

Comparative anatomy of some selected species of the poppy family (Papaveraceae) in Iran

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Abstract

In the present study, a comparative anatomical study of stem, midrib of basal leave and fruit is provided. In this paper, 45 anatomical characters of stem, midrib and fruit of some species such as *Glaucium grandiflorum*, *G. fimbriigerum*, *G. corniculatum*, *G. contortuplicatum*, *G. haussknechtii*, *G. elegans* and other species such as *Roemeria hybrida*, *R. refracta*, *H. pendulum* and *C. majus* are presented. In this study, we report the presence of glandular hair in *G. oxylobum* and *G. pulchrum* for the first time. Among the examined traits, some traits such as shape of placenta, the presence of hairs, carpellary angle, the shape of carpellary angle, the number of external and internal layers of parenchyma of outer wall of ovary, the number of vascular bundles of placenta in the fruit and the presence of the central cavity, existence of hairy glands, the number of vascular bundles of phloem, lack of strengthening tissue surrounding the vascular bundles in the midrib of some species are different and the differences are significant enough to be useful in the delimitation of some species of *Glaucium*. Anatomical features of midrib in these genera indicate, in spite of some differences, the fundamental structure is similar, so cross section of blade by itself cannot be a good scale for identification of the species of the genus *Glaucium* and other genera. Anatomical features of stem are neither a suitable scale for separating species of *Glaucium*, nor for other genera. Anatomical features of fruit are useful in identification and determination species of genus *Glaucium*, but also, for four other genera, especially cross section of the fruit of *H. pendulum* showed significant differences in comparison with other genera. Some anatomical features of fruit in *Glaucium* can be used in taxonomically grouping of the genus. The most important traits are the apparent shape of ovarian placenta.

Key words: Anatomy, *Chelidonium*, *Glaucium*, *Hypecoum*, *Roemeria*, Papaveraceae, Iran

Introduction

Poppy family (Papaveraceae) comprises of approximately 26 to 42 genera and 690 to 800 species in the world (Judd *et al.*, 1999). The members of Papaveraceae are shrub, herbaceous perennials and annuals distributed in the temperate and the subtropical regions of the world. Among five genera of family Papaveraceae in Iran, *Glaucium*, *Hypecoum*, *Chelidonium* and *Roemeria* consist of 10, 1, 1 and 2 species, respectively (Rechinger and

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Cullen, 1966). Moreover, Mobayen (1985) introduced two subspecies *G. fimbrilligerum* Boiss. subsp. *annuum* and *G. fimbrilligerum* subsp. *Ophyocarpum*.

Anatomical structure of leaves (Dickson, 1935; Esau, 1977; Fahn, 1990; Batanouny, 1992) and laticifers (Solereeder, 1908) have been presented for some species. Solereeder (1908) claimed that the type of laticifers, composition and location of them in different organs are among traits that are taxonomically valuable. Metcalfe and Chalk (1950) reported several anatomical traits of poppy family that exclusively can be taxonomically useful in the identification and delimitation of the species.

Furthermore, anatomical characteristics of *Glaucium flavum* Cr. have been investigated (Dickson, 1935; Esau, 1977; Fahn, 1990; Batanouny, 1992). The most important studies, in respect of anatomy, are restricted to few economical species such as *Papaver somniferum* (Dickinson and Fairbairn 1975) and *Glaucium flavum* (Nessler, 1992; Bercu *et al.*, 2006) which mainly concerned to ultra-structure of alkaloid sac and laticifers, respectively. Azizian and Alishahi Norani (1997) studied anatomical characteristics of fruit and blade with emphasis on latex tubes in species of *Glaucium*. Furthermore, Carlquist and Hoekman (1985) studied anatomical structure of wood in *Romneya* and *Dendromecon*. Carlquist and Zona (1988) continued his studies in cooperation with Zona on structure of wood in *Papaveraceae*. Some anatomical features of midrib and fruit of *Glaucium* are of diagnostic value (Solereeder, 1908; Metcalfe and Chalk, 1950). Anatomical characteristics of the fruit, stem and petiole in four studied genera confirm the results of the previous studies. Because of the high variation of morphological characters of *Glaucium*, this research was aimed to 1) provide some anatomical characters of above-named genera, specifically *Glaucium*; 2) assess these characters' value in sorting out of the species.

Materials and methods

In this survey, all voucher specimens are deposited at TUH (acronyms according to Holmgren *et al.*, 1990) listed in Table 1. Because of the high variation of morphological diagnostic features of these species and difficulty of their identification, only representative specimens of any species were used in the study. For anatomical studies, dried basal leaves, fruits and stems were fixed in FAA 70 (Formalin, Glacial acetic acid and 70% Ethanol, 5: 5: 90, respectively), cross sections were made at the middle of blade, fruit, stem and were stained white methyl green and bismarck brown colors and then photographed by Leitz light microscope model Wetzlar, Nikon camera (Coolpix S10). For measuring required characters, Mesurepro software model HASP 2.17 was used.

Table 1. *Glaucium* species, their localities and voucher specimens

Species	Locality
<i>Glaucium elegans</i>	Tehran: Jajrud, Azad, Ganjalizadeh TUH-8864
<i>G. contortuplicatum</i>	Mazandaran: 40 km to Amol, near Andovar village, Attar, Okhovat & Mehdigholi, TUH-26352
<i>G. fimbrilligerum</i>	Tehran: ozaneh near Firuzkuh, Ghahreman, Aghostin, Shikholeslam, TUH-941
<i>G. pulchrum</i>	Zanjan: Abhar, Yazdan dust, TUH-8884
<i>G. corniculatum</i>	Azərbaycan: 10 km after Oshnavieh to Urumieh, American _ Iranian Expedition, TUH-34697
<i>G. grandiflorum</i>	Kermanshah: Bakhtaran. Ghahreman, TUH-8964
<i>G. haussknechtii</i>	Zanjan: Arijan vallage, Zarre, TUH-12633
<i>G. oxylobum</i>	Esfahan: 60 km to Delijan from Esfahan, American _ Iranian Expedition, TUH-33936
<i>Roemeria refracta</i>	Lorestan: Khorramabad, Veissina, Dogar. Veiskarami, TUH-23625
<i>R. hybrida</i>	Khorasan: Gonabad. Mobayen, TUH-24313
<i>Hypecoum pendulum</i>	Lorestan: Khorramabad, Chegeni Khatereh, Veiskarami, TUH-23626
<i>Chelidonium majus</i>	Gilan: Lahijan, Mobayen, TUH-8860

Results and Discussion

Glaucium

Midrib and Stem: In transverse section of the midrib, upper surface was flat and the lower surface was raised (Figure 1, a-t). A thick cuticle was observed on the outer surface of the epidermis (Figure 1: a, d, g, j, m, o and r). Several laminar layers of collenchyma were recognized under the epidermis (Figure 1: a, d, g, j, m, o and r). Under the collenchyma, parenchyma and in the central part, vascular bundles could be seen (Figure 1: a-t). Which were surrounded by sclerenchymatous sheaths (Figure 1: a-t). The continuity of the epidermal cells was interrupted by the presence of hairs. Some of the hairs were short, others were long (Figure 1: c, f, i, l, q and t). There were multilayer hairs (covering hairs) in some species such as *G. pulchrum* (Figure 1: l). These hairs were shorter (3 to 4 cells) and thicker than single row ones and had more cells (Figure 1: a, c, f, i, l, q and t).



Figure 1. ...

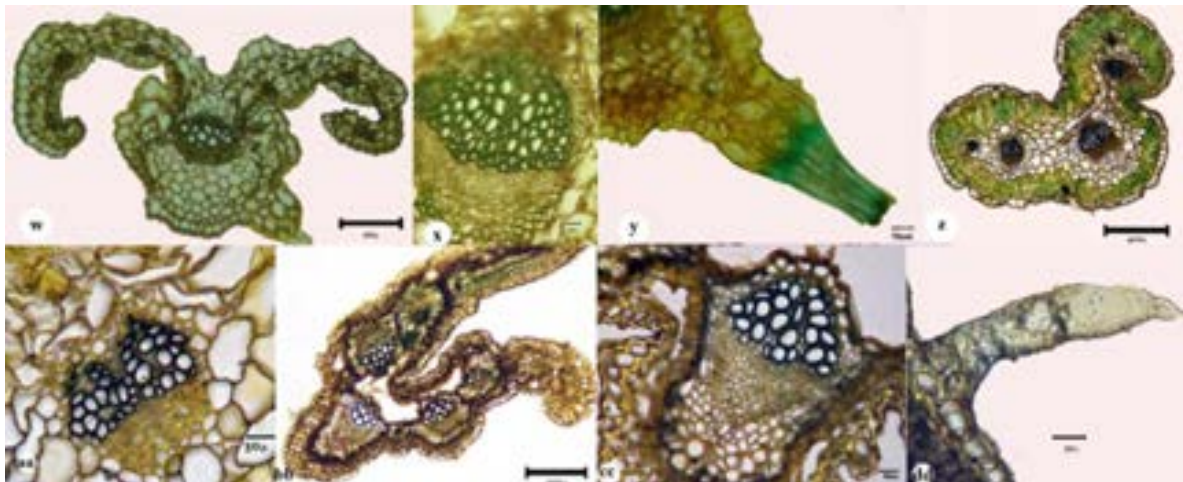


Figure 1. Cross section of midrib in species: *G. corniculatum* (a, b, c), *G. grandiflorum* (d, e, f), *G. haussknechtii* (g, h, i), *G. pulchrum* (j, k, l), *G. contortuplicatum* (m, n), *G. elegans* (o, p, q), *G. oxylobum* (r, s, t), *Roemeria hybrida* (u, v), *R. refracta* (w, x, y), *Hypocoum pendulum* (z, aa), *Chelidonium majus* (bb, cc, dd).

Scale bars in the photos are as: a=200 μ m, b=30 μ m, c=30 μ m, d=200 μ m, e=30 μ m, f=30 μ m, g=200 μ m, h=30 μ m, i=30 μ m, m=200 μ m, n=30 μ m, o=200 μ m, p=30 μ m, q=30 μ m, r=200 μ m, s=30 μ m, t=30 μ m, u=400 μ m, v=30 μ m, w=400 μ m, x=30 μ m, y=30 μ m, z=400 μ m, aa=30 μ m, bb=200 μ m, cc=30 μ m, dd=30 μ m.

Minimum thickness (5 μ m) of cuticle belonged to *G. grandiflorum* (Figure 1: d) and maximum (20 μ m) was observed in *G. contortuplicatum*, *G. pulchrum* and *G. haussknechtii* (Figure 1: g, j and m). Upper epidermis cells were usually larger than the lowers (Figure 1: a, d, g, j, m, o and r). Diameter of epidermal cells varied from 15 μ m in *G. corniculatum* and *G. haussknechtii* to 40 μ m in *G. oxylobum* and *G. contortuplicatum* (Figure 1: o and r). Thickness of upper collenchyma varied from 25 μ m in *G. corniculatum* to 55 μ m in *G. oxylobum* (Figure 1: a, d, g, j, m, o and r). There was no upper collenchyma in *G. contortuplicatum*. Thickness of lower collenchyma ranged from 40 μ m in *G. grandiflorum* and *G. corniculatum* to 280 μ m in *G. oxylobum*; lower parenchyma thickness varied from 40 μ m in *G. grandiflorum* and *G. contortuplicatum* to 280 μ m in *G. oxylobum*. Upper parenchyma thickness varied from 100 μ m in *G. haussknechtii* to 430 μ m in *G. oxylobum*. The range of vascular bundles varied from 110 μ m in *G. pulchrum* to 230 μ m in *G. oxylobum* (Figure 1: k and s). The range of fiber thickness at the upper surface of vascular bundles varied from 25 μ m in *G. corniculatum* to 50 μ m in *G. oxylobum*. Also, in most studied species, phloem tissue was bicolateral except for *G. contortuplicatum* (Figure 1: n). The range of xylem thickness varied from 80 μ m in *G. elegans* to 50 μ m in *G. grandiflorum*, *G. corniculatum*. Midrib cross section in *G. oxylobum* cleared a central cavity (Figure 1; r). In some species such as *G. contortuplicatum*, *G. haussknechtii* and *G. elegans* no hairs were observed on the surface of blade (Figure 1: i and q). Transverse section of the stem included cuticle layer, epidermal cells, parenchyma and vascular bundles. Cortex composed of parenchyma cells and one layer of sclerenchymatous cells. At the central part of stem, the medulla could be seen which was composed of many separated spherical cells, the center was occupied by a large cavity (Figure 3: a-l). Cuticular thickness in *G. fimbriigerum* Boiss. subsp. *annuum* was 5 μ m and in other species was 10 μ m (Figure 3: g). Measured characteristics were shown in the Tables 2, 3 and 4 (Figure 3: a-l).

Fruit: A cross section of fruit showed the placenta in the internal surface and two large cavities. There was a layer of small regular epidermis cells (Figure 2: b, d, f, h, j, l, n and

p). Several layers of parenchyma cells were recognized below the epidermis (Figure 2: a-p). The external area included 3-4 layers of chlorenchyma cells while 10 to 12 layers of the sclerenchymatous cells were observed in the internal region (Figure 2: a-p). At the center, vascular bundles were arranged in one row (Figure 2: a-p). The sclerenchyma tissue of pericarp was considerably occupied by laticifer tubes (Figure 2: a-p). Cuticle thickness varied from 5 μm in *G. fimbriigerum* Boiss. subsp. *annuum* to 20 μm in *G. pulchrum* (Figure 2: i and m). Epidermal cell thickness varied from 15 to 50 μm in *G. oxylobum* and *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: g and o). Inner parenchyma layer thickness varied from 20 μm in *G. corniculatum* to 90 μm in *G. fimbriigerum* subsp. *ophycarpum*. Number of internal layers of parenchyma ranged from three in the *G. corniculatum* to seven in *G. grandiflorum* and *G. haussknechtii* (Figure 2: a, c and e). Thickness of internal parenchyma varied from 60 μm in *G. pulchrum* to 220 μm in *G. haussknechtii*. Thickness of sclerenchyma tissue of fruit wall varied from 70 μm in *G. pulchrum* to 250 μm in *G. corniculatum* (Figure 2: a and m). The thickness of the tissue showed evident differences in *G. corniculatum* with respect to other species (Figure 2: a-p). Laticifer tubes could be seen in the sclerenchymatous sheath of the vascular bundles, the fruit wall, placenta and internal parenchyma layers (Figure 2: a-p). Length of vascular bundles in fruit wall varied from 20 μm in *G. fimbriigerum* Boiss. subsp. *annuum* to 90 μm in *G. corniculatum* (Figure 2: g and b). Carpellary angle varied from 95° in *G. pulchrum* to 170° in *G. oxylobum* (Figure 2: m and o). Carpellary angle form was crescent in *G. corniculatum*, *G. haussknechtii*, *G. elegans* (Figure 2: a, e and k), linear in *G. oxylobum* and *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: g and o), V-shaped in *G. grandiflorum*, *G. fimbriigerum* Boiss. subsp. *annuum* (Figure 2: i and k) and semi-circular in *G. pulchrum* (Figure 2: m). Thickness of ovary wall varied from 300 μm in *G. oxylobum*, *G. grandiflorum* and *G. fimbriigerum* subsp. *ophycarpum* to 450 μm in *G. corniculatum*. The connected wall of placenta to the ovary varied from 100 μm in *G. haussknechtii* to 1500 μm in *G. fimbriigerum* Boiss. subsp. *annuum* (Figure 2: f-i). Thickness of placenta varied from 530 μm in *G. elegans* to 1100 μm in *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: g-k). Among studied species triangular-shaped placenta could be seen in *G. haussknechtii* and *G. corniculatum* (Figure 2: b and f); dentiform in *G. elegans* (Figure 2: l), heart-shaped in *G. oxylobum* and *G. pulchrum* (Figure 2: n and p) and the bean-shaped could be found in *G. grandiflorum*, *G. fimbriigerum* Boiss. subsp. *annuum* and *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: d, h and j). Placental thickness varied from 530 μm in *G. elegans* to 1100 μm in *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: a, s, e, g, i, k, m and o). Total numbers of placental vascular bundles were two in *G. oxylobum*, four in *G. corniculatum*, *G. haussknechtii*, five in *G. fimbriigerum* subsp. *ophycarpum*, six in *G. elegans* and *G. pulchrum*, seven in *G. fimbriigerum* Boiss. subsp. *annuum* and eight in *G. grandiflorum* (Figure 2: a, s, e, g, i, k, m and o). Multicellular appressed trichomes in some species such as *G. corniculatum*, *G. grandiflorum* and *G. haussknechtii* were recognized, while glandular hairs could be found in *G. oxylobum* and *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: a, s, e, g, i, k, m and o).



Figure 2. Cross section of fruit in species: *G. corniculatum* (a, b), *G. grandiflorum* (c, d), *G. haussknechtii* (e, f), *G. fimbriigerum* subsp. *ophycarpum* (g, h), *G. fimbriigerum* subsp. *annuum* (i, j), *G. elegans* (k, n), *G. pulchrum* (m, n), *G. oxylobum* (o, p), *Roemeria hybrida* (q, r), *Roemeria refracta* (s, t), *Hypocoum pendulum* (u, v), *Chelidonium majus* (w, x).

Scale bars in the photos are as: a=400 μ m, b=200 μ m, c=400 μ m, d=200 μ m, e=400 μ m, f=200 μ m, g=400 μ m, h=200 μ m, i=400 μ m, j=200 μ m, k=400 μ m, l=200 μ m, m=400 μ m, n=200 μ m, o=400 μ m, p=200 μ m, q=400 μ m, r=30 μ m, s=400 μ m, t=200 μ m, u=400 μ m, v=200 μ m, w=400 μ m, x=30 μ m.

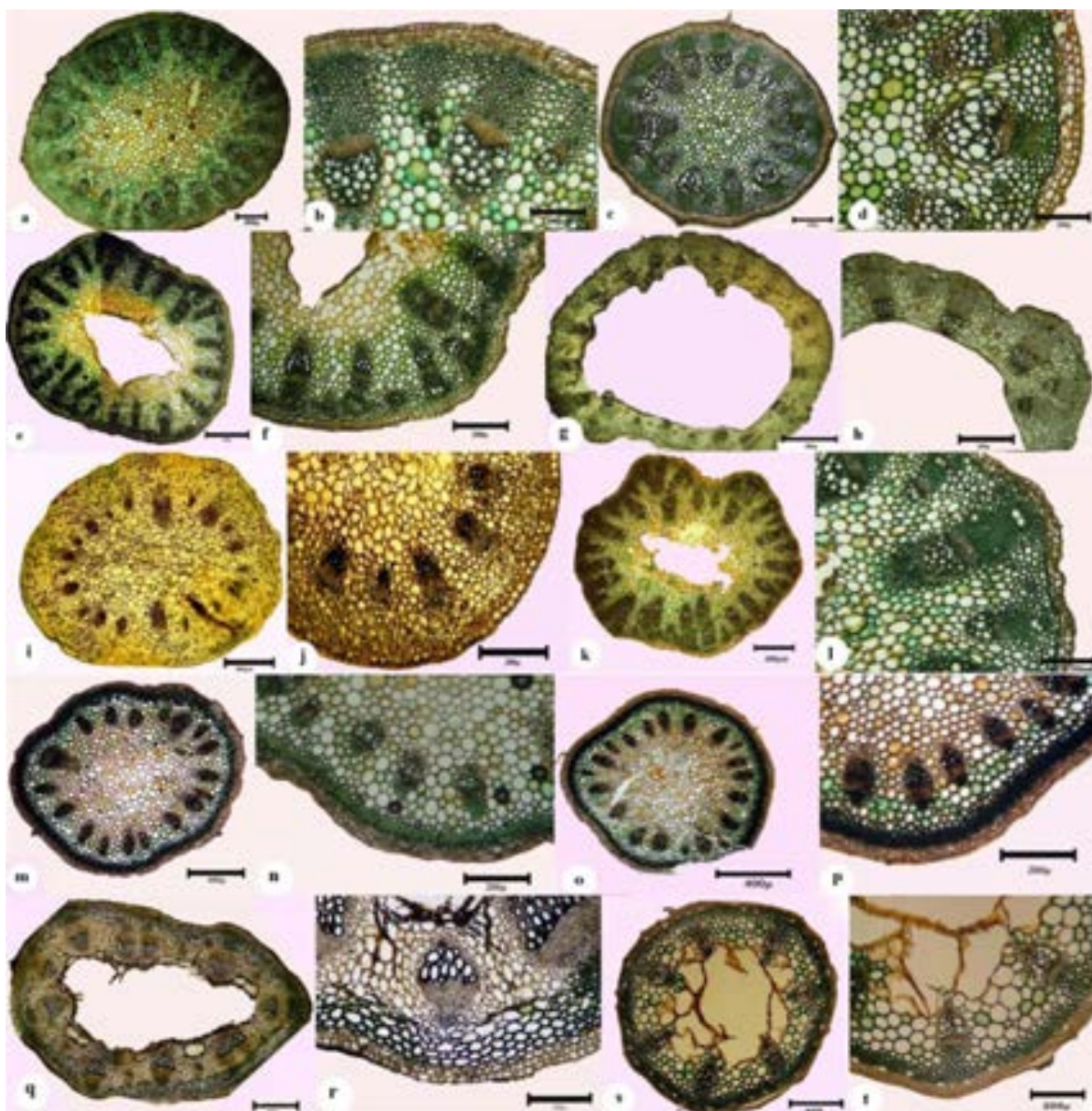


Figure 3. Cross section of stem in species: *G. grandiflorum* (a, b), *G. haussknechtii* (c, d), *fimbrilligerum* subsp. *annuum* (e, f), *G. fimbrilligerum* subsp. *ophycarpum* (g, h), *G. pulchrum* (i, j), *G. oxylebium* (k, l), *Roemeria hybrida* (m, n), *Roemeria refracta* (o, p), *Hypocoum pendulum* (q, r), *Chelidonium majus* (s, t). Scale bars in the photos are as: a=400 μ m, b=200 μ m, c=400 μ m, d=200 μ m, e=400 μ m, f=200 μ m, g=400 μ m, h=200 μ m, i=400 μ m, j=200 μ m, k=400 μ m, l=200 μ m, m=400 μ m, n=200 μ m, o=400 μ m, p=200 μ m, q=400 μ m, r=200 μ m, s=400 μ m, t=200 μ m.

Roemeria*, *Hypocoum* and *Chelidonium

Midrib: Upper cuticle thickness did not show considerable differences in *R. refracta*, *R. heybrida*, *C. majus* and *H. pendulum* but less thickness was measured in most species of *Glaucium* (Figure 1: u-z and aa, bb, cc, dd). Lower cuticle thickness in *R. refracta* was more than *R. heybrida*, *C. majus* and *H. pendulum* but in comparison with most species of *Glaucium* did not show considerable differences. Upper and lower epidermises in *C. majus* in comparison with *H. pendulum*, *R. refracta* and *R. heybrida* had less thickness (Figure 1: u-z and aa, bb, cc, dd).

Thicknesses of the upper parenchyma in *C. majus* and *R. refracta* in comparison with *R. hybrida*, *H. pendulum* and species of *Glaucium* had considerable differences (Figure 1: u-z and aa, bb, cc, dd). Thicknesses of the lower parenchyma in *C. majus* in comparison with other genera had considerable differences. Against *R. hybrida*, *C. majus* and most species of *Glaucium*, upper collenchyma did not exist in *Roemeria refracta* and *H. pendulum* and *R. hybrida* phloem was collateral (Figure 1: u-z and aa, bb, cc, dd). Vascular bundles of midrib in *R. refracta* were one, in *R. hybrida* three and five in *C. majus* and *H. pendulum*. The minimum number of midrib vascular bundles among all four genera belonged to *R. refracta* (Figure 1: u-z and aa, bb, cc, dd). There were some laticifer tubes around vascular bundles, parenchyma, especially sclerenchymatous sheath, cone-shaped, multicellular multi-row hairs were observed in *R. refracta*, while long multicellular and single row hairs were recognized in *R. hybrida* and *C. majus*. No hair was seen in *H. pendulum* (Figure 1: u-z and aa, bb, cc, dd).

Stem: Cuticle and epidermal thickness in *R. hybrida*, *H. pendulum*, *C. majus* were similar, but more thickness was measured in *R. refracta*; maximum thickness of cuticle among four genera belonged to *R. refracta* (Figure 3: m-t). Parenchyma thickness did not show significant differences in the four mentioned species (Figure 3: m-t). Sclerenchyma cortex thickness, width of external and internal phloem in *R. refracta* and *H. pendulum* in comparison with *R. hybrida*, *C. majus* had considerable differences. Laticifer tubes in *Roemeria* species could be seen around vascular bundle and in *C. majus* and *H. pendulum* clearly in the cortex and sclerenchymatous sheath (Figure 3: m-t).

Fruit: Cuticular thickness in *H. pendulum* was more than three other species (Figure 2: q-x). Inner parenchyma layers were superseded by sclerenchymatous in *H. pendulum* (Figure 2: v). Placenta was planar and had a vascular bundle in *Roemeria* species, while in *C. majus* was dentiform with a vascular bundle (Figure 2: q-x). Semi-circular carpellary angle varies from 90° to 130° in *R. refracta*, *R. hybrida* and *H. pendulum*, respectively (Figure 2: q, s, u and w). Linear carpellary angle (170°) was seen in *Chelidonium majus*. Laticifer tubes could be found in placental sclerenchyma and in wall parenchyma in *R. hybrid*. Multicellular spear-like hairs were observed in *Roemeria*, but the others lacked such a character (Figure 2: q and r).

Table 2. Anatomical characters of basal leaf in studied species.

Abbreviations: A: Papile presence, B: Papile layers' number, C: Papile's shape, D: upper cuticle's thickness, E: lower cuticle's thickness, F: upper epidermis thickness, G: lower epidermis thickness, H: upper collenchyma thickness, I: lower collenchyma thicknes, J: upper parenchyma layer thickness, K: lower parenchyma layer thickness, L: upper phloem width, M: lower phloem width, N: xylem width, O: upper tissue strength thickness, P: lower tissue strength thickness, Q: Bundle vessle number, R: Length leaflet, S: Bundle vessel distance between. l: long, Mu: multiseriate, Mc: multicellural, o: oblong, On: Onion shape, g: glandular, u: uniseriate. The unit of all quantity is micrometer.

Species	A	B	C	D	E	F	G	H	I	J
<i>G. corniculatum</i>	+	Un	l, Mc	15	13	15	15	25	120	250
<i>G. elegans</i>	-	-	-	10	10	30	10	30	146	300
<i>G. grandiflorum</i>	+	Un	l, Mc	5	5	28	20	50	40	330
<i>G. contortuplicatum</i>	-	-	-	20	20	40	35	-	40	200
<i>G. pulchrum</i>	+	Mu	l, Mc, g	20	20	20	30	30	140	350
<i>G. husskenechtii</i>	-	-	-	20	10	15	15	50	70	100
<i>G. oxylum</i>	+	-	l, g	10	10	40	40	55	280	430
<i>Roemeria hybrida</i>	+	Mu	On, l	10	15	40	20	20	30	55
<i>R. refracta</i>	+	Un	l, Mc	10	10	20	30	-	50	320
<i>Hypecoum pendulum</i>	+	Un	l, Mc	10	10	30	35	-	-	190
<i>Chelidonium majus</i>	+	Un	l, Mc	10	10	10	15	30	80	50

Table 2. ...

Species	K	L	M	N	O	P	Q	R	S
<i>G. corniculatum</i>	150	20	70	130	80	60	5	2180	210
<i>G. elegans</i>	170	20	40	210	-	100	5	2100	260
<i>G. grandiflorum</i>	180	20	70	150	80	110	4	1500	200
<i>G. contortuplicatum</i>	150	-	60	170	50	150	3	1500	300
<i>G. pulchrum</i>	100	30	-	110	-	140	3	900	200
<i>G. husskenechtii</i>	150	10	20	100	70	85	4	1300	150
<i>G. oxylum</i>	220	10	40	230	70	100	5	2260	200
<i>Roemeria hybrida</i>	110	35	50	65	-	-	1	1200	-
<i>R. refracta</i>	110	-	20	120	30	100	3	1500	230
<i>Hypecoum pendulum</i>	250	35	70	150	-	-	5	1500	250
<i>Chelidonium majus</i>	50	15	60	90	10	90	5	1200	120

Table 3. Anatomical characters of the capsule in studied species

Abbreviations: A: Papile presence, B: Papile layers' number, C: Papile's shape, D: cuticle's thickness, E: epidermis thickness, F: external parenchyma layer number, G: upper parenchyma layer thickness, H: lower parenchyma layer number, I: lower parenchyma layer thickness, J: laticiferous tubes location, K: bundle vessel width, L: upper scleranchyma length, M: placenta's shape, N: Bundle vessle number of placenta, O: shape's Leaflet Angle between, P: Leaflet Angle between, Q: Wall thickness, R: placenta's thickness, S: Attache wall, an: angular, em: embowed, fi: Five form, g: globular, li: linear, l: long, Mo: Monoseriate, Mu: Multiseriate, o: oblong, re: renal, p: Paranchym, pd: Paranchym down, pu: paranchya up, s: short, sc: semicircle, su: sunken, sp: spear, to: tooth, tr: triangle. The unit of all quantity is micrometer. The unit of all quantity is micrometer.

Species	A	B	C	D	E	F	G	H	I	J
<i>G. corniculatum</i>	+	Mu	l, g	10	40	10	20	3	110	Pd, sc/v, sc/p
<i>G. elegans</i>	+	Mo, Mu	s, se, l, o	10	30	3	50	5	100	sc/v, sc/p
<i>G. fimbrilligerum</i> Boiss. subsp. <i>Annuum</i>	+	Mu	l, o	5	40	3	40	6	130	sc/v, sc/p
<i>G. fimmbrilligerum</i> subsp. <i>ophycarpum</i>	+	Mu	L, g	10	50	5	110	4	80	
<i>G. grandiflorum</i>	+	Mu	S, se	10	30	3	50	7	80	sc/v, sc/p
<i>G. husskenechtii</i>	+	Mu	l, o	10	30	5	80	7	220	sc/v, sc/p
<i>G. pulchrum</i>	-	-	-	20	30	6	100	4	60	sc/v, sc/p
<i>G. oxylum</i>	+	Mu	L, g	10	15	3	30	4	70	sc/v, sc/p
<i>R. refracta</i>	-	-	-	10	40	4	170	1-3	80	P
<i>R. hybrida</i>	+	Mu	sp	10	20	6	160	4	100	P
<i>Hypecoum pendulum</i>	-	-	-	23	30	2	150	-	-	sc/p, p
<i>Chelidonium majus</i>	-	-	-	10	6	1	20	1	15	sc/p

Species	K	L	M	N	O	P	Q	R	S
<i>G. corniculatum</i>	90	250	tr	4	em	130	450	600	130
<i>G. elegans</i>	50	100	to	6	em	125	390	530	700
<i>G. fimbrilligerum</i> Boiss. subsp. <i>Annuum</i>	20	110	re	7	an	110	β70	1000	1500
<i>G. fimmbrilligerum</i> subsp. <i>ophycarpum</i>	40	130	re	5	li	160	300	1100	450
<i>G. grandiflorum</i>	50	100	re	8	an	115	300	650	700
<i>G. husskenechtii</i>	40	150	tr	4	em	130	400	580	100
<i>G. pulchrum</i>	50	70	fi	6	sc	95	300	750	250
<i>G. oxylum</i>	70	120	fi	2	li	170	300	800	430
<i>R. refracta</i>	15	-	su	1	sc	93	350	345	-
<i>R. hybrida</i>	45	-	su	1	sc	100	320	320	-
<i>Hypecoum pendulum</i>	50	100	su	1	sc	130	600	550	
<i>Chelidonium majus</i>	10	-	to	1	Li	170	100	250	200

Table 4. Anatomical characters of the stem in studied species

Abbreviations: A: cuticle's thickness, B: epidermis thickness, C: parenchyma cortex thickness, D: scleranchyma cortex thickness, E: external phloem width, F: internal phloem width, G: xylem width. The unit of all quantity is micro meter.

Species	A	B	C	D	E	F	G
<i>G. haussknechtii</i>	10	30	60	200	40	30	300
<i>G. grandiflorum</i>	10	20	60	330	90	50	260
<i>G. fimbriigerum</i> Boiss. subsp. <i>Annuum</i>	5	10	35	80	15	70	150
<i>G. fimbriigerum</i> subsp. <i>ophycarpum</i>	10	20	72	180	30	130	60
<i>G. pulchrum</i>	10	35	150	50	40	20	70
<i>G. oxylobum</i>	10	20	220	130	80	10	110
<i>R. refracta</i>	15	20	30	80	50	40	80
<i>R. hybrida</i>	10	10	30	150	70	60	130
<i>Hypocoum pendulum</i>	10	10	30	70	50	25	120
<i>Chelidonium majus</i>	10	10	20	130	130	40	100

Results of present study showed, anatomical characters of midrib in *Glaucium* species led to finding some traits which could be used for identification for different species. In vascular structure of midrib in most *Glaucium* species, bicollateral phloem and scleranchymatous sheath of vascular bundles could be seen (Figure 1: n, v). Among species of this genus, *G. contortuplicatum* possessed collateral phloem and lacked external collenchyma which was distinguished from other species. This species was easily recognized from other species by its helical fruit. A central cavity can be observed midrib in *G. oxylobum* which in turn, could be used as a differentiating feature for this species. Multicellular single row hairs in *G. grandiflorum* and *G. corniculatum* could be seen (Figure 1: c, f). Although, Metcalfe and Chalk (1950) studied anatomical traits of Papaveraceae but they didn't report on glandular hairs. In this study, glandular hairs were observed in *G. oxylobum* and *G. pulchrum*.

According to present study, some anatomical features of fruit in *Glaucium* can be used in grouping of the genus. The most important traits were the apparent shape of ovarian placenta (Figure 2: b, d, f, h, j, l, n and p). Placenta types were observed as following:

- 1- Triangular: *G. haussknechtii*, *G. corniculatum* (Figure 2: a and e)
- 2- Dentiformis: *G. elegans* (Figure 2: k)
- 3- Heart-shaped: *G. oxylobum*, *G. pulchrum* (Figure 2: o, m)
- 4- Bean-shaped: *G. grandiflorum*, *G. fimbriigerum* Boiss. subsp. *annuum*, *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: c, g and i)

Another distinguishing character was carpellary angle. Carpellary angle varied from 95° in *G. pulchrum* to 170° in *G. oxylobum* (Figure 2: m and o) which was classified as following:

Group I: Lunar-shaped: *G. haussknechtii*, *G. corniculatum*, *G. elegans* and *G. pulchrum* (Figure 2: a, e and k).

Group II: Linear-formed: *G. oxylobum* and *G. fimbriigerum* subsp. *ophycarpum* (Figure 2: g and o).

Group III: V-shaped: *G. fimbriigerum* Boiss. subsp. *annuum* and *G. grandiflorum* (Figure 2: i).

In addition to the above mentioned traits, the differences in the number of external and internal layers of parenchyma in the ovary wall, the number of vascular bundles of placenta and type of hairs might be suitable in identification of unknown species. Considering the anatomical traits of fruit in *Glaucium*, identification of two species, *G. haussknechtii* and *G. grandiflorum*, from each other and other species of *Glaucium* was easily possible. Anatomical characteristics of the stem in species of this genus did not show very important

differences. According to anatomical study of *Roemeria* and the transverse incision of blade of two species there were some significant differences as following:

- Lack of external collenchyma (such as *G. contortuplicatum*) and external parenchyma in the main vein in *Roemeria hybrida*.
- Lack of strengthening tissue surrounding the vascular bundles in *Roemeria refracta* (like *H. pendulum*)
- Presence of 1 and 3 vascular bundle in blade cross section provided from *R. refracta* and presence *R. hybrida* respectively.

Anatomical characteristics of the fruit in *Roemeria* which differed between these two species as follows: lack of hair in cross cutting the fruit of *Roemeria refracta* and its presence in *R. hybrida* and the difference in the overall shape of fruit in the transect so the shape of fruit in *R. refracta* was almost quadrangular (four corners) and the shape in *R. hybrida* was triangular. Anatomical study of the stems of species in this genus did not show very important difference. Blades transect study in two other genera such as *Hypocoum* and *Chelidonium* showed structurally no significant difference with respect to *Glaucium* and *Roemeria*. Cross section of blade in *C. majus* showed more similarity with *G. oxylobum*. Transect of fruit in *H. pendulum* was different from other genera. The general form of the transect was rectangular and lacking any placental bulge so identification of the placental place was difficult. External sclerenchyma could be seen only on the vascular bundles. As like as *Glaucium*, fruit in *C. majus* posed prominent placenta and the placenta shape in latter species was dentiformis. Identification of some species based only on morphological characteristics was difficult and even sometimes impossible. Previous studies and this study on anatomical characters of *Glaucium* indicated that these traits could identify and separate these species more accurately in some cases.

Anatomical study of blade in these genera indicated, in spite of some differences, the fundamental structure was similar, so cross section of blade solely could not be a good scale for separating species of genus *Glaucium* and identification of four genera. Fruit anatomical characters not only were useful in separating species of genus *Glaucium*, but also, for identification and determination of the four other genera. Stem anatomical study indicated that these four genera were very similar in this character, so stem anatomy characters was neither a suitable scale for separating species of *Glaucium*, nor for other genera. However, anatomical characteristics of the fruit, stem and blade in the four genera could confirm previous studies and had a good agreement with previous studies. (Solereeder, 1908; Metcalfe and Chalk, 1950).

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تشریح مقایسه‌ای برخی از گونه‌های تیره خشخاش (Papaveraceae) در ایران

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چکیده

در مطالعه حاضر، بررسی مقایسه‌ای صفات تشریحی ساقه، رگبرگ اصلی برگ‌های قاعده‌ای و میوه در خانواده Papaveraceae (به جز جنس *Papaver*) در ایران ارائه شده است. در این پژوهش، ۴۵ صفت تشریحی مربوط به ساقه، رگبرگ اصلی و میوه در گونه‌های *G. elegans*, *G. haussknechtii*, *G. corniculatum*, *Glaucium grandiflorum*, *Chelidonium majus* مورد بررسی قرار گرفته است همچنین، وجود کرک غده‌ای در *G. pulchrum* و *G. oxylobum* برای نخستین بار گزارش شد. از بین صفات بررسی شده، چندین صفت از جمله: شکل جفت، زاویه برچه‌ای، شکل زاویه برچه‌ای، تعداد لایه‌های پارانشیم داخلی و خارجی دیواره تخمدان، تعداد دستجات آوندی جفت در میوه، وجود حفره مرکزی در میوه، وجود کرک‌های غده‌ای، تعداد دستجات آوندی، تعداد دستجات بافت آبکش، عدم وجود بافت استحکامی در اطراف دستجات آوندی در رگبرگ اصلی برخی گونه‌ها متفاوت است، که می‌تواند در جداسازی گونه‌های جنس *Glaucium* مفید باشد. صفات تشریحی رگبرگ اصلی پهنک در این جنس‌ها، به رغم برخی از تفاوت‌ها، اساساً ساختار مشابهی دارد. بنابراین، صفات تشریحی رگبرگ به تنهایی نمی‌تواند معیار مناسبی برای شناسایی و تشخیص گونه‌های جنس *Glaucium* و چهار جنس دیگر باشد. همچنین، صفات تشریحی ساقه، معیار مناسبی برای تشخیص و جداسازی گونه‌های جنس *Glaucium* و سایر جنس‌ها نیست. از سوی دیگر، صفات تشریحی میوه در شناسایی و جدا کردن گونه‌های جنس *Glaucium* و همچنین چهار جنس دیگر مفید است به ویژه، برش عرضی میوه *H. pendulum* اختلاف قابل توجهی را در مقایسه با دیگر جنس‌ها نشان می‌دهد. برخی از صفات تشریحی میوه در جنس *Glaucium* می‌تواند در گروه‌بندی تاکسونومیک این جنس مفید باشد. مهم‌ترین این صفات، شکل جفت تخمدان است.

واژه‌های کلیدی: آناتومی، *Papaveraceae*, *Roemeria*, *Heypocoum*, *Glaucium*, *Chelidonium*، ایران