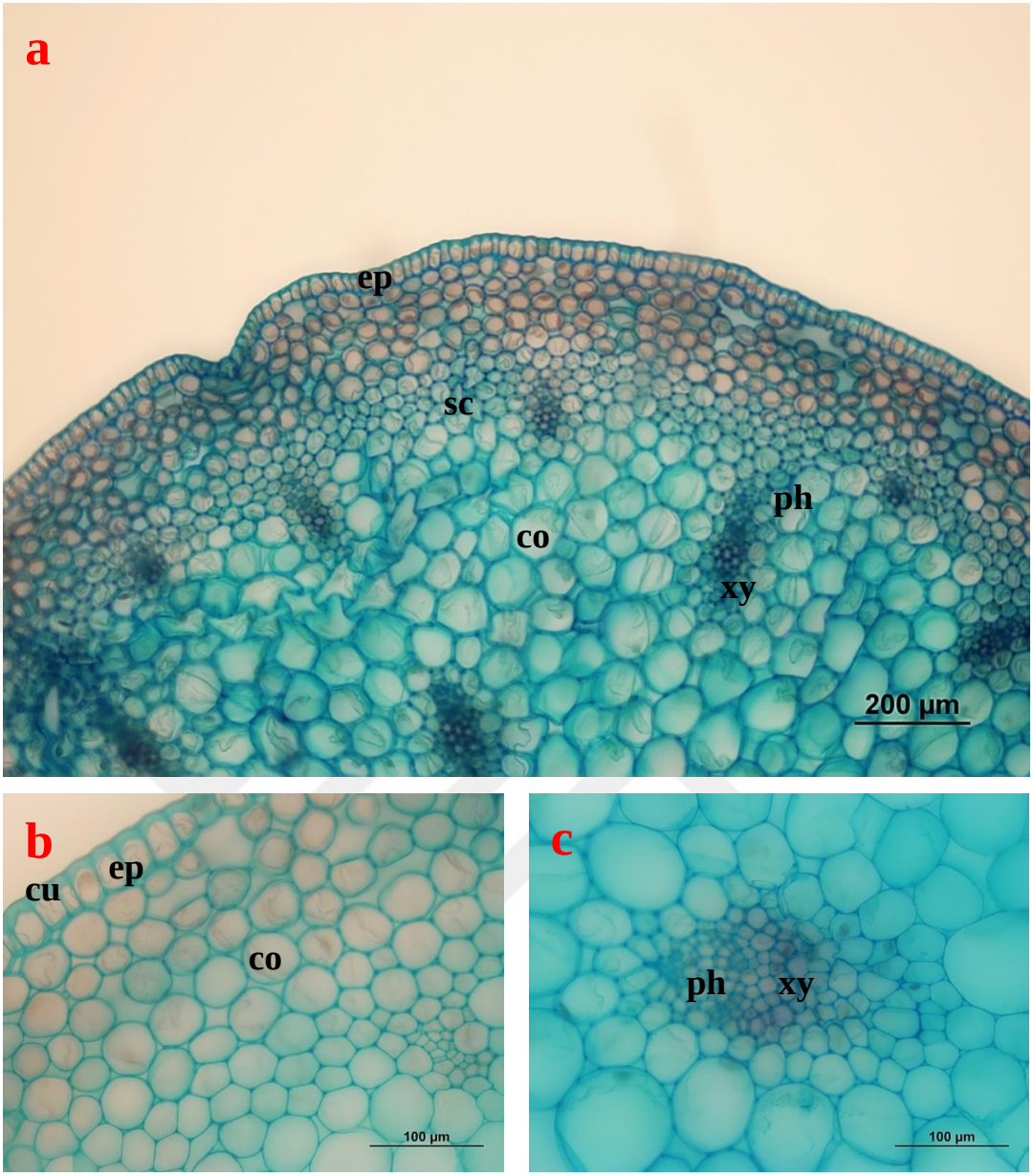

Figure 70. Stem anatomy of *T. sylvestris* subsp. *sylvestris*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.17.3 Leaf Anatomy of *T. sylvestris* subsp. *sylvestris*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are larger than the lower epidermis cells, which are 19−40 × 20−29 and 10−25 × 15−26 µm, respectively. The parenchymatous cells composed of 5−11 layered ovoid or spheroid cells are 25−41 × 29−56 µm (Figure 71).

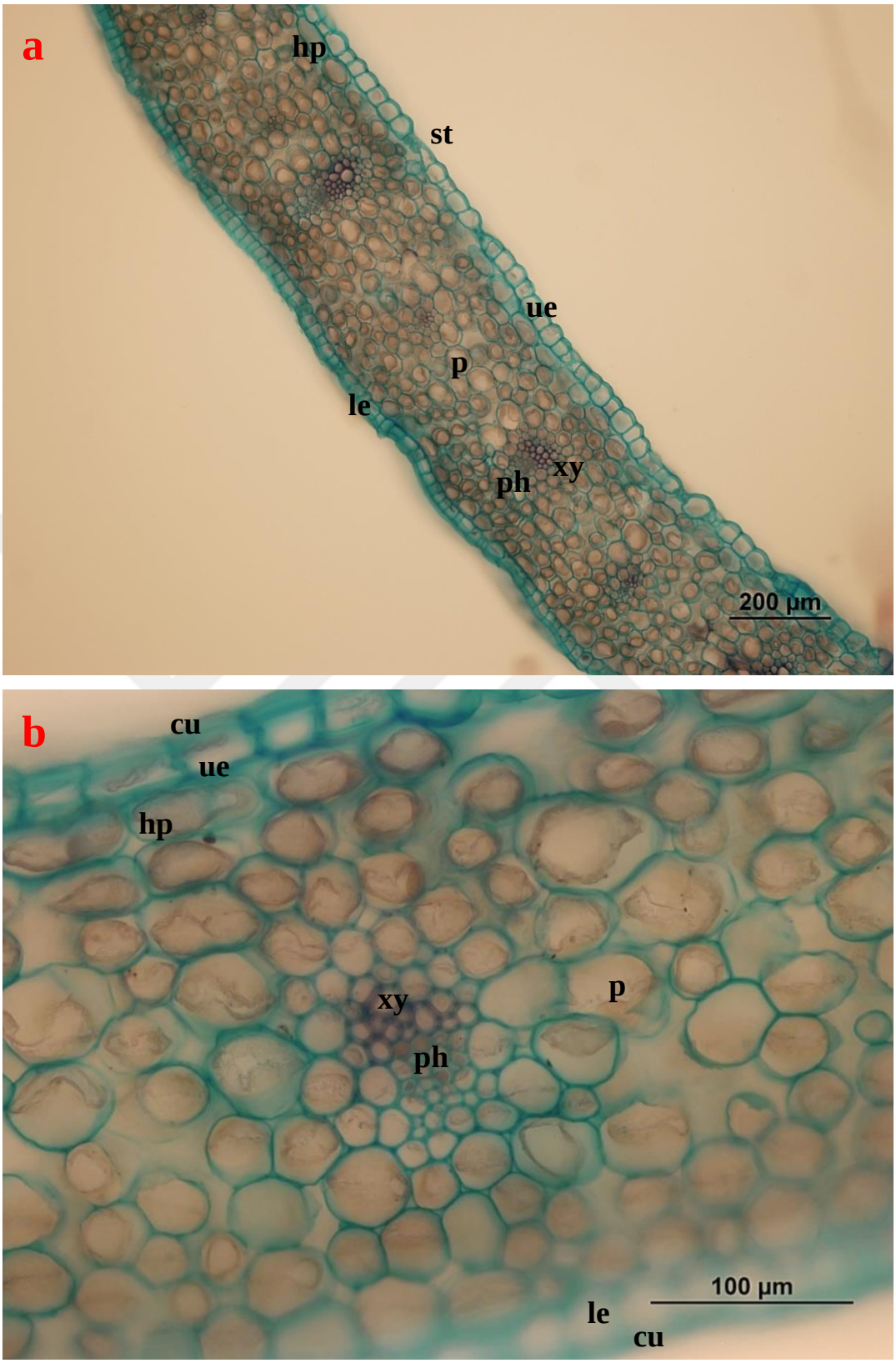

Figure 71. Leaf anatomy of *T. sylvestris* subsp. *sylvestris*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 27 and 70, respectively. Stomata index is 27,83 for the upper epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 32 and 76, respectively. Stomata index is 29,62 for the lower epidermis. Stomata index ratio is found as 0,93 (Figure 72).

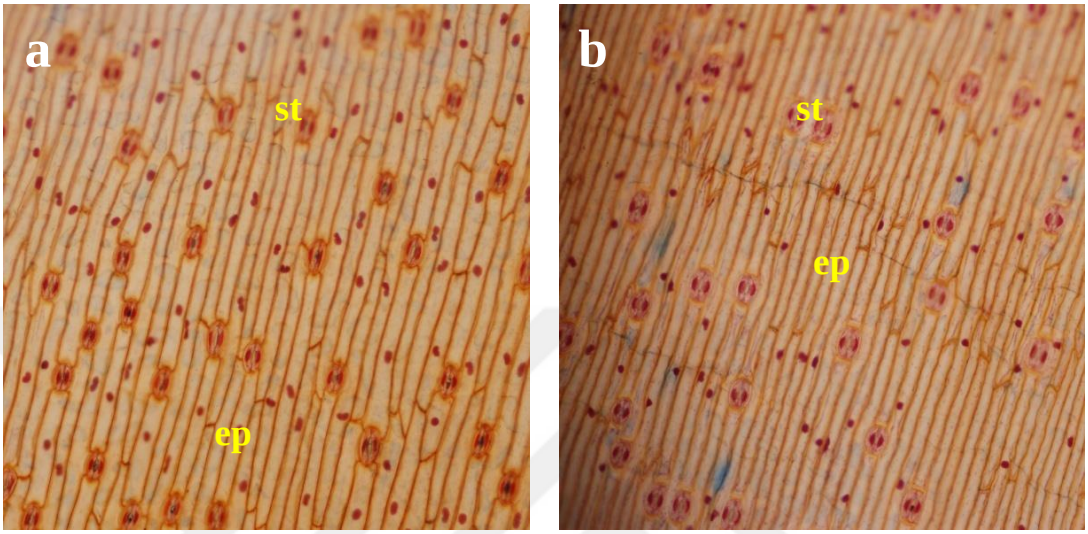

Figure 72. Leaf surface section of *T. sylvestris* subsp. *sylvestris*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.1.18 *Tulipa undulatifolia* Boiss. var. *undulatifolia*

4.1.18.1 Root Anatomy of *T. undulatifolia* var. *undulatifolia*

Transverse section of the root includes a single-layered epidermis composed of irregular shapes and irregular cells at the outermost surface. Epidermis cells are 13−36 × 13−38 µm. The single layered exodermis consisting of irregular shapes cells is found under the epidermis. Exodermis cells are 22−45 × 22−56 µm. The cortex is composed of 4−5 rows of ovoid or spheroid parenchymatous cells under the exodermis. These cells are 29−60 × 22−56 µm. The wall of the endodermis is over thickened and direction of thickning is towards cortex. The phloem components are located around 2−8 protoxylem ridges. 1−2 metaxylem is present on the median part of vascular cylinder (Figure 73).

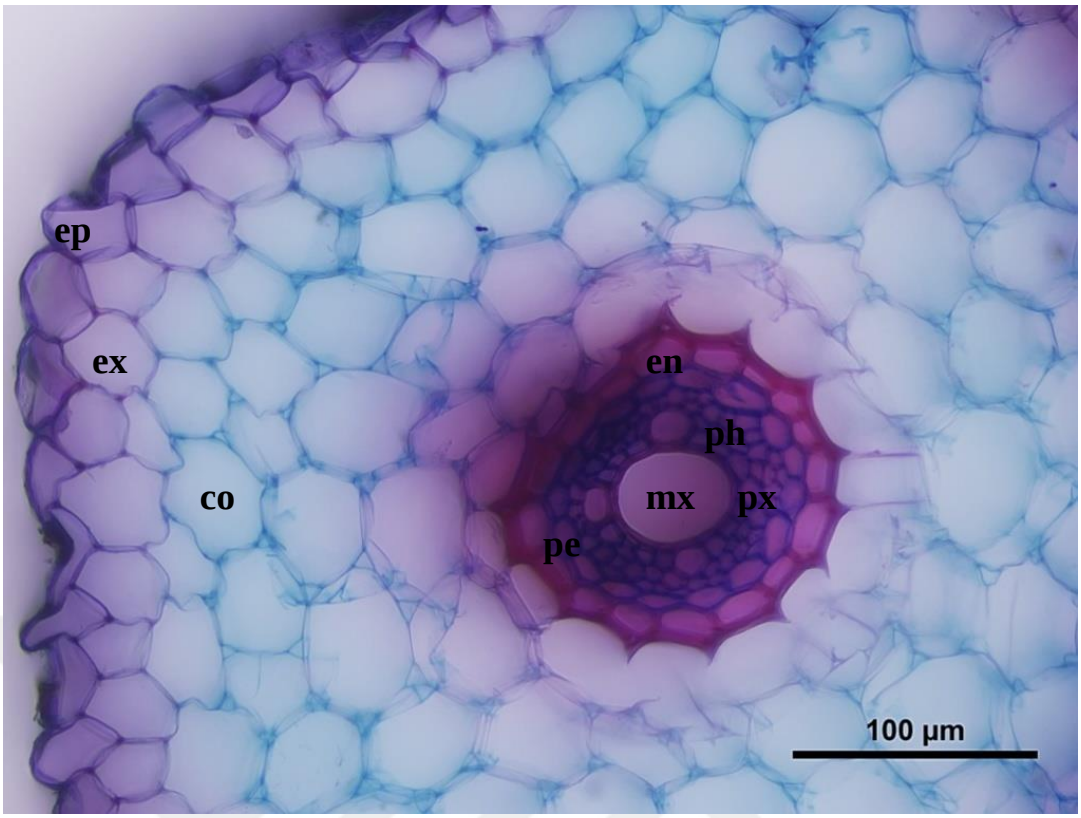

Figure 73. Root anatomy of *T. undulatifolia* var. *undulatifolia*; section of root (40x), ep: epidermis, ex: exodermis, co: cortex, en: endodermis, pe: pericycle, mx: metaxylem, ph: phloem, px: protoxylem.

4.1.18.2 Stem (Scape) Anatomy of *T. undulatifolia* var. *undulatifolia*

The epidermis is composed of rectangular cells which are 10−29 × 6−26 µm. The single-layered lamellar collenchyma is either lacking or found under the epidermis. The collenchyma composes of ovoid cells which are 15−40 × 9−15 µm. The cortex comprises parenchymatous cells and sclerenchymatic tissue. The parenchyma consists of 6−7 layered ovoid or spheroid cells which are 29−71 × 29−71 µm. The sclerenchyma tissue is either lacking or consists of 3−6 layered spheroid cells. The stem contains averagely 65 vascular bundles of various sizes in the vascular cylinder (Figure 74).

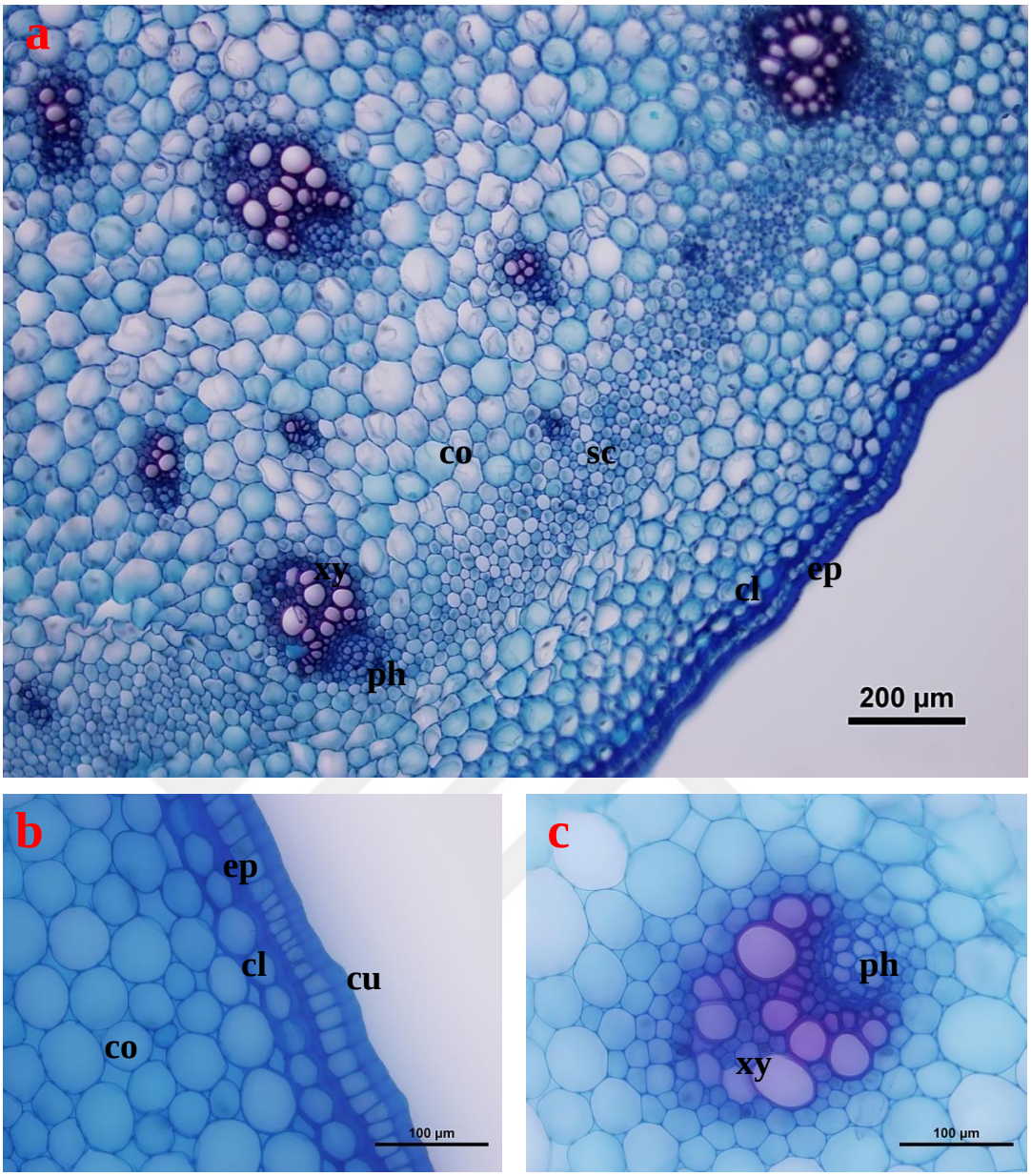

Figure 74. Stem anatomy of *T. undulatifolia* var. *undulatifolia*; a) section of stem (10x), b) epidermis and cortex in the stem section (40x), c) vascular bundle in the stem section (40x), cu: cuticle, ep: epidermis, cl: collenchyma, co: cortex, sc: sclerenchyma, ph: phloem, xy: xylem.

4.1.18.3 Leaf Anatomy of *T. undulatifolia* var. *undulatifolia*

Upper epidermis and lower epidermis consist of rectangular cells. The size of the upper epidermis cells are similir to the lower epidermis cells, which are 12−50 × 14−48 and 10−49 × 12−40 µm, respectively. Also there are basic hairs from epidermal cells. The parenchymatous cells composed of 7−16 layered ovoid or spheroid cells are 20−66 × 20−65 µm (Figure 75).

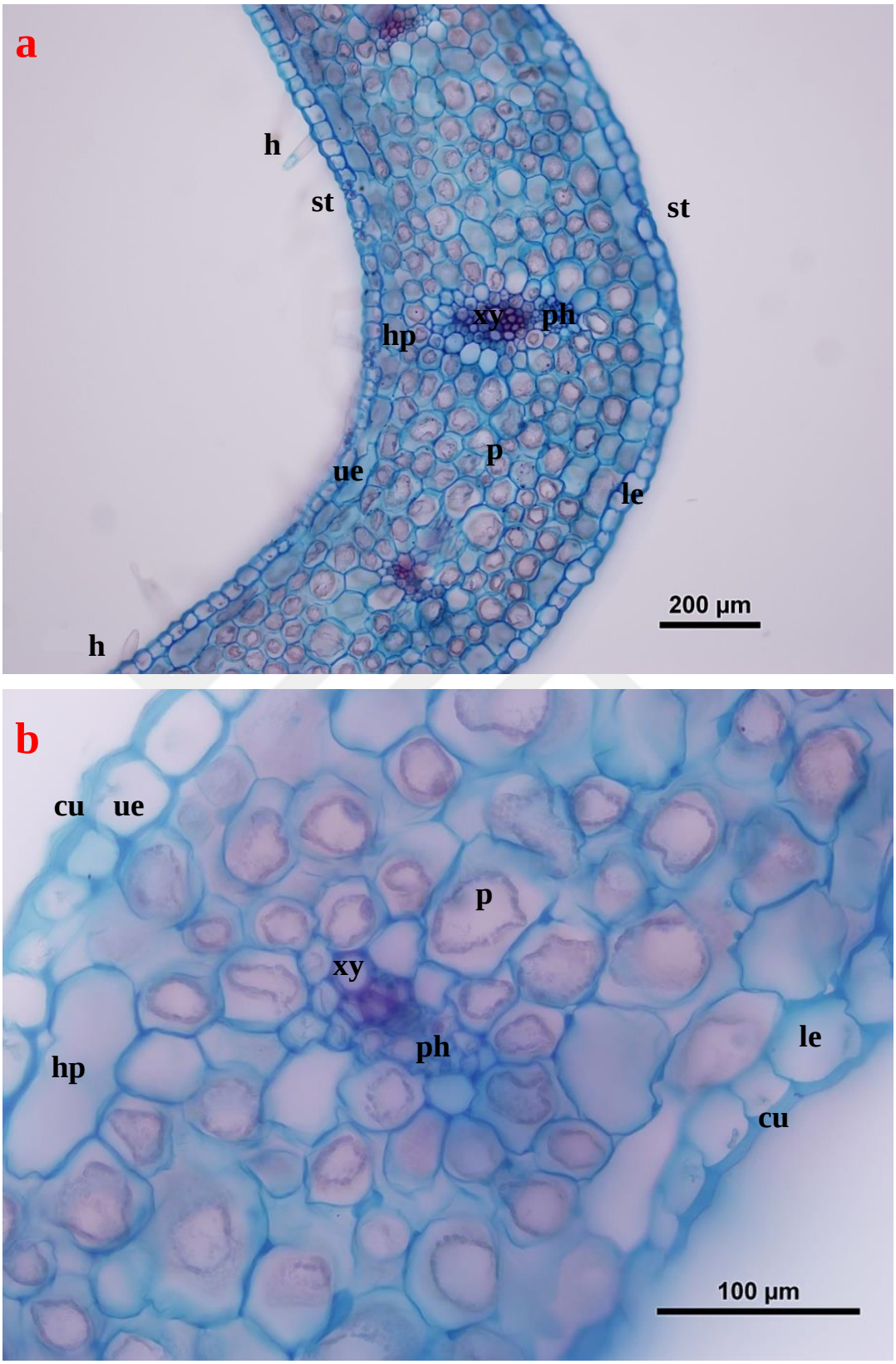

Figure 75. Leaf anatomy of *T. undulatifolia* var. *undulatifolia*; a) section of leaf (10x), b) section of leaf (40x), cu: cuticle, ue: upper epidermis, le: lower epidermis, p: parenchyma, hp: hypodermis, xy: xylem, ph: phloem, st: stomata, h: hair.

Average number of stomata and epidermal cells at 1 mm² on upper epidermis layer are calculated as 36 and 104, respectively. Stomata index is 25,71 for the upper

epidermis. Average number of stomata and epidermal cells at 1 mm² on lower epidermis are 38 and 80, respectively. Stomata index is 32,20 for the lower epidermis. Stomata index ratio is found as 0,79 (Figure 76).

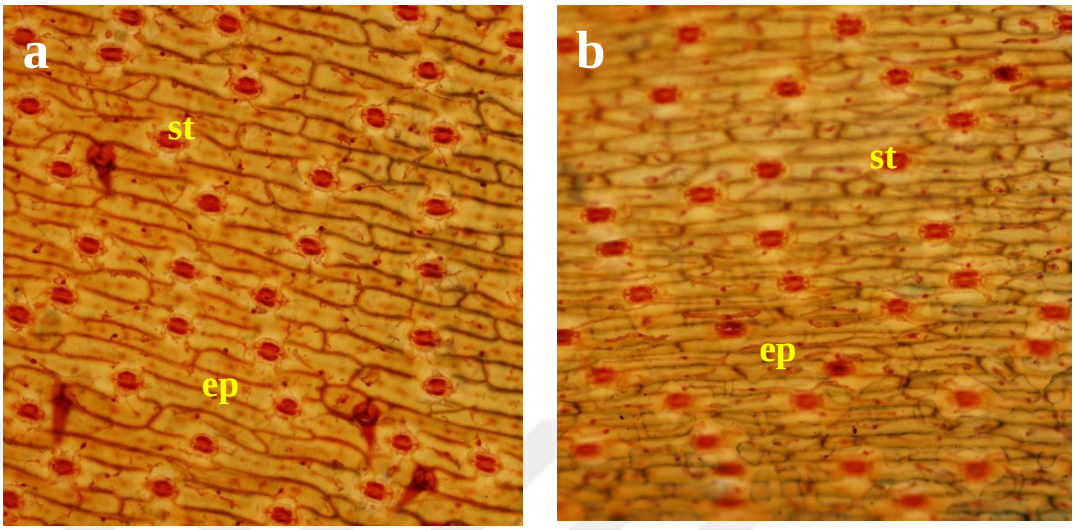

Figure 76. Leaf surface section of *T. undulatifolia* var. *undulatifolia*; a) lower epidermis, b) upper epidermis, ep: epidermis, st: stomata.

4.2 The Presence of Starch

According to studies based on the detection of the presence of starch granules, *T. agenensis* and *T. armena* var. *armena* rarely contain starch granules while *T. biflora, T. clusiana, T. cinnabarina, T. humilis, T. koyuncui, T. pulchella, T. orphanidea, T. saxatilis, T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *sylvestris* contain much more starch granules. However, it was detected that there was no starch granules in *Tulipa aleppensis, T. armena* var. *galatica, T. julia, T. raddii, T. sintenisii, T. undulatifolia* var. *undulatifolia.* The detailed comparison of starch granules presence among taxa are given in Table 10.

Table 10. The presence of starch.

No	Taxon	Stem	Leaf	No	Taxon	Stem	Leaf
1	AG1	rarely on cortex	absent	22	JU5	absent	absent
2	AG2	rarely on cortex	absent	23	KO1	intense on all cells	on stomata
3	AL1	absent	absent	24	OR1	intense on all cells	on stomata
4	AL2	absent	absent	25	OR2	intense on all cells	on stomata
5	AL3	absent	absent	26	OR3	intense on all cells	on stomata
6	AR1	rarely on cortex	absent	27	PU1	normal density on cortex	on stomata
7	AR2	rarely on cortex	absent	28	RA1	absent	absent

Table 10. The presence of starch (continued).

8	AR3	rarely on cortex	absent	29	RA2	absent	absent
9	AR4	rarely on cortex	absent	30	SA1	normal density on cortex	on stomata
10	AR5	rarely on cortex	absent	31	SI1	absent	absent
11	AR6	rarely on cortex	absent	32	SI2	absent	absent
12	AR7	rarely on cortex	absent	33	SI3	absent	absent
13	GA1	absent	absent	34	SI4	absent	absent
14	BI1	normal density on cortex	absent	35	SI5	absent	absent
15	CI1	normal density around of vascular bundles	on stomata	36	AU1	intense on all cells	absent
16	CL1	normal density on cortex	absent	37	AU2	intense on cortex	absent
17	HU1	normal density around of vascular bundles	on stomata	38	SY1	intense around of vascular bundles	on stomata
18	JU1	absent	absent	39	UN1	absent	absent
19	JU2	absent	absent	40	UN2	absent	absent
20	JU3	absent	absent	41	UN3	absent	absent
21	JU4	absent	absent	42	UN4	absent	absent

4.3 Results of Statistical Analyses

As a results of statistical analyses of taxa, ANOVA tests was used to find if there are significant differences in the anatomical characteristics of 42 populations. The statistics for all quantitative characters between populations are shown in Table 11. The level of statistical significance was set at $p<0.05$ in all analysis. The principle component and cluster analyses are used to analyse anatomical relationship of 42 populations using 31 ones among 59 measured/observed anatomical characters. The character states are listed in Table 12 and measurement of the quantitative characters are listed in Table 13.

Table 11. Results of one-way ANOVA for all quantitative characters.

No	Anatomical characters	SS	df	MS	F	P-value
1	Width of cortex region at root section	1112.49	41	27.13	0.99	0.50
2	Width of epidermal cells at root section	6443.45	41	157.16	8.90	0.00
3	Length of epidermal cells at root section	5255.56	41	128.18	7.64	0.00
4	Width of exodermal cells at root section	10329.46	41	251.94	10.56	0.00

Table 11. Results of one-way ANOVA for all quantitative characters (continued).

5	Length of exodermal cells at root section	9338.59	41	227.77	7.47	0.00
6	Width of cortex parenchymatous cells at root section	15167.44	41	369.94	6.11	0.00
7	Length of cortex parenchymatous cells at root section	17760.65	41	433.19	7.01	0.00
8	Row number of endodermal cells at root section	65.39	41	1.59	0.81	0.79
9	Row number of pericycle cells at root section	50.24	41	1.23	0.92	0.61
10	Width of endodermal cells at root section	30.24	41	0.74	0.70	0.91
11	Length of endodermal cells at root section	68.98	41	1.68	1.34	0.09
12	Width of pericycle cells at root section	42.61	41	1.04	1.21	0.19
13	Length of pericycle cells at root section	91.20	41	2.22	0.96	0.55
14	Number of protoxylem at root section	205.44	41	5.01	3.43	0.00
15	Number of metaxylem elements at root section	17.76	41	0.43	2.68	0.00
16	Width of metaxylem elements at root section	466.04	41	11.37	0.85	0.73
17	Length of metaxylem elements at root section	621.30	41	15.15	1.40	0.06
18	Diameter of stem (scape) section	480898263.63	41	11729225.94	95.13	0.00
19	The average number of cell in pith at stem section	77910.05	41	1900.25	1.10	0.32
20	Width of epidermal cells at stem (scape) section	4265.93	41	104.05	6.77	0.00
21	Length of epidermal cells at stem (scape) section	10009.45	41	244.13	17.65	0.00
22	Width of collenchyma cells at stem (scape) section	32950.91	41	803.68	7.76	0.00
23	Length of collenchyma cells at stem (scape) section	20483.71	41	499.60	7.81	0.00
24	Width of parenchymatous cells at stem (scape) section	16227.56	41	395.79	3.37	0.00
25	Length of parenchymatous cells at stem (scape) section	13432.48	41	327.62	3.07	0.00
26	Row number of sclerenchyma cells at stem (scape) section	565.86	41	13.80	8.31	0.00
27	Width of phloem elements at stem section	25.05	41	0.61	0.75	0.87
28	Length of phloem elements at stem section	17.86	41	0.44	0.73	0.89
29	Width of sclerenchyma cells at stem section	265.76	41	6.48	1.41	0.06
30	Length of sclerenchyma cells at stem section	180.85	41	4.41	0.79	0.83
31	Width of xylem elements at stem section	152.24	41	3.71	0.83	0.76
32	Length of xylem elements at stem section	430.88	41	10.51	1.12	0.29
33	Row number of parenchymatous cells at leaf section	2063.79	41	50.34	13.61	0.00
34	Width of upper epidermal cells at leaf section	12114.04	41	295.46	6.08	0.00
35	Length of upper epidermal cells at leaf section	10950.21	41	267.08	11.06	0.00
36	Width of lower epidermal cells at leaf section	18288.31	41	446.06	15.27	0.00

Table 11. Results of one-way ANOVA for all quantitative characters (continued).

37	Length of lower epidermal cells at leaf section	11501.56	41	280.53	13.98	0.00
38	Width of parenchymatous cells at leaf section	28298.21	41	690.20	10.41	0.00
39	Length of parenchymatous cells at leaf section	21192.23	41	516.88	6.23	0.00
40	Width of xylem elements at leaf section	336.25	41	8.20	1.08	0.35
41	Length of xylem elements at leaf section	494.56	41	12.06	1.18	0.22
42	Width of phloem elements at leaf section	30.76	41	0.75	1.06	0.37
43	Length of phloem elements at leaf section	46.85	41	1.14	1.20	0.19
44	Ratio of stoma index	11.81	41	0.29	4.39	0.00

In the PCA graph, the populations of both subgenera *Eriostemones* and *Tulipa* were seperated as two big groups. However, *T. clusiana* was placed far from both groups as being between these groups (Figure 77). On the other hand, populations mixed to each other. For this reason, only the subgenus *Eriostemones* were run for PCA analysis separately from the other subgenus using MINITAB program. In this situation, populations of subgenus *Eriostemones* were clearly separated. Populations of *T. orphanidea* were located in a different part from the remainder of section *Sylvestres*. It was located close to *T. cinnabarina, T. humilis* and *T. pulchella* in section *Saxatiles*. However, *T. saxatilis* was located far from the other taxa according to PCA (Figure 78).

If only section *Sylvestres* were run separately from the other section, all taxa were clearly separated from each other and occured two subsections which was compatible with these results of Eker et al (2014). Moreover, *Tulipa sylvestris* subsp. *australis*, *T. sylvestris* subsp. *sylvestris* and *T. biflora* were also clearly separated from each other, and *T. koyuncui* was placed far from these taxa (Figure 79).

Only the subgenus *Tulipa* were analysed separately from the other subgenus in PCA. Many populations of subgenus *Tulipa* formed a complex group, and only *T. raddii* and *T. undulatifolia* var. *undulatifolia* did not locate inside this complex. These populations clearly separated from others. Also populations of *T. agenensis* were nearer to the complex group but were separated from the other populations (Figure 80). According to the results of PCA analysis, these complex group contained a few problems. Therefore, cluster analysis was performed.

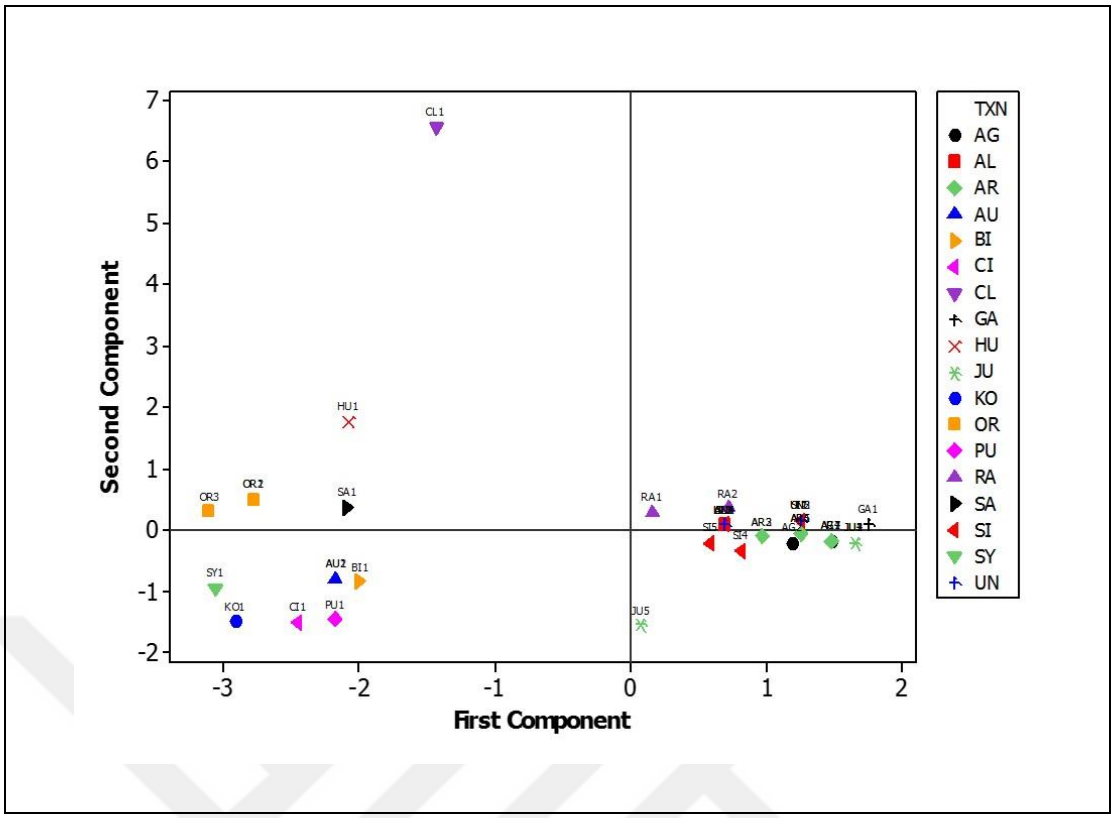

Figure 77. Results of principle component analysis of all taxa.

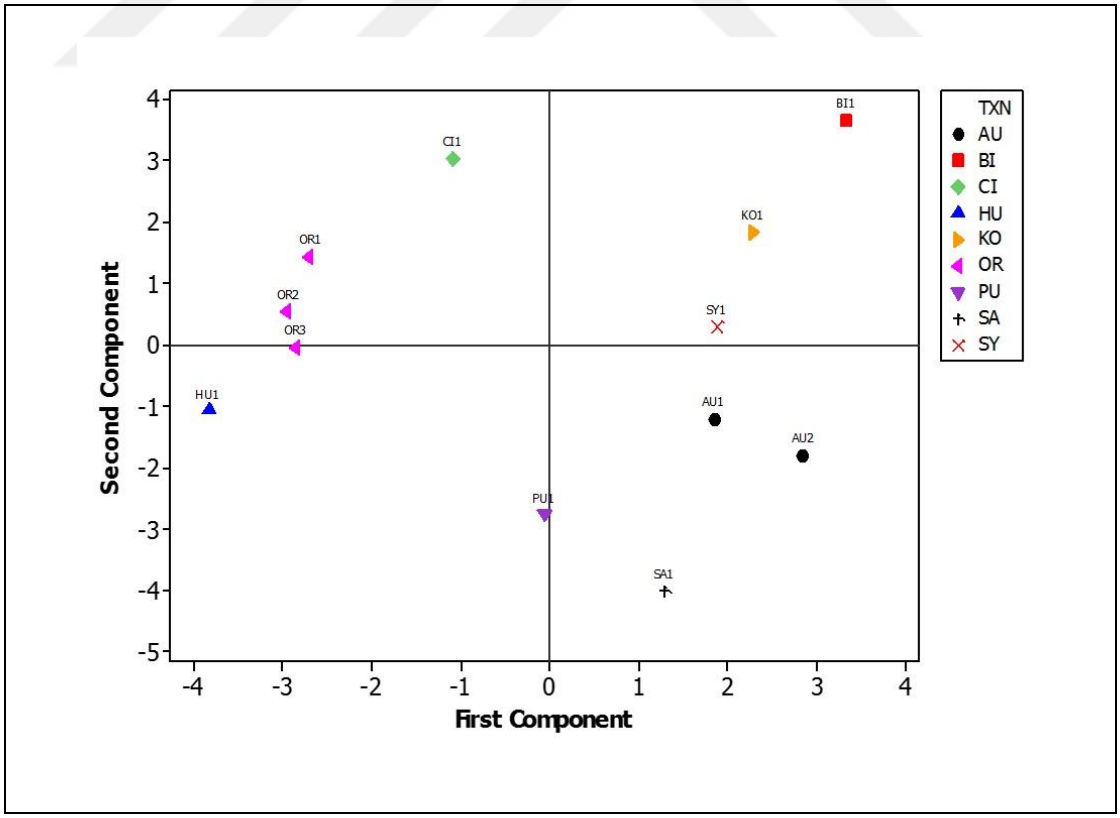

Figure 78. Results of principle component analysis of subgenus *Eriostemones.*

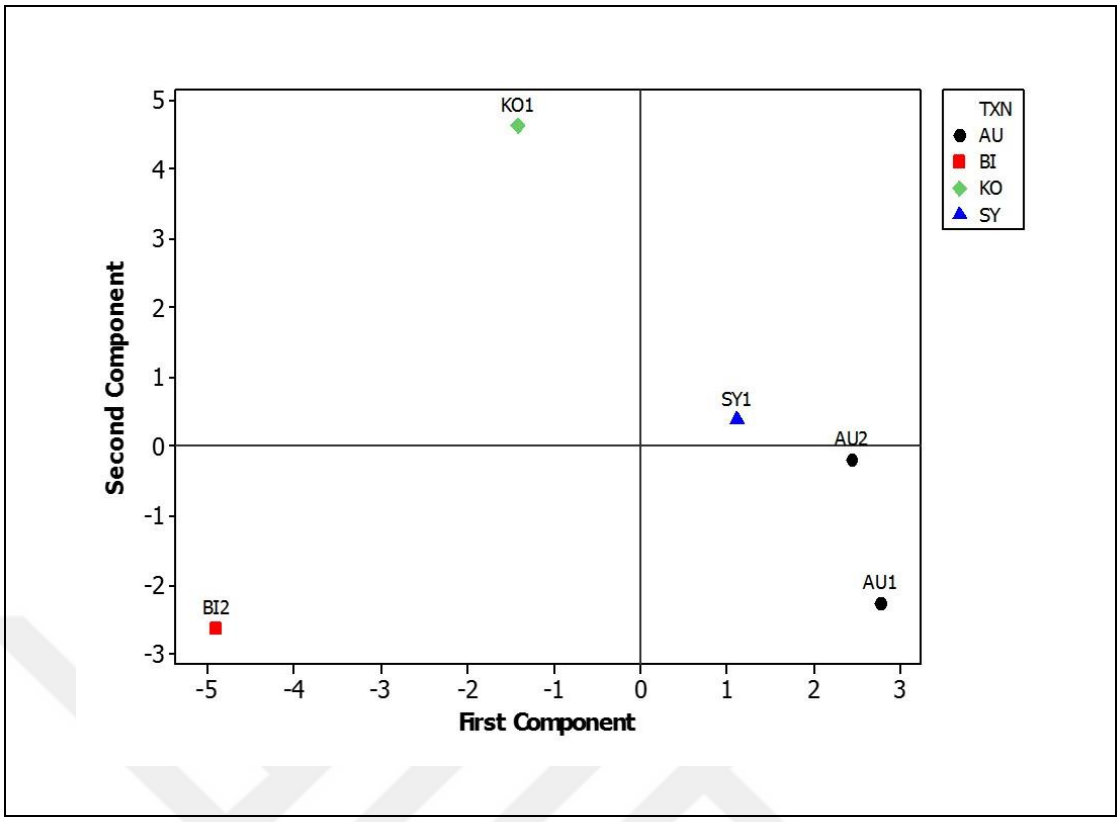

Figure 79. Results of principle component analysis of section *Sylvestres*.

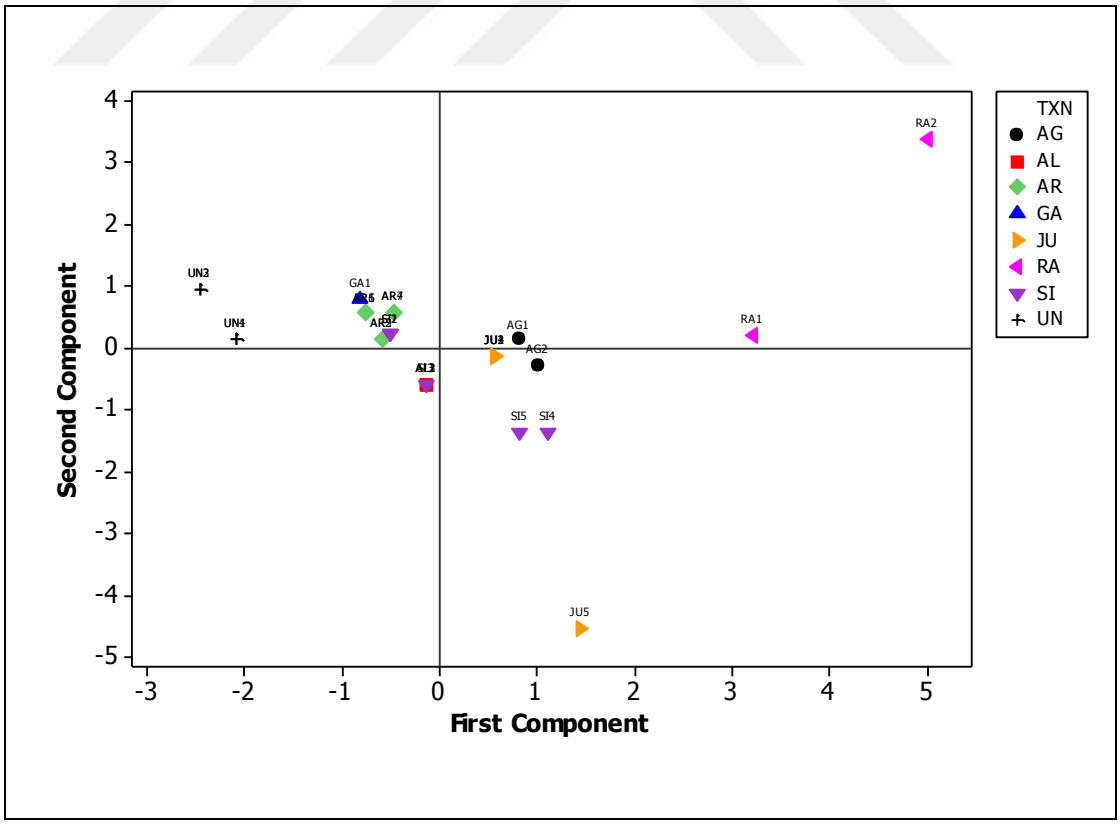

Figure 80. Results of principle component analysis of subgenus *Tulipa*.

The results of cluster analysis can be determined as follows (Figure 81): All the clusters were generated between 21.94-100.00% similarity levels. At 96.80% similarity level (SL), AR1 & AR5 & AR6 ve AR2 & AR3 were generated as the first clusters that they were completely the same with each others. But AR4 & AR7 population showed some differences which was joined to the AR populations at 94.99% SL. Therefore, all AR populations were placed in the same cluster. After, JU1 & JU2 & JU3 & JU4 linked to each other at 100.00% SL. Other JU5 populations showed different clusters at different SLs. Similarly, AG1 & AG2 linked to each other at 96.80% SL. The groups of JU1-JU2-JU3-JU4 and AG1-AG2 were also combined to each other at 91.31% SL. Finally, the homogenous group of AR1-AR5-AR6-AR2-AR3-AR4-AR7 combined to heterogenous group of JU1-JU2-JU3-JU4-AG1-AG2 at 85.55% SL and generated the first subgroup (SG-I).

SI1 & SI2 linked to each other at 100.00% SL. SI3 & AL1 & AL2 & AL3 also linked to each other at 100.00% SL. Additionally, SI1 & SI2 and SI3 & AL1 & AL2 & AL3 combined with each other at 93.59% SL. The unique population GA1 joined to this group at 85.78% SL and then heterogenous group of GA1-SI1-SI2-SI3-AL1-AL2-AL3 generated a second subgroup (SG-II). SG-II merged to the first subgroup (SG-I) at 80.40% SL. After, SI4 & SI5 were generated a cluster at 96.27% SL. JU5 linked to this group at 88.43% SL and generated the third subgroup (SG- III). This SG-III linked to the clusters of SG-I and SG-II at 77.62% SL.

RA1 & RA2 linked to each other at 82.68% SL and generated fifth subgroup (SG-IV). This SG-IV linked to the clusters of SG-I, SG-II and SG-III at 68.14% SL. On the other hand, UN1 & UN4 joined to each other at 100.00% SL. At the same time UN2 & UN3 also joined at 100.00% SL. Then these two groups combined to each other at 93.59% SL and generated the third subgroup (SG-V). Finally, the fifth subgroup (SG-V) containing population of UN1-UN4-UN2-UN3 joined to the clusters of subgroups (SG-I, SG-II, SG-III and SG-IV) at 64.97% SL. Consequently, the first main group (MG-I) that was the represantative of subgenus *Tulipa* was generated.

The second main group (MG-II) contained less subgroups. First of all, KO1 & CI1 linked to each other at 89.04% SL. Secondly, AU1 & AU2 linked to each other at 100.00% SL and then unique population BI1 joined to this group at 92.70% SL.

Later, unique population SY1 linked to the heterogenous group of BI1-AU1-AU2 at 83.46 % SL. Finally the two groups, KO1-CI1 and BI1-AU1-AU2-SY1 combained with each other at 69.12% SL and the sixth subgroup (SG-VI) was generated. OR1 & OR2 generated a cluster at 100.00% SL. OR3 joined to this group at 89.85% SL and then unique population SA1 joined to this group at 77.26% SL. After, PU1 & HU1 joined to each other at 89.72% SL. Then these two clusters, which are SA1-OR1-OR2-OR3 and PU1-HU1 combined to each other at 71.78% SL and they formed the last subgroup (SG-VII). SG-VI and SG-VII linked to one another and then generated the second main group, MG-II at 64.89% SL. Consequently, this main group comprised the members of subgenus *Eriostemones.*

As a final result of this cluster analysis, MG-I and MG-II combined to each other at 37.17% SL. Finally, an unique population of CL1 also linked to MG-I and MG-II, and the third main group, MG-III was generated that comprised the member of subgenus *Clusianae* (Figure 81).

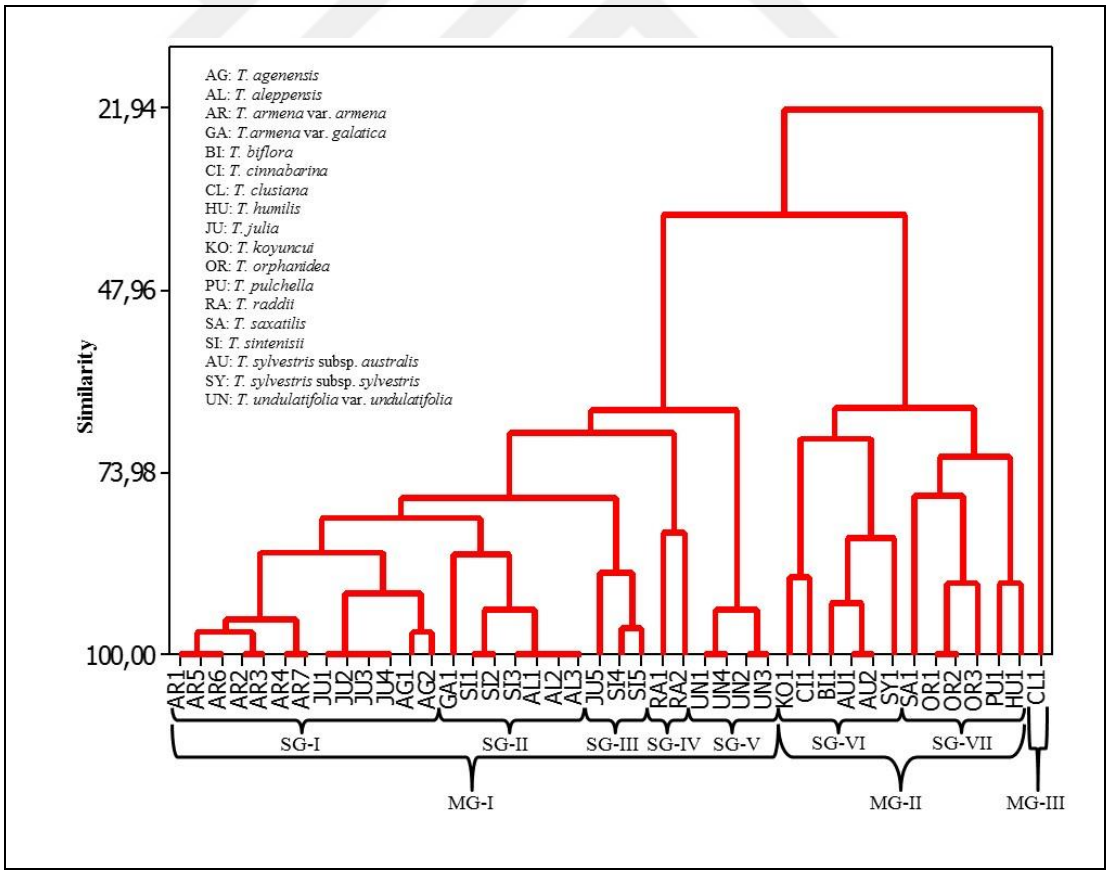

Figure 81. Dendrogram of average linkage (between groups) in the hierarchical cluster analysis of 42 populations.

The results of cluster analysis can be determined as follows using the average of the measurements of populations (Figure 82): All the clusters were generated between 21.94-100.00% similarity levels. Firstly, AR & AG were generated as the first clusters at 90.22% SL. Secondly, RA joined to this group at 77.40% SL. Then, SI & AL linked to each other at 96.78% SL. JU joined to this group at 85.35% SL and GA linked to JU-SI-AL cluster at 83.30% SL. The group of AR-AG-RA combined to group of GA-JU-SI-AL at 74.61% SL and the first subgroup (SG-I) was generated. Finally, UN linked to this group at 54.47% SL and the second subgroup, SG-II was generated. Consequently, MG-I generated the first main group that comprised the members of subgenus *Tulipa.*

The second main group (MG-II) formed as follows: Firstly, KO & CI linked to each other at 87.03% SL and then BI linked to this group at 75.92% SL. The third subgroup (SG-III) was generated. Secondly, PU & HU linked to each other at 87.83% SL and then OR linked to this group at 81.20% SL. The fourth subgroup (SG-IV) was generated. SG-III merged to the fourth subgroup (SG-IV) at 69.76% SL. After, AU & SY linked to each other at 84.91% SL. Additionaly, SA linked to this group at 67.32% SL and the fifth subgroup (SG-V) was generated.

As a result, SG-III and SG-IV combained with SG-V at 57.41% SL. The second main group (MG-II) was generated that comprised the members of subgenus *Eriostemones.* Finally an unique population of CL also linked to MG-I and MG-II. The third main group, MG-III was generated that comprised the member of subgenus *Clusianae* (Figure 82).

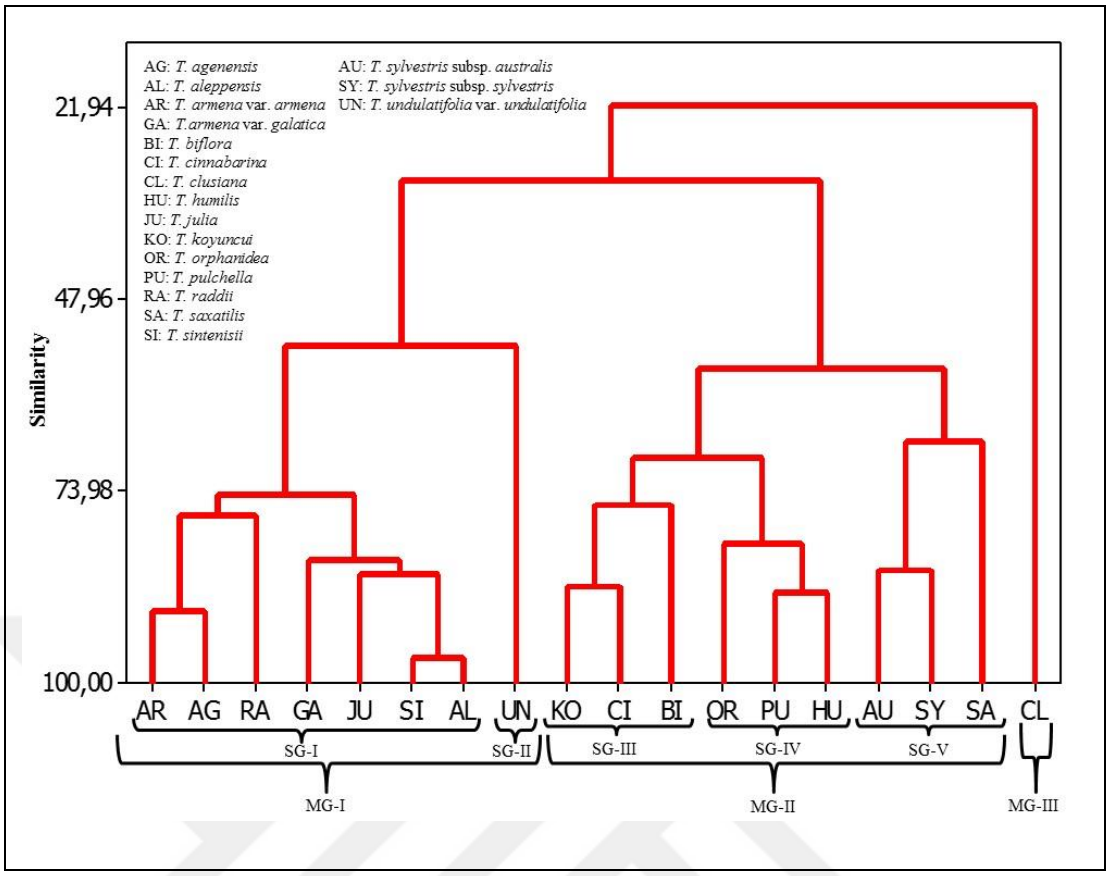

Figure 82. Dendrogram of average linkage in the hierarchical cluster analysis of 18 taxa.

Table 12. Selected characters and character states used in principal component and cluster analyses.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TXN	**ERW**	**ERL**	**EXW**	**EXL**	**COW**	**COL**	**NPR**	**NMR**	**EPW**	**EPL**	**CLW**	**CLL**	**PAW**	**PAL**	**RSS**	**UPW**	**UPL**	**PLW**	**PLL**	**LOW**	**LOL**	**RPL**	**RSI**	**DSS**	**PSC**	**PSS**	**PSL**	**PHL**	**PHY**	**TEC**	**PCB**
AG1	1	1	1	2	1	0	0	0	1	0	0	3	0	1	2	0	0	0	0	0	1	1	1	3	1	1	0	0	1	2	1
AG2	2	1	0	1	1	0	0	0	1	1	0	3	0	1	2	1	1	2	1	0	1	2	1	3	1	1	0	0	1	1	1
AL1	1	2	0	1	2	1	1	0	0	0	0	0	1	1	1	2	2	2	1	2	1	3	1	2	1	0	0	0	1	2	1
AL2	1	2	0	1	2	1	0	1	2	0	0	0	2	1	1	2	0	2	1	1	1	3	1	2	1	0	0	0	1	2	1
AL3	2	2	0	2	2	1	1	1	1	0	0	0	2	0	2	1	1	2	1	2	1	3	1	2	1	0	0	0	1	0	1
AR1	2	1	1	1	2	2	1	0	1	1	0	2	1	1	2	0	0	1	1	0	1	1	1	0	0	1	0	0	1	1	1
AR2	1	1	1	2	2	0	1	1	1	1	0	2	1	2	2	1	1	1	1	1	1	2	1	0	0	1	0	0	1	2	1
AR3	1	1	1	2	2	1	0	0	1	1	0	2	0	1	2	1	0	1	2	2	1	2	1	0	0	1	0	0	1	2	1
AR4	1	1	1	1	1	1	0	0	1	2	0	3	0	0	2	1	1	1	0	2	1	1	1	0	1	1	0	0	1	2	1
AR5	1	1	0	1	1	2	0	0	1	0	0	2	2	1	2	0	0	1	1	2	1	1	1	0	1	1	0	0	1	0	1
AR6	0	1	0	0	1	1	1	0	1	0	0	2	1	1	2	1	0	1	1	1	1	1	1	0	1	1	0	0	1	0	1
AR7	0	1	0	2	1	2	0	0	1	2	0	3	0	1	2	2	1	1	1	1	1	1	2	0	1	1	0	0	1	0	1
GA1	2	2	1	2	1	2	1	0	0	1	0	1	0	0	1	0	0	1	0	1	1	0	1	1	1	0	0	0	1	2	1
JU1	0	1	2	2	1	2	1	0	1	1	0	3	0	0	2	1	1	0	0	1	1	2	0	2	0	0	0	0	1	2	1
JU2	0	1	2	2	1	2	1	0	0	0	0	3	0	1	2	1	1	1	1	1	1	2	1	2	0	0	0	0	1	2	1
JU3	1	1	2	2	1	0	1	0	2	1	0	3	2	2	1	1	0	1	0	1	1	2	1	2	1	0	0	0	1	2	1
JU4	2	1	2	2	1	1	1	0	1	1	0	3	0	1	2	1	2	2	1	1	1	2	1	2	1	0	0	0	1	2	1
JU5	2	2	2	2	1	1	1	0	1	1	0	2	0	0	2	1	0	1	1	0	0	5	1	2	0	0	0	0	1	2	1
SI1	2	1	1	1	1	2	1	0	1	0	0	0	2	2	2	1	0	1	1	1	1	1	1	2	1	0	0	0	1	2	1
SI2	2	1	1	1	1	1	1	0	1	0	0	0	2	1	1	0	0	1	1	1	1	1	0	2	1	0	0	0	1	2	1
SI3	0	1	0	1	1	0	1	0	0	0	0	0	1	1	2	1	1	1	1	1	1	3	1	2	0	0	0	0	1	2	1
SI4	1	1	0	1	1	0	1	1	0	1	0	3	1	1	2	1	0	1	0	1	1	5	1	2	1	0	0	0	1	2	1
SI5	1	1	0	1	1	0	1	0	1	1	0	2	2	1	2	1	0	2	1	2	1	5	1	2	0	0	0	0	1	2	1
RA1	2	1	0	0	1	0	1	0	1	1	0	3	1	1	2	2	2	2	2	2	1	4	0	3	0	0	0	0	1	2	0
RA2	2	1	1	2	2	2	1	0	1	0	0	3	1	0	2	2	0	0	0	0	1	2	1	3	1	0	1	0	1	2	0
UN1	2	1	2	2	1	0	0	0	1	0	0	0	1	1	1	0	0	2	1	2	1	3	1	0	1	0	0	1	1	0	1
UN2	2	1	2	2	1	0	0	0	2	0	0	0	2	2	2	1	1	2	1	0	1	1	1	0	1	0	0	1	1	0	1
UN3	2	1	2	2	1	0	0	0	1	1	0	0	1	1	2	1	0	1	1	2	1	1	1	0	1	0	0	1	1	0	1
UN4	2	1	2	2	1	0	1	1	1	0	0	0	1	1	1	1	0	1	1	2	1	3	1	0	1	0	0	1	1	2	1
CL1	0	0	1	2	0	0	1	1	1	1	0	0	2	2	2	0	1	2	2	2	2	4	1	0	1	2	0	0	0	0	0
BI1	2	1	0	1	1	0	1	1	1	1	2	1	0	0	0	0	0	1	0	0	0	2	1	4	1	2	0	0	1	1	0
CI1	2	1	2	2	2	2	0	0	1	2	4	0	1	1	0	0	1	0	1	0	0	1	0	4	0	2	1	0	1	0	1
HU1	0	0	2	2	2	2	1	0	1	1	3	0	1	0	1	1	1	2	2	2	2	2	1	4	1	2	1	0	1	0	0

Table 12. Selected characters and character states used in principal component and cluster analyses (continued).

KO1	2	1	0	1	0	0	0	0	0	0	2	0	1	1	0	2	1	0	0	0	0	2	1	4	0	3	1	0	1	0	1
OR1	2	1	2	2	2	2	0	0	1	0	4	0	1	0	1	1	1	1	2	1	1	0	0	4	1	3	1	0	1	0	0
OR2	2	1	0	2	1	1	1	0	1	0	4	0	1	2	0	1	0	1	2	1	1	0	1	4	0	3	1	0	1	0	0
OR3	0	1	1	2	1	0	1	0	2	0	4	1	1	1	0	1	1	2	2	0	1	0	0	4	0	3	1	0	1	0	0
PU1	1	0	0	0	0	0	1	0	1	1	3	0	1	1	1	2	2	2	2	1	0	1	1	4	1	2	1	0	1	0	1
SA1	2	1	0	1	1	0	0	0	2	1	1	2	2	2	2	2	1	2	2	2	1	1	2	4	1	2	1	0	1	0	0
AU1	2	1	0	1	0	2	1	0	1	2	2	1	1	1	2	1	0	2	2	1	0	2	1	4	1	3	0	0	1	0	0
AU2	0	1	0	0	0	0	0	0	1	2	2	1	2	1	2	1	1	1	0	0	0	2	1	4	1	3	0	0	1	0	0
SY1	1	1	0	0	0	0	1	1	1	1	2	1	0	1	2	1	1	1	1	0	0	1	1	4	1	3	1	0	1	0	0

Table 13. Measurement of the quantitative characters (minimum and maximum).

TXN	ERW	ERL	EXW	EXL	COW	COL	NPR	NMR	EPW	EPL	CLW	CLL	PAW	PAL	RSS	UPW	UPL	PLW	PLL	LOW	LOL	RPL	DSS
AG1	14−25	14−29	18−40	22−45	36−49	30−50	2−6	1−2	11−21	11−19	13−30	22−40	22−65	29−70	2−5	15−29	19−29	20−33	22−32	14−20	19−25	5−9	3215−3950
AG2	19−28	20−28	19−28	21−33	40−48	28−50	3−5	1−2	13−22	21−29	15−23	22−35	20−59	30−50	3−4	20−39	21−34	42−60	30−56	10−15	16−23	6−11	3100−3860
AL1	16−25	23−38	15−28	20−35	32−60	30−65	4−7	1−2	8−19	8−19	15−29	10−11	19−72	30−80	2−4	22−46	29−40	35−59	32−59	22−39	20−25	9−16	2450−2985
AL2	14−26	21−36	15−32	16−32	29−55	32−56	3−5	1−3	15−30	10−15	10−30	10−11	29−63	29−62	2−3	22−42	18−25	30−70	30−50	17−31	20−39	9−12	2390−2780
AL3	20−25	20−38	12−28	20−38	30−60	30−60	4−5	1−3	16−27	10−24	22−36	10−12	40−56	30−56	3−5	20−49	21−29	30−52	28−60	29−34	19−22	8−16	2120−2720
AR1	20−25	15−25	20−32	20−29	46−56	29−62	5−6	1−2	9−19	19−30	15−35	12−30	29−69	20−74	3−6	14−22	15−21	20−40	27−52	15−20	24−28	5−9	1330−1856
AR2	14−26	10−26	20−26	25−36	20−60	30−60	3−7	1−3	15−20	17−23	21−33	16−25	30−49	35−59	4−5	20−26	20−39	21−40	26−50	17−26	23−30	8−16	1569−1950
AR3	12−26	16−22	19−32	22−45	30−56	36−59	3−6	1−2	12−20	17−30	16−22	12−22	30−62	33−60	2−5	20−40	11−21	30−50	21−68	20−39	20−30	7−11	1215−1850
AR4	10−25	15−25	16−30	20−33	39−57	25−62	4−6	1−2	10−20	25−38	10−30	15−30	29−59	29−61	3−5	22−35	22−29	20−60	28−40	20−42	15−32	5−9	1465−1650
AR5	10−22	15−26	19−29	15−32	30−55	36−60	2−5	1−2	10−20	15−26	19−29	15−30	29−59	20−53	4−5	15−20	12−19	20−42	26−49	19−49	19−32	5−9	1560−1800
AR6	10−25	12−26	15−26	16−27	28−56	20−52	3−7	1−2	10−25	12−25	20−32	12−30	30−62	32−60	3−5	18−31	15−22	22−52	20−59	19−28	20−29	5−9	1350−1903
AR7	10−19	10−20	10−30	23−35	30−50	28−58	3−5	1−2	10−19	22−35	15−35	12−32	30−66	30−61	3−5	22−39	17−29	20−52	30−45	19−27	20−26	5−9	1320−1910
GA1	21−31	21−32	21−32	23−37	40−51	42−60	4−8	1−2	9−14	16−25	20−30	15−17	20−30	25−39	3−5	12−28	11−23	25−37	21−41	17−28	25−34	5−10	1710−1989
JU1	14−23	12−22	16−36	32−45	25−58	45−62	4−7	1−2	9−25	10−29	14−30	18−33	20−61	25−50	2−4	21−38	21−30	19−35	20−46	14−30	20−26	6−15	2700−2960
JU2	10−21	12−22	16−36	32−42	30−58	42−58	4−9	1−2	8−16	15−20	11−27	11−29	32−50	35−47	3−4	17−50	20−40	25−39	30−50	20−26	16−26	5−12	2410−2659
JU3	10−31	20−28	20−37	21−42	33−50	30−55	4−6	1−2	15−37	20−28	22−33	33−37	42−78	45−79	3−4	16−40	20−30	21−40	20−46	12−26	16−30	7−12	2190−2999
JU4	15−30	20−32	21−37	20−45	29−45	30−56	3−8	1−2	11−19	20−26	19−30	22−33	25−49	20−50	2−4	25−37	29−38	30−50	30−50	18−32	20−22	6−11	2145−2874
JU5	16−32	20−32	23−42	20−45	28−46	38−52	4−9	1−2	12−22	17−24	15−35	15−25	30−40	25−42	3−6	15−32	10−20	27−57	28−50	12−30	10−25	11−16	2070−2980
SI1	17−26	15−30	19−35	15−35	35−59	39−60	4−9	1−2	15−24	14−23	24−39	10−12	42−65	30−66	3−5	15−40	16−32	26−50	30−82	20−26	15−26	5−10	1800−4200
SI2	17−29	14−29	20−35	13−32	35−50	35−62	3−7	1−2	8−19	13−25	20−30	10−11	32−60	38−57	2−5	13−30	15−30	29−49	29−50	20−34	20−39	5−11	2111−3698

Table 13. Measurement of the quantitative characters (minimum and maximum) (continued).

SI3	10–20	15–30	18–30	11–40	29–52	38–59	3–7	1–2	8–20	10–15	29–42	10–13	40–70	34–60	2–5	23–32	15–39	25–40	29–45	19–30	25–31	7–15	2059–3569
SI4	12–20	17–29	15–29	16–30	30–60	36–50	3–8	1–2	10–16	16–26	20–30	20–30	22–65	22–55	3–5	20–40	18–26	30–49	26–50	11–29	15–30	10–17	2200–4650
SI5	15–26	16–29	16–26	20–35	30–46	20–45	4–8	1–2	10–17	15–32	10–20	17–22	20–70	25–61	3–4	20–35	10–16	32–56	30–51	12–30	17–30	9–17	2311–4348
RA1	19–30	19–29	20–29	15–29	30–50	30–50	4–6	1–2	8–21	12–30	25–32	30–38	30–57	30–60	3–5	20–50	30–40	32–53	50–70	21–40	20–37	5–16	3504–3981
RA2	20–33	20–28	29–50	21–39	36–78	31–82	3–6	1–2	18–28	10–25	25–40	24–32	38–63	30–49	3–4	25–50	18–26	18–39	23–39	25–59	20–40	8–14	3211–3970
UN1	14–36	16–36	26–42	24–46	32–56	32–46	2–8	1	10–22	10–20	20–40	9–13	29–60	29–65	3–4	12–32	15–26	25–66	25–65	22–49	20–36	7–16	1029–1998
UN2	13–29	15–29	29–40	22–36	29–60	22–45	3–7	1	12–29	6–26	16–33	9–15	32–71	33–71	3–5	19–49	19–48	32–62	20–49	10–18	14–32	7–11	1080–2180
UN3	19–35	13–38	22–40	29–43	32–58	33–56	3–6	1	12–25	17–24	21–35	10–15	39–52	37–51	3–6	15–50	15–30	20–50	29–45	19–40	19–30	7–10	1450–1785
UN4	19–36	15–36	22–45	26–56	32–46	35–52	4–7	1–2	10–22	10–19	15–30	9–13	29–68	29–65	3–5	12–40	14–22	20–50	20–65	24–46	12–40	9–14	1120–1900
CL1	10–20	10–19	17–34	20–35	30–37	20–36	4–8	1–2	12–30	19–22	26–36	9–12	55–70	55–70	2–4	11–28	14–31	35–61	32–59	15–46	29–52	9–14	1040–2750
BI1	16–26	13–21	18–29	15–30	20–49	19–48	3–8	1–2	10–18	18–26	25–39	9–15	30–50	29–50	2–3	8–25	12–39	22–45	24–52	13–21	14–21	7–14	4170–4771
CI1	21–30	19–29	22–38	22–35	35–56	30–59	3–6	1	12–19	26–32	35–48	9–11	30–60	39–55	3–4	10–29	20–30	20–32	20–59	14–20	15–19	6–15	4012–4980
HU1	8–20	10–20	20–37	23–34	37–60	33–59	3–6	1–2	9–21	15–26	34–45	10–12	30–52	33–54	2–4	20–40	20–41	29–49	27–59	19–49	30–42	7–11	4360–4678
KO1	16–26	11–25	20–26	14–33	30–40	30–40	3–5	1	9–15	12–20	30–42	9–11	30–55	33–50	2–3	28–40	20–30	20–37	25–40	10–20	9–16	8–14	3750–4906
OR1	20–29	19–30	25–41	20–39	40–64	39–65	3–7	1–2	10–21	12–19	35–49	10–11	30–59	20–42	3–5	21–39	21–33	28–46	36–59	20–29	20–39	5–6	4055–4455
OR2	20–28	20–26	18–28	21–40	31–59	41–60	4–8	1–2	14–21	10–20	41–49	9–10	34–60	42–62	2–3	21–31	20–25	25–41	32–55	20–38	20–30	5–9	4050–4730
OR3	10–20	15–20	20–37	21–40	30–45	30–50	4–7	1	20–32	10–25	45–49	10–18	35–50	30–52	2–3	19–33	21–33	30–53	34–58	10–20	20–32	5–9	3630–4630
PU1	15–21	13–19	16–21	15–20	25–42	22–41	2–7	1	10–26	20–35	30–49	9–11	20–71	27–65	3–4	19–50	20–50	55–79	50–80	10–29	11–20	5–13	4260–4460
SA1	17–30	20–22	19–29	15–35	28–62	22–60	3–6	1	18–25	19–22	23–39	10–20	39–79	29–76	2–4	25–50	20–49	40–59	40–60	20–39	15–30	5–15	4100–4321
AU1	15–28	15–29	14–26	15–35	30–60	41–60	2–7	1	9–19	25–39	30–39	8–19	28–60	29–62	2–4	19–32	16–32	32–69	35–63	15–30	15–22	7–11	4009–4991
AU2	11–20	10–21	12–20	15–25	23–41	20–49	3–5	1	11–28	25–35	29–40	9–19	39–61	39–58	3–6	12–30	20–30	21–35	20–40	10–25	11–19	7–11	3370–4604
SY1	15–21	17–21	10–22	17–25	22–31	26–38	3–8	1–3	8–26	20–30	30–39	8–19	29–50	29–50	3–4	19–40	20–29	25–41	29–56	10–25	15–26	5–11	3360–4774

5. DISCUSSION

This thesis represents a comprehensive and a comparative anatomical study of the genus *Tulipa* in Turkey for the first time. In the light of anatomical studies, transverse sections of the roots of taxa were divided to epidermis, exodermis, cortex, endodermis, phloem, protoxylem and metaxylem, and these parts were separately measured. According to measured characters, there were some differences between taxa and within populations. *Tulipa clusiana* differed from other taxa in no having wall thickening of the endodermis while the other taxa had thickening of endodermis in which direction of thickning was towards cortex. This kind of thickening of endodermis is common feature in the monocotyledones (Fahn, 1982). In the previous anatomical studies, the thickening of endodermis was also reported for *T. armena* var. *lycica, T. aleppensis* and *T. orphanidea* (Kandemir and Özkan, 2000; Ocak et al., 2004; Satıl and Akan, 2006; Soykan and Meriç, 2012). Additionally, number of protoxylem components showed differences in root sections. All populations of *T. cinnabarina, T. koyuncui, T. pulchella, T. saxatilis* and *T. sylvestris* subsp. *australis* were presented with a single of metaxylem while it might be found much number in other populations.

Transverse sections of the stem were divided to epidermis, cortex, phloem and xylem, and these parts were separately measured. There were important differences among taxa according to anatomical characteristics of sclerenchyma and collenchyma. All populations of *T. agenensis, T. clusiana, T. raddii, T. saxatilis* and *T. sylvestris* subsp. *australis* contained sclerenchymatic tissue in the stem sections. However, some populations of *T. aleppensis, T. armena var. armena, T. armena var. galatica, T. biflora, T. cinnabarina, T. humilis, T. julia, T. koyuncui, T. orphanidea, T. pulchella, T. sintenisii, T. sylvestris subsp. sylvestris* and *T. undulatifolia var. undulatifolia* contained sclerenchymatic tissues as some of them did not contain sclerenchymatic tissue in their stems. According to anatomical studies, *T. armena* var. *armena* and *T. gumusanica* (currently synonym of *T. armena* var. *galatica*) had sclerenchymatic tissues in the stem sections (Coşkunçelebi et al., 2008), which was also reported for *T. armena* var. *lycica* (currently synonym of *T. armena* var. *armena*) by Ocak et al. (2004), but not for *T. aleppensis* and *T. orphanidea* (Satıl and Akan, 2006; Soykan and Meriç, 2012). In our anatomical findings, some populations of *T. aleppensis, T. orphanidea* and *T. armena* var. *armena* contained sclerenchymatic tissue while some populations did not contain it .

In the previous studies, collenchyma under the epidermis was reported for *T. armena* var. *galatica* (=*T. gumusanica*), *T. armena* var. *armena* and *T. orphanidea* (Coşkunçelebi et al., 2008; Soykan and Meriç, 2012), but did not for *T. aleppensis* (Satıl and Akan, 2006). However, for *T. armena* var. *lycica* (currently synonym of *T. armena* var. *armena*), both existence and lack of collenchyma were reported by Kandemir and Özkan (2000) and Ocak et al. (2004), respectively. In our anatomical studies, the populations of *Tulipa* contained either single-layered collenchyma under the epidermis or this tissue was not contained in some of them. The presence of collenchyma varied even in the same species as seen in presence of sclerenchyma. This result suggested that the presence of collenchyma and sclerenchyma were dependent upon the age and environmental factors.

Transverse sections of the leaf were divided to upper epidermis, parenchyma, lower epidermis, phloem, xylem and stomata, and therefore, these parts were separately measured. At first glance, the all populations of *T. undulatifolia* var. *undulatifolia* differed from the other populations in having hairs on epidermal cells in subgenus *Tulipa* and *T. clusiana* differed also from other taxa with no hypodermis cells under the upper epidermis. Moreover, gaps under the stomata of *T. humilis* populations were more than other taxa.

Stomatal characters like stomatal density and stomatal index were found to be affected by environmental factors and showed a direct correlation with altitude (Tiwari et al., 2012). Moreover, differences of number of stomata may be dependent on habitat differences and size of leaves, and thus stomata indexes change with respect to habitat and especially, microclimatic factors (Çakır and Bağcı, 2006). On the other hand, ratio of stomata indexes were constant for species (Bıçakçı and Malyer, 1998). In our anatomical studies, in terms of the properties of stomata on both upper and lower epidermis layers, there was no major differences among taxa. However, the ratio of stomata index for each taxon was found different.

Traditionally, the genus *Tulipa* was divided into two sections: *Tulipa* (syn.: *Leiostemones*) and *Eriostemones*. Van Raamsdonk and de Vries (1992, 1995) raised up these sections to subgenera. Zonneveld (2009) recognised four subgenera: *Clusianae*, *Eriostemones, Orithyia* and *Tulipa.* Similarly, Christenhusz et al. (2013) all tulips have been classified into four subgenera: *Clusianae*, *Eriostemones, Orithyia* and *Tulipa.* The recent study on tulip taxonomy has been performed by Eker et al. (2014), based on detailed morphological, geographic and cytotaxonomic studies. In this study, all tulips in Turkey have

been classified into two subgenera: *Eriostemones* and *Tulipa*. Morphologically, the occurrence of hairs at filament base were basic to separate the subgenera. Subgenus *Eriostemones* with hairy filament base was different than subgenus *Tulipa* which has glabrous filament base. In the present study, the genus *Tulipa* wass divided into three subgenera, *Clusianae, Eriostemones* and *Tulipa*, according to principal component and cluster analyses based on comprehensive and comparative anatomical characters (Figures 77, 81 and 82). Thus, the classification systems of Zonneveld (2009), Christenhusz et al. (2013), Eker et al. (2014) were adopted here which was also supported by our anatomical and statistical analyses.

Van Raamsdonk and De Vries (1992) divided subgenus *Eriostemones* into three sections: *Australes, Biflores* and *Saxatiles.* Veldkamp and Zonneveld (2012) separated into three sections: *Sylvestres, Biflores* and *Saxatiles* in subgenus *Eriostemones.* Also, Christenhusz et al. (2013) did not divide subgenus *Eriostemones* into sections. According to Eker et al. (2014), subgenus *Eriostemones* was divided into two sections: *Saxatiles* and *Sylvestres*. In our anatomical studies according to PCA and cluster analyses, the sections in subgenus *Eriostemones* were clearly separated. Our results indicated two sections, which were already described by Baker (1874, 1883a, 1883b) and Eker et al. (2014) as *Saxatiles* and *Sylvestres.*

In the PCA analyses, *T. biflora, T. koyuncui, T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *sylvestris* were placed in section *Sylvestres* (Figure 78). When only section *Sylvestres* were run separately from the other section, the populations of *T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *sylvestris* were also placed in subsection *Sylvestres* while *T. koyuncui* and *T. biflora* were placed in subsection *Biflores* (Figure 79). This result was also compatible with Eker et al. (2014). Morphologically, *T. sylvestris* subsp. *sylvestris* differed from *T. sylvestris* subsp. *australis* having broader lowest leaves, anthers and globular flowers, and markedly stoloniferous habit. In our cluster analysis, *T. biflora, T. koyuncui*, *T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *sylvestris* grouped in the section *Sylvestres.* But, *T.* cinnabarina was found mixed in this section (Figure 81). If the average values were only used in cluster analysis, *T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *sylvestris* were also mixed with *T. saxatilis* under a subgroup while *T. biflora* and *T. koyuncui* were mixed with *T. cinnabarina* under another cluster. Both subsections were partly taken place far from each other and mixed in clusters with other species (Figure 82). The results of the PCA and cluster

analysis gave good results, but the cluster analysis including average of character states did not give a satisfactory result.

Van Raamsdonk and De Vries (1992) placed *T. orphanidea* and *T. sprengeri* in section *Australes* sensu Hall. However, *T. sprengeri* was found in EW category (IUCN, 2001). Eker et al. (2014) also divided section *Saxatiles* into three subsections: *Humiles, Orphanidetes* and *Saxatiles. Tulipa humilis* and *T. pulchella* were placed into the subsection *Humiles* whereas *T. orphanidea* and *T. cinnabarina* were found close to each other in subsection *Orphanidetes* with *T. sprengeri*. Subsection *Saxatiles* contained only one species, *T. saxatilis*. In our PCA, *T. cinnabarina, T. humilis, T. orphanidea* and *T. pulchella* were placed in section *Saxatiles* except of *T. saxatilis*. *Tulipa saxatilis* was mixed in section *Sylvestres* (Figure 78). These results were substantially compatible with Wilford (2006) and Eker et al. (2014)'s views. In cluster analysis, *T. saxatilis* placed near to *T. orphanidea* but far from the other taxa in section *Saxatiles* at subsection level. *Tulipa pulchella* and *T. humilis* positioned in the same cluster, representing subsection *Humiles* (Figure 81). If the average values only were used in cluster analysis, *T. orphanidea* was positioned near to *T. pulchella* and *T. humilis* and far from *T. cinnabarina.* Also, *T. saxatilis* mixed with *T. sylvestris* subsp. *australis* and *T. sylvestris* subsp. *Sylvestris* taxa. The PCA gave a good results, and partly cluster analysis. But the results of cluster analysis including average values of character states was not so satisfactory.

Marais (1984) reduced *T. pulchella* to a synonym of *T. humilis*, and similarly Van Raamsdonk and De Vries (1992) accepted this species as a form of *T. humilis*. Christenhusz et al. (2013) treated it as a natural variety of *T. humilis*. However, Zonneveld (2009) considered them as separate species. Eker et al. (2014) revealed morphological discriminative characters and accepted as *T. pulchella* to be a distinct species from *T. humilis* with blackish-brown bulb tunics and a bicoloured floral blotch. According to the results of our PCA and cluster analyses, *T. pulchella* was differed from *T. humilis* in section *Saxatiles.* On the other hand, *T. humilis* and *T. pulchella* were found close to each other in subsection *Humiles* (Figure 78, 81 and 82).

Van Raamsdonk and De Vries (1992, 1995) divided subgenus *Tulipa* into five sections: *Tulipa, Tulipanum, Eichleres, Kolpakowskianae,* and *Clusianae*. Veldkamp and Zonneveld (2012) separated subgenus *Tulipa* into six sections: *Tulipa, Tulipanum, Lanatae, Spiranthera, Multiflorae* and *Kolpakowskianae.* Christenhusz et al. (2013) did not divide into sections. Most recently Eker et al. (2014) grouped subgenus *Tulipa* into two sections: *Tulipa* and

Clusianae. Moreover, many populations of subgenus *Tulipa* formed a complex group. In our results of PCA, subgenus *Tulipa* formed a complex group in which only, *T. raddii* and *T. undulatifolia* var. *undulatifolia* were not included. The populations of *T. agenensis* were relatively separated from the tight complex (Figure 80). In the cluster analysis, *T. undulatifolia* var. *undulatifolia* and *T. raddii* were clearly separated from this complex. Moreover, the other populations were very close to each other, such as between 77.62-100.00% SLs (Figure 81). If the average values were only used in cluster analysis, *T. undulatifolia* var. *undulatifolia* was separated from the other taxa and the other populations were very close to each other, such as between 74.61-100.00% SLs (Figure 82).

Marais (1984) stated that *T. agenensis* and *T. raddii* (= *Tulipa praecox* Ten.) might be clones of the same species. According to Eker et al. (2014), *T. raddii* morphologically differed from *T. agenensis* having more robust structures such as a thicker stem and broader lowest leaves. Moreover, populations of *T. armena* var. *armena*, *T. armena* var. *galatica*, *T. julia* and *T. aleppensis* showed high levels of variation between and within populations. The main differences among these taxa were tunic hairiness, habitat preference and geographical distributions. In the cluster analysis, *T. agenensis* was not anatomically similar to *T. raddii.* All populations of *T. agenensis* linked to the closest cluster that was somewhat *T. julia* populations. One population of *T. julia* mixed with two populations of *T. sintenisii.* In addition, *T. agenensis* was anatomically similar to *T. julia*. Also, all populations of *T. armena* var. *armena* were placed in the same cluster and linked the closest cluster that was a group of *T. julia* and *T. agenensis*. *Tulipa sintenisii* and *T. aleppensis* were found close to each other and these taxa were also anatomically similar. *Tulipa armena* var. *galatica* was placed far from *T. armena* var. *armena* and these taxa were distinct from each other. Also, *T. armena* var. *galatica* was near to *T. sintenisii* and *T. aleppensis* populations (Figure 81). Similarly the cluster analysis including average values of character states, *T. sintenisii* and *T. aleppensis* were found close to each other and these taxa were also anatomically similar. *Tulipa armena* var. *galatica* and *T. julia* were obtained near from these taxa. Moreover, *T. armena* var. *armena* was anatomically similar to *T. agenensis* and *T. raddii* then they were linked to the closest cluster that was somewhat *T. armena* var. *armena* and *T. agenensis* (Figure 82).

In subgenus *Tulipa*, cluster results were partly similar to average values used in cluster results, but not for PCA. In the PCA, the most complex group in the genus *Tulipa* contained the populations of *T. aleppensis, T. armena* var. *armena*, *T. armena* var. *galatica, T. julia*, and *T. sintenisii* which was compatible with the result of Eker et al. (2014)'s. Consequently,

anatomical studies were insufficient to distinguish this complex group and there was a need for new methods and approaches for the solution of the problem.

6. CONCLUSIONS AND RECOMMENDATIONS

The first comprehensive evaluation of the systematic value of anatomy of the genus *Tulipa* (root, stem, leaf) was presented. The distinguishing characteristics are indicated in related parts. Especially in Turkey, even in the world comparative anatomical studies are deficient. We expect that this study is filling this deficiency and it will be a good example for other anatomical studies on population level. Additionally, this anatomical studies can contribute to solve in the aspects of systematically taxonomic problems. Also, phylogenetic and palynologic studies of this genus could result in positive consequences in the aspects of systematically problems.

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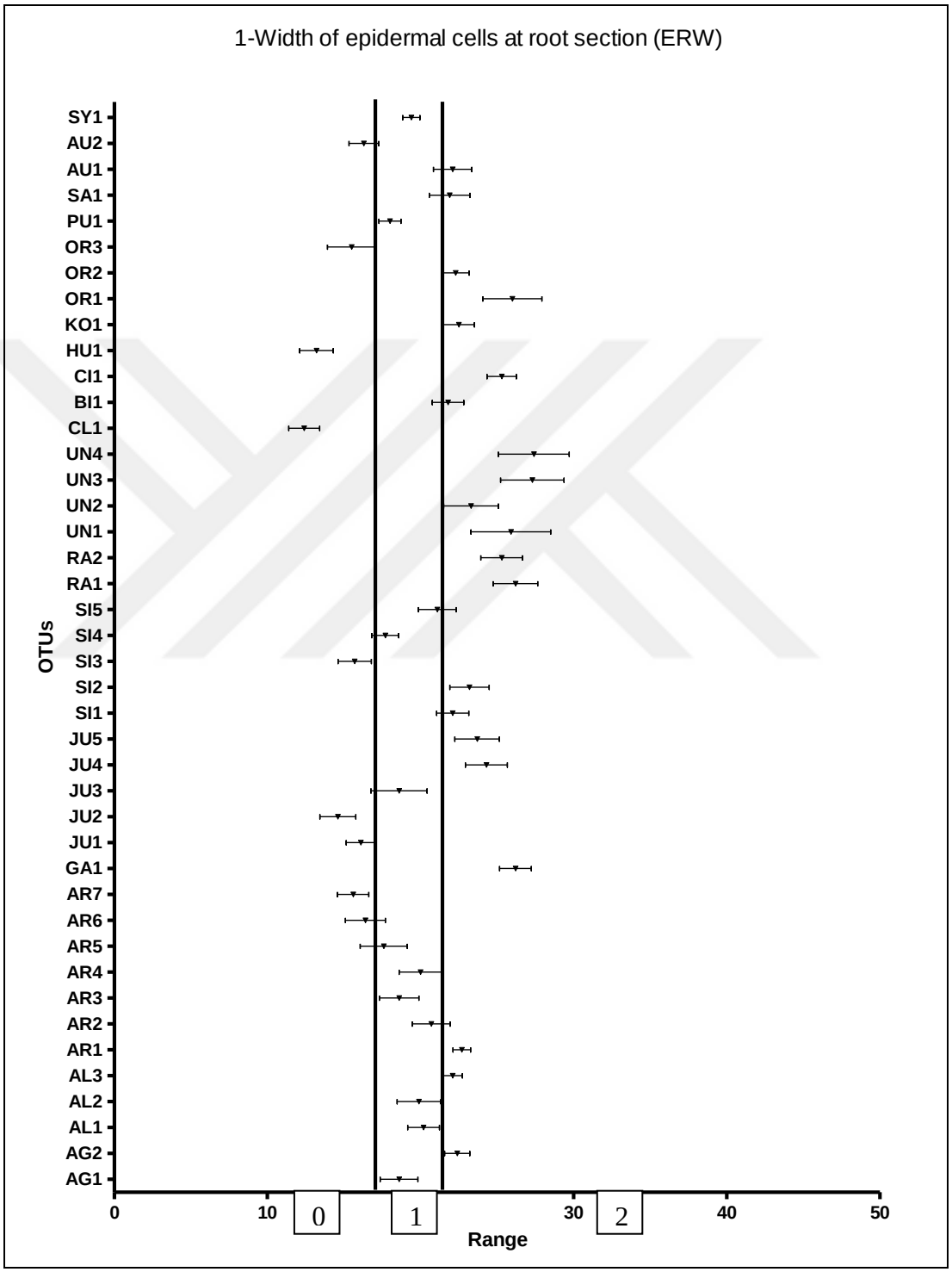
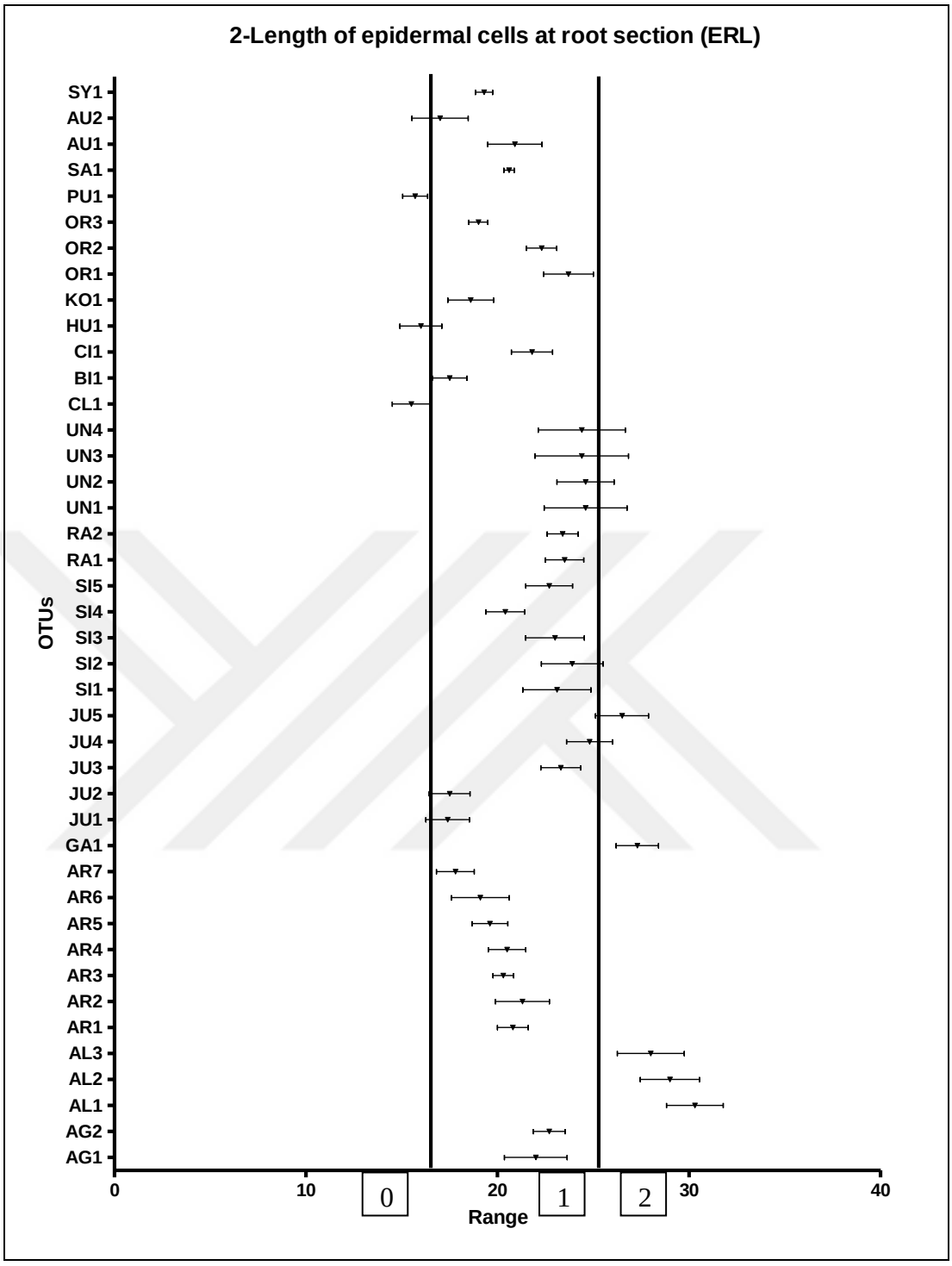
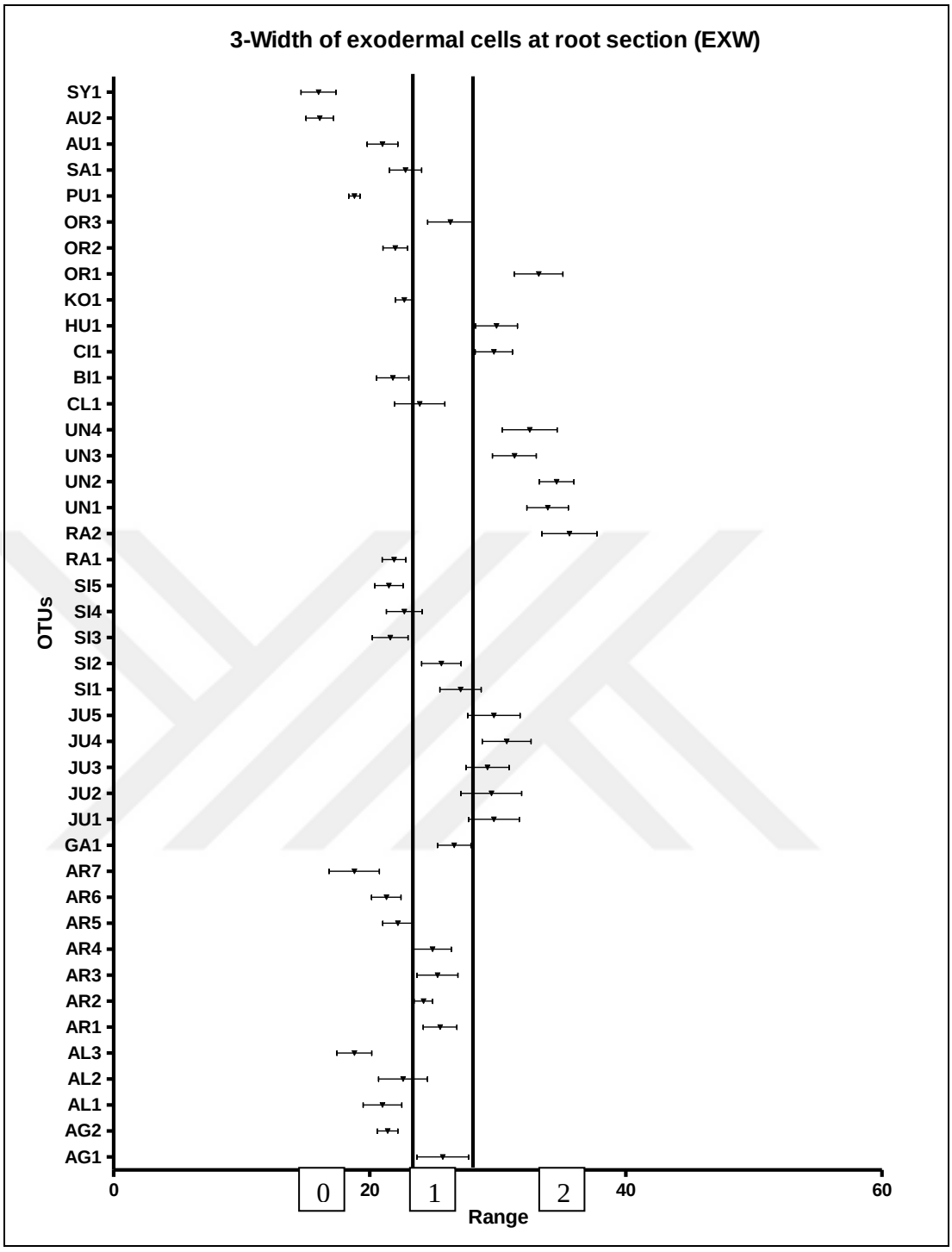
APPENDICES

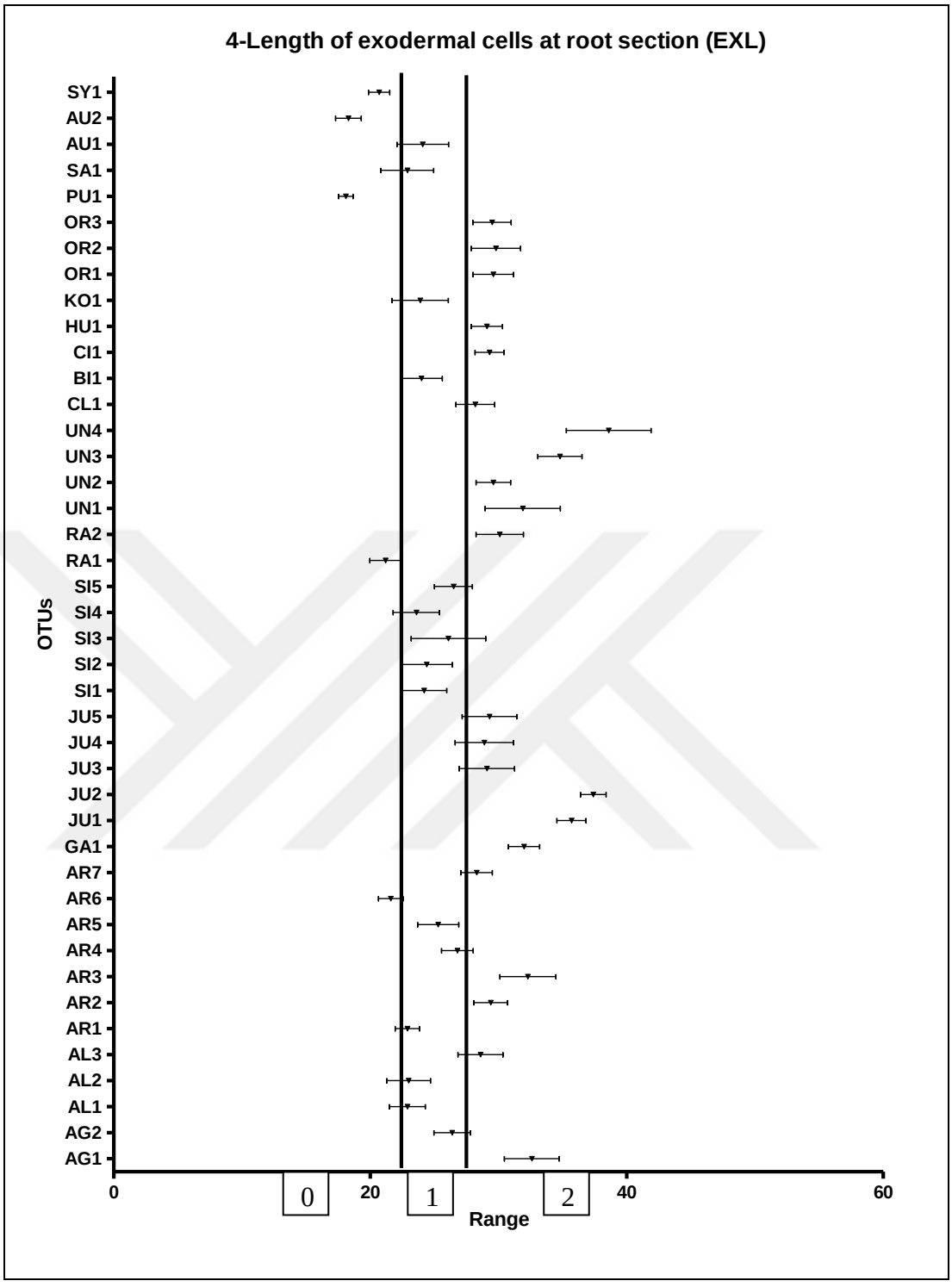
8. APPENDICES

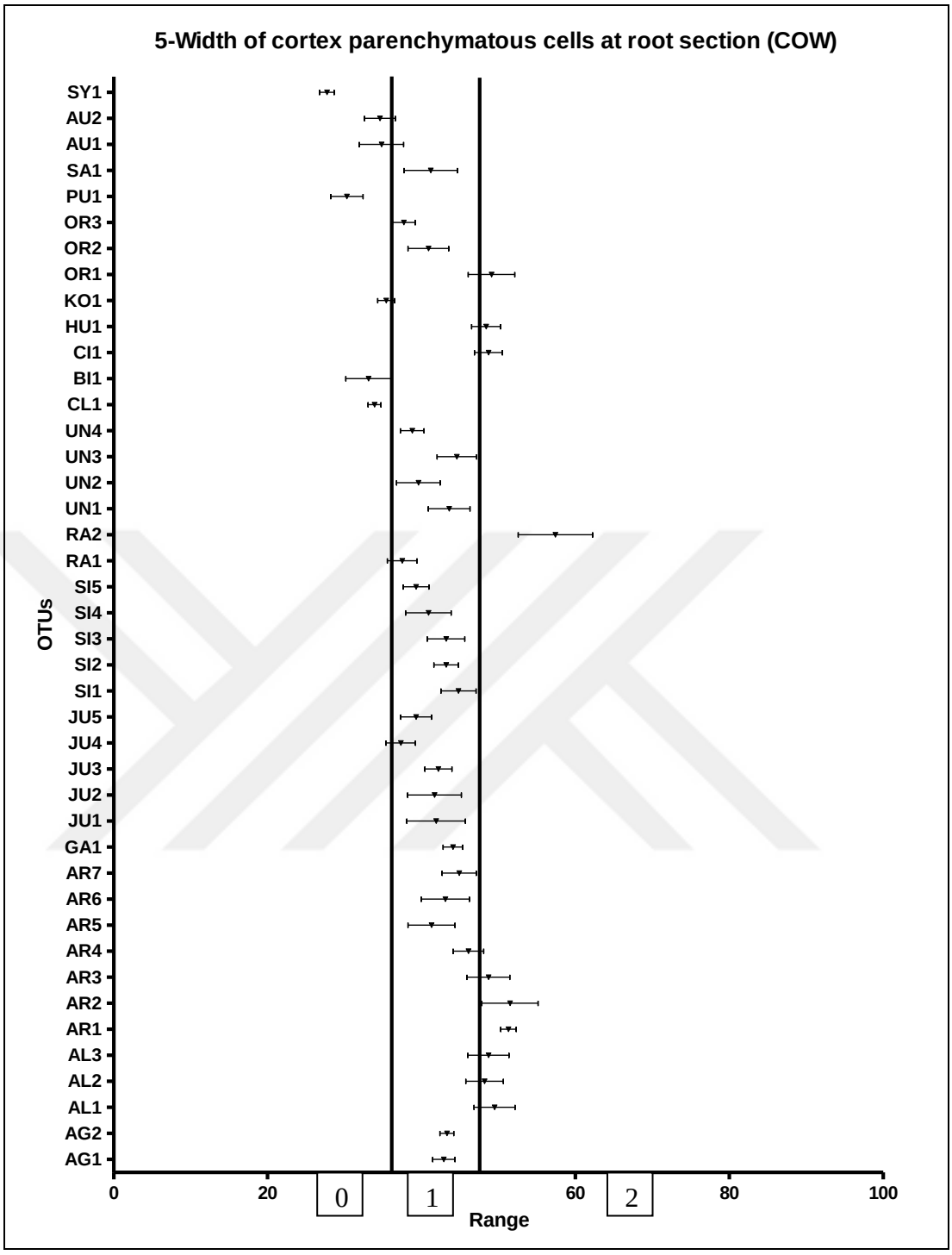
List of codified quantitative characters in Graphpad program (Means with standart error plots).

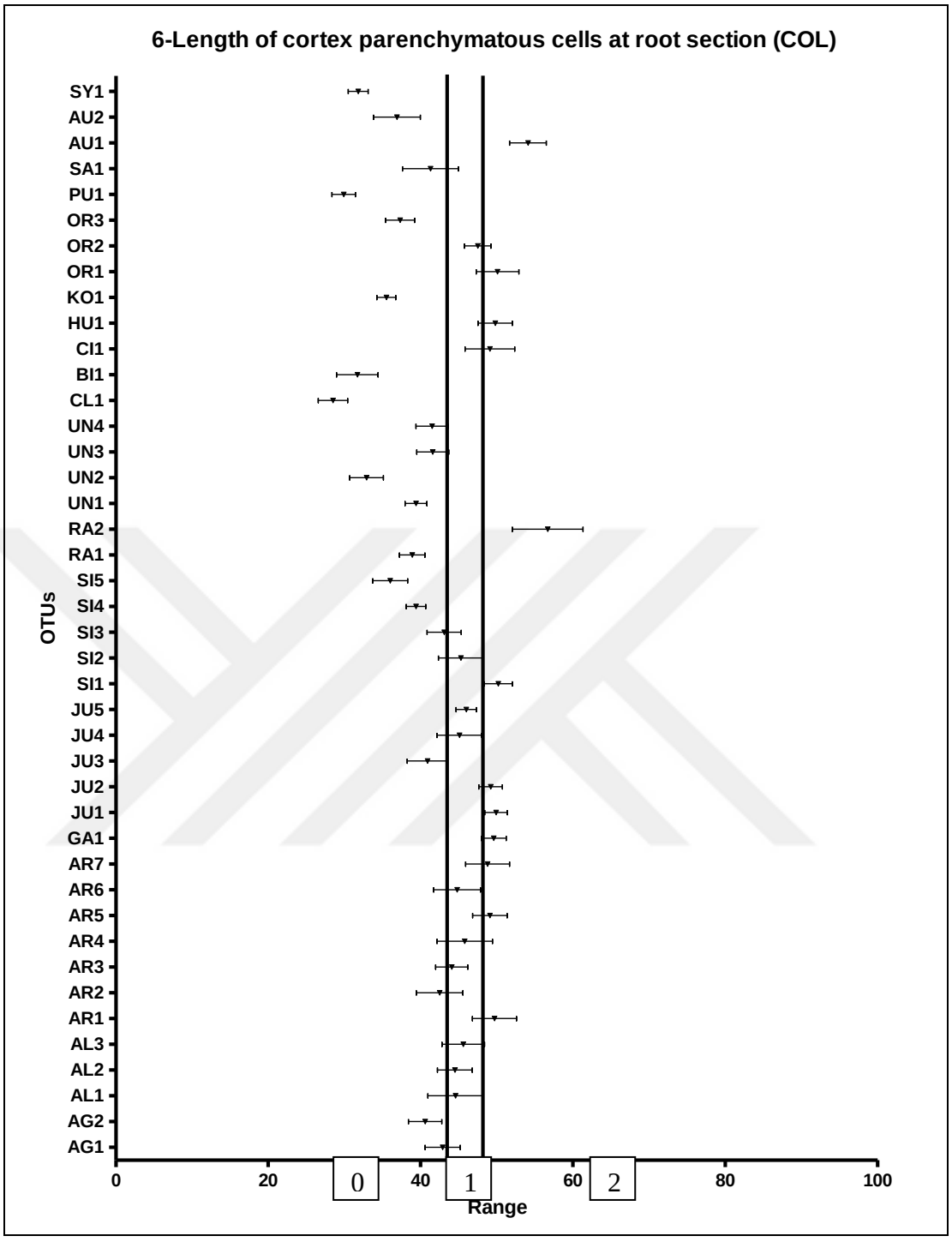


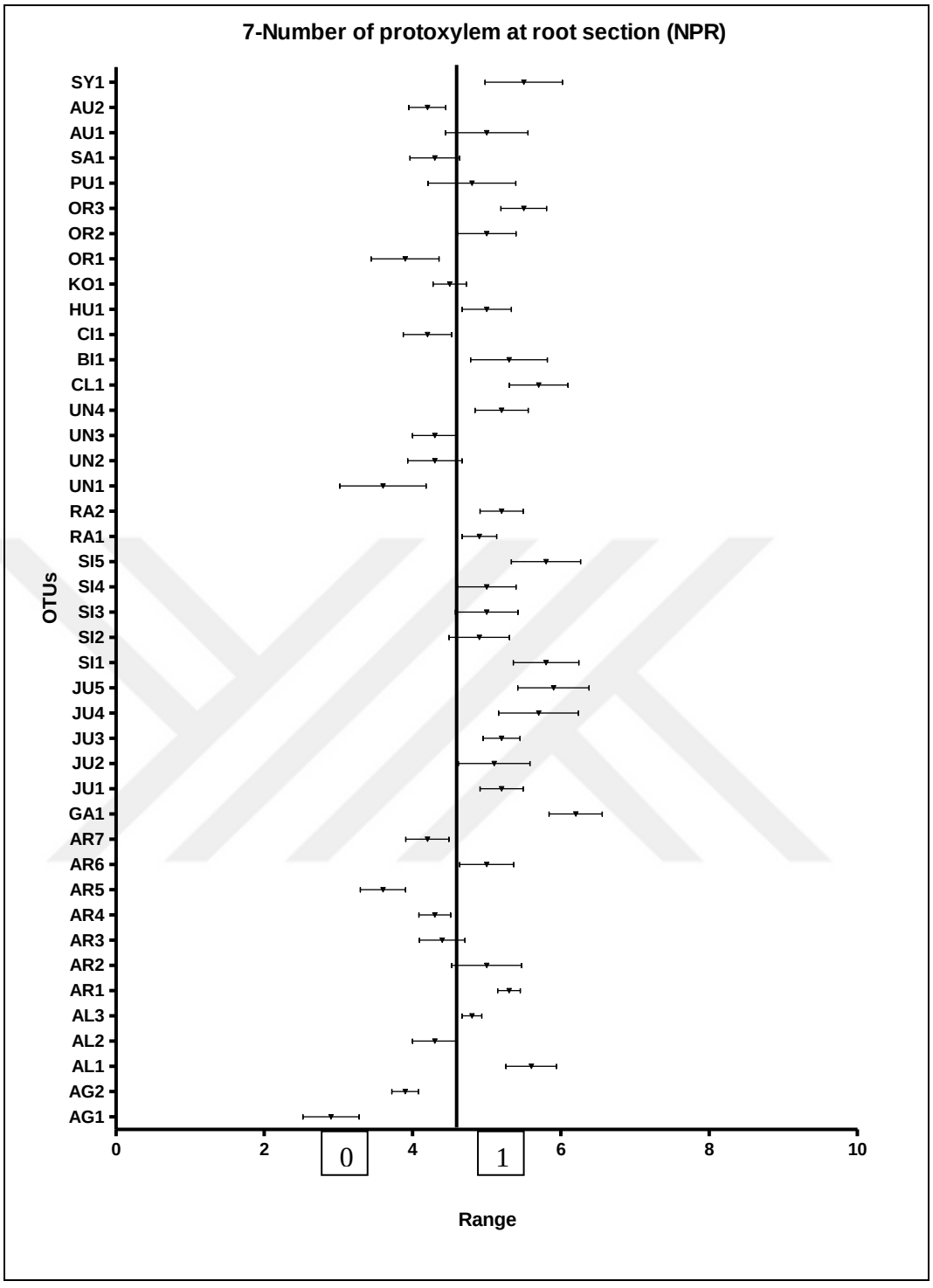

2-Length of epidermal cells at root section (ERL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
10
20
30
40
0
1
2
Range

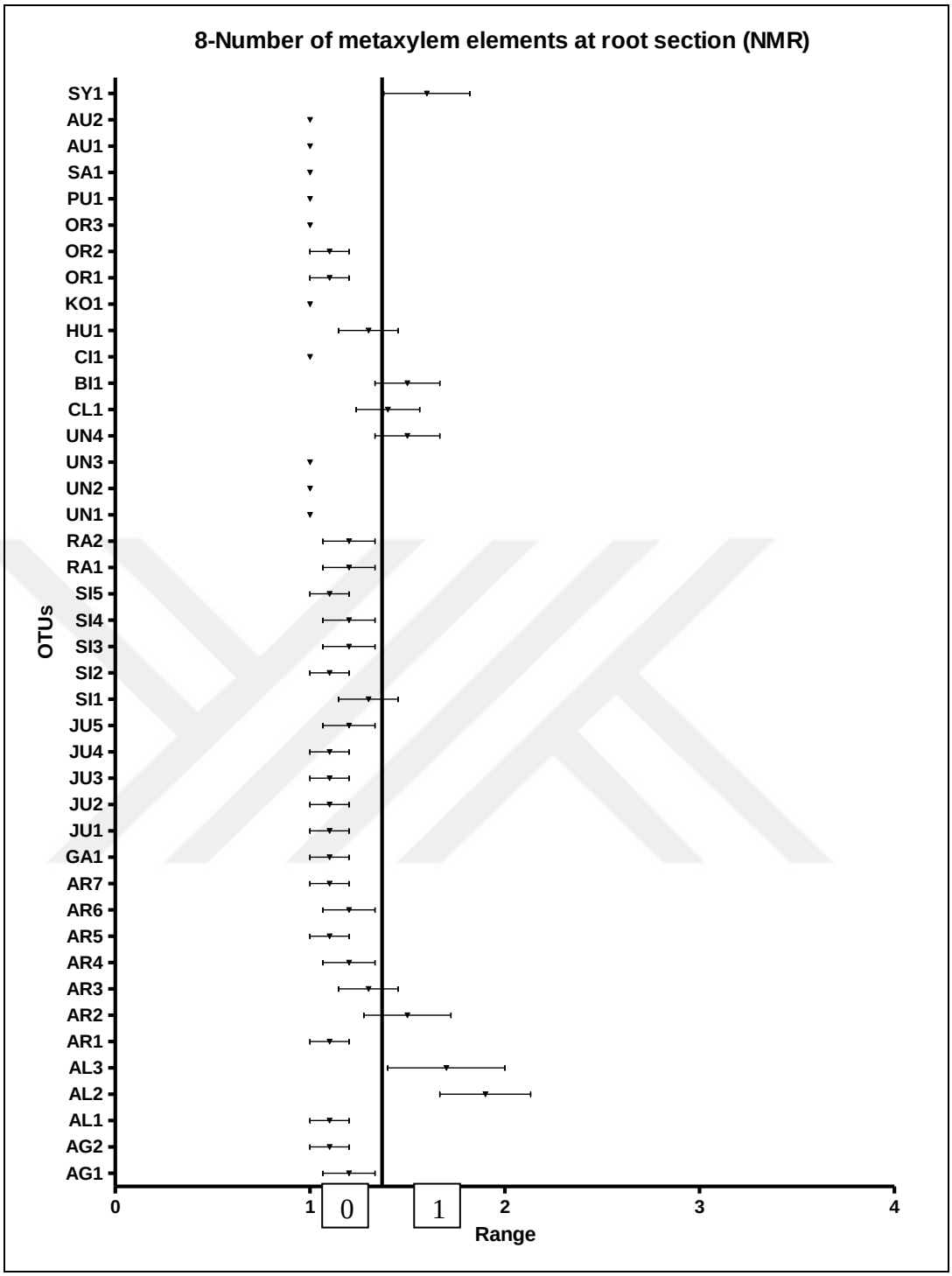

3-Width of exodermal cells at root section (EXW)
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
OTUs
0
20
40
60
0
1
2
Range

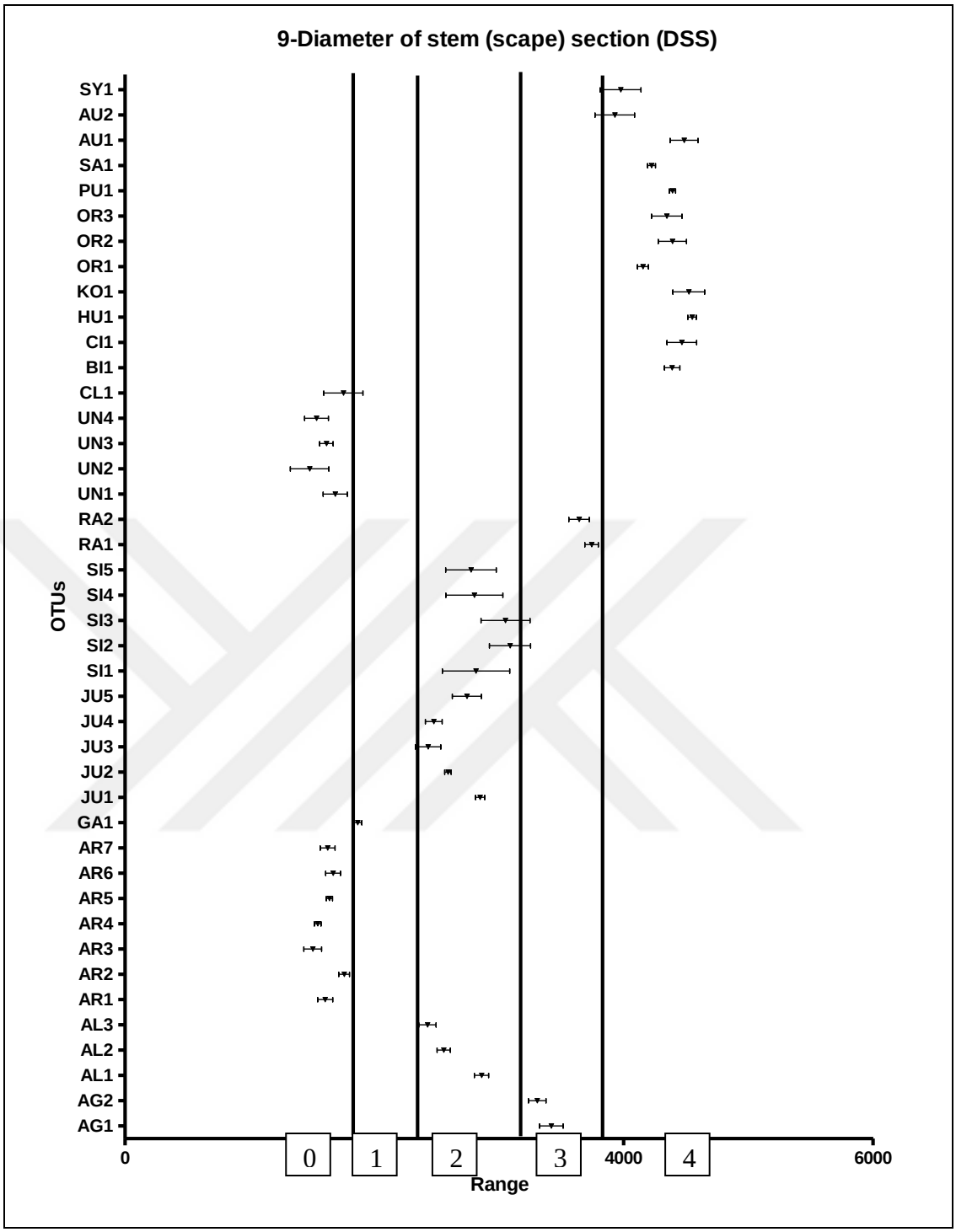

4-Length of exodermal cells at root section (EXL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
0
1
2
Range

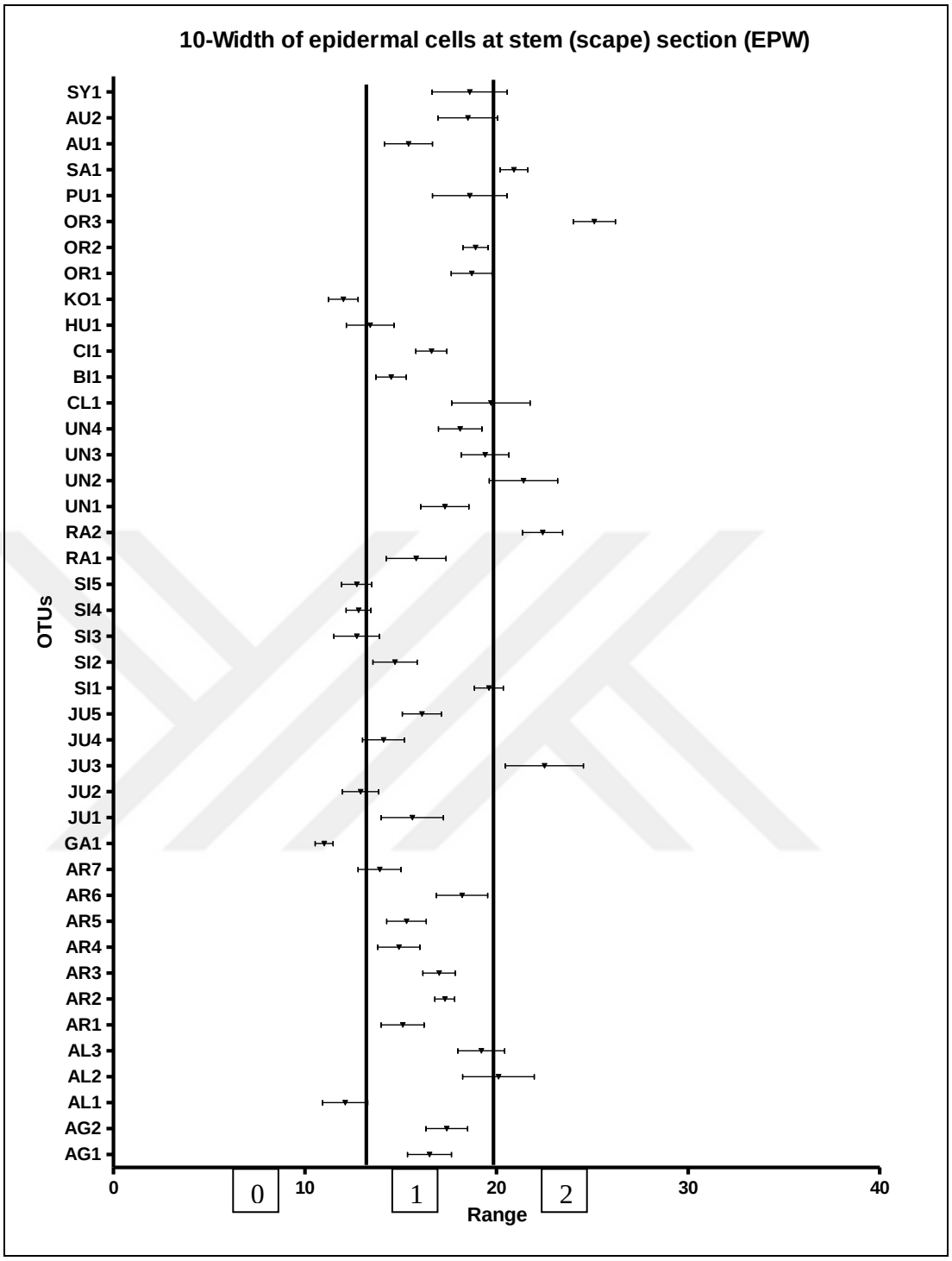

5-Width of cortex parenchymatous cells at root section (COW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
0
1
60
2
80
100
Range

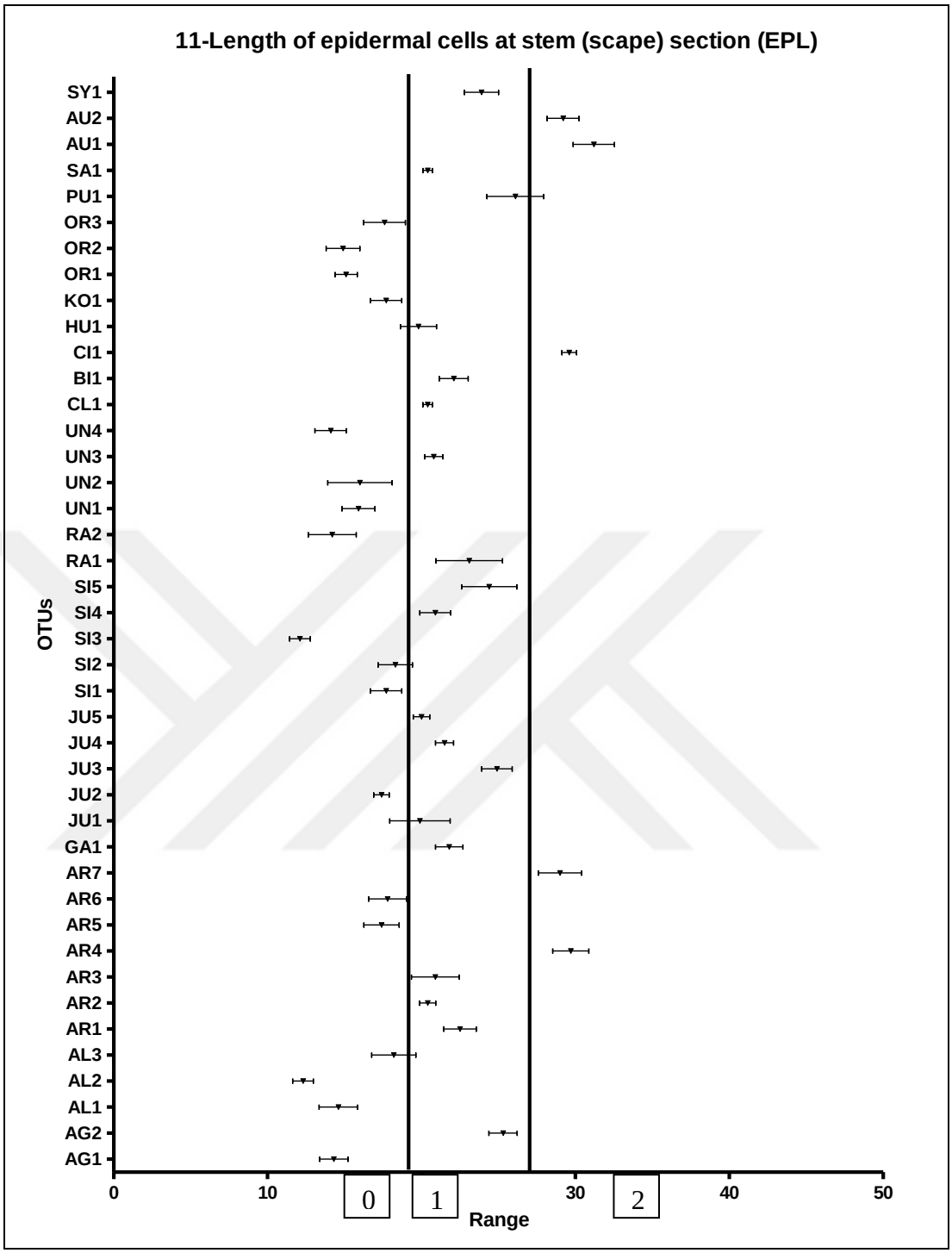

6-Length of cortex parenchymatous cells at root section (COL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
80
100
0
1
2
Range

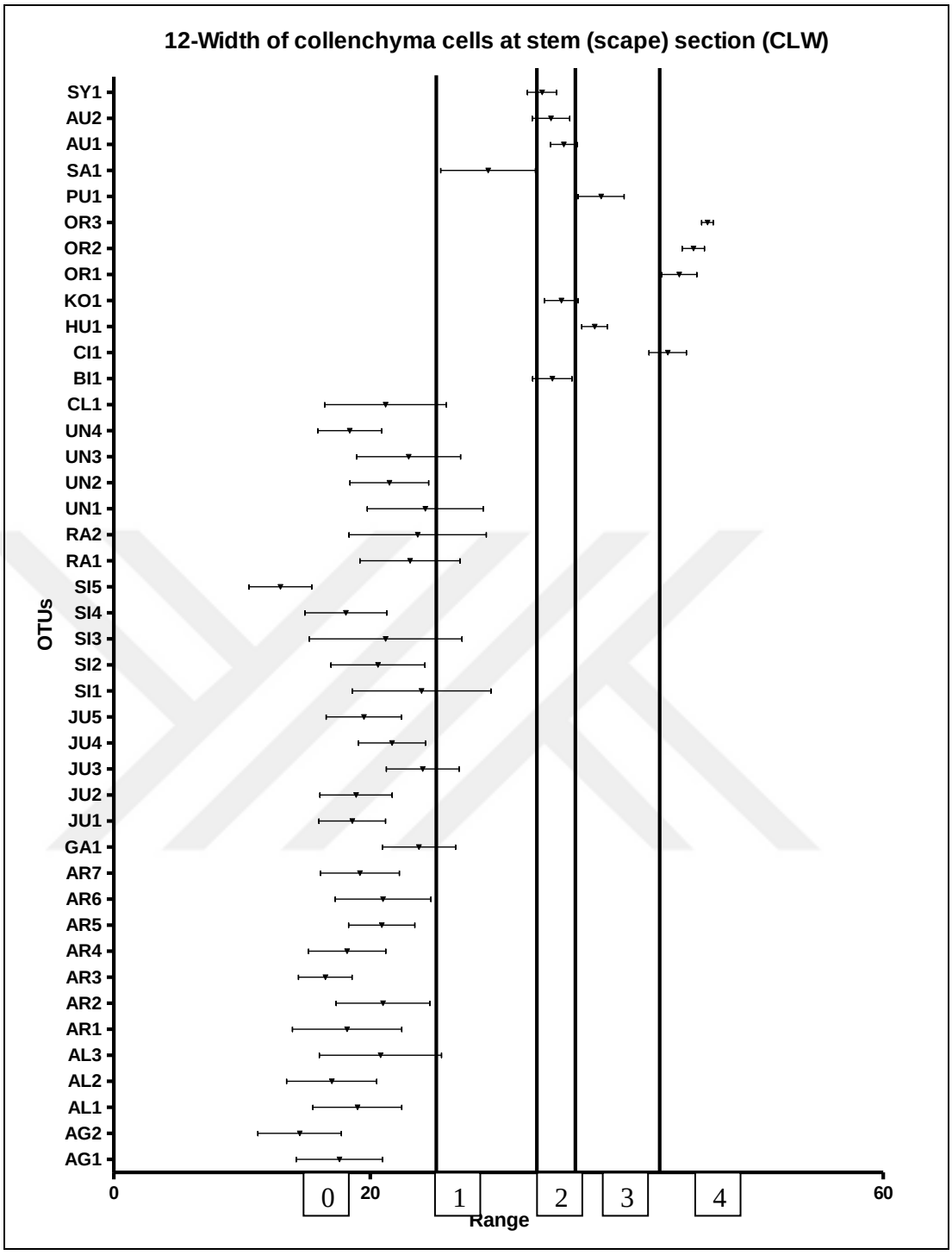

7-Number of protoxylem at root section (NPR)
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
OTUs
0
2
4
6
8
10
0
1
Range

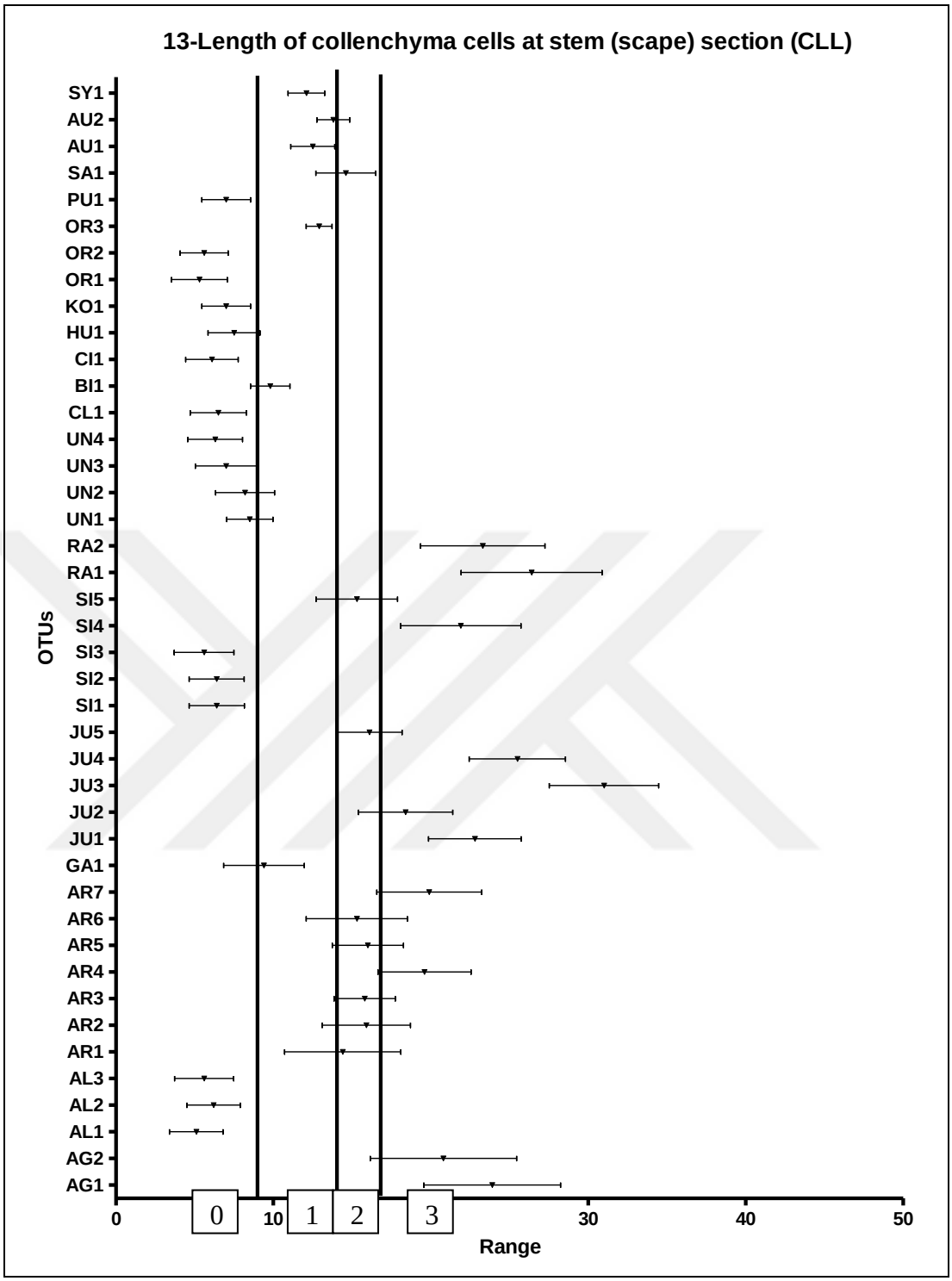

8-Number of metaxylem elements at root section (NMR)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
1
2
3
4
0
1
Range

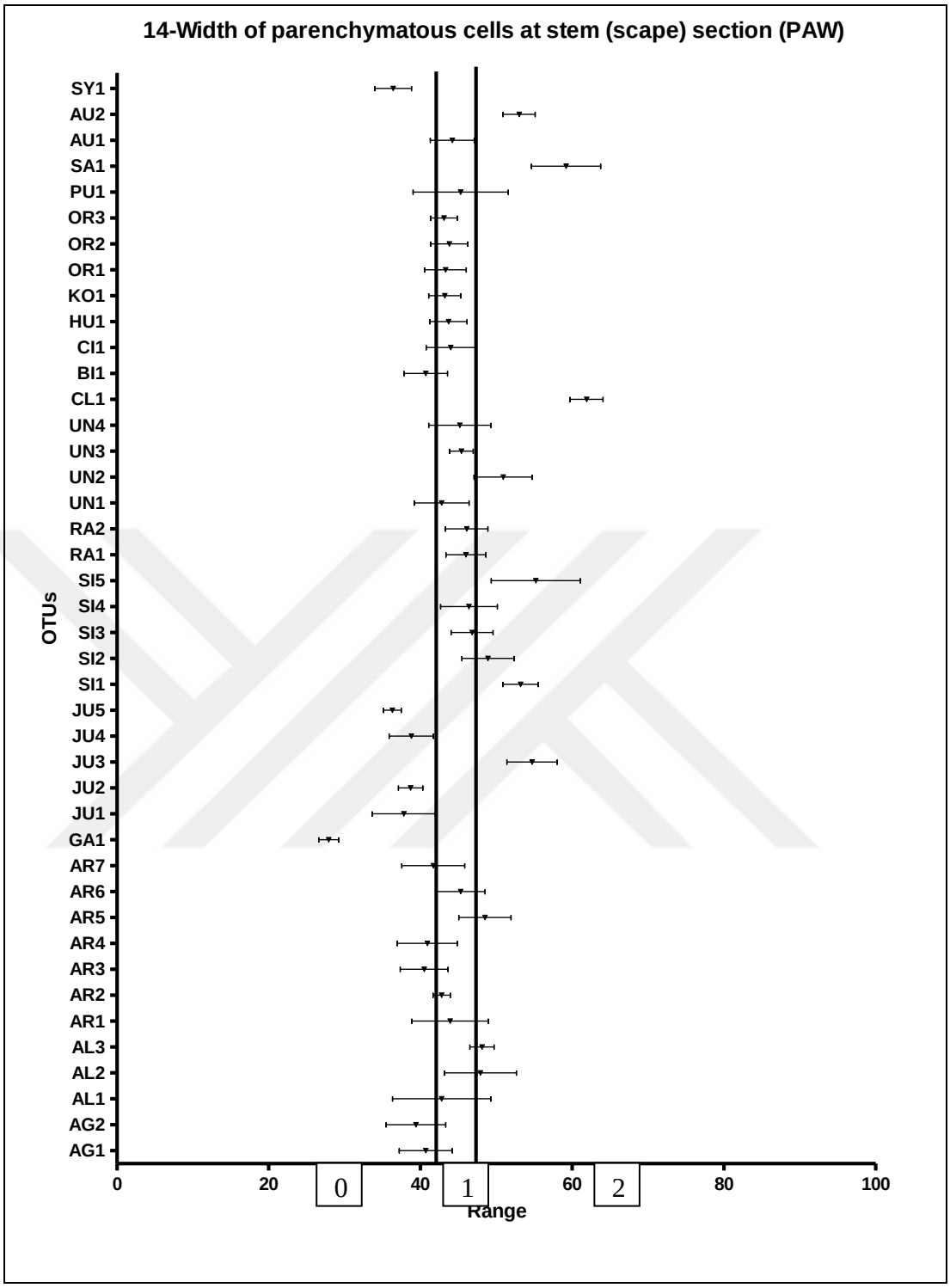

9-Diameter of stem (scape) section (DSS)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
4000
6000
0
1
2
3
4
Range

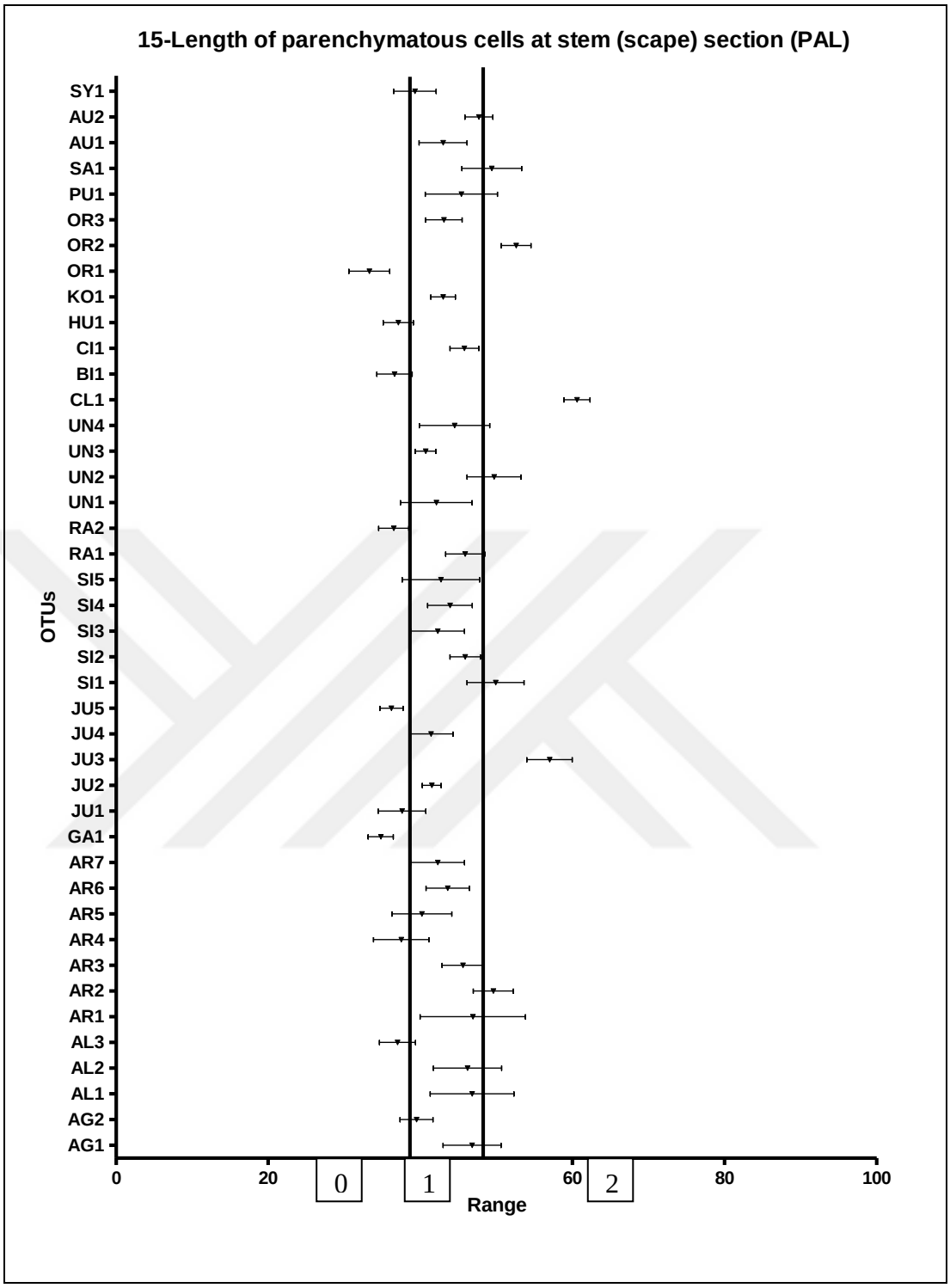

10-Width of epidermal cells at stem (scape) section (EPW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
10
20
30
40
0
1
2
Range

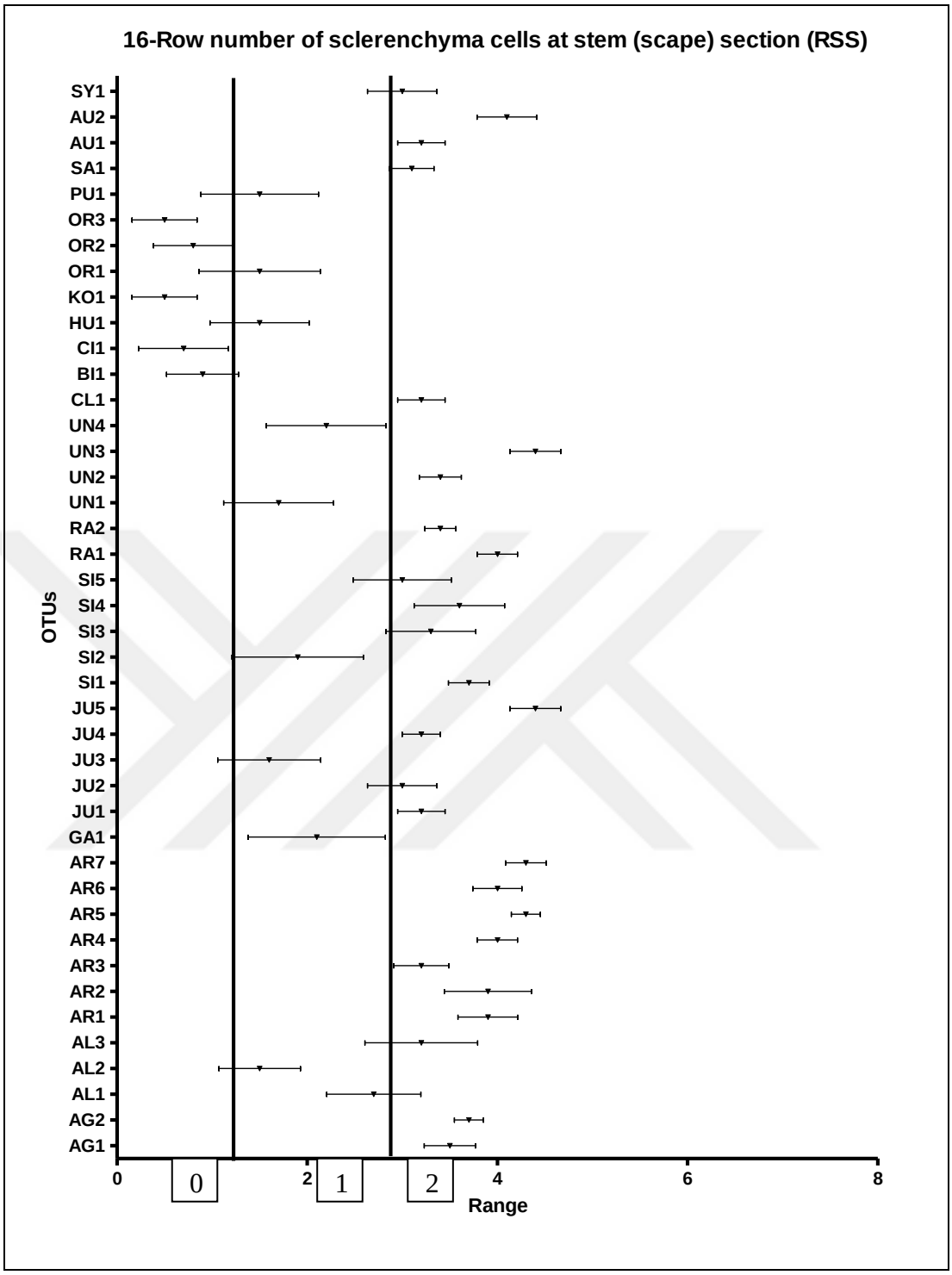

11-Length of epidermal cells at stem (scape) section (EPL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
10
30
40
50
0
1
2
Range

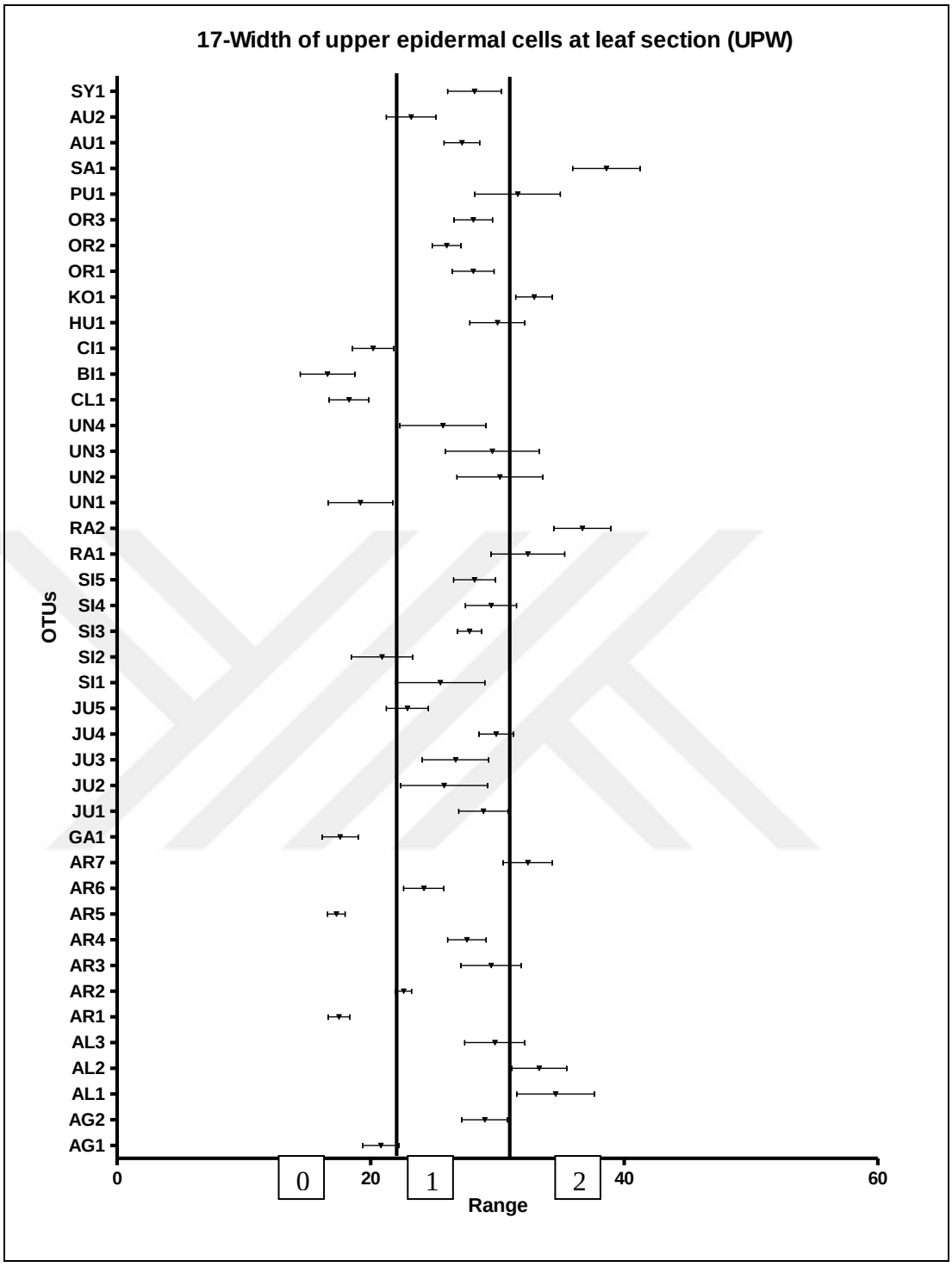

12-Width of collenchyma cells at stem (scape) section (CLW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
60
0
1
2
3
4
Range

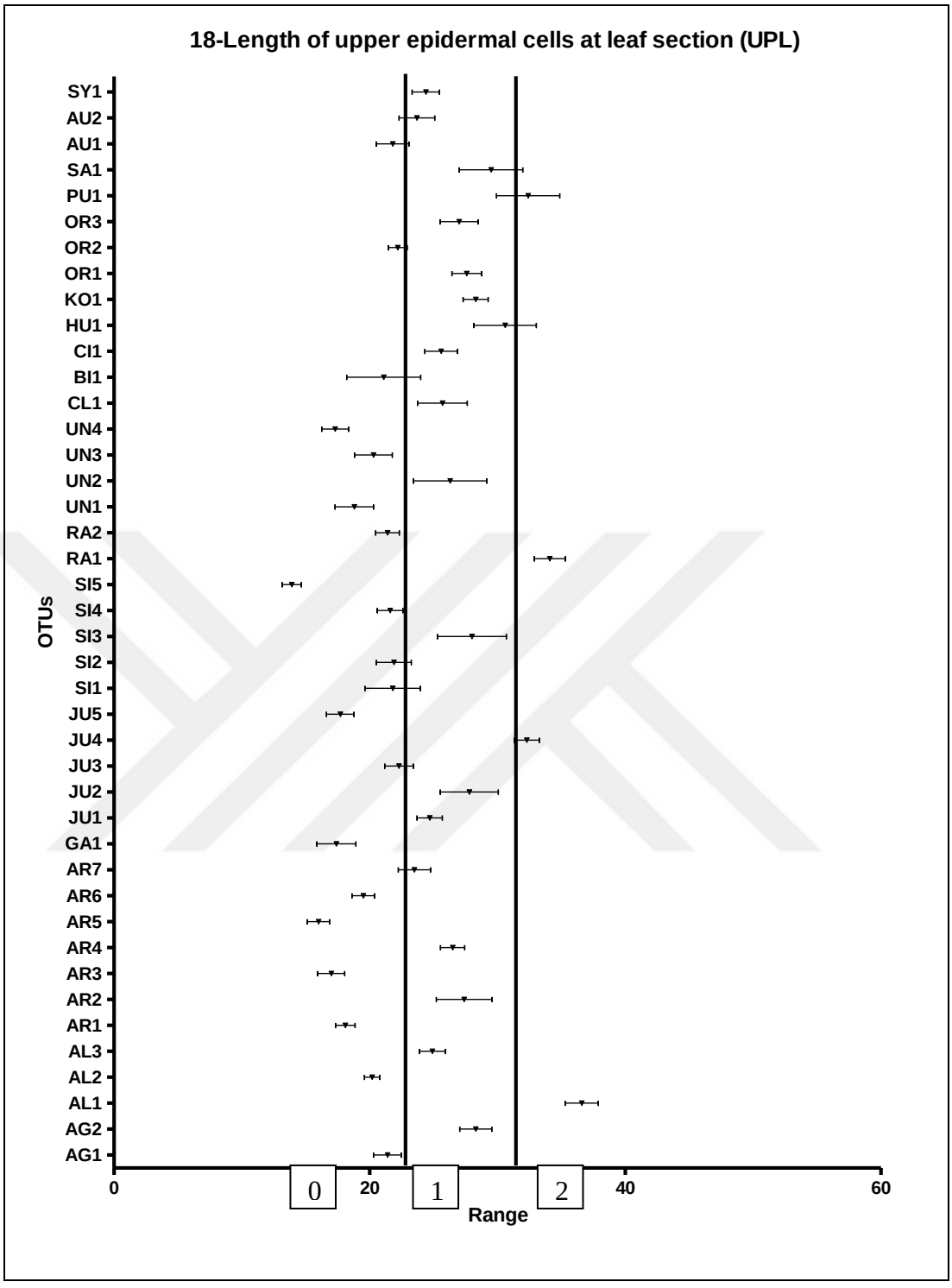

13-Length of collenchyma cells at stem (scape) section (CLL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
10
1
2
3
30
40
50
Range

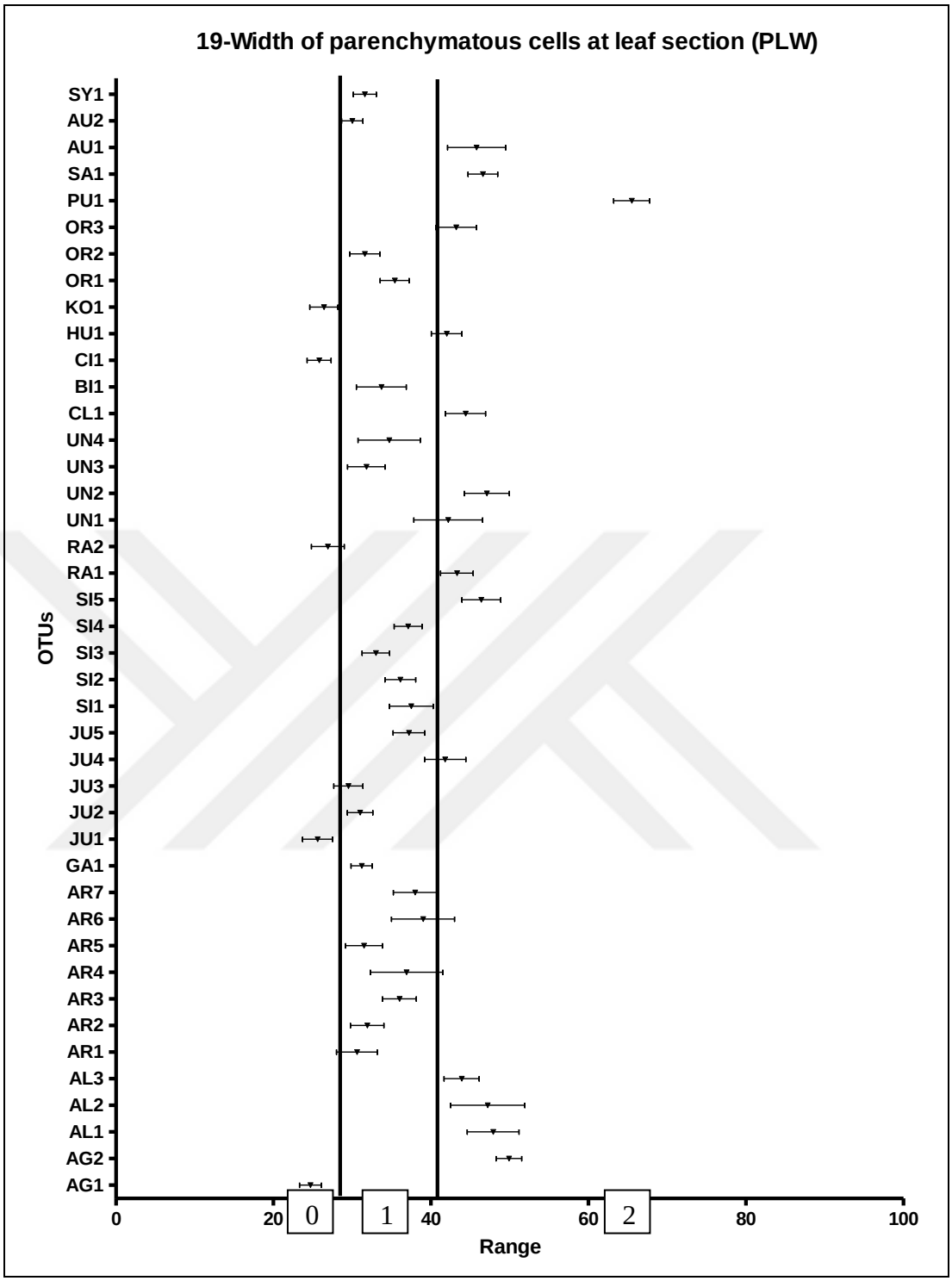

14-Width of parenchymatous cells at stem (scape) section (PAW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
80
100
0
1
2
Range

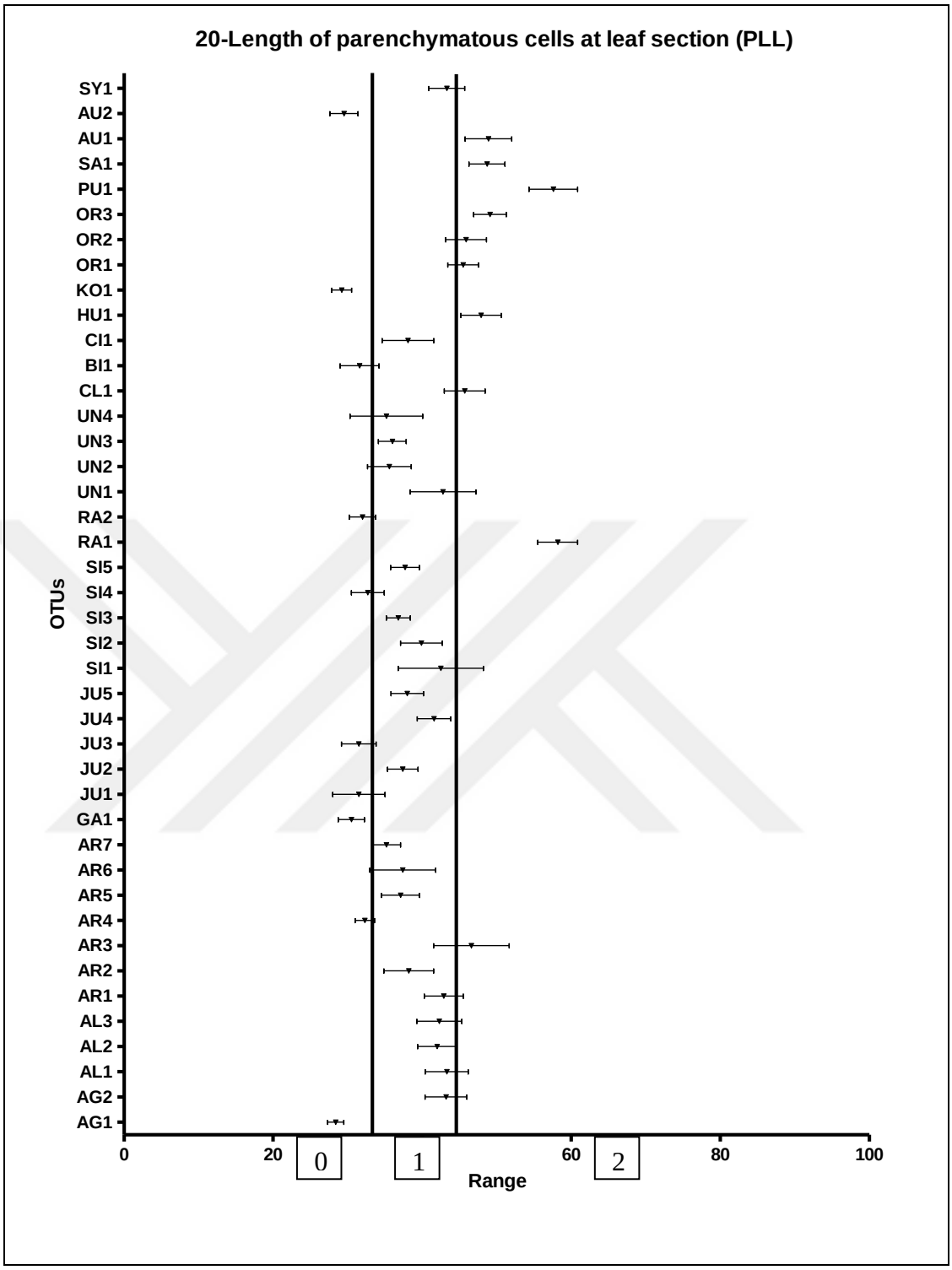

15-Length of parenchymatous cells at stem (scape) section (PAL)
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
OTUs
0
20
0
1
60
2
80
100
Range

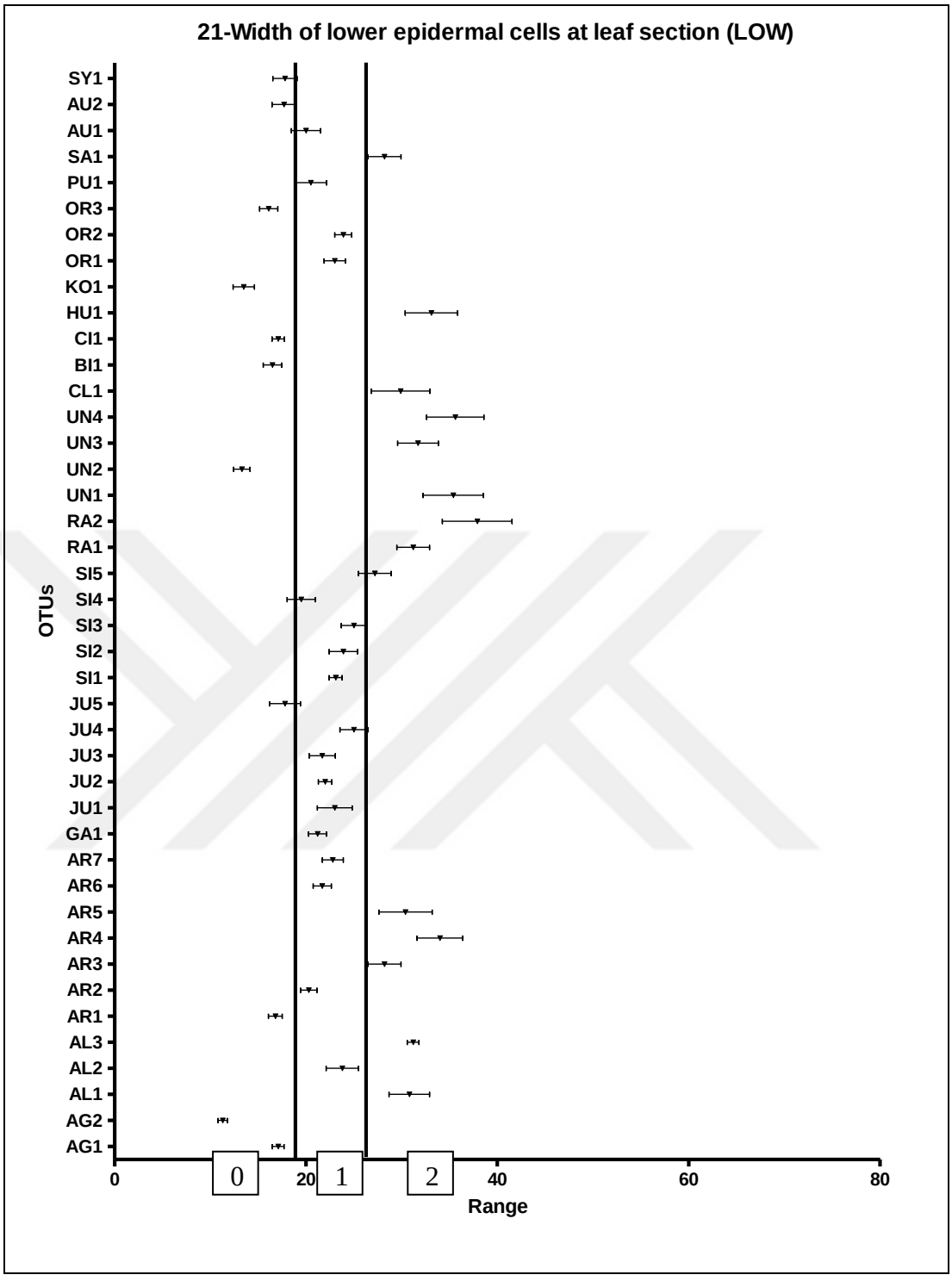

16-Row number of sclerenchyma cells at stem (scape) section (RSS)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
2
4
6
8
0
1
2
Range

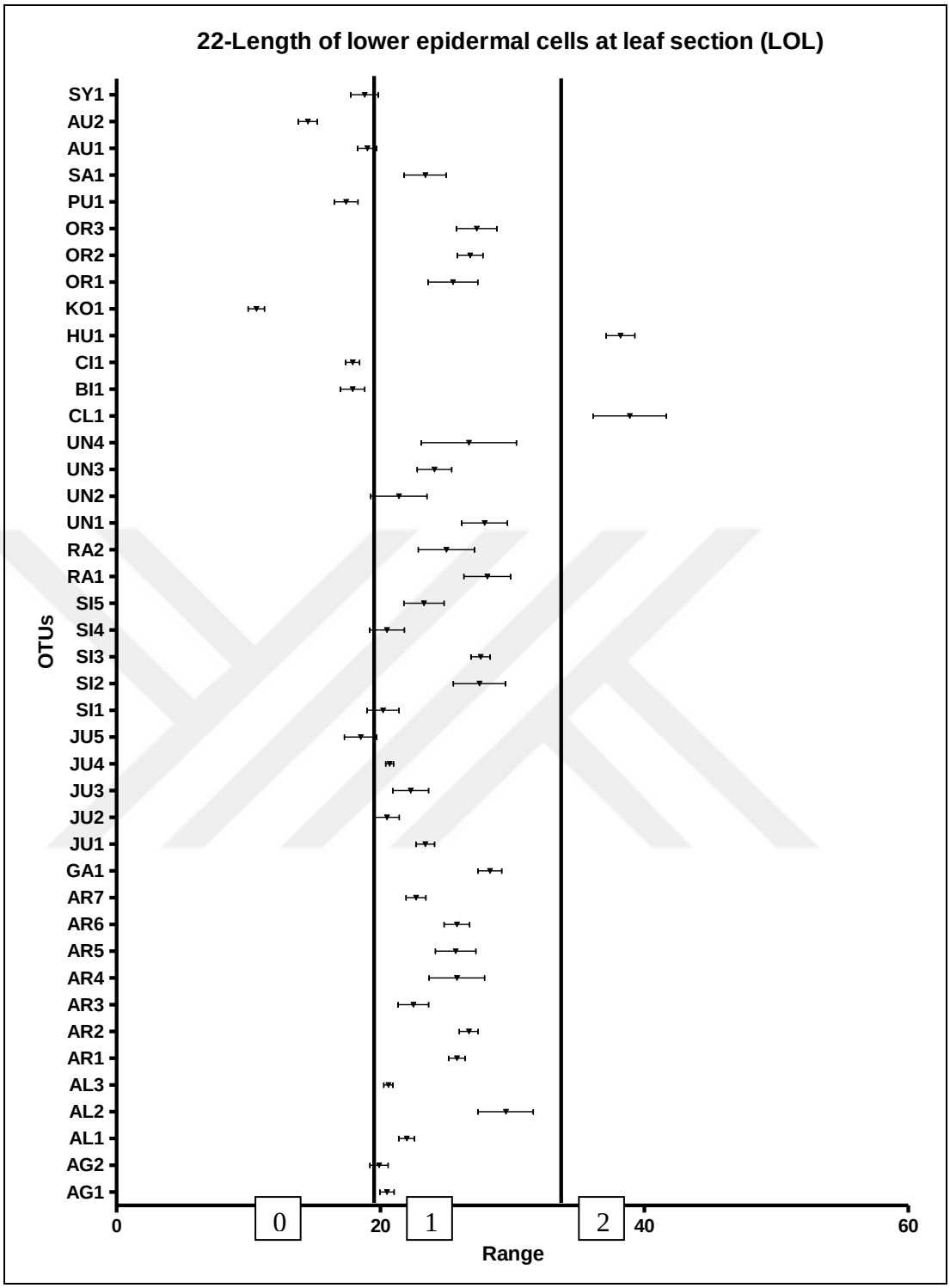

17-Width of upper epidermal cells at leaf section (UPW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
0
1
2
Range

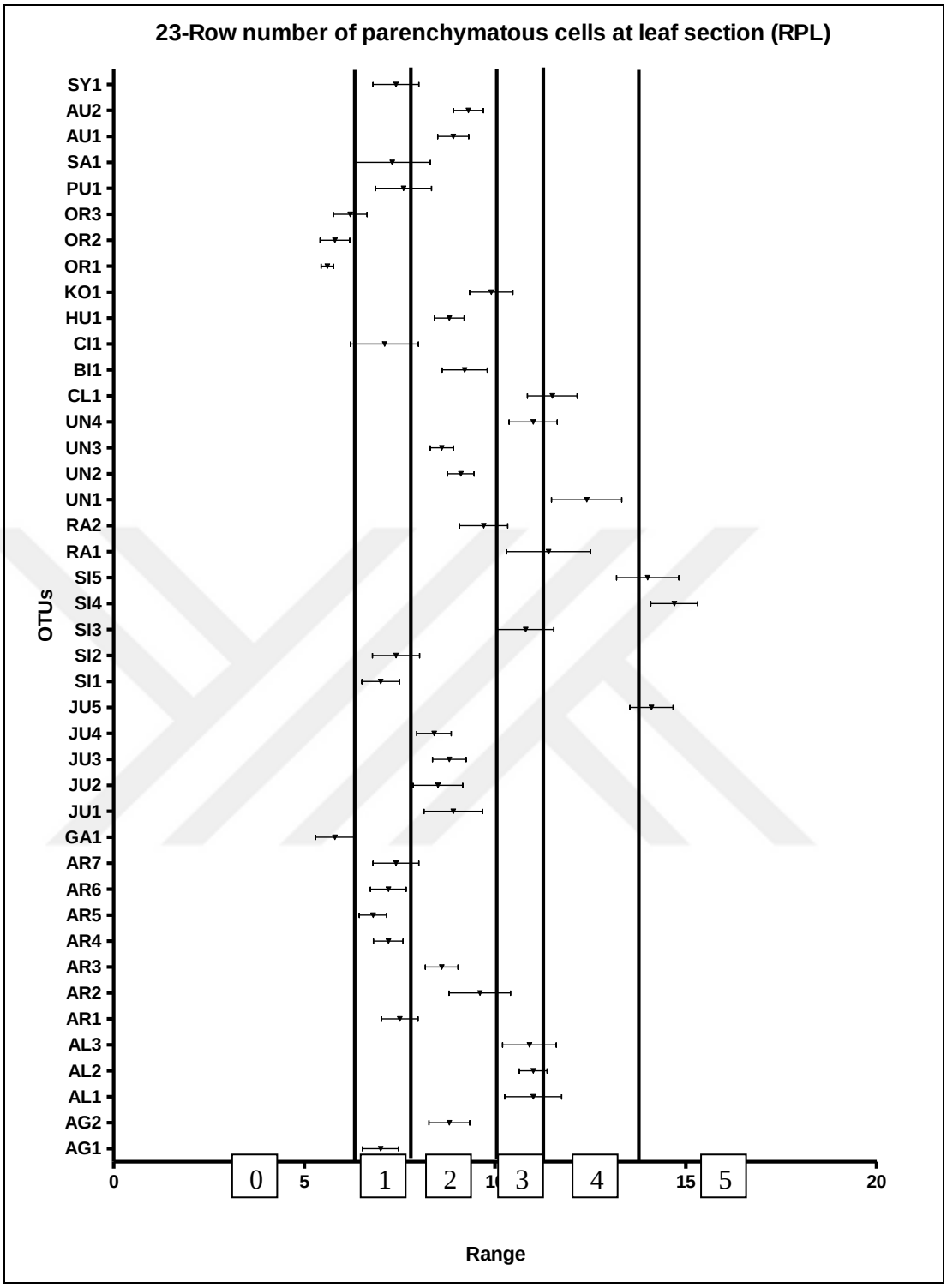

18-Length of upper epidermal cells at leaf section (UPL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
0
1
2
Range

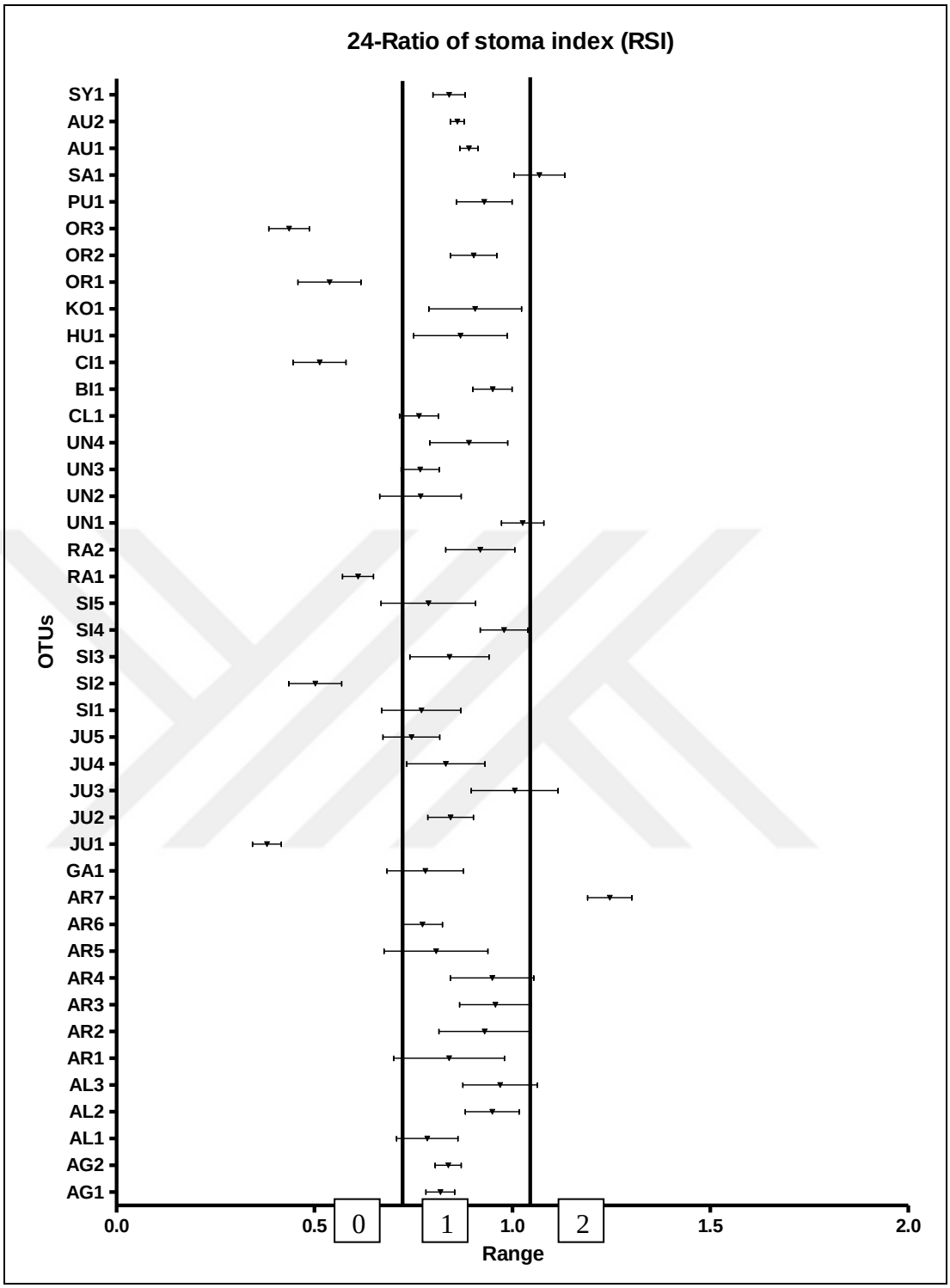

19-Width of parenchymatous cells at leaf section (PLW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
0
1
40
60
2
80
100
Range


20-Length of parenchymatous cells at leaf section (PLL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
60
80
100
0
1
2
Range


21-Width of lower epidermal cells at leaf section (LOW)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
80
Range
0
1
2


22-Length of lower epidermal cells at leaf section (LOL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
20
40
60
0
1
2
Range


23-Row number of parenchymatous cells at leaf section (RPL)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0
5
10
15
20
0
1
2
3
4
5
Range


24-Ratio of stoma index (RSI)
OTUs
SY1
AU2
AU1
SA1
PU1
OR3
OR2
OR1
KO1
HU1
CI1
BI1
CL1
UN4
UN3
UN2
UN1
RA2
RA1
SI5
SI4
SI3
SI2
SI1
JU5
JU4
JU3
JU2
JU1
GA1
AR7
AR6
AR5
AR4
AR3
AR2
AR1
AL3
AL2
AL1
AG2
AG1
0.0
0.5
0
1
1.0
2
1.5
2.0
Range

9. CURRICULUM VITAE

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