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.

[Cite as: Chandra S, Rawat DS, Verma SR & Uniyal P (2019) Trichome diversity in the family Caryophyllaceae from Western Himalaya and their taxonomic implication. Tropical Plant Research 6(3): 397–407]  

INTRODUCTION

Caryophyllaceae Juss. is known as pink family or carnation family, and ranked as 24th 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; pentameric with distinct clawed petals; stamens obdiplostemonous, ten or lesser; ovary superior; placentaion 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: Polycarpaceae, Paronichieae and Corrigioleae), Alsinoideae (tribe: Alsineae, Pycnophylleae, Geocarpeae, Habrosieae and Sclerantheae 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, Paronichieae, Polycarpaceae, Sperguleae, Saginaeae, Sclerantheae, Arenarieae, Alsinieae, Erecomoneae, 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, Erecomone, Facchinia, McNillia, Minuartia s.s., Minuarietia, 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. Eremogene, Odontostemma, Shivparvati, 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 Herniaia cachemiriana J. Gay. Drymaria cordata possess both unicellular eglandular and capitulate unicellular glandular trichomes, while Herniaia cachemiriana possess unicellular hairs on all plant parts except ovary. In the ovary of Herniaia 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. moorcroftana* 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. Har., *S. himalayensis* Majumdar, *S. patens* D.Don, *S. semivestita* Edgew., *S. umbellata* Turcz., *S. uliginosa* Murray, *Thylacospernum caespitosum* (Cambess.) Schischk., *Cherleriopsis 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*, *Shivparvatica 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.

The forth group of the plants bore only uniseriate multicellular glandular trichomes and represented by *Polycarpacea corymbosa* (L.) Lam. and *Spergularia rubra* (L.) J. & K. Presl. The fifth group include *Silene falconeriana* Royle ex Benth., *S. conoidea* L., *S. gangetriana* Pusalkar, D.K. Singh & Lakshmin., *S. indica* var. *indica* Roxb. ex Oth., *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.
Among all species, only few leaf pairs respectively. In *Murray Thylacospermum caespitosum* (Moench) Garcke Cerastium d.* trichomes in different plant parts of studied taxa is shown in table 1. Different plant parts and different types of vestiture can also be used for categorization of taxa. The presence of eglandular trichomes at least at some plant parts. 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 *Herniaia 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 |
|------|----------------------------------|-----------------------------------------------|
| 1    | *Arenaria bhutanica* Majumdar & Babu | ✓ X X X ✓ X X X X X X X X X X X X X X X X X X X |
| 2    | *Arenaria neelherrensis* Wight & Arn. | ✓ X X ✓ X X X X X X X X X X X X X X X X X X X X |
| 3    | *Arenaria orbiculata* Royce ex Edgew. & Hook.f. | ✓ ✓ X X X X X X X X X X X X X X X X X X X X X X |
| 4    | *Arenaria serpyllifolia* L. | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 5    | *Arenaria thangoensis* W.W. Sm. | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 6    | *Cerastium cerastoides* (L.) Britton | ✓ X X X X ✓ X X X X X X X X X X X X X X X X X X |
| 7    | *Cerastium davuricum* Fischer | ✓ X X X X ✓ X X X X X X X X X X X X X X X X X X |
| 8    | *Cerastium fontanum* Baumg. | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 9    | *Cherleria* sp. | ✓ X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 10   | *Dianthus angulatus* Royce ex Benth. | ✓ X X ✓ X X X X X X X X X X X X X X X X X X X X |
| 11   | *Dianthus barbatus* L. | ✓ X X X X X X X X X X X X X X X X X X X X X X X |
| 12   | *Dianthus chinensis* L. | ✓ X X X X X X X X X X X X X X X X X X X X X X X |
| 13   | *Drymaria cordata* (L.) Willd. ex Schult. | ✓ X X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 14   | *Drymaria villosa* Cham. & Schlecht. | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 15   | *Eremogone curvifolia* (Majumdar) Pusalkar & D.K. Singh | ✓ X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 16   | *Eremogone festucoides* (Benth.) Pusalkar & D.K. Singh | ✓ ✓ X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 17   | *Eremogone ferruginea* (Duthie ex F.Williams) Pusalkar & D.K. Singh | ✓ X X X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 18   | *Eremogone kumaonensis* (Maxim.) Pusalkar & D.K. Singh | ✓ X X X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 19   | *Gypsophila cerastoides* D.Don | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 20   | *Herniaia cachemiriana* J. Gay | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 21   | *Lepyrodiclis holostoeides* (C. A. Meyer) Fenzl ex Fischer & C. A. Meyer | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 22   | *Odontostemma glandulosum* Benth. ex D.Don | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 23   | *Polycarpaea corymbosa* (L.) Lam. | ✓ ✓ ✓ X X X ✓ X X X X X X X X X X X X X X X X X |
| 24   | *Polycarpon prostratum* (Forssk.) Asch. & Schweinf. | ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |
| 25   | *Sabulina kashmirica* (Edgew.) Dillenb. & Kaderiet | ✓ X X X X X X X X X X X X X X X X X X X X X X X |
| 26   | *Sagina apetala* Ard. | ✓ X X ✓ X X X X X X X X X X X X X X X X X X X X |
| 27   | *Sagina saginoides* (L.) Karsten | ✓ X ✓ X X X X X X X X X X X X X X X X X X X X X |
| 28   | *Shivparvatia ciliolata* (Edgew.) Pusalkar & D.K. Singh var. ciliolate (Edgew.) | ✓ X ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ |

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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.

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*Stellaria monosperma* var. *paniculata* and *S. monosperma* var. *monosperma*, *S. media*, *S. aquatica*, *Shivparvati ciliolata* var. *ciliolata*, and *Shivparvati 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, *Shivparvattia ciliolata* var. *ciliolata*, *Shivparvattia 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. *Shivparvattia 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*. *Shivparvattia 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    | *Arenaria bhutanica* Majumdar & Babu        | GBPUH823        | E              | Pubescent      |
| 2    | *Arenaria neelgherrensis* Wight & Arn.      | GBPUH810        | E, G           | Scabrous       |
| 3    | *Arenaria orbiculata* Royle ex Edgew. & Hook.f. | GBPUH813 | E              | Scabrous       |
| 4    | *Arenaria serpyllifolia* L.                | GBPUH816        | E, G           | Scabrous       |
| 5    | *Arenaria thangoenensis* W.W. Sm.          | GBPUH826        |                | Pubescent      |
| 6    | *Cerastium cerastoides* (L.) Britton       | BSDL03333       | E, G           | Tomentose      |
| 7    | *Cerastium dawuricum* Fischer              | BSDL9568        | Glabrous       | Glabrous       |
| 8    | *Cerastium fontanum* Baumg.                | GBPUH830        | E, G           | Hirsute        |
| 9    | Chelertia sp.                              | GBPUH609        | E              | Puberulent     |
| 10   | *Dianthus angulatus* Royle ex Benth.        | BSDL10853       | E              | Puberulent     |
| 11   | *Dianthus barbatus* L.                     | GBPUH759        | E              | Glabrous       |
| 12   | *Dianthus chinensis* L.                    | GBPUH760        | E              | Glabrous       |
| 13   | *Drymaria cordata* (L.) Willd. ex Schult.   | GBPUH762        | CG, UE         | Scabrous       |
| 14   | *Drymaria villosa* Cham. & Schlecht.        | GBPUH745        | E              | Villous        |
| 15   | *Eremogone curvifolia* (Majumdar) Pusalker & D.K. Singh | GBPUH819 | E              | Puberulent     |
| 16   | *Eremogone festucoideas* (Benth.) Pusalker & D.K. Singh | GBPUH820 | E, G          | Tomentose      |
| 17   | *Eremogone ferruginea* (Duthie ex F.Williams) Pusalker & D.K. Singh | DD5388 | E              | Strigose       |
| 18   | *Eremogone kumaonensis* (Maxim.) Pusalker & D.K. Singh | GBPUH821 | E              | Tomentose      |
| 19   | *Gypsophila cerastioides* D.Don             | GBPUH757        | E              | Tomentose      |
| 20   | *Herniaria cachemiriana* J. Gay            | BSDL03341       | MSE, UE        | Hirsute        |
| 21   | *Lepyrodiclis holostoeides* (C. A. Meyer) Fenzl ex Fischer & C. A. Meyer | BSDL7340 | E, G          | Tomentose      |
| 22   | *Odontostemma glandulosum* Benth. ex D.Don  | GBPUH825        | E,G            | Hirsute        |
| 23   | *Polycarpacea corymbosa* (L.) Lam.         | BSDL6786        | E              | Tomentose      |
| 24   | *Polycarpon prostratum* (Forssk.) Asch. & Schweinf. | BSDL3208 | BE, E         | Tomentose      |
| 25   | *Sabelina kashmirica* (Edgew.) Dillenb. & Kadereit | GBPUH806 | Glabrous       | Glabrous       |
| 26   | *Sagina apetala* Ard.                     | GUH12807        | E,G            | Puberulent     |
| 27   | *Sagina saginoides* (L.) Karsten           | GBPUH766        | E              | Puberulent     |
| 28   | *Shivparvattia ciliolata* (Edgew.) Pusalker & D.K. Singh | GBPUH807 | E              | Tomentose      |
| 29   | *Shivparvattia ciliolata* var. *pendula* (Duthie ex F. Williams) Pusalker & D.K. Singh | GBPUH808 | E              | Tomentose      |
| 30   | *Shivparvattia glanduligera* (Edgew.) Pusalker & D.K. Singh | GBPUH809 | E,G          | Pubescent      |
| 31   | *Silene baccifera* (L.) Roth               | GBPUH770        | E              | Strigose       |
| 32   | *Silene caespitella* F. Williams           | BSDL1012        | E              | Strigose       |
| 33   | *Silene conoidea* L.                      | GBPUH772        | E,G            | Pubescent      |
| 34   | *Silene falconeriana* Royle ex Benth.      | GBPUH773        | E,G            | Pubescent      |
| 35   | *Silene gangotriana* Pusalker, D.K.Singh & Lakshmin. | GBPUH774 | E              | Tomentose      |
| 36   | *Silene incurvifolia* Kar. & Kir.          | GBPUH777        | E,G            | Strigolose     |
| 37   | *Silene indica* var. *edgeworthii* (Bocquet) Y.J. Nasir. | GBPUH780 | E              | Strigolose     |
| 38   | *Silene indica* Roxb. ex Otth var. *indica* | GBPUH779 | E,G          | Tomentose      |
39. *Silene kumaonensis* F. Williams  
BSD93913  E  Tomentose
40. *Silene moorcroftiana* Wallich ex Benth.  
BSD56258  E  Strigose
41. *Silene nepalensis* Majumdar  
GBPUH781  E  Pubescent
42. *Silene songarica* (Fisch., C.A. Mey. & Ave-Lall.) Bocq  
BSD103901  E  Tomentose
43. *Silene viscosa* (L.) Pers.  
BSD102127  E,G  Tomentose
44. *Silene vulgaris* (Moench) Garcke  
GBPUH785  E
45. *Spergula fallax* (Lowe) E.H. Krause  
GBPUH765  Glabrous  Glabrous
46. *Spergularia rubra* (L.) J. & K. Presl.  
BSD13009  G  Puberulent
47. *Stellaria aquatica* (L.) Scop.  
BSD14901  E,G  Tomentose
48. *Stellaria congestiflora* H. Hara  
GBPUH704  E  Villous
49. *Stellaria decumbens* Edgew. var. *decumbens* Edgew.  
GBPUH787a  E  Strigulose
50. *Stellaria decumbens* Edgew. var. *polyantha* Edgew. & Hook.f.  
GBPUH787b  E  Strigulose
51. *Stellaria depauperata* Edgew.  
GBPUH749  E  Pubescent
52. *Stellaria depressa* Em. Schmid  
KUH1788  Glabrous  Glabrous
53. *Stellaria himalayensis* Majumdar  
GBPUH791  E  Villous
54. *Stellaria media* (L.) Villars  
GBPUH784  E,G  Tomentose
55. *Stellaria monosperma* D.Don var. *monosperma*  
GBPUH788  E,G  Tomentose
56. *Stellaria monosperma* D.Don var. *paniculata* (Edgew.) Majumdar  
GBPUH788  E,G  Tomentose
57. *Stellaria patens* D.Don  
GBPUH791  E  Villous
58. *Stellaria semivestita* Edgew.  
GBPUH796  E  Villous
59. *Stellaria umbellata* Turcz.  
GBPUH802  E  Villous
60. *Stellaria uliginosa* Murray  
GBPUH803  E  Glabrous
61. *Stellaria webbiana* (Benth. ex G. Don) Edgew. & Hook. f.  
GBPUH805  E,G  Strigulose
62. *Thylacospermum caespitosum* (Cambess.) Schischk.  
BSD101818  E  Glabrous

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

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 multisieriate multicellular egladular trichomes on the ovary. Metcalfe & Chalk (1950) also mentioned unicellular trichomes in *Herniaria, Paronychia, Anychia* and *Siphonochila* genus. Multisieriate trichomes are also reported from *Achyronichia* spp., *Cerastium* spp., *Pollichia* spp., *Polycarpaea* spp., *Polytetalum* spp., *Krauseola* spp. and *Stipulicida* spp. (Bittrich 1993b). But the species of *Cerastium, Polycarpaea* and *Polycarpa* studied in the present work does not contain multisieriate 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 pizza* Schischk. *Polycarpon prostratum* possesses multicellular eglandular bifurcate trichomes and same type of trichomes also known in *Pollichia campestris* Aiton (Solereder & Scott 1986). Solereder & Scott (1986) reported eglandular trichomes containing two or more arms in *Cerastium dicrotrichum* Fenzl ex Rohrb., *Polycarpaea* spp. including *P. teneriffae* Lam. and *Stipulicida* spp.

Unisieriate multicellular eglandular or glandular trichomes are present in the *Silene, Stellaria, Arenaria, Odontostemma, Cherleria, Dianthus, Drymaria, Eremogone, Gypsophila, Lepyridichis, Polycarpaea, Sagina, Shivparvatiar, Spergularia* and *Thylacosperum* possess. Similar unisieriate 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 Alisoideae and found simple eglandular unisieriate trichomes in most of the taxa. Genera of subfamily Alisoideae included in the present study are *Stellaria, Arenaria, Odontostemma, Cherleria, Eremogone, Lepyridichis, Sagina, Shivparvatiar* and *Thylacosperum* which show similar morphology of trichomes as reported by Keshavarzi & Bozchaloyi (2014) in the subfamily.

Unisieriate 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 unisieriate multicellular eglandular 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 unisieriate multicellular eglandular 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 unisieriate multicellular eglandular trichomes but unisieriate multicellular glandular trichomes also were found in *G. lepidioides* Boiss. (Ozdemit et al. 2010).

In the most of the genera understudy unisieriate multicellular trichomes with the glandular cell at apex along with unisieriate eglandular trichomes were found. Species of *Silene, Shivparvatiar, Stellaria, Cerastium, Odontostemma, Eremogone, Arenaria, Lepyridichis* and *Sagina* studied during present study possess both unisieriate glandular and eglandular trichomes. Metcalfe & Chalk (1950) mentioned presence of unisieriate multicellular trichomes with glandular cell at apex in the species of *Dysphania* (*D. myrificiophala* Benth.), *Habrosia, Silene, Spergula, Spargularia* and *Loeflingia*. Al-Saadi & Al-Taie (2014) reported presence of unisieriate 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 unisieriate eglandular trichomes while its allied species *D. cordata* has unicellular glandular and eglandular trichomes. *S. incurvifolia* possess both multicellular unisieriate glandular and multicellular unisieriate eglandular trichomes while allied *S. incurvifolia* due to the presence of only multicellular unisieriate eglandular trichomes. Thus, *Silene moorcroftiana* can also be distinguished from *Silene kumaonensis* can also be distinguished from closely related *S. indica* by presence of only multicellular unisieriate eglandular trichomes, while both multicellular unisieriate glandular and multicellular unisieriate eglandular trichomes are found in *S. indica*. *Shivparvatiat ciliolata* can be distinguished from *S. glanduligera* due to presence of only multicellular unisierate eglandular trichomes, while *S. glanduligera* possess both multicellular unisieriate glandular and multicellular unisieriate 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 serpulifolia* 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. *Shiparvaita ciliolata* var. *ciliolata* and *Shiparvaita 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 (Krack & Mraz 2008, Angulo & Dematteis 2014, de Andrade Wagner et al. 2014), Brassicaceae (Abdel 2005, Beilstein 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.

| S.N. | Tribe          | Genera studied                              | Trichomes                                           |
|------|----------------|---------------------------------------------|-----------------------------------------------------|
| 1.   | Scleranthae    | Cherleria                                   | Uniseriate multicellular eglandular and glandular trichomes |
| 2.   | Saginae        | *Sagina* and *Habrosia*                    | Uniseriate multicellular eglandular and glandular trichomes |
| 3.   | Spergulae      | *Spergula* and *Spergularia*               | Uniseriate multicellular eglandular trichomes       |
| 4.   | Polycarpeae    | *Drymaria*, *Polycarpacea*, *Polycarpon*,  | Uniseriate multicellular glandular and E glandular |
|      |                | *Loeflingia*, *Achyronchia*, *Stipulicida* |                                                     |
|      | Exceptions     | *Drymaria cordata*                         | Capitate glandular                                  |
|      |                | *Polycarpon prostratum*, *Polycarpacea* sp.|                                                    |
|      |                | *Stipulicida* sp.                          |                                                    |
|      |                | *Krouseola* sp.                            |                                                    |
|      |                | *Achyronchia* sp.                          |                                                    |
|      |                | *Polycarpon loeflingiae*                   |                                                    |
|      |                | *Krouseola* sp. and *Achyronchia* sp.      |                                                    |
| 5.   | Paronychieae   | *Herniaria*, *Paronychia*, *Siphonynchia* and | Unicellular eglandular trichomes                     |
|      |                | *Pollichia*                                 |                                                     |
|      | Exception      | *Pollichia compesiris*                     |                                                    |
|      |                | *Herniaria cachemiriana*                   |                                                    |
| 6.   | Corrigioleae   | *Corrigiola* and *Telephium*               |                                                    |
| 7.   | Alsincae       | *Cerastium*, *Lepyrodictis*, *Odontostemma*,| uniseriate multicellular eglandular and glandular trichomes |
|      |                | *Shiparavatia* and *Stellaria*             |                                                    |
|      | Exceptions     | *Stellaria vestita* and *Cerastium mollissimum* | Stellate eglandular bifurcate                       |
|      |                | *Cerastium dicrotrichum*                   |                                                    |
| 8.   | Arenarieae     | *Arenaria*                                  |                                                    |
| 9.   | Eremogoneae    | *Eremogone* and *Thylacosphermum*          |                                                    |
| 10.  | Sileneae       | *Agrostemma*, *Silene* and *Viscaria*      |                                                    |
|      | Exceptions     | *Viscaria* sp. and *Silene propinqua*      |                                                    |
| 11.  | Caryophyllae   | *Acanthophyllum*, *Dianthus*, *Gypsophila* and | Uniseriate multicellular eglandular and glandular trichomes |
|      |                | *Vaccaria*                                 |                                                     |
ACKNOWLEDGEMENTS

Authors are thankful to Herbarium curator of Botanical Survey of India Northern Circle Dehradun (BSD), Forest Research Institute Dehradun (DD), H.N.B. Garhwal University Srinagar Garhwal (GUH), Kumaon University Nainital (KUH) and Wildlife Institute of India Dehradun for providing access to their herbaria and libraries. Authors also extend thanks to the anonymous reviewers for their suggestions and critical comments.

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