

LEAF ARCHITECTURE AS AN AID TO THE SPECIFIC DELIMITATION OF THE GENUS *TRIGONELLA* L. (PAPILIONACEAE) FROM PAKISTAN

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ABSTRACT

Leaf architecture and micro-morphology of 15 taxa of the genus *Trigonella* L. from Pakistan were studied by light and scanning electron microscopy. The genus *Trigonella* is characterized by the presence of polymorphic leaves. Among stomata, anomocytic type is dominant and pubescent is the dominant vesture type. It is found that the leaf architecture and micro-morphological features can be used to strengthen the taxonomic delimitation of the genus *Trigonella* from Pakistan.

KEY WORDS: Leaf architecture; Papilionaceae; SEM; stomata; trichomes; *Trigonella*.

INTRODUCTION

The genus *Trigonella* L. belongs to the tribe Trifolieae of the family Papilionaceae (Ali, 1977) it is reported to have ca. 135 species around the world (Mabberly, 1997). In Pakistan it is represented by 16 species and 2 subspecies. The genus is polymorphic in terms of leaf architecture and various workers have used leaf morphology for delimiting the genus (Linnaeus, 1753; Hooker, 1879; Dormer, 1946; Rechinger, 1972; Ali, 1977; Shu, 2010). Similarly, Gupta (1979) from India described the trichomes of 9 species belonging to 4 genera of Trifolieae including 1 species of the *Trigonella*. He discussed the types of trichomes within tribe. Leelavathi *et.al.* (1983) investigated the structure, distribution, and classification of 42 species of Papilionoideae including one species of the *Trigonella*. They determined 28 types of trichomes present on vegetative and floral parts of the taxa and the data was used for taxonomic delimitation. Taia (2004) determined the leaf characters (size, shape, margin, and apex) with stomatal type, trichomes and epidermal cells of 9 species of *Trigonella* and the data was significantly used for taxonomic delimitations of the genus from Egypt. Hargreaves (2006) from Brazil elaborate the vegetative morphology for species identification of the tropical trees of different families including 30 species of Faboideae. He studied the characters such as, stipule, venation, and lamina-symmetry and leaf phyllotaxy and concluded that the data can be used for species identification. Ranjbar *et al.* (2012) described 8 species of genus *Trigonella* from Iran. They also utilized the indumentum characters in description of species and used the data for taxonomic purpose. Zoric *et al.* (2012) analyzed leaf epidermal characters including stomata and trichomes of 18 species of the genus *Trifolium* L. from Republic of Serbia and data was found useful for sectional delimitation. Similarly, Rashid *et.al.* (2018) studied leaf epidermal characters including trichomes and types of stomata of the Trifolieae including 4 species of *Trigonella* from Pakistan. They suggested that leaf epidermal characters along with other traits can significantly be used for taxonomic delimitation of the tribe.

The purpose of the present study was to analyze the leaf architecture including stomata and trichomes to strengthen the taxonomic delimitation of the genus *Trigonella* from Pakistan.

MATERIAL AND METHOD

Leaves of 15 Taxa of the genus *Trigonella* (*T. anguina* Delile, *T. cachemirian* Camb., *T. corniculata* (Linn.) Linn., *T. emodi* Benth., *T. fimbriata* Royle ex. Benth., *T. foenum-graecum* Linn., *T. gharuensis* Rech. f., *T. gracilis* Benth., *T. hamosa* Linn., *T. monantha* ssp. *monantha* (Benth.) Ali comb. & stat. nov., *T. monantha* ssp. *incisa* (Benth.) Ali, *T. monospelica* Linn., *T. occulta* Delile ex. DC, *T. podperae* (Sirj) Vass. and *T. pubescens* Edgew. Ex. Baker) were collected from Karachi University Herbarium (KUH) and National Herbarium Islamabad (RAW) (Appendix-I). The leaf morphological characters like stipules, lamina symmetry, shape, apex, base, margin, indumentum, and teeth (orders, spacing, shape, number per leaflet) were observed under stereomicroscope (Nikon XN model). For micro-morphological characters 1 cm² part of leaf was mounted on metallic stub and placed under sputtering chamber for 6 minutes for gold plating then observed under scanning electron microscope (JSM-6380 A). Terminologies used in the present study are in accordance to Metcalfe & Chalk (1950), Lawrence (1970), Stearn (1983) and Ash *et al.* (1999).

OBSERVATIONS AND RESULTS

General leaf architecture of the genus *Trigonella*

Leaves stipulate, petiolate 10-950 mm long, alternate, tripinnate, leaflets 10-250 × 10-120 mm, symmetrical, 1-veined; blade class nanophyll, microphyll, mesophyll, macrophyll or notophyll; lamina shape oblong, obovate, oblanceolate, orbicular, broad elliptic, elliptic, rhomboid, obcordate; apex obtuse, retuse, truncate, mucronate; base cuneate, attenuate, obtuse; margin dentate; teeth order 1°, irregular tooth spacing, 7-30 teeth per leaf; tooth apical side straight, concave, retroflexed, convex, flexous; tooth basal side straight, convex, retroflexed, concave (Table 1, Figs. 4 & 5).

General stomatal characters of the genus *Trigonella*

Stomata anomocytic, anisocytic, tetracytic, paracytic; sunken or at the level of epidermis, aperture linear, narrow elliptic, elliptic, broad elliptic; aperture length 7.3-12.5 µm, width 1.0-4.5 µm (Table-2, Figs. 1-3).

General trichome characters of the genus *Trigonella*

Indumentum pilose, pubescent, tomentose, eglandular, small oblong, large ribbon like or cylindrical with smooth, pustulate surface or dentate projections; head obtuse or pointed; base flat, cylindrical, broad, stalked, rounded or ring like (Table-3, Figs. 1-3).

Key to the species of the genus *Trigonella*

- 1 + Stomata anomocytic 2
- Stomata anisocytic, tetracytic or paracytic 9
- 2 + Stomata sunken 3
- Stomata at the level of epidermis 4
- 3 + Leaf blade class microphyll or mesophyll, hair ribbon like with pustulate surface *T. fimbriata*
- Leaf blade class notophyll or macrophyll, hair ribbon like with smooth surface *T. monspelica*
- 4 + Leaf base cuneate 5
- Leaf base attenuate or obtuse 6
- 5 + Leaf apex retuse, truncate or obtuse *T. anguina*
- Leaf apex mucronate *T. cachemiriana*
- 6 + Tooth apical side retroflex, tooth basal side concave *T. emodi*
- Tooth apical side not retroflex, tooth basal side not concave 7
- 7 + Hairs cylindrical with dentate projections on surface *T. monantha*
- Hairs not cylindrical with dentate projections on surface 8
- 8 + Leaf apex retuse, indumentum pilose, trichomes ribbon like with pustulate surface *T. corniculata*
- Leaf apex truncate, obtuse, indumentum pubescent, trichomes ribbon like with smooth surface *T. hamosa*
- 9 + Stomata paracytic or tetracytic 10
- Stomata anisocytic 11
- 10 + Stomata tetracytic, lamina shape oblanceolate, tooth apical side straight, tooth basal side straight.... *T. occulta*
- Stomata paracytic, lamina shape obovate, tooth apical side flexous, concave, tooth basal side concave *T. pubescens*
- 11 + Leaf blade class notophyll and macrophyll *T. foenum-graecum*
- Leaf blade class microphyll and mesophyll 12
- 12 + Leaf apex mucronate, indumentum tomentose, stomatal aperture linear *T. podperae*
- Leaf apex obtuse, retuse, indumentum pubescent, stomatal aperture elliptic 13
- 13 + Leaf base cuneate, stomata sunken, hair ribbon like with smooth surface *T. gharuensis*
- Leaf base attenuate, stomata at the level of epidermis, hair cylindrical with dentate projections on surface *T. gracilis*

DISCUSSION

The genus *Trigonella* is characterized by the presence of stipulate, petiolate, alternate, tripinnate, 1-veined, symmetrical leaves (Ali, 1977), dentate margin with 1° teeth order and irregular tooth spacing. While, on the other hand, each species has distinct combination of leaf characters. Regarding to leaf shape, a variety of shapes was found in the genus i.e., oblong, obovate, oblanceolate, orbicular, broad elliptic, elliptic, rhomboid or obcordate. Amongst all the shapes obovate was the most dominant shape. Similarly, microphyll, mesophyll, macrophyll, notophyll leaves were present within the genus. Whereas, nanophyll leaves were exclusive for *T. monantha* ssp. *monantha*. Similarly, great variation was found in trichomes. Pubescent was the dominant vesture type (present in 11 species). Pilose hairs were present in 3 species. While, tomentose hairy leaves were specific to *T. podperae*.

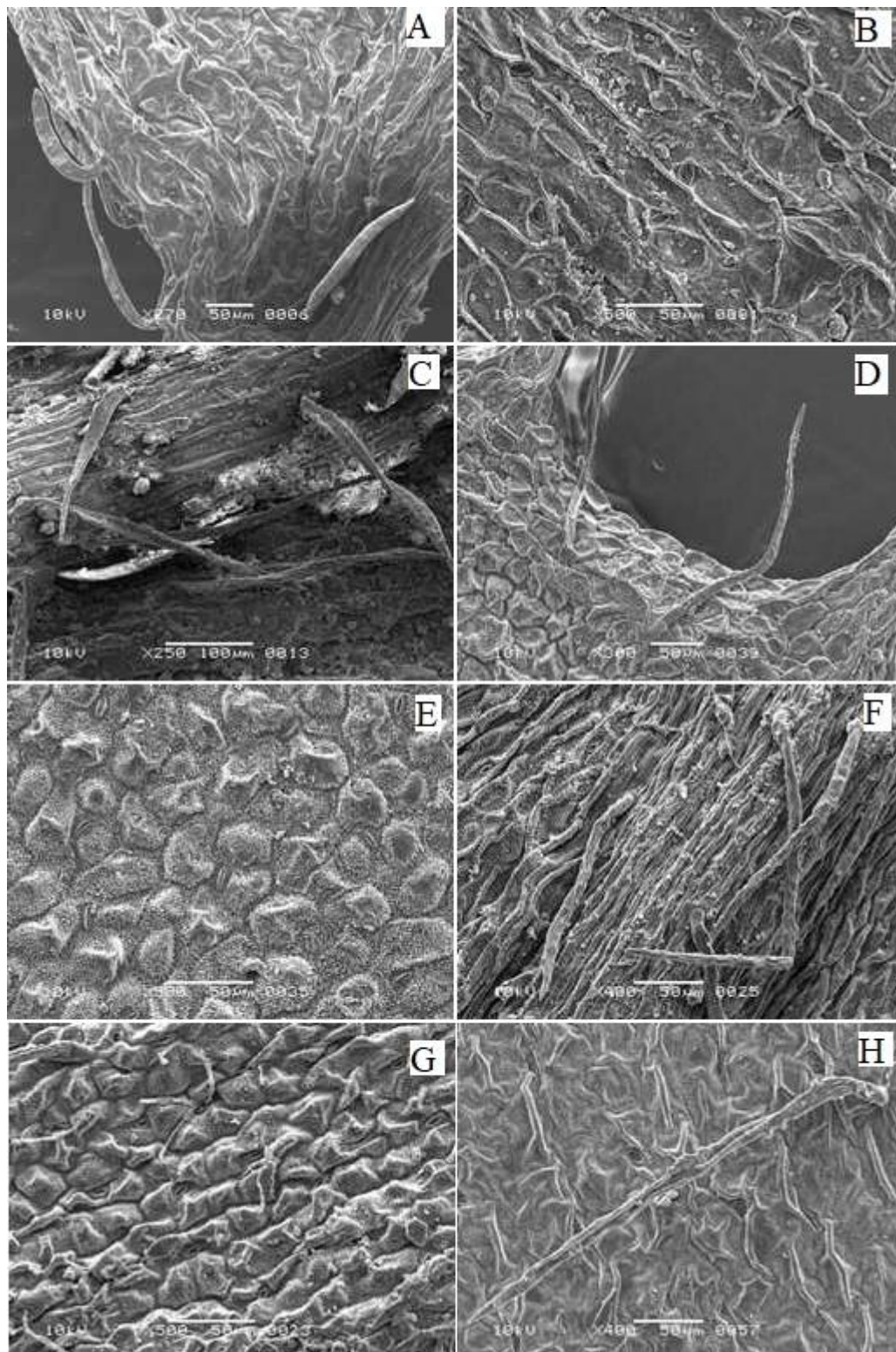


Fig. 1. Scanning electron micrographs showing: *T. anguina* **A**, trichome **B**, stomata; *T. Cachemiriana* **C**, trichome; *T. corniculata* **D**, trichome **E** stomata; *T. emodi* **F**, trichome **G**, stomata; *T. fimbriata* **H**, trichome and stomata. (Scale bar: A, B, D, E, F, G, H = 50 μ m; C = 100 μ)

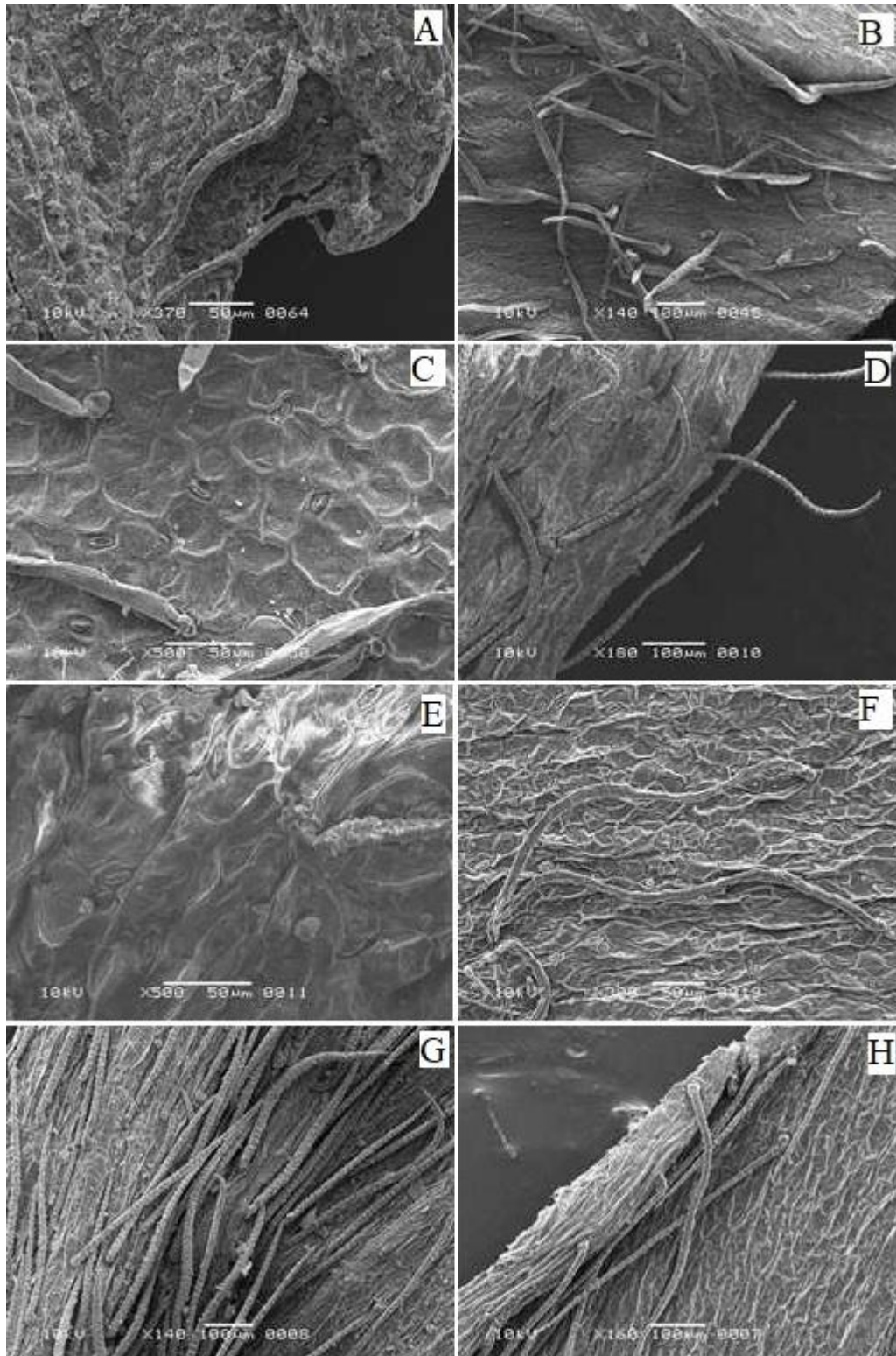


Fig. 2. Scanning electron micrographs showing: *T. foenum-graecum* **A**, trichomes; *T. gharuensis* **B** trichomes, **C** stomata; *T. gracilis* **D**, trichomes, **E** stomata; *T. hamosa* **F**, trichomes & stomata; *T. monantha* ssp. *monantha* **G**, trichomes; *T. monantha* ssp. *incisa* **H**, trichomes. (Scale bar: S, C, E, F = 50 μ m; B, D, G, H = 100 μ m).

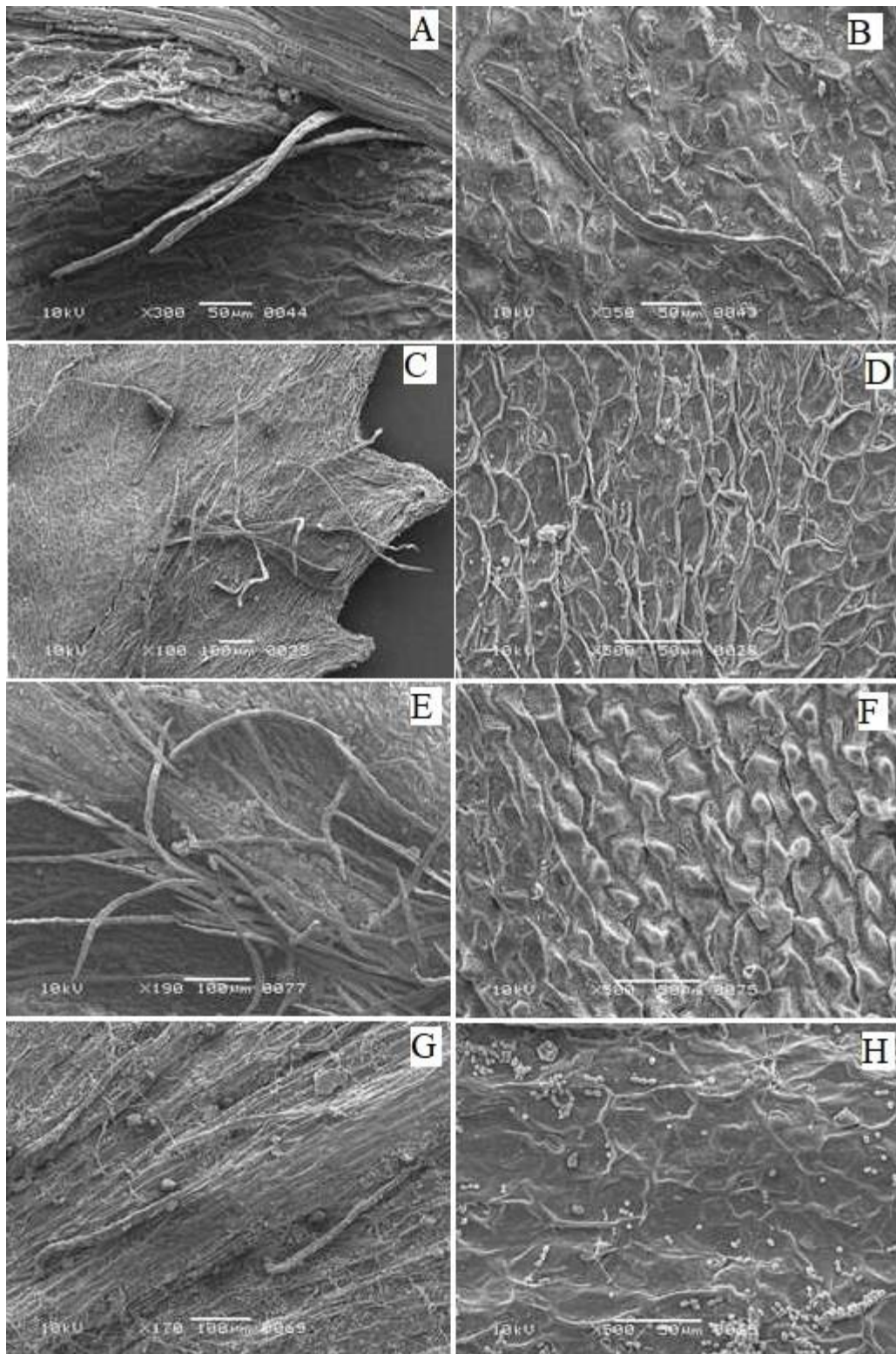


Fig. 3. Scanning electron micrographs showing: *T. monspelica* **A**, trichomes, **B** stomata; *T. occulta* **C**, trichomes, **D** stomata; *T. podperae* **E**, trichomes, **F** stomata; *T. pubescens* **G**, trichomes, **H** stomata. (Scale bar: A, B, D, F, H = 50μm; C, E, G = 100 μm).

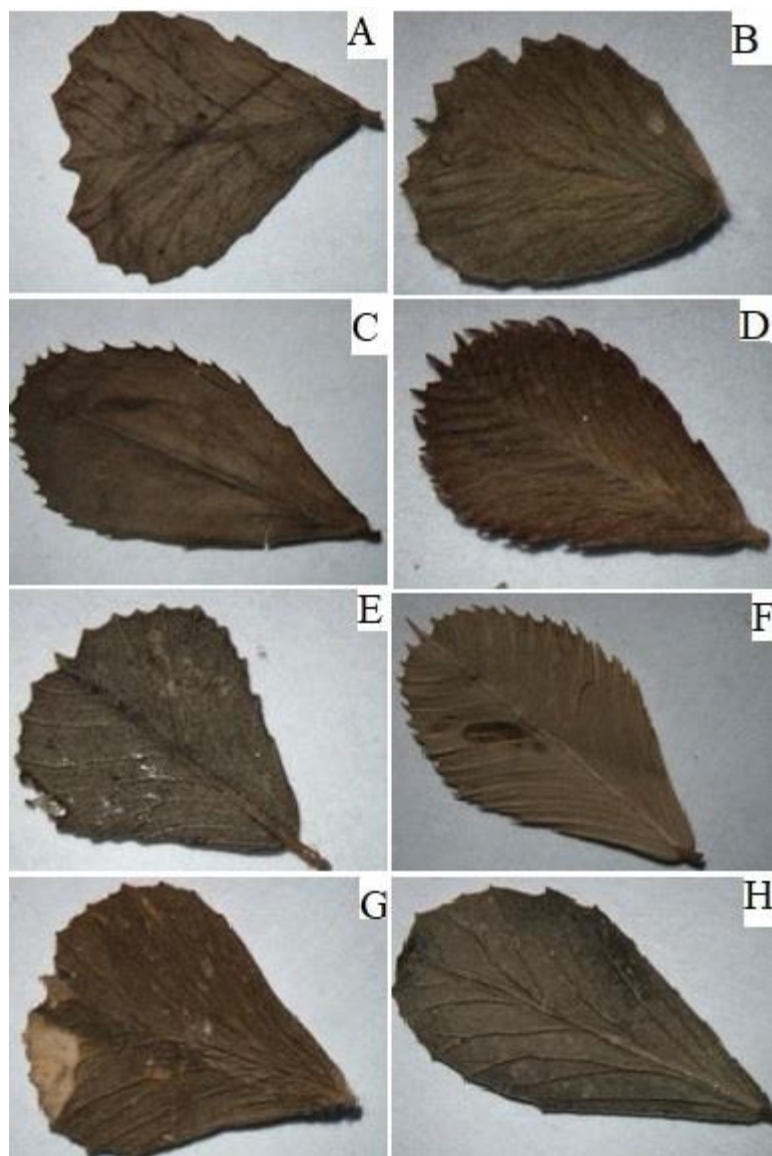


Fig. 4. Light micrographs showing leaf structure: *T. anguina* **A**; *T. cachemiriana* **B**; *T. corniculata* **C**; *T. emodi* **D**; *T. fimbriata* **E**; *T. foenum-graecum* **F**; *T. gharuensis* **G**; *T. gracilis* **H**.

Leaves of the genus *Trigonella* are polymorphic having anomocytic, anisocytic, tetracytic and paracytic stomata with anomocytic as a dominant stomata type (present in 10 species) while, anisocytic stomata were also present in 3 species. Whereas, tetracytic and paracytic stomata were specific to *T. occulta* and *T. pubescens* respectively. These stomata types were also recorded by Shah and Kothari (1975) within the tribe Trifolieae. Species having anomocytic stomata can further be divided based on sunken or not sunken stomata. Sunken stomata were present in *T. fimbriata* and *T. mospelica*. While both the species remain distinct from each other by having microphyll and mesophyll leaves with pustulate hairs surface and notophyll and macrophyll leaves with smooth hair surface, respectively. Species with stomata at the level of epidermis can be divided into two groups based on their leaf bases. i.e., cuneate leaf base was found in *T. anguina* and *T. cachemiriana* but both the species remain distinct from each other by retuse, truncate, obtuse leaf apex in former and mucronate leaf apex in later. The second group with attenuate, obtuse leaf base includes *T. emodi*, *T. monantha*, *T. corniculata* and *T. hamosa*. Among them *T. emodi* remains distinct by having retroflex tooth apical side and concave tooth basal side. Similarly, *T. monantha* have cylindrical hairs with dentate projections. The remaining 2 species i.e., *T. corniculata* and *T. hamosa* remains distinct by retuse

leaf apex, pilose indumentums with pusticulate hairs in *T. corniculata* and truncate leaf apex, pubescent indumentum and smooth hairs in *T. hamosa*.

Table 1. Leaf architecture of the genus *Trigonella*.

| Sno. | Species | Petiole (mm) | Leaflet Length(mm) | Leaflet Width(mm) | Blade Class | Lamina Shape |
|------|--|---------------|--------------------|-------------------|-------------------------|---|
| 1 | <i>Trigonella anguina</i> Delile | 50(83.57)170 | 30(57.85)100 | 20(39.28)80 | Microphyll & mesophyll | Obovate, oblanceolate, orbicular |
| 2 | <i>T. cachemiriana</i> Camb. | 20(59)160 | 30(71)150 | 30(50.5)110 | Microphyll & mesophyll | Obovate, broad elliptic, oblong, rhomboid, obcordate, orbicular |
| 3 | <i>T. corniculata</i> (Linn.) Linn. | 40(130)200 | 50(106.25)150 | 10(61.25)140 | Microphyll & macrophyll | Obovate, elliptic, oblong, rhomboid, oblanceolate, orbicular |
| 4 | <i>T. emodi</i> Benth. | 10(32.5)80 | 30(51.07)80 | 20(39.28)70 | Microphyll & mesophyll | Obovate, broad elliptic, orbicular |
| 5 | <i>T. fimbriata</i> Royle ex Benth. | 20(96.667)110 | 40(65)120 | 20(53.33)90 | Microphyll & mesophyll | Obovate |
| 6 | <i>T. foenum-graecum</i> Linn. | 70(407.69)950 | 150(176.92)250 | 30(54.69)91 | Notophyll & macrophyll | Obovate, oblanceolate |
| 7 | <i>T. ghaniensis</i> Rech. f. | 15(53.75)200 | 40(60)80 | 20(35.9)60 | Microphyll & mesophyll | Obovate |
| 8 | <i>T. gracilis</i> Benth. | 10(41.43)90 | 25(70.25)120 | 15(84.75)90 | Microphyll & mesophyll | Obovate, oblanceolate |
| 9 | <i>T. hamosa</i> Linn. | 50(98.33)180 | 40(60.8)80 | 20(37.5)50 | Microphyll & notophyll | Obovate |
| 10 | <i>T. monantha</i> sp. <i>monantha</i> (Benth.) Ali Cornb. & Stat. nov | 20(68.09)150 | 10(60.65)100 | 10(32.06)90 | Nanophyll & mesophyll | Obovate, obcordate, broad elliptic, oblanceolate. |
| 11 | <i>T. monantha</i> sp. <i>incisa</i> (Benth.) Ali | 20(58.63)180 | 30(74.18)140 | 10(43.37)120 | Microphyll & mesophyll | Obovate, obcordate, orbicular, oblanceolate, oblong, broad elliptic |
| 12 | <i>T. monspeliaca</i> Linn. | 30(78)110 | 50(101.667)190 | 30(60.83)120 | Notophyll & macrophyll | Obovate |
| 13 | <i>T. occulta</i> Delile ex DC. | 40(86.92)160 | 20(48.21)100 | 10(20.7)50 | Microphyll & mesophyll | Oblanceolate |
| 14 | <i>T. podperae</i> (Sif.) Vass. | 30-70 | 70(81.6)100 | 40(56.667)70 | Microphyll & mesophyll | Obovate |
| 15 | <i>T. pubescens</i> Edgew. ex Baker | 50(55)70 | 70(77.5)80 | 50(56.25)65 | Notophyll & mesophyll | Obovate |

Table 1 (Contd.)

| Sno. | Species | Leaflet Apex | Leaflet Base | No of Teeth per leaf | Tooth Apical side | Tooth Basal side |
|------|---|--------------------------|--------------|----------------------|-------------------|-------------------|
| 1 | <i>Trigonella anguina</i> | Retuse, truncate, obtuse | Cuneate | 9 | Straight, concave | Straight |
| 2 | <i>T. cachemiriana</i> | Mucronate | Cuneate | 13 | Straight, concave | Straight, convex |
| 3 | <i>T. corniculata</i> | Retuse | Attenuate | 16 | Concave | Retroflexed |
| 4 | <i>T. emodi</i> | Obtuse, truncate | Obtuse | 17 | Retroflexed | Concave |
| 5 | <i>T. fimbriata</i> | Obtuse, retuse | Obtuse | 17 | Convex | Convex |
| 6 | <i>T. fenem-graecum</i> | Obtuse, truncate | Obtuse | 7 | Concave | Convex, Concave |
| 7 | <i>T. ghanuensis</i> | Obtuse, retuse | Cuneate | 9 | Straight, concave | Straight, concave |
| 8 | <i>T. gracilis</i> | Obtuse, retuse | Attenuate | 13 | Concave | Concave |
| 9 | <i>T. hamosa</i> | Truncate, obtuse | Attenuate | 10 | Convex | Convex |
| 10 | <i>T. monantha</i> ssp. <i>monantha</i> | Obtuse, retuse | Attenuate | 10 | Straight, convex | Straight, convex |
| 11 | <i>T. monantha</i> ssp. <i>incisa</i> | Obtuse, retuse | Obtuse | 11 | Straight, concave | Straight |
| 12 | <i>T. monspeliica</i> | Obtuse | Obtuse | 10 | Straight, convex | Straight, convex |
| 13 | <i>T. occulta</i> | Obtuse, retuse | Cuneate | 7 | Straight | Straight |
| 14 | <i>T. podperae</i> | Mucronate | Attenuate | 30 | Concave | Retroflexed |
| 15 | <i>T. pubescens</i> | Obtuse, retuse | Cuneate | 12 | Flexous, concave | Concave |

Table 2. Leaf stomatal characters of the genus *Trigonella*.

| S. no. | Species | Types of stomata | Position | Aperture shape | Aperture length(μ m) | Aperture width(μ m) |
|--------|---|------------------|---------------------------|-------------------------|---------------------------|--------------------------|
| 1 | <i>Trigonella anguina</i> | Anomocytic | At the level of epidermis | Broad elliptic | 11.91(12.04)12.68 | 3.5(3.72)3.8 |
| 2 | <i>T. cachemiriana</i> | Anomocytic | At the level of epidermis | Narrow elliptic | 7.73(8.24)8.81 | 2.11(2.28)2.63 |
| 3 | <i>T. corniculata</i> | Anomocytic | At the level of epidermis | Oblong, narrow elliptic | 7.56(8.0)8.3 | 2.16(2.28)2.3 |
| 4 | <i>T. emodi</i> | Anomocytic | At the level of epidermis | Broad elliptic | 6.8(7.7)8.1 | 2.56(3.01)3.49 |
| 5 | <i>T. fimbriata</i> | Anomocytic | Sunken | Broad elliptic | 8.8(9.9)10.1 | 3.57(4.24)5.18 |
| 6 | <i>T. foenum-graecum</i> | Anisocytic | Sunken | Narrow elliptic, linear | 9.5(9.71)10.1 | 1.59(2.28)2.41 |
| 7 | <i>T. ghariensis</i> | Anisocytic | Sunken | Narrow elliptic | 6.9(7.38)7.5 | 2.0(2.25)2.64 |
| 8 | <i>T. gracilis</i> | Anisocytic | At the level of epidermis | Broad elliptic | 9.57(10.4)10.8 | 2.96(3.34)3.5 |
| 9 | <i>T. hamosa</i> | Anomocytic | At the level of epidermis | Broad elliptic | 8.51(9.1)9.67 | 3.01(3.26)3.44 |
| 10 | <i>T. monantha</i> ssp. <i>monantha</i> | Anomocytic | At the level of epidermis | Linear | 8.1(8.36)8.95 | 2.0(2.16)2.2 |
| 11 | <i>T. monantha</i> ssp. <i>incisa</i> | Anomocytic | At the level of epidermis | Linear | 7.01(7.37)8.1 | 1.0(1.07)1.25 |
| 12 | <i>T. monspeliaca</i> | Anomocytic | Sunken | Narrow elliptic, linear | 11.18(12.05)12.85 | 2.59(3.98)4.02 |
| 13 | <i>T. occulta</i> | Tetracytic | At the level of epidermis | Elliptic | 6.95(7.45)8.05 | 1.38(1.97)2.18 |
| 14 | <i>T. podberae</i> | Anomocytic | At the level of epidermis | Linear | 7.85(8.44)9.01 | 1.14(1.5)1.81 |
| 15 | <i>T. pubescens</i> | Paracytic | At the level of epidermis | Elliptic | 7.03(7.81)8.46 | 2.43(2.71)2.98 |

Table 3. Leaf indumentum characters of the genus *Trigonella*.

| S. no. | Species | Indumentum | Hair | Head | Base |
|--------|---|-----------------------|--|-----------------|---------------------------|
| 1 | <i>Trigonella anguina</i> | Pubescent | ribbon like, smooth | Obtuse | Flat |
| 2 | <i>T. cachemiriana</i> | Pubescent | ribbon like, smooth | Pointed | Flat |
| 3 | <i>T. corniculata</i> | Pilose | ribbon like, pusticulate surface | Pointed/ obtuse | Flat |
| 4 | <i>T. emodi</i> | Pilose | ribbon like, smooth/ cylindrical, pusticulate/ small, oblong | obtuse/ pointed | flat/cylindrical, stalked |
| 5 | <i>T. fimbriata</i> | Glabrous or Pubescent | ribbon like, pusticulate surface | Pointed | Flat |
| 6 | <i>T. foenum-graecum</i> | Pubescent | cylindrical with pusticulate surface | Pointed | Broad |
| 7 | <i>T. gharnuensis</i> | Pubescent | ribbon like, smooth | Pointed | Flat |
| 8 | <i>T. gracilis</i> | Pubescent | cylindrical with dentate projections on surface | Pointed | Cylindrical |
| 9 | <i>T. hamosa</i> | Pubescent | ribbon like, smooth | Pointed | Flat |
| 10 | <i>T. monantha</i> ssp. <i>monantha</i> | Pubescent | cylindrical with dentate projections on surface | Pointed | ring like structure |
| 11 | <i>T. monantha</i> ssp. <i>incisa</i> | Pubescent | cylindrical with dentate projections on surface | Pointed | Cylindrical |
| 12 | <i>T. monspeliaca</i> | Pilose | ribbon like, smooth | Pointed | Rounded |
| 13 | <i>T. occulta</i> | Pubescent | ribbon like, smooth | Pointed | rounded/ flat |
| 14 | <i>T. podperae</i> | Tomentose | ribbon like, pusticulate surface | Pointed | Flat |
| 15 | <i>T. pubescens</i> | Pubescent | ribbon like, smooth | Pointed | Flat |

Appendix I. List of voucher specimen.

| S.no. | Taxa | Collector, voucher number and Herbarium |
|-------|---|---|
| 1 | <i>Trigonella anguina</i> | Dr. S. A. Farooqi 2198 (KUH); Abdul Ghafoor and Rizwan Yousuf 1090 (KUH); Dr. S. I. Ali, Dr. S. A. Farooqi And Mr. Sultan-ul-Abedin 1022 (KUH); Mr. Sultan-ul-Abedin 1641 (KUH); Sultan-ul-Abedin & Abrar Husain 6454 (KUH); Abdul Ghafoor & M. Qaiser 186 (KUH); A. Ghafoor and Steve M. Goodman 1449 (KUH). |
| 2 | <i>T. cachemiriana</i> | Jan Alam 1140B (KUH); Jan Alam & Abdul Hameed 1093 (KUH); Jan Alam & Saleem 3702B, 3580 (KUH); Haider Ali 846, 2791, 2674, 2800, 1664, 846 (KUH). |
| 3 | <i>T. corniculata</i> | S. W. K. Haranosh 219 (KUH); Abrar Husain s.n. (KUH); D. Phitos 10226 (KUH); Sultan Ahmed s.n. (KUH). |
| 4 | <i>T. emodi</i> | Sajjad & Haider 422, 491 (KUH); Tahir Ali, S. Z. Husain & Ghohar Khan 2189 (KUH); M. Qaiser & A. Ghafoor 1849 (KUH); Jaffèri & Akbar 2052 (KUH); S. N. Anwar Kazmi s.n. (KUH). |
| 5 | <i>T. fimbriata</i> | Haider Ali 4489, 4233, 3151, 4489 (KUH). |
| 6 | <i>T. foenum-graecum</i> | R. R. Stewart 28667 (KUH); Sajjad Haider 375 (KUH); Shaukat Ali 542, 768 (KUH); S. M. H. Jaffèri 3867 (KUH); Sultan-ul-Abedin 5765 (KUH). |
| 7 | <i>T. gharnensis</i> | Tahir Ali & G. R. Sarwar 2602, 2599 (KUH); M. Qaiser 2462 (KUH); Sultan 28032 (KUH); A. Ghafoor & S. Omer 2706 (KUH); Jan Alam & Saleem 3663 (KUH). |
| 8 | <i>T. gracilis</i> | Haider Ali 3258, 4390, 1195, 3021 (KUH); Tahir Ali, M. Qaiser & Ajmal Khan 249 (KUH); Sher Wali Khan 474, 922 (KUH); S. Omer & M. Qaiser 2567 (KUH); R. R. Stewart s.n. (KUH); Ali Noor 1242 (KUH). |
| 9 | <i>T. hamosa</i> | Sultan-ul-Abedin 365 (KUH); Abrar s.n. (KUH); S. I. Ali, S. A. Farooqi & Sultan-ul-Abedin 4412 (KUH). |
| 10 | <i>T. monantha</i> ssp. <i>monantha</i> | Jaffèri & Akbar 1829, 1723 (KUH); Sultan-ul-Abedin & Abrar Husain 6998, 7249, 7090 (KUH); Abdul Ghafoor & Rizwan Yousuf 1581 (KUH); A. Ghafoor & S. Omer 3126, 3001 (KUH); S. M. A. Kazmi 1514, 1526 (KUH); Shaukat Ali 300 (KUH); Jennifer Lamond 885, 1017 (KUH); Sultan-ul-Abedin 4695, 3174, 4598 (KUH); Haider Ali 1912, 20A (KUH); G. S. Sarwar, M. Qaiser & S. Omer 382 (KUH); M. Qaiser & Sultan-ul-Abedin 6219, 6276 (KUH); M. Qaiser & A. Ghafoor 1240, 1259 (KUH). |
| 11 | <i>T. monantha</i> ssp. <i>incisa</i> | Abdul Ghafoor & Rizwan Yousuf 1235, 1259 (KUH); M. Qaiser & A. Ghafoor 7431 (KUH); Sultan-ul-Abedin 4940 (KUH); S. Nazim, Sultan-ul-Abedin & Hameed-ullah 566 (KUH); S. M. H. Jaffèri 2899 (KUH); Saood Omer & A. Ghafoor 1410, 1706, 3126, 3001 (KUH); Abrar Husain s.n. (KUH); M. Qaiser & Sultan-ul-Abedin 5891 (KUH); Sher Wali Khan 892 (KUH); Haider Ali 1471, 4815, 1885, 891, 1621 (KUH); A. Ghafoor & Steve M. Goodman 5117, 5178 (KUH). |
| 12 | <i>T. monspeliica</i> | Sultan-ul-Abedin & Abrar Hussain 6652 (KUH); A. Ghafoor & Steve M. Goodman 4675, 4622, 4742, 4715 (KUH); Tahir Ali 872 (KUH). |
| 13 | <i>T. occulta</i> | Haider Ali 22a (KUH); Dr. S. Farooqi & Sultan-ul-Abedin 345, 344 (KUH); S. I. Ali, S. A. Farooqi & Sultan-ul-Abedin 4409, 1048 (KUH); Dr. S. A. Farooqi, Sultan-ul-Abedin 315 (KUH). |
| 14 | <i>T. podberae</i> | R. R. & I. D. Stewart 22611, 19181, 18433A, 19676 (RAW); R. R. Stewart 9690, 22618, 19690, 4403, 19676 (RAW). |
| 15 | <i>T. pubescens</i> | Haider Ali 7157 (KUH); S. Omer & M. Qaiser 2567 (KUH). |

Similarly, species having anisocytic stomata include *T. foenum-graecum*, *T. podperae*, *T. gharuensis*, and *T. gracilis*. Among them *T. foenum-graecum* remains distinct by notophyll and macrophyll leaves. *T. podperae* by having tomentose indumentum. While *T. gharuensis* and *T. gracilis* are different due to cuneate base, sunken stomata, smooth hairs and attenuate base, not sunken stomata and hairs with dentate projections respectively. Thus, from the discussion it is evident that the data obtained from leaf architecture and micromorphology can be significantly used for strengthening the taxonomic decisions within the genus *Trigonella* from Pakistan.

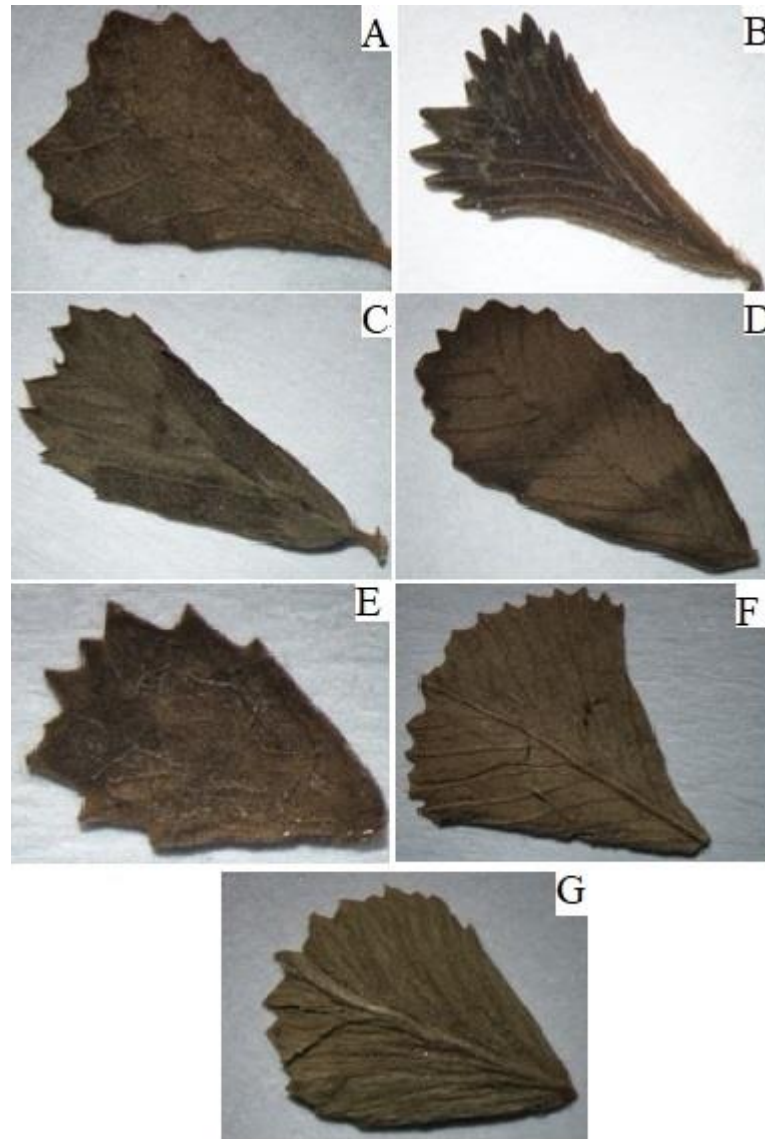


Fig. 5. Light micrographs showing leaf structure: *T. hamosa* A; *T. monantha* ssp. *monantha* B; *T. monantha* ssp. *incisa* C; *T. monspelica* D; *T. occulta* E; *T. podperae* F; *T. pubescens*. G.

REFERENCES

- Ali, S. I. (1977). *Papilionaceae* .No. 100. Pp 290-301. In: *Flora of West Pakistan*. E. Nasir and S.I. Ali (Eds.), Department of Botany, University of Karachi, Pakistan.
- Ash, A., B. Ellis, L.J. Hickey, K. Johnson, P. Wilf and S. Wing (1999). *Manual of Leaf Architecture*, Smithsonian Institute Washington DC.

- Dormer, K. J. (1946). Vegetative Morphology as a Guide to the Classification of the Papilionoideae. *New Phytologist*, 45(1), 145-161.
- Gupta, M. (1979). Trichomes in Trifolieae 2. *Proc. Indian Academy of Science*. Pp 391-395.
- Hargreaves, P. (2006). Vegetative morphology for species identification of Tropical Trees: Family Distribution. *Cerne. Lavras*, 1(12): 1-7.
- Hooker, D. J. (1879). Leguminosae. Pp 87-89. *Flora of British India*. vol. 2. Reeve, London.
- Lawrence, G.H.M. (1970). *Taxonomy of Vascular Plants*, Toronto, Ontario, New York, The Macmillan Company, Collier- Macmillan Canada, Ltd.
- Leelavathi, P. and N. Ramayya (1983). Structure, distribution and classification of planytrichomes in relation to Taxonomy III. Papilionaceae. *Proceedings of Indian academy of science (Plant Sciences)* 92: 421-441.
- Linnaeus, C. (1753). Leguminosae. *Species Plantarum* vol. 2. Pp. 776-778. Printed for the Bay society.
- Mabberly D.J. 1997. The plant-book: *A Portable Dictionary of the Higher Plants*. Cambridge University Press, Cambridge, UK
- Metcalf, C.R., and L. Chalk (1950). *Anatomy of the Dicotyledons*. Vol. 1. Oxford, Clarendon Press.
- Ranjbar, M., R. Karamian. And Z. Hajmoradi (2012). A new species and taxonomic studies in *Trigonella* sect *Ellipticae* (Fabaceae) in Iran. *Annales Botanici Fennici*, 49: 279-287.
- Rashid, N., M. Zafar, M. Ahmad, M.K. Ajab, K. Malik, S. Sultana and S. Nasar (2018). Taxonomic significance of Leaf epidermis in tribe Trifolieae L. (Leguminosae; (Papilionoideae). *Plant Biosystematics*. An International Journal dealing with all aspect of biology. <https://doi.org/10.1080/11263504.2018.1492995>
- Rechinger, H. K. (1972). Papilionaceae II. Pp. 213-253. In: *Flora Iranica*. Vol. 157. Austria Press.
- Shah, G., and M. Kothari (1975). Observations on stomata and hairs on vegetative and floral organs in the tribe *Trifolieae* (Family Papilionaceae). *Australian Journal of Botany*. 23(1): 111–122.
- Shu, H.L.B. (2010). *Trigonella* In: Zhengyi, W., Raven, P.H., Deyuan H (Eds.) Fabaceae. *Flora of China*, vol.10. 557-559. Missouri Botanical Garden Press (St Louis).
- Stearn, W. T. (1983). *Botanical Latin* (3rd Ed.). Britain, David & Charles.
- Taia, W, K. (2004). Leaf Characters within Tribe Trifolieae (Family Leguminosae). *Pakistan Journal of Biological Sciences*, 7(8): 1463-1472.
- Zoric, L., L. Merkulov, J. Lukovic and P. Boza (2012). Comparative analyses of qualitative anatomical characters of *Trifolium* L. (Fabaceae) and their taxonomic implications: preliminary results. *Plant Systematics and Evolution*, 298: 205-219.