



## Research article

## Trichome diversity of the family Caryophyllaceae from Western Himalaya and their taxonomic implication

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**Abstract:** Information about trichomes diversity and distribution of the family Caryophyllaceae is rare and the present work is intended to fill this knowledge lacuna. In the present work 62 taxa belonging to 19 genera were studied. For the analysis of trichomes diversity and vestiture type, dried plant specimens were rehydrated with water. The final illustrations of trichomes were made by using camera lucida. Six types of trichomes viz., Unicellular eglandular, Unicellular glandular, Multicellular uniseriate glandular, Multicellular uniseriate eglandular, Multicellular eglandular bifurcate and Multicellular multiseriate eglandular trichomes reported in the studied taxa. Diversity of trichome and their distribution does not play any significant role in the taxonomic delimitation either generic or tribal level of the family Caryophyllaceae. Although, few closely allied species can be distinguished from each other either on the basis of the presence of trichomes or vestiture patterns.

**Keywords:** *Arenaria* - *Silene* - *Stellaria* - Taxonomy - Vestiture.

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### INTRODUCTION

Caryophyllaceae Juss. is known as pink family or carnation family, and ranked as 24<sup>th</sup> largest family of Angiosperms with 93 genera and 2395 species (Thorne & Reveal 2007). Though, number of species and genera of the family varies from different sources as: The plant list (2013) reported 88 genera with 2295 species and Mabberley (2017) reported 96 genera with 2500 species. The family is worldwide in distribution with exception in the wet tropics. Members of the family Caryophyllaceae often have distinctive swollen nodes; simple opposite leaves; dichasial cymes inflorescence or solitary flowers; flower usually actinomorphic; pentamerous with distinct clawed petals; stamens obdiplostemonous, ten or lesser; ovary superior; placentation free-central; and fruit capsule opening by teeth or valves (Bittrich 1993a, b).

On the basis of stipulate or exstipulate leaves, free or connate sepals, styles fused at base or free, the family is further subdivided by Bittrich (1993b) into three subfamilies Paronychioideae (tribe: Polycarpeae, Paronychieae and Corrigioleae), Alsinoideae (tribe: Alsineae, Pycnophylleae, Geocarpeae, Habrosieae and Scleranthaeae and Caryophylloideae (tribe: Caryophylleae, Drypideae and Sileneae). Harbaugh *et al.* (2010) proposed a new classification for tribes of the family on the basis of monophyly and abandoned traditional three subfamily classification of family. They proposed eleven tribes namely Corrigioleae, Paronychieae, Polycarpeae, Sperguleae, Sagineae, Scleranthaeae, Arenarieae, Alsineae, Eremogoneae, Caryophylleae, and Sileneae for the family.

Recently, some large genera (*Arenaria*, *Minuartia*, etc.) of the family have undergone splitting on the basis of molecular data. Dillenberger & Kadereit (2014) divided genus *Minuartia* s.l. into eleven genera *i.e.* *Cherleria*, *Eremogone*, *Facchinia*, *Mcnillia*, *Minuartia* s.s., *Minuartiella*, *Mononeuria*, *Pseudocherleria*, *Rhodalsine*, *Sabulina* and *Triplateia* on the basis of monophyly. New generic delimitation for *Arenaria* s.l. was

proposed by Harbaugh *et al.* (2010), Greenberg & Donoghue (2011), Dillenberger & Kadereit (2014), Sadeghian *et al.* (2015), and Pusalkar & Singh (2015). In the revised circumscription *Arenaria s.l.* is divided into five genera *i.e.* *Eremogone*, *Odontostemma*, *Shivparvatia*, *Himgiria*, and *Arenaria s.s.*

Trichomes are epidermis originated cells found on the plant surface. There is amazing variability of trichomes in the form of variation in shape, size and structure. For the delimitation and differentiation of certain taxa variability of trichomes is used (Werker 2000). Information about trichomes diversity and distribution of the family is little known. Metcalfe & Chalk (1950) studied trichomes diversity in some species and genera of the family. Bittrich (1993b) compiled morphological characteristics of the family and also focused on trichome diversity of some species. Some other workers Solereder & Scott (1986), Cowie (1994), Shamsabad *et al.* (2013), Selvi *et al.* (2014), Bozchaloyi & Keshavarz (2014) tried to document trichome diversity of the family but their study either focused on several genera or particular subfamily. Thus, present work intends to illustrate trichomes diversity and distribution in the family Caryophyllaceae and evaluate the relevance of this information for the family's taxonomy.

## MATERIALS AND METHODS

### *Plant material*

Trichome diversity and distribution were studied in 62 taxa including 58 species and four varieties belonging to 19 genera during present work. Plant specimens of 46 taxa were collected from the Western Himalaya, India during the year July 2012 to 2016 and specimens deposited in the herbarium of Govind Ballabh Pant University of Agriculture and Technology Pantnagar, Uttarakhand, India (GBPUH). Most of the specimens were collected from Uttarakhand Himalaya. Remaining taxa studied from specimens housed in herbaria of Botanical Survey of India Northern Circle Dehradun (BSD), Hemvati Nandan Bahuguna Garhwal University Srinagar Garhwal (GUH), Forest Research Institute Dehradun (DD) and Kumaon University Nainital (KUH).

### *Light microscopy*

For the analysis of trichomes diversity and vestiture type, dried plant specimens were rehydrated with water. Trichomes from stem were obtained through scraping. Other plant parts as leaves, bracts and floral parts were observed under the light microscope and freehand horizontal and longitudinal sections were made to study trichomes morphology. The final illustrations of trichomes were made by using camera lucida. About 5–6 specimens for each taxa and 3–5 plant parts for each specimens were studied to assess the trichome diversity and distribution.

### *Trichomes classification*

Payne (1978), Prabhakar & Leelavathi (1989), Krak & Mraz (2008) and de Andrade *et al.* (2014) were followed for classification, identification and characterization of trichomes in the present work. The vestiture types were determined following Lawrence (1951) and Simpson (2010).

## RESULTS

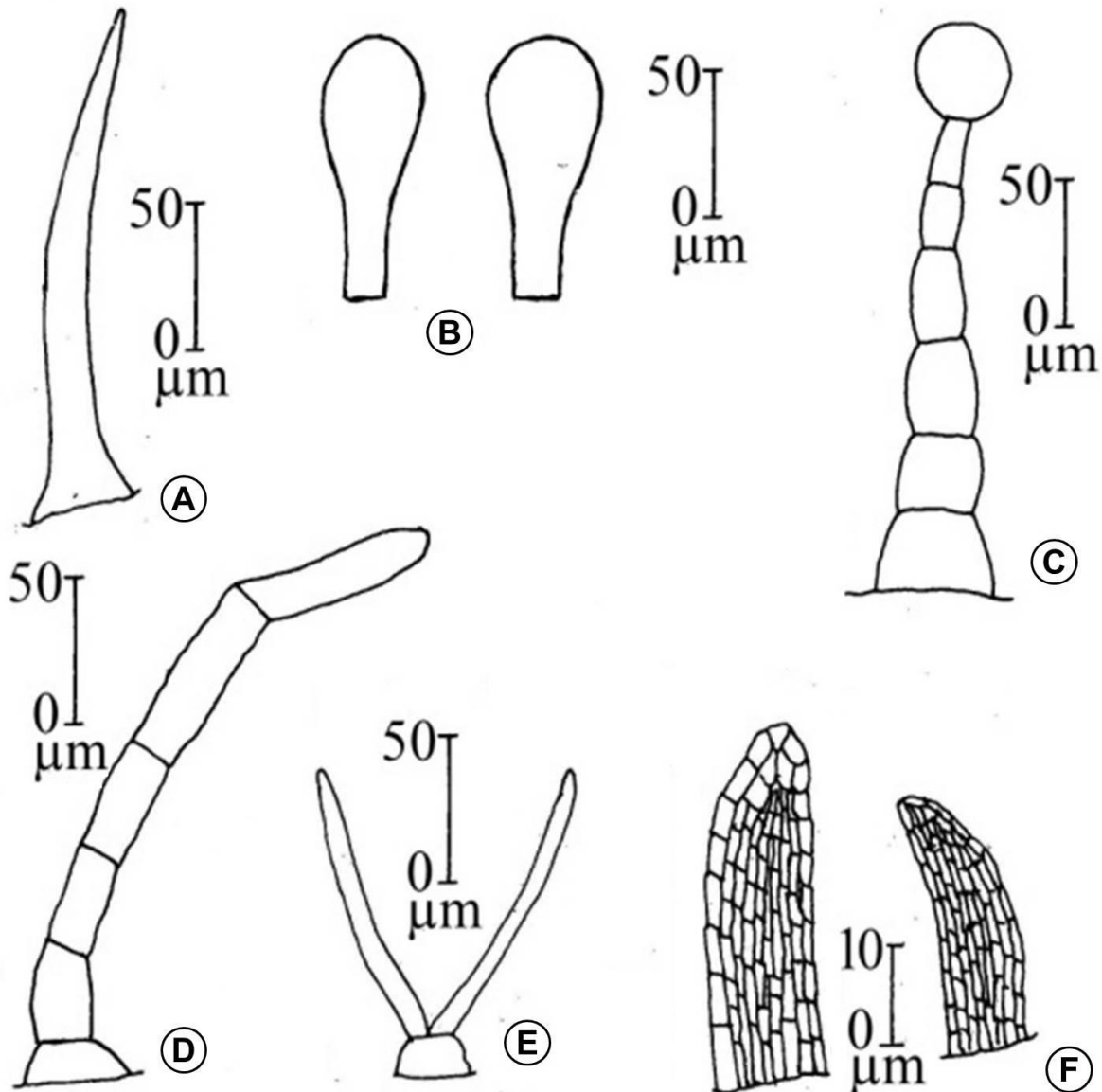
### *Trichomes diversity*

Six types of trichomes were recorded in the studied taxa; (1) Unicellular eglandular trichomes, (2) Unicellular glandular trichomes, (3) Multicellular uniseriate glandular trichomes, (4) Multicellular uniseriate eglandular trichomes (5) Multicellular eglandular bifurcate trichomes and (6) Multicellular multiseriate eglandular trichomes (Fig. 1). Apart from above mentioned categories stellate trichomes are also reported in *Stellaria vestita* Kurz, *Cerastium mollissimum* Poir., *Polycarpon loeflingiae* (Wall. ex Wight & Arn.) Benth. & Hook.f. (Solereder & Scott 1986, Majumdar 1993). However, these species were not included in the present work.

On the basis of trichomes types, all the studied taxa (62 taxa) can be categorized into five groups. *Stellaria depressa* Em. Schmid, *Spergula fallax* (Lowe) E.H. Krause and *Cerastium davuricum* Fischer were completely glabrous and constitute the first group. Second group possess unicellular trichomes and represented by *i.e.* *Drymaria cordata* (L.) Willd. ex Schult. and *Herniaria cachemiriana* J. Gay. *Drymaria cordata* possess both unicellular eglandular and capitate unicellular glandular trichomes, while *Herniaria cachemiriana* possess unicellular hairs on all plant parts except ovary. In the ovary of *Herniaria cachemiriana* multiseriate multicellular eglandular trichomes were found.

The third group of the plants contains strictly eglandular trichomes. This group further divided into two subgroups *i.e.* bifurcate eglandular trichomes and uniseriate multicellular eglandular trichome. *Polycarpon prostratum* (Forssk.) Asch. & Schweinf. possesses eglandular bifurcated trichomes and also possesses simple

multicellular uniseriate eglandular trichomes. The taxa i.e. *Silene baccifera* (L.) Roth, *S. caespitella* F. Williams, *S. kumaonensis* F. Williams, *S. moorcroftiana* Wallich ex Benth., *S. nepalensis* Majumdar, *S. vulgaris* (Moench) Garcke, *Stellaria decumbens* var. *decumbens* Edgew., *S. decumbens* var. *polyantha* Edgew. & Hook.f., *S. congestiflora* H. Hara, *S. himalayensis* Majumdar, *S. patens* D. Don, *S. semivestita* Edgew., *S. umbellata* Turcz., *S. uliginosa* Murray, *Thylacospermum caespitosum* (Cambess.) Schischk., *Cherleria* sp., *Drymaria villosa* Cham. & Schlecht., *Dianthus angulatus* Royle ex Benth., *D. barbatus* L., *D. chinensis* L., *Arenaria thangoensis* W.W. Sm., *Stellaria depauperata* Edgew., *Arenaria bhutanica* Majumdar & Babu, *Eremogone ferruginea* (Duthie ex F. Williams) Pusalkar & D.K. Singh, *E. curvifolia* Kar. & Kir., *E. kumaonensis*, *Shivparvatia ciliolata* var. *ciliolata* (Edgew.) Pusalkar & D.K. Singh, *S. ciliolata* var. *pendula* (Duthie ex F. Williams) Pusalkar & D.K. Singh, *Gypsophila cerastioides* D. Don, *Sagina saginoides* (L.) Karsten of this group possess only simple uniseriate multicellular eglandular trichomes. Only eglandular trichomes present on at least one plant part of this group.



**Figure 1.** Different types of trichomes in family Caryophyllaceae: **A**, Unicellular eglandular trichome (*Herniaria cachemiriana*); **B**, Unicellular glandular trichome (*Drymaria cordata*); **C**, Multicellular uniseriate glandular trichome (*Shivparvatia glanduligera*); **D**, Multicellular uniseriate eglandular trichome (*Arenaria bhutanica*); **E**, Multicellular eglandular bifurcate trichome (*Polycarpon prostratum*); **F**, Multicellular multiseriate eglandular trichome (*Herniaria cachemiriana*).

The fourth group of the plants bore only uniseriate multicellular glandular trichomes and represented by *Polycarpha corymbosa* (L.) Lam. and *Spergularia rubra* (L.) J. & K. Presl. The fifth group include *Silene falconeriana* Royle ex Benth., *S. conoidea* L., *S. gangotriana* Pusalkar, D.K. Singh & Lakshmin., *S. indica* var. *indica* Roxb. ex Otth, *S. indica* var. *edgeworthii* (Bocquet) Y.J. Nasir., *S. incurvifolia* Kar. & Kir., *S. viscosa* (L.) Pers., *Stellaria aquatica* (L.) Scop., *S. media* (L.) Villars, *S. monosperma* var. *monosperma* D. Don, *S.*

*monosperma* var. *paniculata* (Edgew.) Majumdar, *S. webbiana* (Benth. ex G. Don) Edgew. & Hook. f., *Cerastium cerastioides* (L.) Britton, *C. fontanum* Baumg., *Odontostemma glandulosum* Benth. ex D. Don, *Eremogone festucoides* (Benth.) Pusalkar & D.K. Singh, *Shivparvatia glanduligera* (Edgew.) Pusalkar & D.K. Singh, *Arenaria neelgherrensis* Wight & Arn., *A. serpyllifolia* L., *Lepyrodiclis holosteoides* (C. A. Meyer) Fenzl ex Fischer & C. A. Meyer and *Sagina apetala* Ard., which possessed both uniseriate multicellular glandular and eglandular trichomes at least at some plant parts.

#### Presence of trichomes in different plant parts

Trichomes in all plants are not uniform in length and distribution. Hence, the presence of trichomes in different plant parts and different types of vestiture can also be used for categorization of taxa. The presence of trichomes in different plant parts of studied taxa is shown in table 1. *Stellaria depressa*, *Spergula fallax* and *Cerastium davuricum* were completely glabrous nature. *Dianthus barbatus* L., *D. chinensis* and *Silene vulgaris* (Moench) Garcke had trichomes only at calyx teeth apex, otherwise these were glabrous plants. In *Thylacospermum caespitosum* trichomes were found only at abaxial surface of leaf, while in *Stellaria uliginosa* Murray, *S. umbellata* trichomes were found at abaxial surface of leaf toward leaf base and leaf base of upper few leaf pairs respectively. In *Polycarpaea corymbosa* trichomes found only upper parts of stem and pedicel. Among all species, only *Herniaria cachemiriana* had trichomes on the ovary surface, while in all other taxa ovary were glabrous.

**Table 1.** Presence of trichomes on different plant parts of the studied taxa.

S.N.	Name of Taxa	Presence of Trichomes on different plant parts												
		St	Lad	Lab	Lm	Lb	B	P	Cb	Ca	Pt	S	O	Sti
1	<i>Arenaria bhutanica</i> Majumdar & Babu	✓	×	×	×	✓	×	✓	×	×	×	×	×	×
2	<i>Arenaria neelgherrensis</i> Wight & Arn.	✓	×	×	✓	✓	×	✓	×	×	×	×	×	×
3	<i>Arenaria orbiculata</i> Royle ex Edgew. & Hook.f.	✓	×	✓	×	×	×	✓	×	×	×	×	×	×
4	<i>Arenaria serpyllifolia</i> L.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
5	<i>Arenaria thangoensis</i> W.W. Sm.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
6	<i>Cerastium cerastioides</i> (L.) Britton	✓	×	×	×	✓	×	✓	✓	✓	×	×	×	×
7	<i>Cerastium davuricum</i> Fischer	×	×	×	×	×	×	×	×	×	×	×	×	×
8	<i>Cerastium fontanum</i> Baumg.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
9	<i>Cherleria</i> sp.	✓	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×
10	<i>Dianthus angulatus</i> Royle ex Benth.	✓	×	×	✓	✓	×	✓	✓	✓	×	×	×	×
11	<i>Dianthus barbatus</i> L.	×	×	×	×	×	×	×	×	✓	×	×	×	×
12	<i>Dianthus chinensis</i> L.	×	×	×	×	×	×	×	×	✓	×	×	×	×
13	<i>Drymaria cordata</i> (L.) Willd. ex Schult.	✓	×	×	×	✓	✓	✓	✓	✓	×	×	×	×
14	<i>Drymaria villosa</i> Cham. & Schlecht.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
15	<i>Eremogone curvifolia</i> (Majumdar) Pusalkar & D.K. Singh	✓	×	×	×	✓	×	✓	✓	×	×	×	×	×
16	<i>Eremogone festucoides</i> (Benth.) Pusalkar & D.K. Singh	✓	✓	×	×	✓	✓	✓	✓	✓	×	×	×	×
17	<i>Eremogone ferruginea</i> (Duthie ex F. Williams) Pusalkar & D.K. Singh	✓	×	×	×	✓	×	✓	✓	×	×	×	×	×
18	<i>Eremogone kumaonensis</i> (Maxim.) Pusalkar & D.K. Singh	×	×	×	×	✓	✓	✓	✓	×	×	×	×	×
19	<i>Gypsophila cerastioides</i> D. Don	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
20	<i>Herniaria cachemiriana</i> J. Gay	✓	✓	✓	✓	✓	×	×	✓	✓	×	×	✓	✓
21	<i>Lepyrodiclis holosteoides</i> (C. A. Meyer) Fenzl ex Fischer & C. A. Meyer	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
22	<i>Odontostemma glandulosum</i> Benth. ex D. Don	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
23	<i>Polycarpaea corymbosa</i> (L.) Lam.	✓	✓	×	×	×	✓	×	×	×	×	×	×	×
24	<i>Polycarpon prostratum</i> (Forssk.) Asch. & Schweinf.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	✓
25	<i>Sabulina kashmirica</i> (Edgew.) Dillenb. & Kadereit	×	×	×	×	×	×	×	×	×	×	×	×	×
26	<i>Sagina apetala</i> Ard.	✓	×	×	✓	×	×	✓	×	×	×	×	×	×
27	<i>Sagina saginoides</i> (L.) Karsten	✓	×	×	✓	×	×	✓	×	×	×	×	×	×
28	<i>Shivparvatia ciliolata</i> (Edgew.) Pusalkar & D.K. Singh var. <i>ciliolate</i> (Edgew.) Pusalkar & D.K. Singh	✓	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×

29	<i>Shivparvatia ciliolata</i> var. <i>pendula</i> (Duthie ex F. Williams) Pusalkar & D.K. Singh	✓	✓	✓	×	✓	✓	✓	✓	✓	×	×	×	×
30	<i>Shivparvatia glanduligera</i> (Edgew.) Pusalkar & D.K. Singh	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
31	<i>Silene baccifera</i> (L.) Roth	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
32	<i>Silene caespitella</i> F. Williams	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
33	<i>Silene conoidea</i> L.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
34	<i>Silene falconeriana</i> Royle ex Benth.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
35	<i>Silene gangotriana</i> Pusalkar, D.K.Singh & Lakshmin.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
36	<i>Silene incurvifolia</i> Kar. & Kir.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
37	<i>Silene indica</i> var. <i>edgeworthii</i> (Bocquet) Y.J. Nasir.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
38	<i>Silene indica</i> Roxb. ex Otth var. <i>indica</i> Roxb. ex Otth	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
39	<i>Silene kumaonensis</i> F. Williams	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
40	<i>Silene moorcroftiana</i> Wallich ex Benth.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
41	<i>Silene nepalensis</i> Majumdar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
42	<i>Silene songarica</i> (Fisch., C.A. Mey. & Ave-Lall.) Bocq	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
43	<i>Silene viscosa</i> (L.) Pers.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
44	<i>Silene vulgaris</i> (Moench) Garcke	×	×	×	×	×	×	×	×	✓	×	×	×	×
45	<i>Spergula fallax</i> (Lowe) E.H. Krause	×	×	×	×	×	×	×	×	×	×	×	×	×
46	<i>Spergularia rubra</i> (L.) J. & K. Presl.	✓	×	×	×	×	×	✓	✓	✓	×	×	×	×
47	<i>Stellaria aquatica</i> (L.) Scop.	✓	×	×	×	✓	✓	✓	✓	✓	×	×	×	×
48	<i>Stellaria congestiflora</i> H. Hara	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
49	<i>Stellaria decumbens</i> Edgew. var. <i>decumbens</i> Edgew.	✓	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×
50	<i>Stellaria decumbens</i> Edgew. var. <i>polyantha</i> Edgew. & Hook.f.	✓	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×
51	<i>Stellaria depauperata</i> Edgew.	✓	×	×	✓	✓	✓	✓	✓	×	×	×	×	×
52	<i>Stellaria depressa</i> Em. Schmid	×	×	×	×	×	×	×	×	×	×	×	×	×
53	<i>Stellaria himalayensis</i> Majumdar	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
54	<i>Stellaria media</i> (L.) Villars	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
55	<i>Stellaria monosperma</i> D.Don var. <i>monosperma</i> D.Don	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
56	<i>Stellaria monosperma</i> D.Don var. <i>paniculata</i> (Edgew.) Majumdar	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
57	<i>Stellaria patens</i> D.Don	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
58	<i>Stellaria semivestita</i> Edgew.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
59	<i>Stellaria umbellata</i> Turcz.	×	×	×	×	✓	×	×	×	×	×	×	×	×
60	<i>Stellaria uliginosa</i> Murray	×	×	✓	×	✓	×	×	×	×	×	×	×	×
61	<i>Stellaria webbiana</i> (Benth. ex G. Don) Edgew. & Hook. f.	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
62	<i>Thylacospermum caespitosum</i> (Cambess.) Schischk.	×	×	✓	×	×	×	×	×	×	×	×	×	×

**Note:** St= Stem; Lad= Leaf adaxial surface; Lab= Leaf abaxial surface; Lm= Leaf margin; Lb= Leaf base; B= Bract; P= Pedicel; Cb= Calyx base; Ca= Calyx apex; Pt= Petal; S= Stamen; O= Ovary; Sti= Stipule.

#### Vestiture Type

Different types of vestiture depict relative length and pattern of trichome and hence can be used for further categorization of taxa. Different arrangements of trichomes on the stem surface were studied. In the plants under study, eight different types of vestitures were recorded *viz.* (1) Pubescent- more or less straight, short, soft, somewhat scattered, slender trichomes, (2) Puberulent- minutely pubescent with very short scattered trichomes, (3) Tomentose- plant parts covered with very dense interwoven trichomes, (4) Villous- long, soft, highly twisted trichomes, (5) Scabrous- rough trichomes, as of sandpaper, (6.) Hirsute- long stiff trichomes, (7) Strigose- dense coarse, bent and flat trichomes often with bulbous base, and (8) Strigulose- minutely strigose.

*Stellaria monosperma* var. *paniculata* and *S. monosperma* var. *monosperma*, *S. media*, *S. aquatica*, *Shivparvatia ciliolata* var. *ciliolata*, and *Shivparvatia ciliolata* var. *pendula* had tomentose vestiture. But, these were further differentiated on the basis of single line of trichomes, two lines of trichomes or diffused trichomes



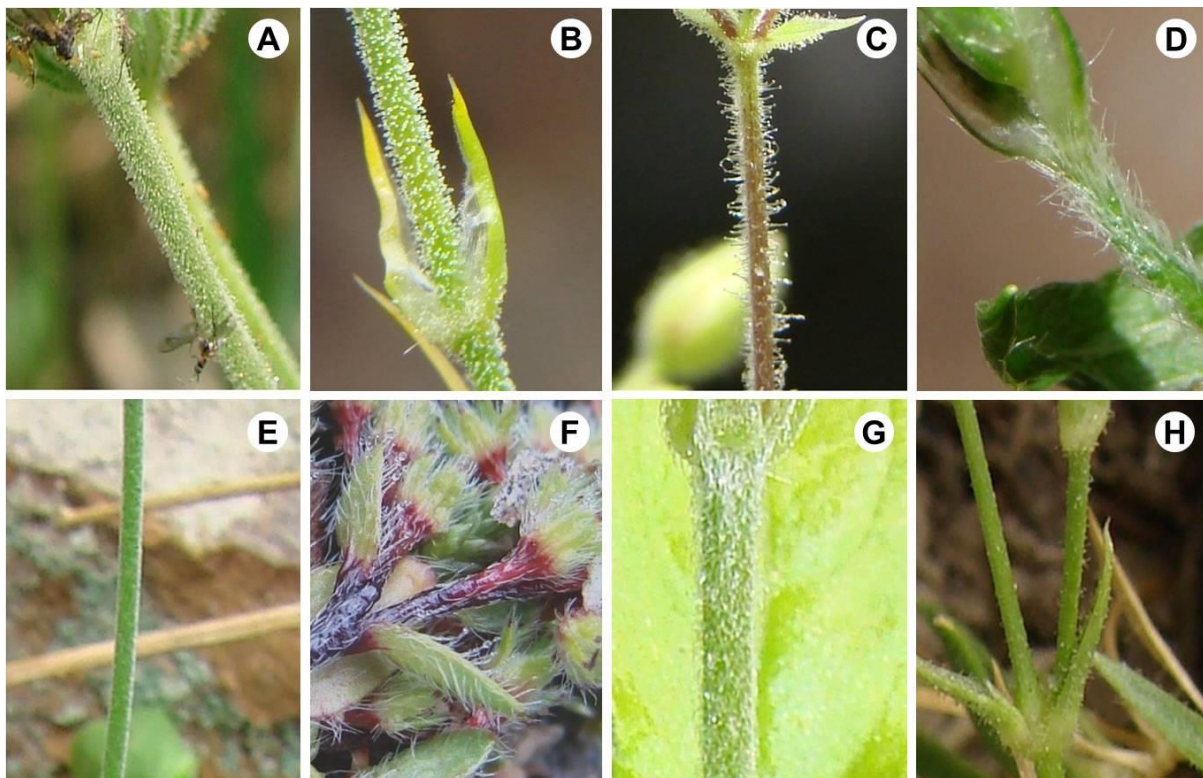
throughout the stem. *Stellaria monosperma* var. *paniculata* and *S. monosperma* var. *paniculata* both possess trichomes in one line; *Stellaria media* has two lines of trichomes or sometimes diffused, *Shivparvatia ciliolata* var. *ciliolata*, *Shivparvatia ciliolata* var. *pendula* has two lines of trichomes. *Arenaria orbiculata* Royle ex Edgew. & Hook.f. and *Stellaria aquatica* both possess two lines of trichomes, but in *Arenaria orbiculata* vestiture is scabrous, while in *Stellaria aquatica* vestiture is tomentose. *Shivparvatia glanduligera*, *Silene conoidea*, *S. falconeriana*, *S. nepalensis*, *Stellaria depauperata* and *Arenaria bhutanica* had pubescent vestiture. *Stellaria depauperata* and *Arenaria bhutanica* are distinguished due to presence of only one line of trichomes in *Arenaria bhutanica* and both one and two lines of trichomes are present in *Stellaria depauperata*. *Shivparvatia glanduligera* possess trichomes either in two lines or in diffused manner and hence separated from the rest of taxa. The species *Silene conoidea*, *S. falconeriana*, *S. nepalensis* and rest of the species possess trichomes in diffused manner. The presence of different types of vestiture in studied taxa is summarized in table 2. In figure 2, representatives of aforementioned eight categories are depicted.

**Table 2.** Trichome types and vestiture of studied plant taxa of the family Caryophyllaceae.

S.N.	Name of Taxa	Specimen Number	Trichome Type*	Vestiture Type
1.	<i>Arenaria bhutanica</i> Majumdar & Babu	GBPUH823	E	Pubescent
2.	<i>Arenaria neelgherrensis</i> Wight & Arn.	GBPUH810	E, G	Scabrous
3.	<i>Arenaria orbiculata</i> Royle ex Edgew. & Hook.f.	GBPUH813	E	Scabrous
4.	<i>Arenaria serpyllifolia</i> L.	GBPUH816	E, G	Scabrous
5.	<i>Arenaria thangoensis</i> W.W. Sm.	GBPUH826	E	Pubescent
6.	<i>Cerastium cerastoides</i> (L.) Britton	BSD103333	E, G	Tomentose
7.	<i>Cerastium davuricum</i> Fischer	BSD89568	Glabrous	Glabrous
8.	<i>Cerastium fontanum</i> Baumg.	GBPUH830	E, G	Hirsute
9.	<i>Cherleria</i> sp.	GBPUH609	E	Puberulent
10.	<i>Dianthus angulatus</i> Royle ex Benth.	BSD101853	E	Puberulent
11.	<i>Dianthus barbatus</i> L.	GBPUH759	E	Glabrous
12.	<i>Dianthus chinensis</i> L.	GBPUH760	E	Glabrous
13.	<i>Drymaria cordata</i> (L.) Willd. ex Schult.	GBPUH762	CG, UE	Scabrous
14.	<i>Drymaria villosa</i> Cham. & Schlecht.	GBPUH745	E	Villous
15.	<i>Eremogone curvifolia</i> (Majumdar) Pusalkar & D.K. Singh	GBPUH819	E	Puberulent
16.	<i>Eremogone festucoides</i> (Benth.) Pusalkar & D.K. Singh	GBPUH820	E, G	Tomentose
17.	<i>Eremogone ferruginea</i> (Duthie ex F.Williams) Pusalkar & D.K. Singh	DD5388	E	Strigose
18.	<i>Eremogone kumaonensis</i> (Maxim.) Pusalkar & D.K. Singh	GBPUH821	E	Tomentose
19.	<i>Gypsophila cerastioides</i> D.Don	GBPUH757	E	Tomentose
20.	<i>Herniaria cachemiriana</i> J. Gay	BSD103341	MSE, UE	Hirsute
21.	<i>Lepydodictis holosteoides</i> (C. A. Meyer) Fenzl ex Fischer & C. A. Meyer	BSD7340	E, G	Tomentose
22.	<i>Odontostemma glandulosum</i> Benth. ex D.Don	GBPUH825	E,G	Hirsute
23.	<i>Polycarpaea corymbosa</i> (L.) Lam.	BSD67856	G	Tomentose
24.	<i>Polycarpon prostratum</i> (Forssk.) Asch. & Schweinf.	BSD32008	BE, E	Tomentose
25.	<i>Sabulina kashmirica</i> (Edgew.) Dillenb. & Kadereit	GBPUH806	Glabrous	Glabrous
26.	<i>Sagina apetala</i> Ard.	GUH12807	E,G	Puberulent
27.	<i>Sagina saginoides</i> (L.) Karsten	GBPUH766	E	Puberulent
28.	<i>Shivparvatia ciliolata</i> (Edgew.) Pusalkar & D.K. Singh var. <i>ciliolata</i>	GBPUH807	E	Tomentose
29.	<i>Shivparvatia ciliolata</i> var. <i>pendula</i> (Duthie ex F. Williams) Pusalkar & D.K. Singh	GBPUH808	E	Tomentose
30.	<i>Shivparvatia glanduligera</i> (Edgew.) Pusalkar & D.K. Singh	GBPUH809	E,G	Pubescent
31.	<i>Silene baccifera</i> (L.) Roth	GBPUH770	E	Strigose
32.	<i>Silene caespitella</i> F. Williams	BSD1102	E	Strigose
33.	<i>Silene conoidea</i> L.	GBPUH772	E,G	Pubescent
34.	<i>Silene falconeriana</i> Royle ex Benth.	GBPUH773	E,G	Pubescent
35.	<i>Silene gangotriana</i> Pusalkar, D.K.Singh & Lakshmin.	GBPUH774	E,G	Tomentose
36.	<i>Silene incurvifolia</i> Kar. & Kir.	GBPUH777	E,G	Strigulose
37.	<i>Silene indica</i> var. <i>edgeworthii</i> (Bocquet) Y.J. Nasir.	GBPUH780	E,G	Strigulose
38.	<i>Silene indica</i> Roxb. ex Otth var. <i>indica</i>	GBPUH779	E,G	Tomentose

39. <i>Silene kumaonensis</i> F. Williams	BSD93913	E	Tomentose
40. <i>Silene moorcroftiana</i> Wallich ex Benth.	BSD56258	E	Strigose
41. <i>Silene nepalensis</i> Majumdar	GBPUH781	E	Pubescent
42. <i>Silene songarica</i> (Fisch., C.A. Mey. & Ave-Lall.) Bocq	BSD103901	E	Tomentose
43. <i>Silene viscosa</i> (L.) Pers.	BSD102127	E,G	Tomentose
44. <i>Silene vulgaris</i> (Moench) Garcke	GBPUH785	E	
45. <i>Spergula fallax</i> (Lowe) E.H. Krause	GBPUH765	Glabrous	Glabrous
46. <i>Spergularia rubra</i> (L.) J. & K. Presl.	BSD13009	G	Puberulent
47. <i>Stellaria aquatica</i> (L.) Scop.	BSD14901	E,G	Tomentose
48. <i>Stellaria congestiflora</i> H. Hara	GBPUH704	E	Villous
49. <i>Stellaria decumbens</i> Edgew. var. <i>decumbens</i> Edgew.	GBPUH787a	E	Strigulose
50. <i>Stellaria decumbens</i> Edgew. var. <i>polyantha</i> Edgew. & Hook.f.	GBPUH787b	E	Strigulose
51. <i>Stellaria depauperata</i> Edgew.	GBPUH749	E	Pubescent
52. <i>Stellaria depressa</i> Em. Schmid	KUH1788	Glabrous	Glabrous
53. <i>Stellaria himalayensis</i> Majumdar	GBPUH791	E	Villous
54. <i>Stellaria media</i> (L.) Villars	GBPUH784	E,G	Tomentose
55. <i>Stellaria monosperma</i> D.Don var. <i>monosperma</i>	GBPUH788	E,G	Tomentose
56. <i>Stellaria monosperma</i> D.Don var. <i>paniculata</i> (Edgew.) Majumdar	GBPUH788	E,G	Tomentose
57. <i>Stellaria patens</i> D.Don	GBPUH791	E	Villous
58. <i>Stellaria semivestita</i> Edgew.	GBPUH796	E	Villous
59. <i>Stellaria umbellata</i> Turcz.	GBPUH802	E	Villous
60. <i>Stellaria uliginosa</i> Murray	GBPUH803	E	Glabrous
61. <i>Stellaria webbiana</i> (Benth. ex G. Don) Edgew. & Hook. f.	GBPUH805	E,G	Strigulose
62. <i>Thylacospermum caespitosum</i> (Cambess.) Schischk.	BSD101818	E	Glabrous

**Note:** BE= Bifurcate E glandular; CG= Capitate Glandular; E= Uniseriate Multicellular E glandular; G= Uniseriate Multicellular Glandular; MSE= Multiseriate E glandular, UE= Unicellular E glandular.



**Figure 2.** Different types of vestiture: **A**, Pubescent (*Silene conoidea*); **B**, Puberulent (*Eremogone curvifolia*); **C**, Tomentose (*Stellaria monosperma* var. *monosperma*); **D**, Villous (*Stellaria patens*); **E**, Scabrous (*Drymaria cordata*); **F**, Hirsute (*Herniaria cachemiriana*); **G**, Strigose (*Silene baccifera*); **H**, Strigulose (*Stellaria webbiana*).

## DISCUSSION

Some of the investigated species had peculiar trichome morphology which can be used to distinguish them from the rest of the allied species. Moreover, trichome morphology and distribution do not play any significant

role in separation of genera. *Herniaria cachemiriana* has long unicellular stiff eglandular trichomes on different plant parts and multiseriate multicellular eglandular trichomes on the ovary. Metcalfe & Chalk (1950) also mentioned unicellular trichomes in *Herniaria*, *Paronychia*, *Anychia* and *Siphonychia* genus. Multiseriate trichomes are also reported from *Achyronichia* spp., *Cerastium* spp., *Pollichia* spp., *Polycarpon* spp., *Polycarpaea* spp., *Polytepalum* spp., *Krauseola* spp. and *Stipulicida* spp. (Bittrich 1993b). But the species of *Cerastium*, *Polycarpon* and *Polycarpaea* studied in the present work does not contain multiseriate trichomes. *Drymaria cordata* is characterized by presence of unicellular capitate glandular trichomes on stem, pedicel and sepal abaxial surface. Metcalfe & Chalk (1950) and Keshavarzi & Bozchaloyi (2014) also reported similar type of unicellular sessile capitate glandular trichomes in *Viscaria* spp. and *Silene propinqua* Schischk. *Polycarpon prostratum* possesses multicellular eglandular bifurcate trichomes and same type of trichomes also known in *Pollichia campestris* Aiton (Solereider & Scott 1986). Solereider & Scott (1986) reported eglandular trichomes containing two or more arms in *Cerastium dicotrichum* Fenzl ex Rohrb., *Polycarpaea* spp. including *P. teneriffae* Lam. and *Stipulicida* spp.

Uniseriate multicellular eglandular or glandular trichomes are present in the *Silene*, *Stellaria*, *Arenaria*, *Odontostemma*, *Cherleria*, *Dianthus*, *Drymaria*, *Eremogone*, *Gypsophila*, *Lepyrodiclis*, *Polycarpaea*, *Sagina*, *Shivparvatia*, *Spergularia* and *Thylacospermum* possess. Similar uniseriate glandular or eglandular trichomes are also reported from *Acanthophyllum* spp., *Stellaria* spp., *Agrostemma* spp. (Shamsabad *et al.* 2013, Keshavarzi & Bozchaloyi 2014, Selvi *et al.* 2014). Keshavarzi & Bozchaloyi (2014) examined some taxa of subfamily Alsinoideae and found simple eglandular uniseriate trichomes in most of the taxa. Genera of subfamily Alsinoideae included in the present study are *Stellaria*, *Arenaria*, *Odontostemma*, *Cherleria*, *Eremogone*, *Lepyrodiclis*, *Sagina*, *Shivparvatia* and *Thylacospermum* which show similar morphology of trichomes as reported by Keshavarzi & Bozchaloyi (2014) in the subfamily.

Uniseriate multicellular eglandular and glandular trichomes present in all species of *Silene* understudy. Yildiz & Minareci (2008), Kilic (2009), Sahreen *et al.* (2010), Khan *et al.* (2013), Bagci & Bicer (2015) have also reported similar type of trichomes in different *Silene* species. All *Stellaria* species understudy possess uniseriate multicellular glandular or eglandular trichomes which correspond well with the results of Bozchaloyi & Keshavarzi (2014) who reported similar type of trichomes in different *Stellaria* species. During the present study uniseriate multicellular glandular and eglandular trichomes were found in *Cerastium fontanum* and *C. cerastioides*. Arcus *et al.* (2012) have also reported similar trichomes in *Cerastium bulgaricum* Uechtr., *C. tomentosum* L., *C. brachypetalum* Desp. ex Pers. and *C. glomeratum* Thuill. *Gypsophila cerastioides* possess only uniseriate multicellular eglandular trichomes but uniseriate multicellular glandular trichomes also were found in *G. lepidioides* Boiss. (Ozdemir *et al.* 2010).

In the most of the genera understudy uniseriate multicellular trichomes with the glandular cell at apex along with unicellular eglandular trichomes were found. Species of *Silene*, *Shivparvatia*, *Stellaria*, *Cerastium*, *Odontostemma*, *Eremogone*, *Arenaria*, *Lepyrodiclis* and *Sagina* studied during present study possess both uniseriate glandular and eglandular trichomes. Metcalfe & Chalk (1950) mentioned presence of uniseriate multicellular trichomes with glandular cell at apex in the species of *Dysphania* (*D. myriocephala* Benth.), *Habrosia*, *Silene*, *Spergula*, *Spergularia* and *Loeflingia*. Al-Saadi & Al-Taie (2014) reported presence of uniseriate multicellular glandular and eglandular trichomes in different *Minuartia* species. Some completely glabrous species *Stellaria depressa*, *Spergula fallax* and *Cerastium davuricum* reported during present work *Corrigiola* sp., and *Telephium imperati* L. also show similar pattern (<https://www.infoflora.ch/fr/flore/339-telephium-imperati.html>, <https://florabase.dpaw.wa.gov.au/browse/profile/22402>).

In Caryophyllaceae, trichome presence and diversity can be used for delimitation of certain species *i.e.* *Spergula fallax* can be distinguished from morphologically similar *Spergularia rubra* due to having fully glabrous plant body. *Drymaria villosa* has strictly long multicellular uniseriate eglandular trichomes while its allied species *D. cordata* has unicellular glandular and eglandular trichomes. *S. incurvifolia* possess both multicellular uniseriate glandular and multicellular uniseriate eglandular trichomes while allied *S. incurvifolia* due to the presence of only multicellular uniseriate eglandular trichomes. Thus, *Silene moorcroftiana* can also be distinguished from former due to presence of the trichomes. *Silene kumaonensis* can also be distinguished from closely related *S. indica* by presence of only multicellular uniseriate eglandular trichomes, while both multicellular uniseriate glandular and multicellular uniseriate eglandular trichomes are found in *S. indica*. *Shivparvatia ciliolata* can be distinguished from *S. glanduligera* due to presence of only multicellular uniseriate eglandular trichomes, while *S. glanduligera* possess both multicellular uniseriate glandular and multicellular uniseriate eglandular trichomes. *Eremogone kumaonensis* and *E. festucoides* can also be distinguished by due to



presence of trichomes. *E. kumaonensis* contains multicellular uniseriate eglandular hairs and in *E. festucoides* both multicellular uniseriate glandular and multicellular uniseriate eglandular hairs present. *Sagina apetala* and *S. saginoides* also show same pattern. In *S. saginoides* only multicellular uniseriate eglandular trichomes are found, while both multicellular uniseriate glandular and multicellular uniseriate eglandular trichomes are found in *S. apetala*. Vestiture type can also be used to differentiate closely allied *Stellaria congestiflora* and *S. decumbens*. *Stellaria congestiflora* has villous vestiture while *S. decumbens* has strigulose vestiture. Similarly, *Silene indica* var. *indica* and *S. indica* var. *edgeworthii* can also be distinguished due to presence of tomentose vestiture in first and strigulose vestiture in later. Closely allied *Arenaria serpyllifolia* and *A. neelgherrensis* can be distinguished on the basis of hairy leaf surface and sepal in first and glabrous leaf surface and sepal in the second. *Shivparvatia ciliolata* var. *ciliolata* and *Shivparvatia ciliolata* var. *pendula* also differ due glabrous leaf surface in the first variety and hairy leaf surface in second variety.

Trichome diversity and distribution in some angiosperm family as Asteraceae (Krak & Mraz 2008, Angulo & Dematteis 2014, de Andrade Wagner *et al.* 2014), Brassicaceae (Abdel 2005, Beilstein *et al.* 2006), Cucurbitaceae (Ali & Al-Hemaid 2011) Ranunculaceae (Hoot 1991), and some genera as *Colquhounia* (Hu *et al.* 2012), *Teucrium* (Navarro & El Oualidi 1999) of Lamiaceae has taxonomic significance and can be used for delimitation of tribes, genera, sections and series. But in the family Caryophyllaceae trichomes diversity and distribution does not have such significance.

After perusing literature and present work trichome types of 33 genera belonging to all eleven tribes of the family analysed and summarized in table 3. Interestingly, glabrous plants present in all tribes of the family. Further, it is concluded that trichome diversity and distribution does not play any significant role in the taxonomic delimitation neither generic nor tribal level of the family. Although, few closely allied species can be distinguished from each other either on the basis of presence of trichomes or vestiture pattern.

**Table 3.** Tribes and trichome types of the family Caryophyllaceae (after pursuing literature and present study).

S.N.	Tribe	Genera studied	Trichomes
1.	Scleranthaeae	<i>Cherleria</i>	Uniseriate multicellular eglandular and glandular trichomes
2.	Saginaeae	<i>Sagina</i> and <i>Habrosia</i>	Uniseriate multicellular eglandular and glandular trichomes
3.	Spergulaeae	<i>Spergula</i> and <i>Spergularia</i>	Uniseriate multicellular eglandular trichomes
4.	Polycarpeae	<i>Drymaria</i> , <i>Polycarpaea</i> , <i>Polycarpon</i> , <i>Loeflingia</i> , <i>Achyronichia</i> , <i>Stipulicida</i> and <i>Krouseola</i>	Uniseriate multicellular glandular and Eglandular
	Exceptions	<i>Drymaria cordata</i> <i>Polycarpon prostratum</i> , <i>Polycarpaea</i> sp. and <i>Stipulicida</i> sp <i>Krouseola</i> sp. and <i>Achyronichia</i> sp. <i>Polycarpon loeflingiae</i>	Capitate glandular Bifurcate eglandular Eglandular multiseriate Stellate
5.	Paronychieae	<i>Herniaria</i> , <i>Paronychia</i> , <i>Siphonichia</i> and <i>Pollichia</i>	Unicellular eglandular trichomes
	Exception	<i>Pollichia compestris</i> <i>Herniaria cachemiriana</i>	Bifurcate eglandular Multiseriate eglandular
6.	Corrigioleae	<i>Corrigiola</i> and <i>Telephium</i>	Glabrous
7.	Alsineae	<i>Cerastium</i> , <i>Lepyrodiclis</i> , <i>Odontostemma</i> , <i>Shivpaarvatia</i> and <i>Stellaria</i>	uniseriate multicellular eglandular and glandular trichomes
	Exceptions	<i>Stellaria vestita</i> and <i>Cerastium mollissimum</i> <i>Cerastium dicrotrichum</i>	Stellate eglandular bifurcate
8.	Arenarieae	<i>Arenaria</i>	Uniseriate multicellular eglandular and glandular trichomes
9.	Eremogoneae	<i>Eremogone</i> and <i>Thylacospermum</i>	Uniseriate multicellular eglandular and glandular trichomes
10.	Sileneae	<i>Agrostemma</i> , <i>Silene</i> and <i>Viscaria</i>	Uniseriate multicellular eglandular and glandular trichomes
	Exceptions	<i>Viscaria</i> sp. and <i>Silene propinqua</i>	Capitates glandular trichome
11.	Caryophylleae	<i>Acanthophyllum</i> , <i>Dianthus</i> , <i>Gypsophila</i> and <i>Vaccaria</i>	Uniseriate multicellular eglandular and glandular trichomes

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