Studies on the Genus *Saxifraga* L. (Saxifragaceae) in Western Himalaya, India

Thesis

SUBMITTED TO

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"Gratitude without expressing is similar to wrapping a gift and not giving it away."

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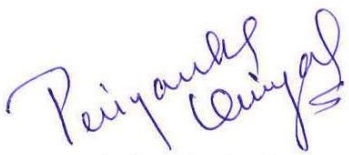

(Priyanka Uniyal)
Authoress

CERTIFICATE

This is to certify that the thesis to entitled **"Studies on the Genus *Saxifraga* L. (Saxifragaceae) in Western Himalaya, India"** submitted in fulfillment of the requirements for the degree of **MASTER OF SCIENCE** with major in **BOTANY** of the College of Post Graduate studies G.B. Pant University of Agriculture & Technology, Pantnagar is a record of bonafide research carried out by **Ms. Priyanka Uniyal**, Id. No. **48123**, under my supervision and no part of this thesis has been submitted for any other degree and diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

Pantnagar
August, 2016

(D.S. Rawat)
Chairman
Advisory committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. Priyanka Uniyal, Id. No. 48123** a candidate for the degree of **MASTER OF SCIENCE** with major in **BOTANY** agree that the thesis entitled **Studies on the Genus *Saxifraga* L. (Saxifragaceae) in Western Himalaya, India"** may be submitted in partial fulfillment of the requirements for the degree.

(D. S. Rawat)
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Advisory Committee

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Member

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Introduction

The Earth is thought to have been formed around 4.54 billion years ago and, nearly 4.1 billion years ago life came into existence on Earth **(www.pnas.org).** As the temperature of this hot planet reduced the life originated and evolved on it. After a long history of evolution of life on Earth, today the total number of eukaryotic species on Earth accounts for 8.7 million, out of which 6.5 million are terrestrial while the rest are marine. Despite of this enormous diversity of life, till now only about 1.2 million of eukaryotic species have been identified and described, but 86% of the present terrestrial and 91% that of marine species are yet to be described **(Mora *et al.*, 2011).** In addition to Eukaryotic life on Earth a plethora of prokaryotic diversity also exists on it. A recent study estimated the global microbial biodiversity to be 1 trillion **(Locey & Lennon, 2016).**

All the living organisms on Earth, prokaryotic or eukaryotic, have been broadly grouped under three domains – Eubacteria, Archaea and Eukarya. Eukarya, the most evolved group of organisms is further divided into 5 kingdoms, namely Plantae, Animalia, Fungi, Protista and Monera. Plants are the multicellular, autotrophic eukaryotes of the Kingdom Plantae, and comprises of about 350,699 known species in the world **(The Plant List, 2013)**. These include traditional group of plants like bryophytes, pteridophytes, gymnosperms and angiosperms.

Flowering plants or Angiosperms, also known as Magnoliophyta, form the largest group of plant kingdom, and are considered to be the highest evolved plants on the surface of the Earth. Among the land plants, nearly 91.1% of all extant land plant species are angiosperms. These plants appeared in Cretaceous age nearly 65 million years ago and diversified rapidly. Amazed by the origin and diversification of angiosperms Charles Darwin called it as 'abominable mystery'. Today, angiosperms are represented by 304,419 species on the Earth **(The Plant List, 2013)**.

1.1 Diversity of Angiosperms

Angiosperms are the most important and diversified group of plants in the world. These can be found in every type of habitat and climate. They dominate almost

all types of terrestrial vegetation except for coniferous forest of Siberia and moss-lichen dominated tundra. Angiosperms have a great morphological diversity. The angiosperms are found in different kinds of habitat like deserts, seabed, rocks, marshes, lakes, mountains etc. They occur in different forms, such as herbs, shrubs, trees, lianas and climbers, and in different habits as symbiotic, parasitic, epiphytic, saprophytic and insectivorous plants.

The estimated number of angiosperms in the world varies with the sources. According to **Govaerts (2001)**, there are 422,127 species of angiosperms in the world. **Scotland & Wortley (2003)** estimated 223,300 species of flowering plants in the world. **Thorne & Reveal (2007)** calculated 253,300 species under 13,000 genera and 562 families worldwide while **Paton *et al.* (2008)** estimated 352,000 species of angiosperms across the world. According to **Joppa *et al.* (2011)**, the current number of species should grow by 10-20%. **The Plant List (2013)** lists 405 families, 14,559 genera and 304,419 species of angiosperms across the globe. Recently, **Pimm & Joppa (2015)** have estimated 450,000 species of flowering plants worldwide. **Christenhusz & Byng (2016),** however, states the known angiosperm species as 295,383 in 13,164 genera and 416 families.

India is a mega-diverse country with 12 bio-geographical provinces, 5 biomes and 3 bioregion domains **(Cox & Moore, 1993).** The total geographical area of the country is about 3.287 million km^2 and a coastline of about 7,517 km. India has a great ecological diversity, from hot arid northwest to cold arid Trans-Himalaya, from coastal regions to highest mountain ranges in the world, from water-scarced Thar Desert to the wettest place in the world. India is home to 47,513 plant species which is about 11.4% of world's flora **(Singh & Dash, 2014)**. The endemic plant species comprises about 28%, out of which 4,500 species belongs to angiosperms **(Karthikeyan *et al.*, 2009)**. **Khoshoo (1995)** estimated 17,000 spp. of angiosperms in India. There are 17,527 species of angiosperms under 2,991 genera and 251 families in India, representing approximately 7% of the described species in the world (**Karthikeyan *et al.*, 2009**). However, the recent estimate accounts a total of 18,159 species of angiosperms in the country (**Singh & Dash, 2015**). On the basis of diversity and distribution of the endemic species, **Nayar (1996)** has provided 3 mega-centres (Eastern Himalayas, Western Ghats and Western Himalayas) and 25 micro-centres of endemic plants in

India. The recent estimates by Botanical Survey of India indicate 4381 endemic species of Vascular plants in India of which 4303 are angiosperms. It clearly indicates that 23-24% of Indian angiosperm flora is endemic **(Singh *et al.*, 2015)**.

Uttarakhand is the 27th state of India lying in the western Himalayan region. It encompasses an area of 53,483 km^2 which accounts for 1.69% of geographical area of India. The state is home to more than 4700 species of Angiosperms belonging to 1503 genera and 182 families (**Uniyal *et al.*, 2007**). A recent study enumerated 81 species of vascular plants endemic to the state **(Singh *et al.*, 2015).**

1.2 Family Saxifragaceae Juss.

Saxifragaceae, in the eudicot, order Saxifragales **(APG III, 2009)**, contains approximately 640 species in 33 genera **(Deng *et al.*, 2015)**. According to **Stevens (2001)**, the family has 33 genera and 600 spp. worldwide, while **The Plant List (2013)** enumerated 48 genera and 775 spp. under the family worldwide thus suggesting 0.25% species of the total angiosperms on Earth. In India, there are 17 genera and 148 species of Saxifragaceae **(Karthikeyan, 2000)**. Saxifragaceae has 4 genera and 45 species in Uttarakhand **(Uniyal *et al.*, 2007)**.

A study of divergence time on Saxifragaceae calculated the age of the family to be 38.37 million years **(Deng *et al.*, 2015)**. The family was initially placed under the Order Rosales by **Bentham and Hooker (1862)** but today it is well placed in the Order Saxifragales (**APG IV, 2016**). Saxifragaceae are found mostly in the Northern Hemisphere, with centers of diversity in Europe, Himalayas, East Asia, and Western North America. They show greater diversity in the Pacific Northwest region of North America (**Deng *et al.*, 2015**).

The family is further classified into two subfamilies – Saxifragoideae Beilschmied, including 2 genera *Saxifraga* and *Saxifragella*, and Heucheroideae Burnett, that includes rest of the genera **(Deng *et al.*, 2015; Stevens, 2001)**. In the recent DNA based phylogenetic studies, the former sects. *Micranthes* and *Merkianae,* in the *Saxifraga* genus, are found closer to the *Boykinia* and *Heuchera* than to other species of *Saxifraga* (**Soltis *et al.*, 1996**), consequently the most recent floras now treat *Micranthes* and *Saxifraga* as separate genera.

Members of the family Saxifragaceae are cosmopolitan in distribution but are mainly native to northern cold and temperate regions. They are annual, biennial or perennial herbs, rhizomatous or stoloniferous. Leaves are usually simple and alternate, but are sometimes compound or deeply notched or cut, and may be opposite. Basal leaves usually form rosette. They are usually exstipulate. Inflorescence is a cyme, raceme or panicle, or a solitary flower. Flowers are bisexual, actinomorphic, pentamerous and cyclic. Calyx has usually 5 sepals; polysepalous, or gamosepalous; regular; imbricate, or valvate. Corolla has usually 5 petals; polypetalous, or gamopetalous; imbricate, or valvate; regular; white, yellow, red, or pink. Androecium consists of 10 (usually) or 5 stamens, usually alternisepalous (obdiplostemonous). Gynoecium is usually 2-3 carpelled, more or less joined at base.The fruit is a capsule with many seeds. **(Pan *et al.*, 2001; Wells & Elvander, 2009)**

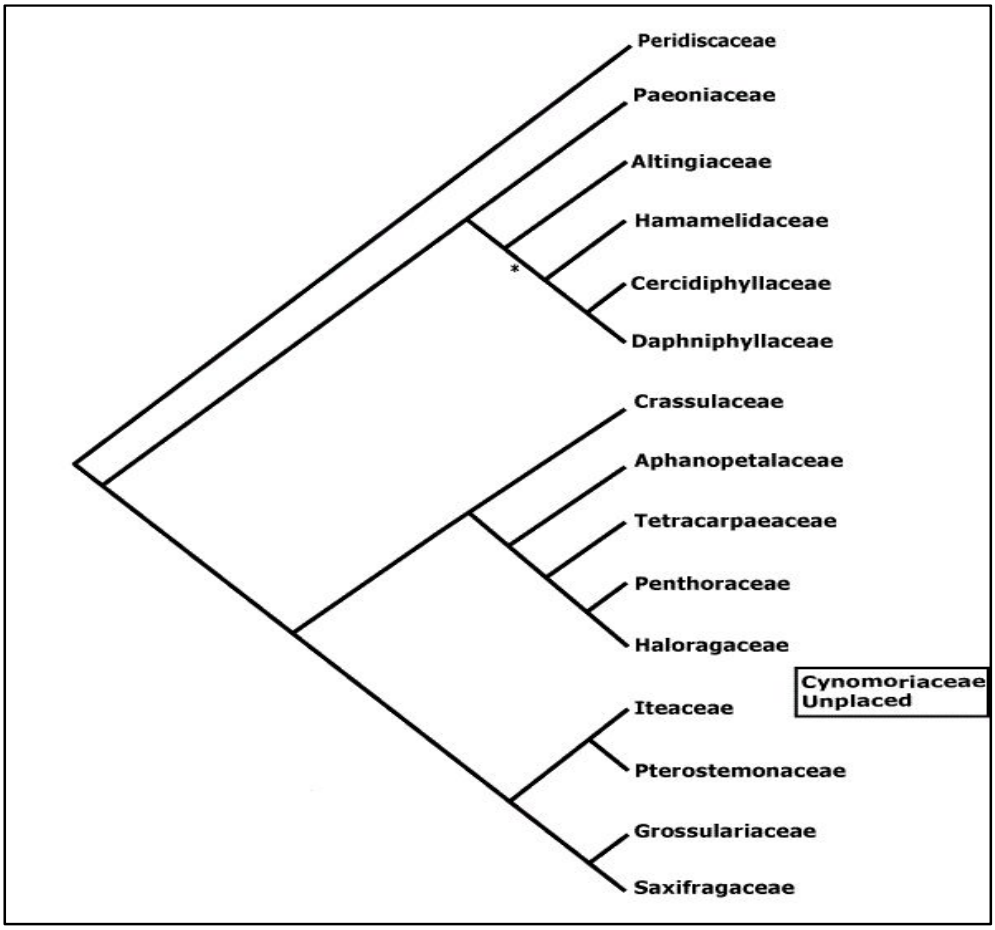


Figure 1.1: The cladogram of the order Saxifragales depicting position of Saxifragaceae and other groups (Stevens, 2001)

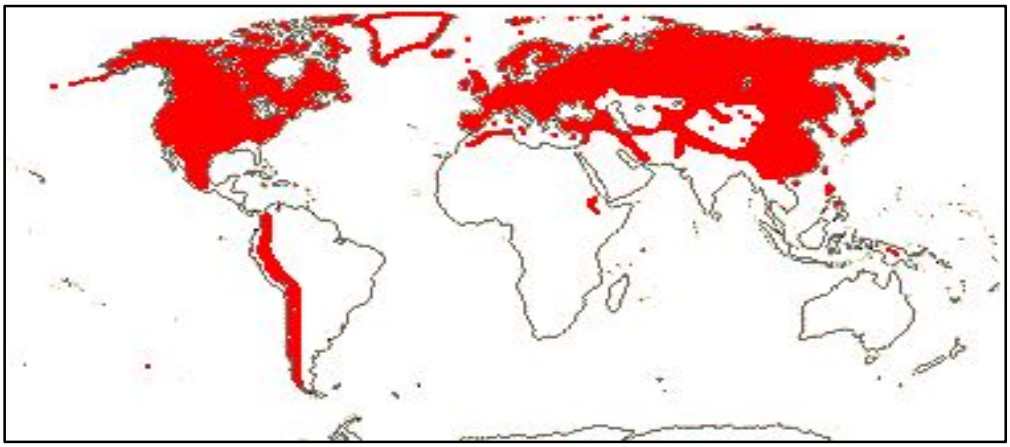


Figure 1.2: Map showing distribution of the family Saxifragaceae in the world (source: Stevens, 2001)

1.3 The Genus *Saxifraga* L.

Saxifraga L., the largest genus in the family Saxifragaceae, is found mostly in the cold rocky terrains of Europe, North America and the Sino-Himalayan region. The plants dwell in arctic-alpine ecosystems. The word '*Saxifraga*' means 'stone breaker' from Latin words, '*saxum*' (rock or stone) and '*frangere*' (to break). The name is derived from the traditional knowledge of using the plant for the treatment of kidney stones. It is also referred to the habit of the plant of growing in rock crevices, and appears as if they are breaking the rock. They are commonly known as saxifrages or rockfoils. In Western Himalayan region, the members of this genus are found in altitudes between 2000-5500 m above sea level. Members of the genus *Saxifraga* section *Porphyrion* have characteristic lime-secreting glands along the leaf margins.

The members of the genus *Saxifraga* are usually perennial herbs, rarely annual or biennial. Stem is densely branched or simple. Leaves are basal or basal and cauline, petiolate or sessile; leaf lamina is simple, entire, margin dentate or lobate; cauline leaves usually alternate, rarely opposite. Some species form evergreen rosettes of succulent, stiff leaves with lime-secreting pores (pits) on the margins or adaxial surface. Inflorescence is a solitary flower, or cyme, or panicle. Flowers are usually pentamerous (rarely tetramerous), bisexual; actinomorphic; receptacle cyathiform or saucer-shaped. Sepals are 5(4). Petals are 5 (4) or rarely absent, yellow, white, or red to purple, distinctly veined, margin usually entire. Stamens are 8 (when flower is tetramerous) or

10, filaments subulate or clavate. Carpels are 2 (3), usually connate at least in placental region; ovary superior to inferior, usually 2-loculed; placentation usually axile; ovules many; integuments 1 or 2; nectary disc sometimes well developed, annular or semi-annular. Fruit is a 2-valved capsule with many seeds (**Pan *et al.*, 2001**).

In the world, the number of species under the genus *Saxifraga* varies with the sources, i.e. 450 spp. (**Pan *et al.*, 2001; The Plant List, 2013**), 480 spp. **(SaxBase 2016)**, 460 spp**. (Akiyama & Gornall, 2011; Zhang, 2013)**, 370 spp. **(http://www.tropicos.org/Name/)** and 390 spp. **(Brouillet & Elvander, 2009)**. In Indian Himalayan region, *Saxifraga* L. is represented by 64 species **(Agnihotri & Husain, 2013)**. In Western Himalayan region, the total number of species of the genus decreases from Uttarakhand to Kashmir, i.e. 21 spp. in Himachal Pradesh **(Chowdherry & Wadhwa, 1984)**, 13 spp. in Lahaul-Spiti **(Aswal & Mehrotra, 1994)**, 6 spp. in Ladakh **(Kachroo *et al.,* 1977)**, 7 spp. in Kashmir Himalaya (**Dhar & Kachroo, 1983)** and 37 spp. in Uttarakhand **(Uniyal *et al.*, 2007)**.

Table 1.1: Systematic Position of the genus *Saxifraga* L. in different systems of classification

Bentham & Hooker (1862)	**Engler (1964)**	**Hutchinson (1973)**
Division – Phanerogams Class – Dicotyledons Subclass – Polypetalae Series – Calyciflorae Order – Rosales Family – Saxifragaceae Genus – *Saxifraga*	Division –Embryophyta Siphonogama Class – Dicotyledoneae Subclass – Archichlamydeae Order – Rosales Family – Saxifragaceae Genus - *Saxifraga*	Phylum – Angiospermae Subphylum – Dicotyledones Division – Herbaceae Order – Saxifragales Family – Saxifragaceae Genus - *Saxifraga*
Cronquist (1988)	**Thorne (2007)**	**Takhtajan (2009)**
Division – Magnoliophyta Class – Magnoliopsida Subclass – Rosidae Order – Rosales Family – Saxifragaceae Genus – *Saxifraga*	Class – Magnoliopsida Subclass – Magnoliidae Super Order- Rosanae Order – Saxifragales Family – Saxifragaceae Genus - *Saxifraga*	Phylum – Magnoliophyta Class – Magnoliopsida Subclass – Rosidae Order – Rosales Family – Saxifragaceae Genus –*Saxifraga*

APG III (2009)	Reveal (2012)	APG IV (2016)
Clade – Angiosperms Clade – Eudicots Clade – Core eudicots Order – Saxifragales Family – Saxifragaceae Genus – *Saxifraga*	Subclass – Magnoiidae Super Order – Saxifraganae Order – Saxifragales Family – Saxifragaceae Genus - *Saxifraga*	Clade – Angiosperms Clade – Eudicots Clade – Core eudicots Clade – Super Rosids Order – Saxifragales Family – Saxifragaceae Genus - *Saxifraga*
Shipunov (2016)	**Catalogue of life (www.catalogueoflife.org/col/)**	**Kubitzki (1990 onwards)**
Class – Angiospermae Subclass – Magnoiidae Order – Saxifragales Sub Order – Saxifragineae Family – Saxifragaceae Genus – *Saxifraga*	Kingdom – Plantae Phylum – Tracheophyta Class – Magnoliopsida Order – Saxifragales Family – Saxifragaceae Genus – *Saxifraga*	Division – Magnoliophyta Class – Dicotyledoneae Subclass – Eudicots Order – Saxifragales Family – Saxifragaceae Genus - *Saxifraga*

1.3.1 Economic Importance of the Genus *Saxifraga*

Horticultural uses: The most important economic use of the saxifrage plants is as ornamentals. These plants are grown in rock gardens, alpine gardens and as border ornamentals. The members of genus *Saxifraga* section *Porphyrion, Ligulatae, Saxifraga* and *Gymnopera* are the common ornamental plants cultivated worldwide. Some of the examples are *Saxifraga burseriana, S. andersonii* (section *Porphyrion), S. paniculata, S. callosa* (section *Ligulatae*), *S. hypnoides*, *S. trifurcate* (section *Saxifraga*) and London pride saxifrages (section *Gymnopera*). Numerous hybrids have also been developed **(SaxBase, 2016).** However in India, these plants are not as such used as ornamental plants, and are wild-grown mainly in the alpine Himalayan region.

Medicinal uses: Though the saxifrages are generally grown as ornamentals, only a few of the members are known for their medicinal values in some regions. In Japan, *Saxifraga oppositifolia* was used as herbal remedy, and is found to have anti-cancer activity due to the presence of quercitin. The plant is widely used for treating ear infection in the East and South-east Asian countries. *Saxifraga przewalskii* is used in

Tibet for curing ear infection **(Zhang, 2013).** *Saxifraga ligulata* is an ancient medicinal plant, known as 'Pashanabheda' in Sanskrit, mentioned for the first time in Charakasamhita (600 B.C.), used as a remedy for renal calculi, urinary troubles and diabetes. However this taxon is separated from *Saxifraga* genus as *Bergenia ligulata*. **(Goswami *et al.,* 2013)**

Cosmetic uses: Researches are going on for the use of the saxifrages in cosmetics. It was found that the plant extract can be used for artificial tanning of human skin **(Martin *et al.*, 2002)**, and can be used as a part of herbal composition helpful in maintaining or caring the skin around the eye **(Mitra *et al.*, 2010).**

1.4 Trichomes

Trichomes are fine epidermal outgrowths or appendages on the surface of a plant **(Simpson, 2010).** The word 'trichome' comes from a Greek word '*trikhoma*', meaning 'hair'. They may be unicellular or multicellular, branched or unbranched, and are either glandular, consisting of a stalk with a terminal glandular head, or non-glandular, consisting of elongated tapering end. The glandular trichomes secretes various kinds of secondary products – polysaccharides, sugars, mucilage, salts, essential oils, resins, gums, lipids, proteins, digestive enzymes, terpenes, phenolics, alkaloids etc. The trichomes may also be divided on the basis of the number of rows of constituent cells as uniseriate, biseriate, intermediate and multiseriate. They also differ in their shapes such as spiral, stellate, scaly, spiny, dendritic, rounded, flattened etc. **(Figure-1.3)**. A plant may have more than one type of trichome on its surface, on one or different locations. They are present on stem, petiole, pedicel, seed coat, floral parts, and surfaces of the leaf and along leaf margin, varying among different species. Trichomes may be persistent or they may senesce early. Basic and very useful information on structure, function and classification of plant trichomes was provided by **Metcalfe and Chalk (1950)** which later initiated many studies on trichomes.

1.4.1 Functions of trichomes

Protection from herbivores: It is one of the primary functions of trichomes. Trichomes provide protection against the herbivores. The walls of the trichomes may be cutinized, suberized, or lignified **(Peterson & Vermeer, 1984)**. There may be deposition of silica or calcium carbonate that makes them hard and abrasive. Dense

trichome cover hinders the movement of feeding insects through them. Certain glandular trichomes secrete toxic substances, or repellants to keep the feeders away. Trichomes of *Gossypium hirsutum* produce secretions that are anti-fungal and pesticidal in nature **(Mellon *et al.,* 2012).** Another special type of trichomes are 'stinging hairs', present in *Urtica* spp., that have a basal bulb with a tapering end terminating into a hook-like knob. When an animal comes in contact with this trichome, the knob breaks off and the sharp pointed end readily penetrates the animal skin releasing a toxic liquid inside its body. This causes an irritation and then skin surface swells **(http://www.daviddarling.info/encyclopedia/T/trichome.html).** Sometimes, trichomes of some plants produces some psychoactive chemicals which gives herbivores an upset stomach, hence keeping them away from the plant, like in *Datura stramonium, Papaver somniferum* etc. **(http://steephilllab.com/lets-talk-trichomes/).** In addition to the protection against herbivores and pathogens, trichomes also provide protection from extensive light, extreme temperatures and excessive water loss.

Reduce transpiration: Trichomes protect the plant surface from the action of wind and heat, and thus helps to reduce transpiration. **(http://indianapublicmedia.org/amomentofscience/plant-hair/)**

Protection from extreme temperature: Dense trichome cover reflects a larger amount of sunlight, protecting the underlying tissue in hot or cold, dry climate. It also protects them from the harmful ultraviolet radiations coming from the Sun. The dense cover of trichomes also maintains the temperature and moisture of the plant surface by trapping a boundary layer of air around it. **(http://www.daviddarling.info/encyclopedia/T/trichome.html).** Trichomes also insulate the plant surface by keeping the frost away from it. **(http://indianapublicmedia.org/amomentofscience/plant-hair/)**

Climbing: In some plants, trichomes help in climbing and adhering to a supporting surface. In goose-grass (*Gallium aparine*), hooked trichomes are present on the surface of the plant which helps to support the weak stem of the plant. **(Werker, 2000)**

Trapping prey: The insectivorous plants, like *Drosera* and *Drosophyllum,* having 'flypaper traps' consists of tentacle-shaped and capitate trichomes that secrete sticky mucilage, which helps to trap and digest the insect prey **(Voigt & Gorb, 2008).**

In pitcher plants, insects are lured in a 'pitfall trap' and cannot escape out because of the downward-pointing trichomes. In bladderworts (*Utricularia* spp.) and Venus' flytrap (*Dionaea muscipula*), sensory trichomes are found, which also helps in trapping the insect prey. **(http://www.botgard.ucla.edu/html/botanytextbooks/lifeforms/insectivorousplants/fulltextonly.html)**

Attracting pollinators: In some plants, trichomes produce odour by the secretion of terpenes and flavonoids and thus attracts pollinators. In *Aristolochia* spp. flowers, specialize trichomes underlining the perianth helps to trap pollinating insects. **(Oelschlägel *et al.*, 2009)**

Water absorption: In some Bromeliaceae such as *Tillandsia* and *Ananas comosus*, trichomes help to absorb moisture from the atmosphere. T-shaped trichomes in *Spartocytisus filipes* also suggests their importance in absorbing water. **(Werker, 2000)**

1.5 Leaf venation

Leaf venation refers to the pattern of veins and vein branching in a leaf **(Simpson, 2010).** Foliar veins and veinlets help to conduct water, minerals, hormones and food between the leaf and the stem, and within the leaf. They also provide mechanical support to the leaf. Different variations in leaf vein patterns in different plant species have been used in plant identification in palaeobotany. Even one of the main differences between monocots and dicots is the different type of vein pattern present in them, i.e. parallel and reticulate venation respectively, with a few exceptions. It is thus an important trait of a plant used in specifying and grouping plants **(Walls, 2011)**. Patterns of veins can be used as fingerprints to characterize plant taxa **(Corner, 1968)**. The most widely used and comprehensive classification of leaf venation was produced by **Hickey (1973, 1979)**. The Hickey classification was developed further in the Manual of leaf architecture **(Ellis *et al.*, 2009).**

1.6 Taxonomic Significance of Trichomes and Leaf Venation

Trichomes have been used quite often in resolving the systematic position of disputed taxa like *Nyctanthes* **(Inamdar, 1967)**. Some of the families like Malvaceae (stellate trichomes) can be readily identified by observing their trichomes only. Similarly, stinging trichomes are common in Urticaceae. However, trichomes are more

useful in differentiating infra familial taxa like genera or species. Trichomes are helpful in classifying genera as in Vicieae tribe of Fabaceae **(Shah & Kothari, 1975)**, identification of species in *Nicotiana* **(Goodspeed, 1954)**, and understanding advanced or primitive position of taxa as in Asteraceae where **Ramayya (1962, 1969)** demonstrated that Helianthae is a primitive tribe.

Study of trichome diversity of 213 species of the Saxifrages was attempted by **Gornall (1986),** though it included few species of the Himalaya. The diversity and distribution of trichomes in the genus was found useful in classification of this genus.

Leaf venation is another important taxonomic character utilized in plant taxonomy for differentiating dicot and monocot taxa. More recently, **Zhang (2013)**, for the first time, studied leaf venation of 156 *Saxifraga s.l.* species though it included few species from the Himalaya.

1.7. Objectives of the Study

At present following gaps in the information on the *Saxifraga s.l.* genus exists in the world literature:

1. No checklist of *Saxifraga* in Western Himalaya exists today.
2. Trichome diversity and distribution is not well studied in Western Himalaya.
3. Venation pattern of many Western Himalayan *Saxifraga* are not known.

Considering trichome diversity and variations in leaf venation within the genus *Saxifraga* and above mentioned lacuna in information, the present study entitled **"Studies on the Genus *Saxifraga* L. (Saxifragaceae) in Western Himalaya, India"** is conducted with following objectives:

- Preparation of checklist of *Saxifraga s.l.* genus in Western Himalaya.
- Study of trichomes of the plant specimens available in G.B. Pant University herbarium.
- Implication of trichome study in taxonomy of *Saxifraga* genus.
- Study of leaf venation of available plant specimens in G.B. Pant University herbarium.
- Implication of leaf venation in taxonomy of *Saxifraga* genus.

Review of Literature

The Indian Western Himalaya comprises the states of Jammu & Kashmir, Himachal Pradesh and Uttarakhand, following **Hooker (1906)** and **Rau (1975)**. However, **Balakrishnan (1996)** referred it as North-West Himalaya. It lies at the western end of Himalayan mountain chain and comprises of lofty mountain peaks in the northern side. Such high altitude areas in the Himalaya are suitable habitats for the species of *Saxifraga* L. This area is placed in Trans-Himalayan and the Himalayan Zones by **Rodgers & Panwar (1988)** and comprises of 4 biotic provinces - 1) Trans-Himalayan Mountains in the Western Ladakh and North-western Himachal Pradesh, 2) Eastern plateau of Ladakh covering Changthang and Spiti, 3) North-west Himalaya west of Satluj, 4) Western Himalaya between Satluj and Sharada in Uttarakhand. This area is mainly a hilly terrain and well botanized.

2.1 Botanical Explorations

Botanical explorations in this part of the Himalaya were carried out by the European botanists first and Thomas Hardwicke is credited to be the first person as a plant collector in Western Himalaya who collected plants as early as 1796 (**Burkill, 1965**). He collected plants from the Alaknanda valley. Later, J.D. Hooker, H. Collett, V. Jacquemont, J.E. Winterbottom, G.T. Vigne, Baron von Huegel, H. Falconer, J.F. Royle, C.B. Clarke, J.F. Duthie, W. Moorcroft, Schlagintweit brothers, J.L. Stewart, H. Strachey, R. Strachey, T. Thomson etc. also made notable plant collections in different parts of the Western Himalaya. After the end of 19th century, Keshavananda, W. Koelz, Rupchand Thakur, U.N. Kanjilal, R.N. Parker, N.L. Bor, R.R. Stewart, S.P. Sethi, M.V. Laurie, G.S. Puri, C.R. Brown and M.B. Raizada etc. made collections from remote areas of Western Himalaya. Later, in the second half of 20th century botanists like M.A. Rau, T.A. Rao, N.C. Nair, U.C. Bhattacharyya, A.S. Rao, B.M. Wadhwa, J.N. Vohra, P.K. Hajra, M.Vishwanathan, H.J. Chowdhery, J.R. Sharma, S.K. Murti, P.C. Pant, B.D. Naithani, B.P. Uniyal, P.K.Pusalkar and many others collected plants from this region (**Uniyal *et al*., 2007**). A brief botanical history of different parts of Western Himalaya is given below:

2.1.1 Jammu & Kashmir

Jammu & Kashmir was first botanized by Victor Jacquemontin 1831. His collections were later published by Cambessedes & Decaisne in 1844. Jacquemont was followed by G.T. Vigne, Carl von Huegel, H. Falconer, J.E. Winterbottom, Thomas Thomson, William Munew, J.H.Lance, Schlagintweit, J.L. Stewart, Henderson & Hume, C.B. Clarke, J.E.T. Aitchison and D. Brandis, J.F. Duthie and R.R. Stewart. Prominent plant collectors from the post-independent era included R.N. Chopra, R.L. Badhwar, L.D. Kapur, M.L. Dhar, Y.K. Sarin, B.K. Kapathi, T.N. Srivastava, A.K. Kaul, B.M. Sharma, P. Kachroo, Uppeandra Dhar, B.L. Sapru, A. Navchoo, A.R. Oleg Polunin, K.M. van Joest, M.K. Wali, S.N. Tiku etc. **(Singh *et al.*, 2002).**

Royle (1839) in his illustrative book mentioned large number of plants from Kashmir including few species of *Saxifraga*. **Duthie (1893-94)** published the account of Kashmir flora and collected large number of plants from this area. Based on his collections and the collections of his local collectors two new species of *Saxifraga* namely, *Saxifraga lilacina* Duthie and *Saxifraga duthiei* Gand. were published. **Coventry (1923-30)** and **Blatter (1927)** were the noteworthy illustrative contributions to the flora of Kashmir wherein authors also mentioned few species of *Saxifraga*. A comparatively species rich catalogue of *Saxifraga* was included in the document of **Rau (1975)** in which he listed 35 species from entire Northwest Himalaya showing presence of 17 species in Jammu and Kashmir. One of the important documents for the high altitude flora of Kashmir was published by **Dhar & Kachroo (1983)** under the title "*Alpine Flora of Kashmir*'. In this flora authors listed six species of *Saxifraga,* including one new species *Saxifraga kashmiriana* Dhar & Kachroo from Poshpatri alpine (3900m) locality.

Ladakh is a cold desert in the state of Jammu & Kashmir and situated in the elevation range of 2900-5900 m above sea level. This region sustains sparse vegetation due to very low rainfall and its extreme climatic conditions. The first flora of Ladakh was compiled by **Stewart (1869)**, enumerating flowering plants and describing physical features of the region. Later he published another important document on flora of Ladakh in second decade of 20th century (**Stewart, 1916-17**). A more detailed document on plants of Ladakh was published by **(Kachroo *et al.,* 1977)** as '*Flora of Ladakh*' in which authors described 07 species of *Saxifraga*. Recently, **Klimes &**

Dickore have published "Flora of Ladakh (NW Himalaya) - A Preliminary Checklist" on the web (available at **http://www.butbn.cas.cz/klimes/desert.html**) which indicates presence of 18 species of *Saxifraga* in Ladakh.

2.1.2 Himachal Pradesh

Himachal Pradesh is located between Jammu & Kashmir and Uttarakhand in Western Himalaya. The pioneer plant collectors from this region were Royle, Brandis and Parker. **Burkill (1908)** gave an account of the spring flora of Shimla hills **Collett (1903)** published '*Flora Simlensis'* and described *Saxifraga brunoniana*, *S. diversifolia* and *S. filicaulis* from the area. Different collectors have collected plants from different parts of Himachal Pradesh and some of the important ones are - Jain & Bharadwaj, Nair & Pant, Bir, Maheshwari, Khullar in first three quarters of 20th century **(Chowdherry & Wadhwa, 1984)**. In the fourth quarter of 20th century and later few district floras and checklists have been published for Himachal Pradesh. **Nair (1977)** published the '*Flora of Bushahr Himalaya*" in which he listed six species (*Saxifraga brunoniana, S. diversifolia, S. filicaulis, S. jacquemontiana, S. moorcroftiana* and *S. sibirica*) from the area. A checklist of flowering plants of Himachal Pradesh is available and published by **Chowdhery & Wadhwa (1984)** under the title '*Flora of Himachal Pradesh Analysis*' in which authors have listed 19 species (*S. brunonis, S. cernua, S. corymbosa, S. diversifolia, S. filicaulis, S. fimbriata, S. flagellaris, S. hirculus, S. jacquemontiana, S. lychnitis, S. moorcroftiana, S. odontophylla, S. nutans, S. pallida, S. parnassifolia, S. pseudo-pallida, S. pulvinaria, S. sibirica* and *S. stella-aurea*) of *Saxifraga*. Lahaul-Spiti area of Himachal Pradesh is an arid area resembling to Ladakh. '*Flora of Lahaul-Spiti*' was published by **Aswal & Mehrotra (1994)** and the authors have described 13 species (*S. asarifolia, S. brachypoda, S. brunonis, S. cernua, S. flagellaris, S. hirculus, S. jacquemontiana, S. moorcroftiana, S. pallida, S. parnassifolia, S. pseudo-pallida, S. pulvinaria* and *S. sibirica*) from this arid zone. **Dhaliwal & Sharma (1999)** have published the '*Flora of Kullu District (Himachal Pradesh)*' in which authors have described only two species of *Saxifraga* (*S. brunonis, S. diversifolia*) from the district. Himachal Pradesh also hosts few national parks and sanctuaries where large number of flowering plants can be assumed growing. **Singh & Rawat (2000)** have published '*Flora of Great Himalayan National Park Himachal Pradesh*' wherein authors have enlisted eight species (*S. brunonis, S. ciliata,*

S. diversifolia, S. filicaulis, S. jacquemontiana, S. moorcroftiana, S. sibirica and *S. stenophylla*) of *Saxifraga*. Similarly, **Chandrasekar & Srivastava (2009)** have worked out the flora of Pin Valley National Park in Himachal Pradesh and have listed few species of *Saxifraga* from the area. **Kaur & Sharma (2004)** in '*Flora of Sirmaur District (Himachal Pradesh)*' described only one species (*Saxifraga diversifolia*) from this district. Interestingly, '*Flora of Chamba District (Himachal Pradesh)*' by **Singh & Sharma (2006)** cover elevation range up to 4200m but no species of *Saxifraga* was described from the district. **Chawla *et al.* (2012)** have listed 869 species of angiosperms from Kinnaur district of Himachal Pradesh which includes only three species of *Saxifraga* (*S. diversifolia, S. jacquemontiana, S. parnassifolia*) despite of the fact that the study area reaches beyond 5000m.

2.1.3 Uttarakhand

Uttarakhand constitutes the easternmost part of the Indian Western Himalaya and share its borders with Himachal Pradesh on the west, Uttar Pradesh in south, Nepal in the east and China in north. Thomas Hardwick in 1796 AD was the earliest plant collector in this part of the Himalaya and he explored the flora in Alaknanda valley (**Burkill, 1965**). Afterwards, William Spencer Webb explored Yamunotri and the Himalayas west of the river Kali. William Moorcroft explored the interiors of the mountains, Edward Madden explored Pindari Glacier, George William Trail and A.D. Linday explored some parts of Uttarakhand, Hugh Falconer made a significant collection from the whole countryside up to the Niti Pass (**Uniyal *et al.*, 2007**). Richard Strachey and J.E. Winterbottom also botanized Uttarakhand. They made excellent collections in 1846-49 during their expedition to Mansarovar and Rakshas Tal (Tibet) area via Niti Pass which started from foothills of Kumaon. In this expedition they accumulated the plants and this collection was widely referred as "Strachey and Winterbottom Herbarium" (**Duthie, 1906**). This collection was one of the best collections on the flora of Himalayas and it included many species of *Saxifraga*. Based on this collection and the plants later collected by J.F. Duthie the well-known '*Catalogue of the Plants of Kumaon and of the adjacent portions of Garhwal & Tibet'* was published by **Duthie (1906).** It this catalogue nearly 27 species of *Saxifraga* collected in the elevation range of 7000-17000 ft above sea level from moist and dry areas were listed. Some of the species like *Saxifraga hemisphaerica*, *Saxifraga*

lycopodioides and *Saxifraga stolitzkae* were never recollected from Uttarakhand after that collection. **J.F. Duthie (1903-29)** published '*Flora of Upper Gangetic Plain and of the adjacent Siwalik and sub-Himalayan Tracts*' but since the flora covered indo-gangetic plains and few Siwalik Hills no *Saxifraga* species were described in the document. Similarly, **A.E. Osmaston (1927)** wrote '*Forest Flora of Kumaon*' devoid of any species of *Saxifraga*. The English mountaineer **Frank S. Smythe** visited the Valley of Flowers in Chamoli district in the years 1931 and 1938 and wrote the book '*The Valley of Flowers*' (**1938**) in which he also listed flora of the valley including six species of *Saxifraga* (*S. cernua, S. hirculus, S. diversifolia, S. jacquemontiana, S. fimbriata* and *S. flagellaris*).

In 20th century some important plant collectors of Uttarakhand were K.C. Sahni, Sinha, Gupta, A.C. Dey, M.R. Uniyal, V. Shankar, F.S. Smythe, M.A. Rau, M.B. Raizada, Saxena, T.A. Rao, N.C. Nair, U.C. Bhattacharyya, C.M. Arora, P.K. Hajra, P.C. Pant, A. S. Rao, B.D. Naithani, M.V. Viswanathan, B.V. Shetty, B.P. Uniyal, J.R. Sharma, B.S. Aswal, A.K. Goel, Neelam Ghildiyal, Sunita Garg, Bipin Balodi, D.K. Singh, S.K. Murti, J.N. Vohra, R.R. Rao, Surendra Singh, C.R. Babu, Khanna, Som Deva, H.B. Naithani, G.S Rawat, Prashant K. Pusalkar, R.D. Gaur etc. (**Uniyal *et al.*, 2007**).

One of the important floras of plants of Kumaon was published by **Gupta (1968)** under the title '*Flora Nainitalensis*' in which the author mentioned only one species *Saxifraga diversifolia* of the genus *Saxifraga*. **Raizada & Saxena (1978)** published '*Flora of Mussoorie volume 1*' and listed only one species of *Saxifraga* (*S. parnassifolia*) in the area. Some of the district floras of Uttarakhand are available. **Naithani (1984)** published '*Flora of Chamoli*' and described 14 species of *Saxifraga* (*Saxifraga asarifolia, S. brachypoda, S. brachypoda var. fimbriata, S. brunonis, S. diversifolia, S. filicaulis, S. granulifera, S. hirculus, S. hispidula, S. jacquemontiana, S. pallida, S. parnassifolia, S. pulvinaria* and *S. stenophylla*) from the district. **Semwal (1981, 84)** listed six species (*S. brachypoda* var. *fimbriata, S. brunoniana, S. diversifolia* var. *parnassifolia, S. filicaulis, S. hispidula, S. pallida*) in Tungnath area and four species of *Saxifraga* (*S. brachypoda* var. *fimbriata, S. brunoniana, S. diversifolia, S. pallida*) in Kedarnath area of Rudraprayag district. **Gaur *et al.* (1995)**

listed flowering plants of Kuari Pass-Dalisera alpine zones and mentioned presence of eight species of *Saxifraga* (*S. asarifolia*, *S. brachypoda, S. diversifolia, S. filicaulis, S. hispidula, S. jacquemontiana, S. parnassifolia, S. roylei*) in the area. One of the exhaustive district floras in Uttarakhand was published by **Gaur (1999)** under the title '*Flora of District Garhwal North West Himalaya (with ethnobotanical notes)*' describing 2035 species in the elevation range of 300- 3000m above sea level. Since the flora area was low and mid altitude only one species *Saxifraga diversifolia* of the genus *Saxifraga* was described in it. **Uniyal *et al.* (2007)** compiled the checklist of flowering plants of Uttarakhand in which the authors listed 36 species of *Saxifraga* in Uttarakhand. More recently, **Gornall *et al.* (2012)** described a new species of *Saxifraga* (*Saxifraga minutissima* D.S. Rawat) from Kedarnath area of Uttarakhand. **Pusalkar & Singh (2012)** have published a well-illustrated '*Flora of Gangotri National Park Western Himalaya, India*' in which authors have described 17 species of *Saxifraga* within the boundaries of the park. More recently, **Pusalkar & Singh (2013)** reported *Saxifraga lepida* as a new record to flora of Uttarakhand and West Himalaya.

2.2 Diversity of *Saxifraga* L.

Saxifraga is the largest genus in the family Saxifragaceae with species number reported from 440 to 500 and this large number of species accounts for nearly two third of the total species number in the family Saxifragaceae (**Zhmylev, 2004**). The total number of species of *Saxifraga* genus in the world varies with different sources, i.e. 450 spp. (**Pan *et al.*, 2001; The Plant List, 2013**), 480 spp. **(http://www.saxifraga.org/)**, 370 spp. **(http://www.tropicos.org/Name/)**, 460 spp. (**Akiyama & Gornall, 2012; Zhang, 2013**), 390 spp. (**Brouillet & Elvander, 2009**) and 440 species (**Mabberly, 2008**). The diversity of *Saxifraga* in the world and different areas is also shown in the **table-2.1**.

Saxifraga L. *s.l.* is distributed in temperate and alpine zones of high mountains in Europe, Asia, North and South America with few species occurring as far south as Tierra del Fuego (**Zhang, 2013**). Within this wide spread distribution two main centers of diversity are Europe with about half of the total diversity of the world and another half exists in Sino-Himalayan region (**Pan *et al.*, 2001**). In flora of China **Pan *et al.***

(2001) have given the account of *Saxifraga* which indicates presence of 216 species with 139 species being endemic to China. **Clarke (1878)** in Hooker's '*Flora of British India*' described 32 species of *Saxifraga* under 8 sections. Two most important accounts of *Saxifraga* in the Himalaya were written by **Smith (1958, 1960)** and in these two documents he described 57 new species from the Himalaya and Tibet. The Indian Himalayan region adjacent to China sustains a considerable number of *Saxifraga* being 64 species, 4 subspecies and 5 varieties **(Agnihotri & Husain, 2013).** These species are mainly distributed in the sub-alpine and alpine zones of the Himalaya. Nearly 30% (19 taxa) of the total *Saxifraga* species are endemic with 23 species confined to Western Himalaya and 17 species confined to Eastern Himalaya. Sikkim has the highest species richness (61%) including two endemic species, followed by Uttarakhand (37 species). The richest elevation range for *Saxifraga* is 4000-4500m above sea level where most of the species can be seen growing. In the Eastern Himalayan region Bhutan-Sikkim is another area enriched with *Saxifraga* species and **Grierson (1987)** have reported 75 species in the area which is even higher than the entire Indian Himalayan region. Nepal Himalaya in central part of the Himalayan mountain chain is also a rich area for alpine dwelling *Saxifraga* species and **Akiyama & Gornall (2011)** have reported 91 species from the area. Westward to Nepal, Uttarakhand is a small state of Indian republic and sustain 37 species of *Saxifraga* (**Uniyal *et al*., 2007**) including one endemic species. Similarly, Himachal Pradesh hosts 21 species (**Chowdhery & Wadhwa, 1984**), Lahaul-Spiti 13 species (**Aswal & Mehrotra, 1994**), Ladakh 18 species **(http://www.butbn.cas.cz/klimes/desert.html)** and Kashmir Valley ca. 7 species (**Dhar & Kachroo, 1983**). Westward to Kashmir **Ghazanfar (1977)** enumerated 19 species in Pakistan.

Beyond the political boundaries in the Himalayan zone and adjacent area it seems that the number of species richness reduces from eastern side to western side. Accordingly, the number of species of *Saxifraga* decreases from Nepal to Kashmir in Western Himalaya and further westward to Pakistan and Iran, being 91 species in Nepal (**Akiyama & Gornall, 2011)**, 37 species in Uttarakhand (**Uniyal *et al.,* 2007**), 21 species in Himachal Pradesh (**Chowdherry & Wadhwa, 1984)** and 7 species in Kashmir **(Dhar & Kachroo, 1983)** 19 species in Pakistan **(Ghazanfar, 1977)** and only 10 species in Iran (**Aghaahmadi *et al.,* 2014**).

Table 2.1: Diversity of the genus *Saxifraga* in the world and in Sino-Himalayan Region

Region	Species No.	Reference
World	450	**The Plant List (2013)**
World	440	**Mabberly (2008)**
Europe	123	**Tutin *et al.* (1964)**
North America	28	**Brouillet & Elvander (2009)**
China	216	**Pan *et al.* (2001)**
Pakistan	19	**Ghazanfar (1977)**
Nepal	91	**Akiyama & Gornall (2011)**
Bhutan	62	**Grierson (1987)**
Sikkim	54	**Grierson (1987)**
Central and Western Himalaya	86	**Polunin & Stainton (1985)**
Indian Himalayan Region	64	**Agnihotri & Husain (2013)**
West Himalaya	35	**Rau (1975)**
Uttarakhand	37	**Uniyal *et al.*(2007)**
Himachal Pradesh	21	**Chowdhery & Wadhwa (1984)**
Lahaul-Spiti	13	**Aswal & Mehrotra (1994)**
Kashmir	7	**Dhar & Kachroo (1983)**
Ladakh	18	**http://www.butbn.cas.cz/klimes/desert.html**

2.3 *Saxifraga* taxonomy

The great morphological differences among different species in *Saxifraga* genus gave rise to different lines of evolutions and consequent infra-generic classification of the genus. Initially, the classifications were provided based on the morphology and anatomy of the genus. But later, cladistic analyses involving many

different types of characters were also used for the subgeneric classification of *Saxifraga*. **Haworth (1803)** firstly divided the *Saxifraga* genus into 6 sections namely, *Ciliatae, Irregulares, Ligulatae, Lobatae, Nudicaules* and *Stoloniferae*. Later, **Haworth (1812)** further increased the number of sections to 10 by adding 4 new sections namely, *Micranthes, Miscopetalum, Robertsonia,* and *Saxifraga*. In his third revision **Haworth (1821)** splitted *Saxifraga s.l.* genus into 17 separate genera and distributed 117 species known at that time to these genera but it didn't lasted long as **Sternberg (1822, 31)** and **Tausch (1823)** reduced the 17 Haworth's genera to 17 sections within single genus *Saxifraga*.

Don (1822) in his monograph on *Saxifraga* genus identified only 5 sections (*Bergenia, Gymnopera, Leiogyne, Micranthes* and *Saxifraga*) in the genus while **Seringe (1830)** segregated 150 species of *Saxifraga* genus into 8 sections. Until mid-1900s a majority of the Sino-Himalayan species of *Saxifraga* were not known. These species were described and afterwards included in the infra-generic classification of *Saxifraga* genus by **Engler & Irmscher (1916/19)**.

Engler & Irmscher (1916/19) provided a detailed account of 302 species of *Saxifraga* genus and subdivided the genus into 15 sections (*Boraphila, Cymbalaria, Dactyloides, Diptera, Euaizoonia, Hirculus, Kabschia, Miscopetalum, Nephrophyllum, Porphyrion, Robertsonia, Tetrameridium, Trachyphyllum, Tridactylites* and *Xanthizoon*) and further into subsections and 'greges' (equivalent to present series). They also studied a number of hybrids belonging to the same genus and justified the classification of *Saxifraga* by providing a broad range of taxonomic evidences. Their classification was the most exhaustive system of infra-generic classification though it was mainly based on the morphological features of leaf, flower, and seed, anatomy of trichomes and modes of vegetative reproduction.

Gornall (1987) provided a revised classification of *Saxifraga* genus which was an upgradation of Engler and Irmscher's system. He classified the genus into 15 sections, 19 subsections and 34 series. He accounted for 394 species and divided the genus *Saxifraga* into 15 sections (*Ciliatae, Cotyle, Cymbalaria, Gymnopera, Heterisia, Irregulares, Ligulatae, Merkianae, Mesogyne, Micranthes, Odontophyllae, Porphyrion, Saxifraga, Trachyphyllum* and *Xanthizoon*). Among these sections, *Ciliatae* is the largest section consisting of 179 species.

More recently, **Zhang (2013)** have partially modified the classification of *Saxifraga* genus as proposed by **Gornall (1987)**. She classified the genus into following 12 sections:

1. Sect. ***Heterisia*** (Raf. ex Small) A.M.Johnson
2. Sect. ***Irregulares*** Haw.
3. Sect. ***Saxifragella*** (Engler) Gornall & Zhang
4. Sect. ***Trachyphyllum*** (Gaud) W.D.K. Koch
5. Sect. ***Ciliatae*** Haw. [further divided into Subsections - ***Gemmiparae*** Engler & Irmsch.; ***Flagellares*** (C.B.Clarke) Engl. & Irmsch.; ***Hirculoides*** Engl. & Irmsch.; ***Rosulares*** Gornall; ***Hemisphaericae*** (Engl. & Irmsch.) Gornall]
6. Sect. ***Cymbalaria*** Grisebach
7. Sect. ***Saxifraga*** [further divided into Subsections - ***Saxifraga*** and ***Tridactylites*** (Haw.) Gornall]
8. Sect. ***Cotylea*** Tausch
9. Sect. ***Mesogyne*** Sternb.
10. Sect. ***Gymnopera*** D.Don
11. Sect. ***Ligulatae*** Haw.
12. Sect. ***Porphyrion*** Tausch [further divided into Subsections - ***Oppositifolae*** Hayek; ***Florulentae*** (Engl. & Irmsch.) Gornall; ***Engleriana*** (Sundermann) Gornall; ***Kabschia*** (Engl.)]

Modern molecular studies have also helped in improving the sub-generic classification of *Saxifraga*. **Soltis *et al.* (1996)** phylogenetically analyzed *matK* and *rbcL* DNA sequences in different species of genus *Saxifraga* and concluded that *Saxifraga* L. genus as a polyphyletic taxon. **Soltis *et al.* (2001b)**, with the help of a six gene analysis, thus suggested that to make *Saxifraga* genus monophyletic *Micranthes* must be segregated from the genus and must be treated as a separate genus. He also suggested the treatment of monospecific *Cascadia* as another genus. According to **Webb & Gornall (1989),** differences in their morphological characters also suggested

segregation of *Micranthes* from *Saxifraga*. **Soltis *et al.* (2001a)** also suggested the incorporation of genus *Saxifragella* into *Saxifraga* genus.

Most recently, **Tkach *et al.* (2015)** have studied about 245 species of the genus *Saxifraga s.s.* (*Saxifraga* excluding sect. *Micranthes*) representing all sections, subsections of previous classifications. They derived a phylogenetic tree of species based on plastid *turnL-turnF* DNA markers and nuclear ribosomal internal transcribed spacer (ITS). Their phylogenetic tree suggested at least 13 sections and 9 subsections within the genus. Their scheme of infrageneric classification of *Saxifraga* is summarized below:

1. Section ***Irregulares*** Haw.
2. Section ***Saxifragella*** (Engl.) Gornall & Zhou-Xin Zhang
3. Section ***Pseudocymbalaria*** Zhmylev
4. Section ***Bronchiales*** DeChaine
5. Section ***Ciliatae*** Haw.
6. Section ***Cymbalaria*** Griseb.
7. Section ***Cotylea*** Tausch
8. Section ***Gymnopera*** D.Don
9. Section ***Mesogyne*** Sternb.
10. Section ***Trachyphyllum*** (Gaudin) W.D.J. Koch
11. Section ***Ligulatae*** Haw.
12. Section ***Porphyrion*** Tausch
    a. Subsection ***Squarrosae*** (Engl.& Irmsch.) Tkach, Röser & M.H. Hoffm.
    b. Subsection ***Mutatae*** (Engl. & Irmsch.) Gornall
    c. Subsection ***Oppositifoliae*** Hayek
    d. Subsection ***Florulentae*** (Engl. & Irmsch.) Gornall
    e. Subsection ***Kabschia*** (Engl.) Rouy & Camus

13. Section ***Saxifraga***

    a. Subsection ***Tridactylites*** (Haw.) Gornall

    b. Subsection ***Androsaceae*** (Engl. & Irmsch.) Tkach, Röser & M.H. Hoffm.

    c. Subsection ***Arachnoideae*** (Engl. & Irmsch.) Tkach, Röser & M.H. Hoffm.

    d. Subsection ***Saxifraga***

However, **Tkach *et al.* (2015)** were not able to study any representative of the section ***Odontophyllae*** Gornall (*S. odontophylla*) and section ***Porphyrion*** subsection ***Oppositifoliae*** (*S. nana* and related species). Consequently, their position in this infrageneric classification was mentioned as ***Incertae sedis.***

2.4 Trichome Study in *Saxifraga*

Grenier (1848) firstly applied the trichome study of the genus for taxonomic purpose, and recognized two types: articulated (glandular) and non-articulated (non-glandular). **Engler (1869)** recognized two other types: multiseriate and uniseriate. He stated that trichome type was constant within a section and thus is of taxonomic importance, but he didn't take this character into consideration completely. However, **Johnson (1923)** and **Huber (1963)** used trichome anatomy in their accounts of several groups of North American and European *Saxifraga* species, respectively. They both also believed that species under one section had same trichome type. Later, **Moreau (1976)** investigated trichome anatomy of 18 *Saxifraga* species (from 14 Engler & Irmscher's sections) and supported the Huber's generalization.

Gornall (1986) conducted a detailed study of trichomes on leaves and pedicels in 213 species of the genera *Saxifraga*, *Zahlbrucknera, Saxifragella, Saxifragodes,* and *Saxifragosis*. He concluded that trichome structure agree with the sectional classification. He found mainly following four types of trichomes in the genus *Saxifraga*:

1. Multiseriate glandular type (occurring in 4 series of *Saxifraga* sect. *Micranthes*, part of sect. *Gymnopera*, and in sects. *Ciliatae*, *Trachyphyllum, Xanthizoon, Ligulatae, Porophyllum, Porphyrion* and *Irregulares*)

2. Uniseriate glandular type (occuring in 5 series of *Saxifraga* sect. *Micranthes,* part of sects. *Gymnopera* and *Irregulares*, and in sects. *Miscopetalum, Cymbalaria, Tridactylites, Saxifraga* and *Stoloniferae*)
3. Eglandular multicellular type (occurring in sects. *Xanthizoon, Porophyllum* and *Porphyrion,* occasionally in sects. *Micranthes, Gymnopera*, *Ciliatae* and *Ligulatae*)
4. Sessile glandular type (occurring in some species of sect. *Stoloniferae*).

Despite of the exhaustive study of **Gornall (1986)**, many *Saxifraga* species of the Western Himalaya are yet to be studied for trichome types, leaf venation and stomata. Later, **Al-Shammary & Gornall (1994)** also studied trichomes of 25 Saxifragaceae genera from southern hemisphere and found following types of trichomes:

1. Multiseriate with a glandular head type
2. Uniseriate with a glandular head type
3. Uniseriate eglandular type
4. Unicellular eglandular type

2.5 Leaf venation study in *Saxifraga*

Leaf venation in *Saxifraga* was little studied till the start of 21st century. The earliest reference of leaf venation study is of **Galloe (1910)** who provided an account of ten arctic *Saxifraga* species. Later, **Watari (1939)** studied vascular anatomy of the leaves of Saxifragaceae which included eleven species of *Saxifraga*. At the start of 21st century **Fuller & Hickey (2005)** also studied venation of two species of *Saxifraga* as out group while making their studies in Gunneraceae.

The leaf vein patterns in the genus *Saxifraga* have been studied by **Zhang (2013)** and she found mainly 3 types of leaf venation: acrodomous, actinodromous and camptodromous. She further concluded that species of sects. *Cotylea, Mesogyne, Irregulares*, *Heterisia* and *Saxifraga* (except subsect. *Holophyllae*) have actinodromous venation, that of sects. *Ciliatae, Trachyphyllum* and *Saxifraga* subsect. *Holophyllae* have acrodromous venation, and that of sect. *Ligulatae, Xanthizoon, Porphyrion* and

Gymnopera have camptodromous venation. She also recorded occurrence of dark stained vascular cells and foliar sclereids in some sections (species from sect. *Porphyrion* subsect. *Engleria* and few from subsect. *Kabschia*, and in some species from sect. *Saxifraga* subsect. *Triplinervium*). Her studies led to a pattern of evolutionary trend in leaf venation in the genus, and also to the fact that the distribution and diversity of different types of leaf venation in the genus are of systematic importance for the infrageneric classification of the genus.

Recently, **Zhang *et al.* (2015)** have reported leaf venation patterns in 150 species of *Saxifraga* representing 13 sections of the genus. Three main types of venation patterns in the genus were reported as acrodromous, camptodromous and palinactinodromous. The authors also conclude that palinactinodromous type of venation may be the ancestral venation in *Saxifraga*.

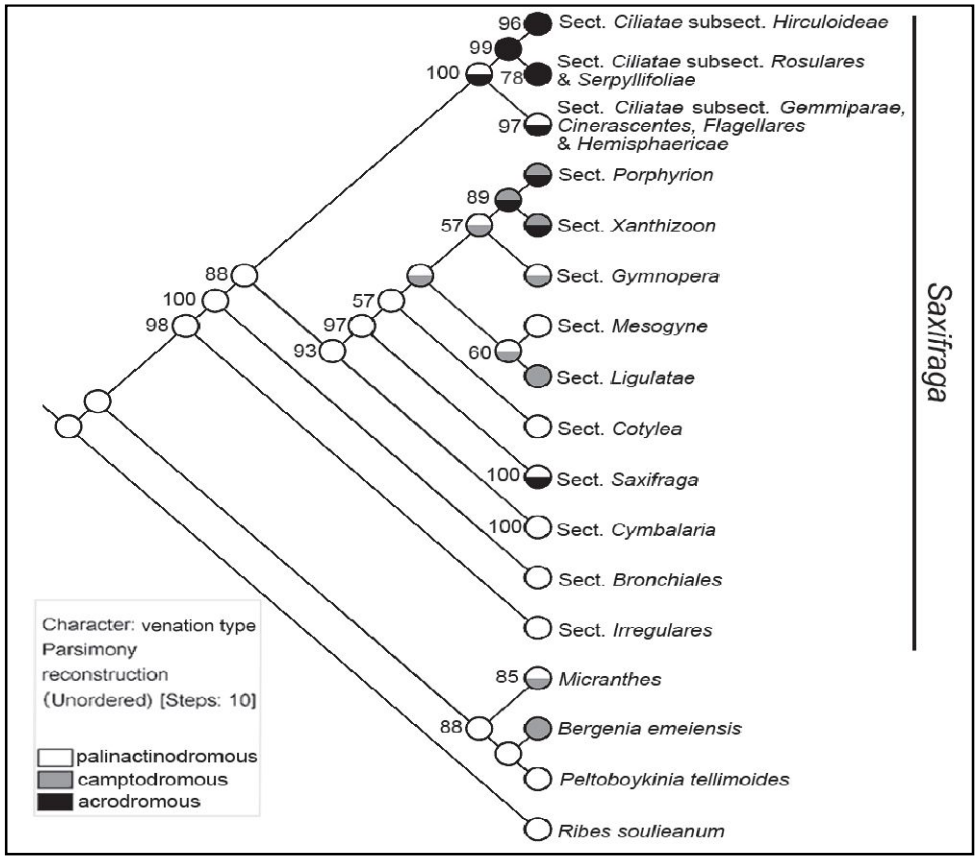


Figure 2.1: Representation of venation type on a phylogenetic tree of *Saxifraga* based on *psb*A - *trn*H, *trn*L-F, and ITS sequence (retrieved from Zhang *et al.* 2015)

The review of literature indicates that despite of large number of floras and floristic reports for Western Himalaya a complete checklist of the species of *Saxifraga* is yet not available. Similarly, even after the detailed studies of **Zhang (2013)** and **Zhang *et al.* (2015)** many Himalayan species of *Saxifraga* are yet not studied for their trichomes and leaf venation. An attempt has been made to study some of these species in the present work.

Materials & Methods

3.1 Study Area

The Himalayan mountain range was formed around 50 million years ago after a collision between Indian tectonic plate and Eurasian plate, making them one of the youngest and tallest mountain ranges in the world **(www.geolsoc.org.uk)**. The mountain-building process is still ongoingin this part of the Asia and the earthquake tremors felt in the area reminds it again and again. Extending for about 2500 km from east to west, the Himalayan Arc separates Tibetan Plateau from Indo-Gangetic Plain. India, Nepal and Bhutan covers the major part of the Himalayas and some smaller parts are under the political boundaries of Pakistan and China. The Indian Himalayan Region is extended over 10 Indian states (west to east- Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Tripura) and hill regions of Assam and West Bengal **(http://gbpihedenvis.nic.in/)**. **Singh & Singh (1987)** recognized three major botanical regions in the Himalayan arc, viz., the Western, the Central and Eastern Himalaya.

The study area of the present work is the land area covered by the Western Himalayas within the political boundaries of India (**Map-3.1**). The Western Himalayas is mainly comprised of three Indian states – Jammu & Kashmir, Himachal Pradesh and Uttarakhand, extending at latitudinal range of $28^0$43'N-$37^0$05'N and at longitudinal range of $72^0$02'E-$81^0$02'E **(Sidhu & Surya, 2014)**. **Hooker (1906)** and **Rau (1975)** also used the same term for this region. However, **Balakrishnan (1996)** while describing phytogeographical regions of India referred it as North-West Himalaya. This area is placed in Trans-Himalayan and the Himalayan Zones by **Rodgers & Panwar (1988)** and comprises of 4 biotic provinces- 1) Trans-Himalayan Mountains in the Western Ladakh and North-western Himachal Pradesh, 2) Eastern plateau of Ladakh covering Changthang and Spiti, 3) North-west Himalaya west of Satluj, 4) Western Himalaya between Satluj and Sharada in Uttarakhand. It covers a geographical area of about 62.10% of the total Indian Himalayan Region (Jammu & Kashmir – 41.65%,

Himachal Pradesh – 10.43%, Uttarakhand, 10.02%) **(http://gbpihedenvis.nic.in/ him_states.htm)**.

Covering a geographical area of 331,392 km^2 **(http://gbpihedenvis.nic.in/ him_states.htm)**, the Western Himalaya is featured with great mountain peaks, precipitous slopes, gorges, glaciers, rivers, great river valleys, innumerable lakes, exotic flora and fauna etc. Siachen, Pindari, Gangotri, Milam, Ralam and Panchchuli are some important glaciers found in this region. Some important valleys are Kashmir valley, Bhadarwah valley (in Jammu & Kashmir), Kangra and Kulu valley (in Himachal Pradesh), Doon valley, Bhagirathi valley and Mandakini valley (in Uttarakhand). The major rivers belonging to the western Himalayan region includes Indus, Chenab, Satluj, Ravi, Beas, Ganga, Yamuna, Saraju and Kali.Average annual rainfall in parts of Western Himalaya varies between 100-1900 mm (Ladakh – 103 mm, Dehradun – 1896 mm) **(http://en.climate-data.org/)**. The climate ranges from cold arid type to temperate to subtropical type. Average temperature can be as low as less than 0^0C to 25^0C **(www.mapsofindia.com)**.

The topography of Western Himalayan region is irregular or rugged, intercepted by valleys and plateaus, and thus the stratification is not clear. There is also a great diversity in the floristic pattern due to great altitudinal variation, coupled with rainfall factor which become lesser and lesser from east to west. The vegetation of the alpine heights is influenced by various climatic factors like rainfall, humidity, ultraviolet radiation, temperature and winter precipitation apart from the topographical considerations like the direction and steepness of the slopes, exposure etc. **Nayar (1996)** considered 'Western Himalayas' as one of the 3 megacentres of endemic plants in India. **Hajra & Vohra (1996)** divided Western Himalayan vegetation into the following types and subtypes, based on the altitude and climate:

1. Subtropical semi-desert type or Artemisia steppe type
2. Tropical forests:
    (i) Scrub forests
    (ii) Deciduous forests

(iii) Tree savannah forests

(iv) Swamp forests

3. Subtropical forests:

   (i) Broad-leaved forests

   (ii) Pine forests

   (iii) Subtropical evergreen sclerophyllous forests

4. Temperate forests:

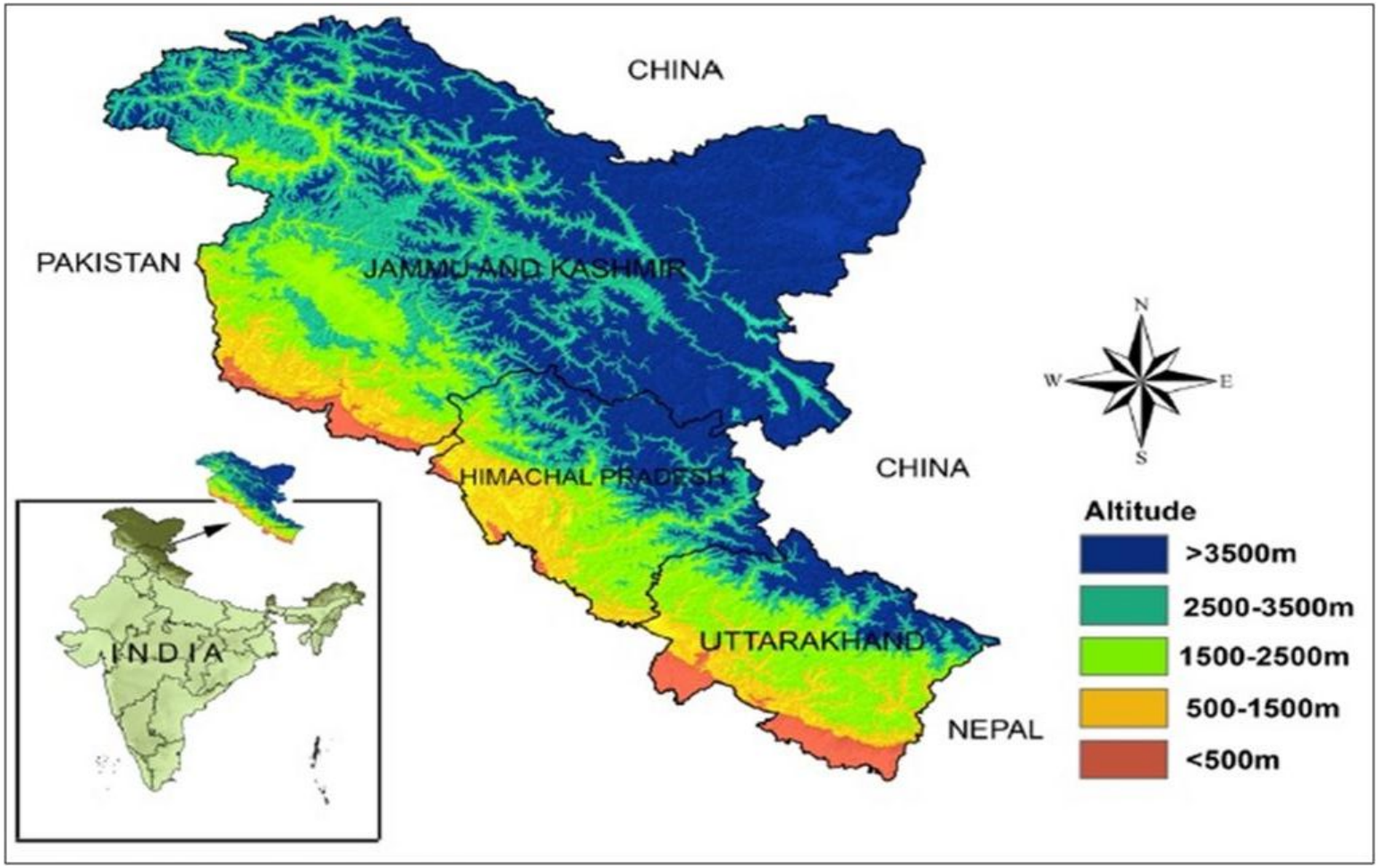
   (i) Broad-leaved forests

   (ii) Coniferous forests

5. Subalpine forests

6. Alpine vegetation

In **Map-3.1** blue, green and light green areas in Western Himalaya represent the temperate and alpine zones which are the suitable areas for the species of *Saxifraga* genus. As obvious in the map this area is wide spread in Western Himalaya and so are the species of *Saxifraga*. In the phytogeographical classification of the Earth by **Takhtajan (1986)** the Indian Western Himalaya falls in the Holarctic kingdom, Tethyn subkingdom, Irano-Turanian region, Western Asiatic subregion and Western Himalayan province. The timberline in this area fluctuates between 3300-3600m and separates two visually very different communities of temperate forests below and treeless alpine zones above. These alpine zones are the most important areas where large numbers of *Saxifraga* species are found growing.



Map-3.1 Location of Indian Western Himalalaya (after Jalal & Jayanthi, 2015)

3.2 Compilation of the Checklist

The checklist of *Saxifraga* species compiled in this work is based on herbarium study and perusal of authentic literature only. Majority of the plant specimens are located in the herbarium of G.B. Pant University, Pantnagar. In addition to this, two renowned herbaria housing the plants of Western Himalaya collected in the last 150 years, i.e., Herbarium of Forest Research Institute, Dehradun (DD) and Herbarium of Botanical Survey of India, Northern Regional Circle Dehradun (BSD) were consulted for compiling the list of *Saxifraga* species in Western Himalaya. Besides physical herbaria, virtual herbarium of Kew available online at **http://apps.kew.org/herbcat/navigator.do** was also checked for digital images of herbarium specimens from Western Himalaya.

A checklist based on only herbarium species cannot be complete and, therefore, available floristic literature was also surveyed for reported *Saxifraga* species from different parts of the Western Himalaya. The important flora checked for *Saxifraga* species in Jammu & Kashmir state are **'***Flora of Ladakh*' **(Kachroo *et al.,* 1977),** '*Alpine Flora of Kashmir*' (**Dhar & Kachroo, 1983), '***Flora of Upper Lidder Valleys of Kashmir Himalaya*' (**Sharma & Jamwal, 1988**) and '*Flora of Ladakh (NW Himalaya)- A Preliminary Check-list*' (**Klimes & Deckore**, available on internet). In addition to this account of Saxifragaceae in Flora of Pakistan (**Ghazanfar, 1977**) was also checked since it has also provided information of *Saxifraga* species occurring in Kashmir area.

For compiling the list of *Saxifraga* species known in Himachal Pradesh '*Flora Simlensis*' (**Collett, 1902**), '*Flora of Bashahr Himalaya*' (**Nair, 1977**), '*Flora of Himachal Pradesh volume-1'* (**Chowdhery & Wadhwa, 1984**), '*Flora of Lahaul – Spiti (A Cold Desert in North West Himalaya)*' (**Aswal & Mehrotra, 1994**), '*Flora of Kullu District (Himachal Pradesh)*'(**Dhaliwal & Sharma, 1999**), '*Flora of Great Himalayan National Park*' (**Singh & Rawat, 2000**), '*Flora of Sirmaur (Himachal Pradesh)*' (**Kaur & Sharma, 2004**), '*Flora of Chamba District Himachal Pradesh*' (**Singh & Sharma, 2006**), '*Flora of Pin Valley National Park Himachal Pradesh*' (**Chandra Sekar & Srivastava, 2009**) and important floristic reports like **Chawla *et al.* (2012)** and **Devi *et al.* (2014**) were also checked.

Uttarakhand is the easternmost state in the Indian Western Himalaya and comparatively richer in *Saxifraga* species. For compilation of species '*Catalogue of the plants of Kumaon and of the adjacent portions of Garhwal and Tibet*' (**Duthie, 1906**), '*Flora Nainitalensis*' (**Gupta, 1968**), '*Flora of Mussoorie*' (**Raizada & Saxena, 1978**), '*Flora of Chamoli*' (**Naithani, 1984-85**), '*Plant Wealth of Nanda Devi Biosphere Reserve*' (**Hajra & Balodi, 1995**) '*Flora of District Garhwal Northwest Himalaya*' (**Gaur, 1999**), '*Flowering plants of Uttarakhand (A Checklist)*' (**Uniyal *et al.* 2007**) and '*Flora of Gangotri National Park*' (**Pusalkar & Singh, 2013**) were checked.

In addition to district or state floras literature for entire India, Indian Himalaya, Western Himalaya, Nepal, Bhutan and China were also checked. These are **Clarke (1878), Smith (1958, 1960)**, **Polunin & Stainton (1984)**, **Grierson (1987), Stainton (1988)**, **Pan *et al.* (2001)**, **Akiyama & Gornall (2012)**, **Agnihotri & Hussain (2013)** etc. New species reports **Wadhwa (1988)** and **Gornall *et al.* (2012)** were also consulted.

3.3 Trichome Study

Plant specimens of total 30 species of *Saxifraga* genus, were obtained from G.B. Pant University Herbarium. Different parts to be observed for trichomes were dissected out and submerged in washing powder solution (1 tbsp. washing powder in 250 mL tap water) for 4-10 days for clearing, depending upon different species **(http://www.u.arizona.edu/~bblonder/leaves/The_secrets_of_leaves/Making_skeletons.html)**. After clearing, the plant specimens were dissected and different plant parts – stem, pedicel, leaves, petiole, sepal, petal, stamen and carpel – were collected from each specimen. These plant parts were then mounted in glycerin on separate glass slides and covered with cover slips. These slides were observed in 5x, 10x, 45x magnifications under a compound microscope. Illustrations were drawn with the help of camera lucida, and measurements were made using occulometer and stage micrometer. Illustrations were marked in the line drawing in metric system. Description of trichomes is written after providing currently accepted name of species studied, author citation, and citation of the relevant flora. While describing, the structure of trichomes terminology given by **Payne (1978)** and illustrated in **Figure-3.1** was adapted and the vestiture types were adapted from **Simpson (2010)** and illustrated in **Figure-3.2.**

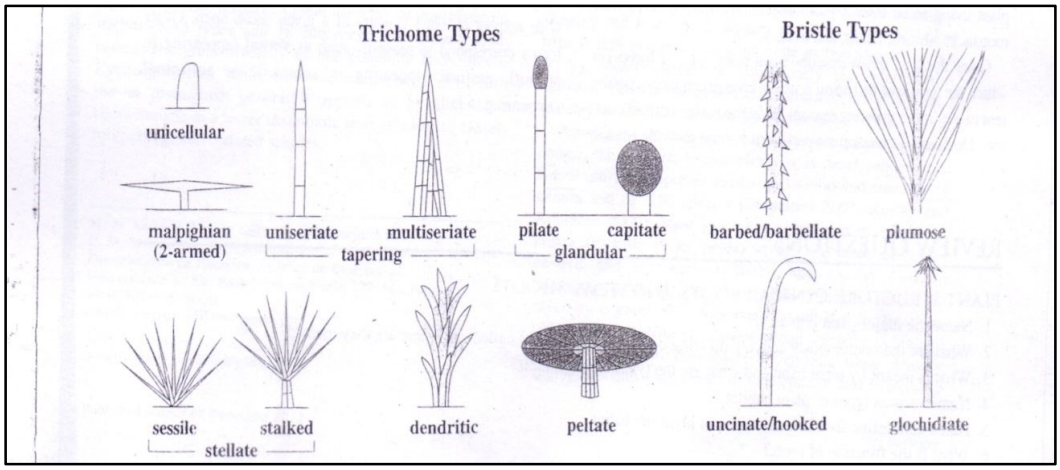


Figure 3.1: Different types of trichomes (Payne, 1978)

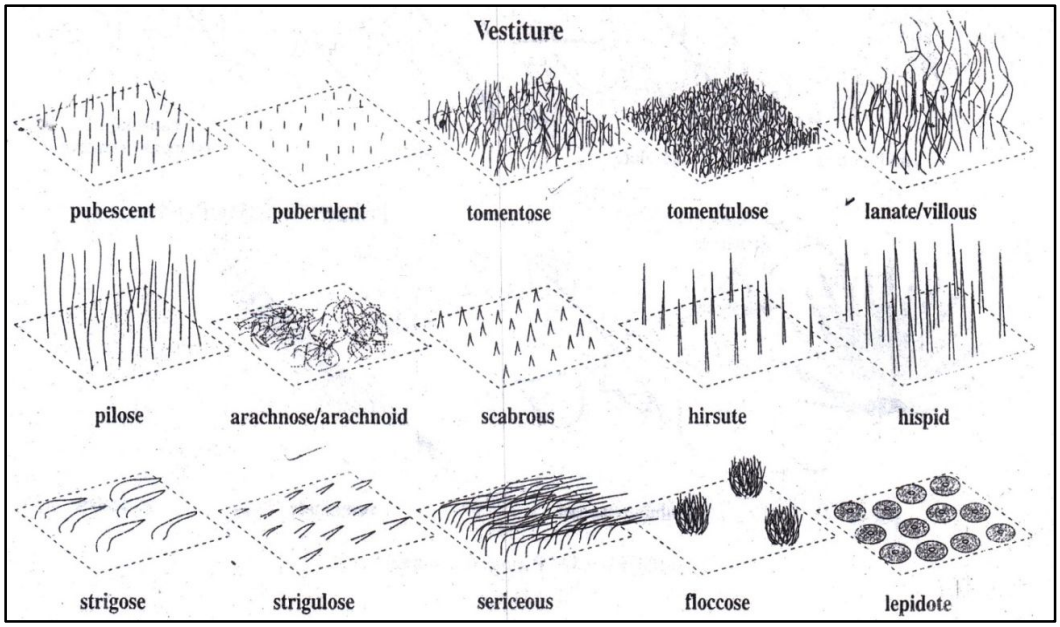


Figure 3.2: Different types of vestiture or trichome cover (Simpson, 2010)

3.4 Leaf Venation Study

Leaves from the 30 species of genus *Saxifraga* available in G.B. Pant University Herbarium were collected. Leaf venation of the specimens were drawn and studied by modifying the method given by **Payne (1969)**. Leaves from different species were submerged in 10% KOH solution in separate petri dishes at room temperature for 3-10 days (depending upon the thickness/ texture etc. of the leaves) till they became

translucent. Then the translucent leaves are washed with tap water 2-3 times and placed in 50% commercial bleach solution for 10-20 minutes. The leaves are again washed with tap water 2-3 times and mounted in glycerin on separate glass slides and covered with cover slips. The leaves are then viewed under a dissecting microscope (10x) and illustrations were drawn. The venation pattern is identified using the classification of leaf architecture described by **Hickey (1973, 1979)** and illustrated in **Figure-3.3.**

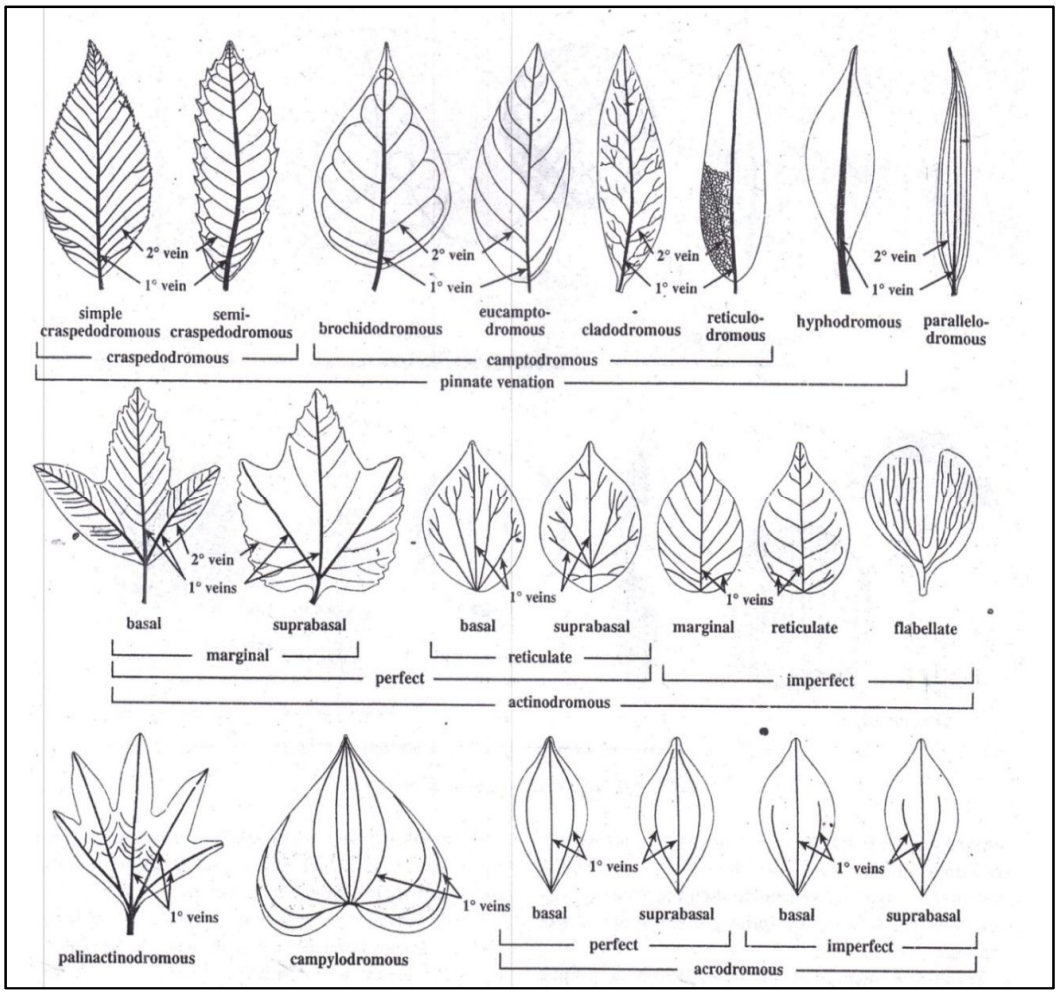


Figure 3.3: Types of Leaf venation (from Hickey, 1973)

Results & Discussion

4.1 Results

4.1.1 Checklist of *Saxifraga* L. *s.l.* in Indian Western Himalaya

4.1.1.1 ***Saxifraga andersonii*** Engl. *Bot. Jahrb. Syst.* 48(3-4): 609. 1912; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 497. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 343. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 A**)

Specimen Examined: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley, 3200-3800m, 18.6.2012, *D.S. Rawat s.n., Acc. No- 882*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.2 ***Saxifraga afghanica*** Aitch. & Hemsl., *J. Linn. Soc., Bot*. 18: 56. 1880; Pan *et al.* in Wu *et al.* Fl. China. 8: 343. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of distribution given by **Akiyama & Gornall (2012)** and **Pan *et al*. (2001)**.

4.1.1.3 ***Saxifraga androsacea*** L. Sp. Pl. 1: 399. 1753.

Specimen Examined: INDIA. Kashmir, Kargil Valley, 30.8.93, *C.H.M.*? (illegible) *13918* (DD!)

4.1.1.4 ***Saxifraga aristulata*** Hook.f. & Thomson *J. Proc. Linn. Soc. Bot.* 2: 68. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 510. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 310. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Kumaun: Pithoragarh District, Ralam Valley, 15-16000 ft., 24 August 1884, *J.F. Duthie 2887(a)* (DD!)

4.1.1.5 ***Saxifraga asarifolia*** Sternb. *Rev. Saxifr. Suppl*. 2. 33. t. 24. 1831; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 502. 1987; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Hemkund on way, 4000m, 17.8.1963, *U.C.Bhattacharyya 29457* (BSD!)

4.1.1.6 ***Saxifraga brachypoda*** D.Don *Trans. Linn. Soc. London* 13(2): 378. 1822; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 503. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 320. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 B**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Tungnath, 3400-3600m, Sept. 1998, *D.S. Rawat s.n., Acc. No- 883*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.7 ***Saxifraga brunoniana*** Wall. ex Ser. in DC., *Prodr.* 4: 45. 1830; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 499. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 337. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 C**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Neelkanth Valley, Badrinath area, 3400m, Sept. 2013, *D.S. Rawat s.n., Acc. No- 884*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.8 ***Saxifraga cernua*** L. Sp. Pl. 1: 403. 1753; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 503. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 340. 2001.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Kuari Pass, 3600m, Aug. 2006, *D.S. Rawat s.n., Acc. No- 885*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.9 ***Saxifraga ciliatopetala*** (Engl. & Irmsch.). J.T.Pan in C.Y.Wu, Index Fl. Yunnan. 1: 235. 1984; Pan *et al.* in Wu *et al.* Fl. China. 8: 314. 2001.

Specimen Examined: No specimen examined. Included here on the basis of **Klimes & Dickore** (http://www.butbn.cas.cz/klimes/desert.html)

4.1.1.10 ***Saxifraga chadwellii*** Wadhwa *Bull. Bot. Surv. India 28: 157. 1988.*

Specimen Examined: INDIA. Jammu & Kashmir, Pense La on way to Kargil, 13500 ft, 26.7.81, C.A. Chadwell 185 (K, K000732316 image !)

4.1.1.11 ***Saxifraga coarctata*** W.W.Sm., *Rec. Bot. Surv. India* 4: 194. 1911; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 503. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 347. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of distribution given by **Akiyama & Gornall (2012)**.

4.1.1.12 ***Saxifraga corymbosa*** Hook.f. & Thomson *J. Proc. Linn. Soc., Bot.* 2: 70. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 508. 1987.

Specimen Examined: INDIA, Uttarakhand, Garhwal: Chamoli District, Panga Chuli, 12-13000 ft, 9.9.1883, *J.F. Duthie 4001(a)* (DD!)

4.1.1.13 ***Saxifraga diversifolia*** Wall. ex Ser. in DC., *Prodr.* 4: 44. 1830; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 507. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 395. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Kuari Pass area, 3400m, Aug. 2006, *D.S. Rawat s.n., Acc. No- 886*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.14 ***Saxifraga duthiei*** Gand. *Bull. Soc. Bot. France* 46: 419. 1900.

Specimen Examined: No specimen examined. Included here on the basis of **Agnihotri & Husain (2013)**, **Akiyama & Gornall (2012)**, **Ghazanfar (1977)** and **Stewart (1972)** and http://data.rbge.org.uk/herb/E00726952

4.1.1.15 ***Saxifraga elliptica*** Engl. & Irmsch., *Bot. Jahrb. Syst.* 48: 585. 1912; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 511. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 316. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of **Klimes & Dickore** (http://www.butbn.cas.cz/klimes/desert.html)

4.1.1.16 ***Saxifraga filicaulis*** Wall. ex Ser. in DC., *Prodr.* 4: 46. 1830; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 504. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 319. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Bedni Bugyal, 3700m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 887*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.17 ***Saxifraga flagellaris*** Willd. ex Sternb. *Revis. Saxifrag.* 25. t. 6. 1810; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 499. 1987.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Uttarkashi District, Gangotri National Park, Kedarkharak, 1.8.2003, *P.K. Pusalkar 103981* (BSD!)

4.1.1.18 ***Saxifraga giraldiana*** Engl. ex Diels *Bot. Jahrb. Syst*. 29(3-4): 365. 1900; Pan *et al.* in Wu *et al.* Fl. China. 8: 303. 2001.

Specimen Examined: INDIA.Himachal Pradesh, Spiti, Kunzum Base, 4300m, 24 July 1972, *U.C. Bhattacharyya 48988* (BSD!)

4.1.1.19 ***Saxifraga granulifera*** Harry Sm. *Bull. Mus. (Nat. Hist.)* 2: 259. 1960; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 502. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 340. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA, Uttarakhand, Garhwal: Chamoli District, near Kuari Pass, 12-13000 ft, 8.9.1885, J.F. Duthie 3998 (DD!), same number also by same collector at Kew (K000961675 image!)

4.1.1.20 ***Saxifraga hemisphaerica*** Hook.f. & Thomson J. *Proc. Linn. Soc., Bot*. 2: 62. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 503. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 323. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA, Uttarakhand, Garhwal: Uttarkashi District, Rudhughera, 15-16000 ft., 20.7.1883, J.F. Duthie 684 (DD!)

4.1.1.21 ***Saxifraga hirculoides*** Decne., in Jacquem., Voy. Inde 4(1): 67, t. 78, f. 1. 1841; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 508. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 316. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Uttarkashi District, Nandanvan area, 4500m, Aug. 1996, *D.S. Rawat s.n., Acc. No- 888*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.22 ***Saxifraga hirculus*** L. Sp. Pl. 1: 402. 1753; Pan *et al.* in Wu *et al.* Fl. China. 8: 313. 2001.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4500m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 889*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.23 ***Saxifraga hispidula*** D.Don. *Trans. Linn. Soc. London* 13(2): 380. 1822; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 500. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 318. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 D**)

Specimen Examined: INDIA. Uttarakhand: Garhwal: Chamoli District, Pattarnachauniya, 4200m, 31.8.2014, *D.S. Rawat s.n., Acc. No- 890*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.24 ***Saxifraga jacquemontiana*** Decne., in Jacquem., Voy. Inde 4(1): 68, t. 78, f. 2. 1841; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 514. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 323. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 I**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli district, Bhagwa Basa, 4400m, 31 Aug. 2014, *D.S. Rawat s.n., Acc. No- 891*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.25 ***Saxifraga kashmeriana*** U.Dhar & Kachroo Alpine Fl. Kashmir Himalaya 207. 1983.

Specimen Examined: no specimen examined, included here on the basis of protologue in **Dhar & Kachroo (1983)**.

4.1.1.26 ***Saxifraga kumaunensis*** Engl., in Engl., Pflanzenr. IV. 117 (Heft 69): 576. F.119. 1919; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 F**)

Specimen Examined: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley, Timli, 3800m, 19.6.2012, *D.S. Rawat s.n., Acc. No- 892*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.27 ***Saxifraga lepida*** Harry Sm., *Bull. Brit. Mus. (Nat. Hist.), Bot.* 2: 239, t. 17A. 1960; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 510. 1987; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand: Bageshwar District, Pindari valley, Furkia-Dwali, 3000-3500m, 25.9.1957, *T.A.Rao 4593* (BSD!). This species was reported as a new record to Indian flora by Pusalkar & Singh (2013).

4.1.1.28 ***Saxifraga lilacina*** Duthie Gard. Chron. t. 290. 1904. (**Plate 31 G**)

Specimen Examined: INDIA. Uttarakhand: Kumaon: Pithoragarh District, Kalamuni area, 2500-2650m, 25.4.2013, *D.S. Rawat s.n., Acc. No- 893*, G.B. Pant University Herbarium, Pantnagar!

4.1.1.29 ***Saxifraga lychnitis*** Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2: 68. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 504. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 306. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 H**)

Specimen Examined: INDIA.Uttarakhand: Uttarkashi district, Suralaya, 5000m, July 1996, *D.S. Rawat s.n. Acc. No- 894* (G.B.Pant University Herbarium Pantnagar, Uttarakhand, India!)

4.1.1.30 ***Saxifraga meeboldii*** Engl. & Irmsch. In Engl., *Bot. Jahrb.* 48(3-4): 609. 1913.

Specimen Examined: No specimen examined. Included here on the basis of the note by **Ghazanfar (1977)** who have examined lectotype of species collected from Kanji La, Ladakh by Meebold (326 WU), specimen collected by Duthie from Gilgit (12428) and by Koelz (21065) from Bedang Glacier, Kumaon (Uttarakhand).

4.1.1.31 ***Saxifraga melanocentra*** Franch. *J. Bot [Morot]* 10: 263. 1896; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 502. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 283. 2001.

Specimen Examined: No specimen examined. Included here on the basis of distribution given by **Akiyama & Gornall (2012).**

4.1.1.32 ***Saxifraga microphylla*** Royle ex Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2: 72. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 515. 1987; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 32 A**)

Specimen Examined: INDIA. Uttarakhand: Garhwal: Chamoli District, on way to Roopkund, 4600-4700m, 2.9.2014, *D.S. Rawat s.n., Acc. No- 895* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.33 *Saxifraga minutissima* D.S.Rawat, *Edinburgh J. Bot.* 69(2): 211. 2012. (**Plate 32 D**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area near Kedarnath, 4600-4800m, 10.9.2001, Holotype, *D.S. Rawat s.n., Acc. No- 442* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.34 *Saxifraga moorcroftiana* (Ser.) Wall. ex Sternb., *Revis. Saxifrag. Suppl*. 2: 28. T.24. 1831; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 507. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 301. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA, Jammu & Kashmir, Zoji Pass, 10-11000 ft, 30.8.1940, *R.R. Stewart 88659* (DD!)

4.1.1.35 *Saxifraga mucronulata* Royle, Ill. Bot. Himal. Mts. 7: 227. 1835; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 499. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 336. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area near Kedarnath, 4500-4600m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 896* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.36 *Saxifraga nakaoi* Kitam., in H.Kihara, Fauna Fl. Nepal Himalaya: 144. F. 25. 1955;Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of **Uniyal *et al.* (2007)** and distribution given by **Akiyama & Gornall (2012)**.

4.1.1.37 *Saxifraga nanella* Eng. & Irmsch., *Bot. Jahrb. Syst*. 50 (Beibl.144): 44. 1914.

Specimen Examined: No specimen examined. Included here on the basis of **Klimes & Dickore** (http://www.butbn.cas.cz/klimes/desert.html)

4.1.1.38 *Saxifraga oppositifolia* L. Sp. Pl. 1: 402. 1753.

Specimen Examined: INDIA, Jammu & Kashmir, Rangdum, Zanskar, 11000 ft, 12.9.1937, *Walters Koelz 60379* (DD!)

4.1.1.39 ***Saxifraga pallida*** Wall. ex Ser. in DC., *Prodr.* 4: 38. 1830; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 501. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 282. 2001.

Specimen Examined: INDIA, Himachal Pradesh: Spiti, Pin Valley National Park, Mud-Tharbik, 4000m, 1.8.2002, *K. Chandra Sekar 102804* (BSD!)

4.1.1.40 ***Saxifraga palpebrata*** Hook.f. et Thomson, *J. Proc. Linn. Soc., Bot.* 2: 67. 1857; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4600m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 897* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.41 ***Saxifraga parnassifolia*** D.Don, *Trans. Linn. Soc. London* 13(2): 405. 1821; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 507. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 398. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 32 E**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Vedni Bugyal, 3500m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 898* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.42 ***Saxifraga poluniniana*** Harry Sm. var. ***mucronata*** U.C.Bhattach. & M.V.Viswan. *Bull. Bot. Serv. India* 15(3-4): 269. 1976; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Kumaon: Pithoragarh District, on way to Garbyang, 3100m, 13.6.1960, *T.A. Rao 11849B* (BSD!)

4.1.1.43 ***Saxifraga pseudopallida*** Engl. & Irmsch., *Bot. Jahrb. Syst*. 50, Beibl. 114: 40. 1914; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 502. 1987. (**Plate 32 C**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli district, Kalu Vinayak, 4300m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 899* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.44 ***Saxifraga pulvinaria*** Harry Sm., *Bull. Brit. Mus. (Nat. Hist.), Bot.* 2: 105. t. 4. F. m. 1958; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 498. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 346. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 31 E**)

Specimen Examined: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley, 3800m, 18.6. 2012, *D.S.Rawat s.n., Acc. No- 900* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.45 *Saxifraga ramulosa* Wall. & Ser., in DC. *Prodr*. 4: 21. 1830.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Uttarkashi District, on way to Yamunotri, 3000m, 14.6.1961, *M.A. Rau 15698* (BSD!)

4.1.1.46 *Saxifraga roylei* Harry Sm., *Bull. Brit. Mus. (Nat. Hist.), Bot*. 2: 95. f.o. 1958; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined; included here on the basis of **Uniyal *et al.* (2007)**

4.1.1.47 *Saxifraga saginoides* Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot*. 2: 68. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 513. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 317. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012. (**Plate 32 B**)

Specimen Examined: INDIA. Uttarakhand, Garhwal: Chamoli District, Bhagwa Basa, 4600m, Aug. 2014, *D.S.Rawat s.n., Acc. No- 901* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.48 *Saxifraga sibirica* L. Syst. Nat., ed. 10. 2: 1027. 1759; Pan *et al.* in Wu *et al.* Fl. China. 8: 339. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Kashmir, Kalotti glacial Valley, 12500ft., 19 July1956, *T.A. Rao 717* (BSD!)

4.1.1.49 *Saxifraga sinomontana* J.T.Pan & Gornall, *Novon* 10: 377. 2000. *S. hirculus* var. *indica* C.B.Clarke in Hook.f. Fl. Brit. India 2: 392. 1878; Pan *et al.* in Wu *et al.* Fl. China. 8: 312. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA, Uttarakhand, Garhwal: Uttarkashi District, Gangotri National Park, Kedar Kharak, 4-4500m, *P.K. Pusalkar 104062* (BSD!)

4.1.1.50 *Saxifraga stella-aurea* Hook. f. et Thomson, *J. Proc. Linn. Soc., Bot.* 2: 72. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 513. 1987; Pan *et al.* in Wu *et al.*

Fl. China. 8: 324. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Uttarkashi District, Chaturangi Glacier Valley, Suralaya on way to Kalindi Pass, 5000m, July 1996, *D.S. Rawat s.n., Acc. No- 902* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.51 ***Saxifraga stenophylla*** Royle, Ill. Bot. Himal. Mts. 7: 227. T. 50. f.1. 1835; Pan *et al.* in Wu *et al.* Fl. China. 8: 335. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4600m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 903* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.52 ***Saxifraga stolitzkae*** Duthie ex Engl. & Irmsch., in Engl.,*Pflanzenr. IV*. 117(Heft 69): 569, f. 116D. 1919; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 497. 1987; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Kumaon: Pithoragarh District, Kali Valley, Byans, on a glacial moraine above Napalchu, 13.9.1884, *J.F. Duthie 2892* (DD!)

4.1.1.53 ***Saxifraga strigosa*** Wall. & Ser., in DC. *Prodr*. 4: 41. 1830; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 500. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 318. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of **Uniyal *et al.* (2007)** and the distribution given by **Akiyama & Gornall (2012)** and **Pan *et al.* (2001)**.

4.1.1.54 ***Saxifraga subspathulata*** Engl. & Irmsch., *Bot. Jahrb. Syst.* 48(3-4): 584. 1913; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 512. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 312. 2001.

Specimen Examined: INDIA. Uttarakhand, Kumaon: Pithoragarh District, rocks above Chialekh, Byans, Kali Valley, 11-12000 ft., 23.7.1886, J.F. Duthie 5539 (K, image K000732458!)

4.1.1.55 *Saxifraga tangutica* Engl., *Bull. Acad. Imp. Sci. Saint-Petersbourg* 29: 115. 1883; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 508. 1987; Pan *et al.* in Wu *et al.* Fl. China. 8: 314. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA, Jammu & Kashmir, Ladakh, Collector (illegible) *2399* (K, Image K000732289!)

4.1.1.56 *Saxifraga viscidula* Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2: 69. 1857; Griers. in Griers. & Long. Fl. Bhutan. 1(3): 505. 1987; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: No specimen examined. Included here on the basis of distribution given in **Akiyama & Gornall (2012)**.

4.1.1.57 *Saxifraga wallichiana* Sternb., *Revis. Saxifrag. Suppl*. 2: 21. t. 22. 1831; Pan *et al.* in Wu *et al.* Fl. China. 8: 320. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal. Saxifragaceae. 10. 2012.

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Chamoli, Kuari Pass area, 3600m, Aug. 2006, *D.S. Rawat s.n., Acc. No- 904* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.58 *Saxifraga* species A (**Plate 32 G**)

This species is allied to *S. nakaoi* Kitam. and *S. mallae* H. Ohba & Wakab., and the character clearly suggest its position in sect. *Ciliatae.*

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Chamoli, Bhagwabasa area, 4600m, Sept. 2014, *D.S. Rawat s.n., Acc. No- 905* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.59 *Saxifraga* species B

This species is closely allied to *S. matta-viridis* Harry Sm. and belongs to the sect. *Ciliatae.*

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Chamoli, Bhagwabasa area, 4500m, Aug. 1993, *D.S. Rawat s.n., Acc. No- 906* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.60 *Saxifraga* species C

This species have tetramerous flowers and chalk gland in the leaves which clearly indicate its position in sect. *Porphyrion.*

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Rudraprayag, Vasuki Tal area, 4700m, Aug. 2000, *D.S. Rawat s.n., Acc. No- 907* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.61 *Saxifraga* species D (**Plate 32 H**)

This species is closer to *S. brahypoda* D. Don. and belongs to the sect. *Ciliatae.*

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Chamoli, Homkundi area, 4000m, Sept. 2014, *D.S. Rawat s.n., Acc. No- 908* (G.B. Pant University Herbarium, Pantnagar!)

4.1.1.62 *Saxifraga* species E (**Plate 32 I**)

This species is closely allied to *S. hemishaerica* Hook.f. & Thomson and *S. perpusilla* Hook.f. & Thomson. It belongs to the sect. *Ciliatae.*

Specimen Examined: INDIA. Uttarakhand, Garhwal: District Chamoli, Roopkund area, 4600-4700m, Sept. 2014, *D.S. Rawat s.n., Acc. No- 909* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2 Trichomes and Leaf Venation in *Saxifraga* L. *s.l.* Species

4.1.2.1. *Saxifraga andersonii* Engl. *Bot. Jahrb. Syst.* 48(3-4): 609. 1912; Griers.in Griers. & Long, Fl. Bhutan 1(3): 497. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 343. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.1A. Trichomes (Plate 1 A-I)

Stem: Trichomes glandular only; present throughout, horizontal orientation, vestiture villous, biseriate and intermediate types, multicellular, 285-570μm long, glandular head 45 x 45 μm.

Adaxial surface of leaf: Trichomes glandular only; present on lower portion of the surface, antrorse, biseriate and multiseriate types, multicellular, 285 μm long, glandular head 60 x 60 μm.

Abaxial surface of leaf: Trichomes glandular only; present on lower portion of the leaf surface, antrorse orientation, biseriate and multiseriate types, multicellular, 300 µm long, glandular head 45 x 45 µm.

Leaf margin: Trichomes glandular only; present along lower portion of the leaf margin, antrorse, biseriate, intermediate and multiseriate types, multicellular, 600 µm long, glandular head 45-60 x 45-60µm.

Pedicel: Trichomes glandular and eglandular; glandular trichomes present throughout, horizontal orientation, vestiture villous, glandular uniseriate, biseriate and intermediate types, multicellular, 150-495 µm long, glandular head 30-45 x 30-45 µm; eglandular trichomes uniseriate type, multicellular, 150-495 µm long.

Abaxial surface of sepal: Trichomes glandular only; present throughout, horizontal orientation, biseriate type, multicellular, 255 µm long, glandular head 45 x 45 µm.

Sepal margin: Trichomes glandular type only; present throughout, horizontal orientation, biseriate type, multicellular, 255 µm long, glandular head 45 x 45 µm.

*No trichomes were found on petals, stamens and carpels.

4.1.2.1B. Venation (Plate 1 J)

Leaf venation: Acrodromous, imperfect, Suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley, 32-3800m, 18.6.2012, *D.S. Rawat s.n., Acc. No- 882*, G.B. Pant University Herbarium, Pantnagar.

4.1.2.2. *Saxifraga aristulata* Hook.f. & Thomson in *J. Proc. Linn. Soc. Bot.* 2: 68. 1857; C.B.Clarke in Hook.f., Fl. Brit. India 2: 392. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 510. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 310. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.2A. Trichomes (Plate 2 A-C, E-G)

Stem: Trichomes glandular only; scarce, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 195 µmlong, glandular head 75 x 60 µm.

Pedicel: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, glandular, biseriate type, multicellular, 135µmlong, glandular head 60 x 75µm.

Sepal margin: Trichomes glandular only; present throughout, antrorse orientation, biseriate type, multicellular, 105 µmlong, glandular head 75 x 75µm.

*No trichomes were found on leaf, sepal surface, petal, stamen and carpel.

4.1.2.2B. Venation (Plate 2D)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Kumaun: Pithoragarh District, Ralam Valley, 15-16000 ft., 24 August 1884, *J.F. Duthie 2887(a)* (DD).

4.1.2.3. *Saxifraga brachypoda* D.Don Trans. Linn. Soc. London 13(2): 378. 1822; C.B. Clarke in Hook.f., Fl. Brit. India 2: 396. 1878; Griers.in Griers. & Long, Fl. Bhutan 1(3): 503. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 320. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.3A. Trichomes (Plate 3 A-E)

Leaf margin: Trichomes eglandular only; present throughout, antrorse orientation, multiseriate type, multicellular, 750-1200 µmlong.

Pedicel: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, multiseriate type, multicellular, 300-750 µmlong, glandular head 60 x 75 – 75 x 75 µm.

Abaxial surface of sepal: Trichomes glandular only, present throughout, antrorse orientation, biseriate type, multicellular, 225-750 µmlong, glandular head 60 x 90 – 75 x 90 µm.

Sepal margin: Trichomes glandular only; present throughout, antrorse orientation, biseriate type, multicellular, 150-375 µmlong, glandular head 60 x 90 µm.

*No trichomes were found on stem, leaf surfaces (adaxial and abaxial), petal, stamen and carpel.

4.1.2.3B. Venation (Plate 1 E)

Leaf venation: Campylodromous.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Tungnath, 3400-3600m, Sept. 1998, *D.S. Rawat s.n., Acc. No-883*, G.B. Pant University Herbarium, Pantnagar.

4.1.2.4. *Saxifraga brunoniana*Wall. ex Ser. in DC., *Prodr.* 4: 45. 1830; C.B. Clarke in Hook.f., Fl. Brit. India 2: 397. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 499. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 337. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.4A. Trichomes (Plate 4 A, B, D, E)

Stem: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, glandular, biseriate type, multicellular, 300-450 µm, glandular head 45 x 60 µm.

Leaf margin: Trichomes glandular only; present throughout, antrorse orientation, multiseriate type, multicellular, 480 µm, glandular head 60 x 45 µm.

Pedicel: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 300-450 µmlong, glandular head 45 x 60 µm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal, petal, stamen and carpel.

4.1.2.4B. Venation (Plate 1 C)

Leaf venation: Acrodromous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli District, Neelkanth Valley, Badrinath area, 3400m, Sept. 2013, *D.S. Rawat s.n., Acc. No- 884*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.5. *Saxifraga cernua* L. Sp. Pl. 1: 403. 1753; C.B. Clarke in Hook.f., Fl. Brit. India 2: 390. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 503. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 340. 2001.

4.1.2.5A. Trichomes (Plate 5 A-D, F-J)

Stem: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, uniseriate type, multicellular, 45-450 µm, glandular head 75 x 30 µm.

Adaxial surface of leaf: Trichomes glandular only, present throughout, horizontal orientation, uniseriate type, multicellular, 150-270 µmlong, glandular head 75 x 30 µm.

Abaxial surface of leaf: Trichomes glandular only, present throughout, horizontal orientation, uniseriate type, multicellular, 150-270 µm, glandular head 75 x 30 µm.

Leaf margin: Trichomes glandular only; present throughout, horizontal orientation, uniseriate type, multicellular, 150-270 µm, glandular head 75 x 30 µm.

Petiole: Trichomes glandular only; scarce, horizontal orientation, vestiture pubescent, uniseriate type, multicellular, 165µmlong, glandular head 45 x 30 µm.

Pedicel: Trichomes glandular only; present throughout, horizontal orientation, vestiture pubescent, uniseriate type, multicellular, 45-300 µmlong, glandular head 45-60 x 30µm.

Abaxial surface of sepal: Trichomes glandular only; present throughout, horizontal orientation, uniseriate type, multicellular, 180µm, glandular head 75 x 30 µm.

Sepal margin: Trichomes glandular only; present throughout, horizontal orientation, uniseriate type, multicellular, 150µmlong, glandular head 60 x 30 µm.

*No trichomes were found on petal, stamen and carpel.

4.1.2.5B. Venation (Plate 5 E)

Leaf venation: Young leaves have acrodromous, perfect, basal venation; whereas mature leaves have palinactinodromous venation.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli District, Kuari Pass, 3600m, Aug. 2006, *D.S. Rawat s.n., Acc. No- 885*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.6. *Saxifraga filicaulis* Wall. ex Ser. in DC., *Prodr.* 4: 46. 1830; C.B. Clarke in Hook.f., Fl. Brit. India 2: 396. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 504. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 319. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.6A. Trichomes (Plate 6 A-J)

Stem: Trichomes glandular and eglandular; present throughout, antrorse orientation, vestiture pubescent; glandular biseriate type, multicellular, 150-225 µmlong, glandular head 30-60 x 45-75 µm; eglandular uniseriate, biseriate and intermediate types, multicellular, 75-150 µmlong.

Leaf margin: Trichomes glandular only; present throughout, one long trichome present on either side at leaf base laterally, antrorse orientation, biseriate type, multicellular, 150-525 µmlong, glandular head 30-60 x 45-75 µm.

Pedicel: Trichomes glandular and eglandular; present throughout, antrorse orientation, vestiture pubescent; glandular trichome biseriate type, multicellular, 150-195 µmlong, glandular head 45-60 x 60 µm; eglandular trichomes uniseriate, biseriate and intermediate types, multicellular, 75-90 µm long.

Abaxial surface of sepal: Trichomes glandular only; present throughout, antrorse orientation, biseriate type, multicellular, 150-255 µmlong, glandular head 30-60 x 45-75 µm.

Sepal margin: Trichomes glandular only, present throughout, antrorse orientation, biseriate type, multicellular, 150-255 µm long, glandular head 30-60 x 45-75 µm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), petal, stamen and carpel.

4.1.2.6B. Venation (Plate 6 K)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli District, Bedni Bugyal, 3700m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 887*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.7. *Saxifraga hirculoides* Decne., in Jacquem., Voy. Inde 4(1): 67, t. 78, f. 1. 1841; Griers. in Griers. & Long, Fl. Bhutan 1(3): 508. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 316. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.7A. Trichomes (Plate 7 A-F)

Stem: Trichomes eglandular only; present throughout, horizontal orientation, vestiture tomentose, uniseriate type, 3675µm long.

Adaxial surface of leaf: Trichomes eglandular only; present throughout, horizontal orientation, uniseriate type, 2625µm long.

Abaxial surface of leaf: Trichomes eglandular type; present throughout, horizontal orientation, uniseriate type, 2025μm long.

Leaf margin: Trichome eglandular type; present throughout, horizontal orientation, uniseriate type, 3000 μm long.

Petiole: Trichomes eglandular type; present throughout, horizontal orientation, vestiture pilose, uniseriate type, 3300 μm long.

Pedicel: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, uniseriate type, 2775 μm long.

Sepal margin: Trichomes eglandular type; present throughout, horizontal orientation, uniseriate type, 1950 μm long.

*No trichomes were found on sepal surface, petal, stamen and carpel.

8B. Venation (Plate 7 G)

Leaf venation: Acrodomous, perfect, basal.

Vaucher Specimen: Uttarakhand, Garhwal: Uttarkashi District, Nandanvan area, 4500m, Aug. 1996, *D.S. Rawat s.n., Acc. No- 888*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.8. *Saxifraga hirculus* L. Sp. Pl. 1: 402. 1753; C.B.Clarke in Hook.f., Fl. Brit. India 2: 392. 1878; Pan *et al.* in Wu *et al.,* Fl. China 8: 313. 2001.

4.1.2.8A. Trichomes (Plate 8 A-H)

Stem: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, uniseriate and intermediate types, multicellular, 1650-2325 μm long.

Petiole: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, uniseriate and intermediate types, multicellular, 1650-2325 μm long.

Pedicel: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, uniseriate and intermediate types, multicellular, 1650-2325 μm long.

Sepal margin: Trichomes eglandular type; present throughout, horizontal orientation, uniseriate and intermediate types, multicellular, 1650-2325 μm long.

*No trichomes were found on leaf surfaces (adaxial and abaxial), leaf margin, sepal surface, petal, stamen and carpel.

4.1.2.8B. Venation (Plate 8 I)

Leaf venation: Acrodomous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4500m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 889*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.9. *Saxifraga hispidula* D.Don. in *Trans. Linn. Soc. London* 13(2): 380. 1822; C.B.Clarke in Hook.f., Fl. Brit. India 2: 396. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 500. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 318. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.9A. Trichomes (Plate 9 A-J)

Stem: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture pubescent; glandular trichomes uniseriate type, multicellular, 450-675 µm long, glandular head 45 x 45-60 µm; eglandular trichomes uniseriate and intermediate types, multicellular, 75-675 µm long.

Adaxial surface of leaf: Trichomes glandular and eglandular types; present throughout, antrorse orientation; glandular trichomes intermediate type, multicellular, 180 µm long, glandular head 30 x 45 µm; eglandular trichomes uniseriate, intermediate and multiseriate types, multicellular, 450-900 µm long.

Abaxial surface of leaf: Trichomes eglandular type; present throughout, antrorse orientation, uniseriate, intermediate and multiseriate types, multicellular, 225-675 µm long.

Leaf margin: Trichomes eglandular type; present throughout, antrorse orientation, uniseriate, intermediate and multiseriate types, multicellular, 225-900 µm.

Pedicel: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture pubescent; glandular trichomes biseriate type, multicellular, 225-450 µm long, glandular head 45-60 x 45-75 µm; eglandular trichomes uniseriate and intermediate types, multicellular, 75-270µm long.

Abaxial surface of sepal: Trichomes glandular and eglandular types; present throughout, antrorse orientation; glandular trichomes biseriate type, multicellular, 420-

450 µm long, glandular head 45 x 45-60 µm, eglandular trichomes multiseriate type, multicellular, 300-525 µm long.

Sepal margin: Trichomes eglandular type; present throughout, antrorse orientation, multiseriate type, multicellular, 300-525 µm long.

*No trichomes were found on petal, stamen and carpel.

4.1.2.9B. Venation (Plate 9 K)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand: Garhwal: Chamoli District, Pattarnachauniya, 4200m, 31.8.2014, *D.S. Rawat s.n., Acc. No- 890*, G.B. Pant University Herbarium, Pantnagar.

4.1.2.10. ***Saxifraga jacquemontiana*** Decne., in Jacquem., Voy. Inde 4(1): 68, t. 78, f. 2. 1841; C.B.Clarke in Hook.f., Fl. Brit. India 2: 394. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 514. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 323. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.10A. Trichomes (Plate 10 A-C, E-H)

Stem: Trichomes glandular type; scarce, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 90-105 µm long, glandular head 30-45 x 45-60 µm.

Adaxial surface of leaf: Trichomes glandulartype; present throughout, antrorse orientation, biseriate type, multicellular, 105-150 µm long, glandular head 30-45 x 45 µm.

Abaxial surface of leaf: Trichomes glandulartype; present throughout, antrorse orientation, biseriate type, multicellular, 105-150 µm long, glandular head 30-45 x 45 µm.

Leaf margin: Trichomes glandular type; present throughout, antrorse orientation, biseriate type, multicellular, 105-150 µm long, glandular head 30-45 x 45 µm.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 75-90 µm, glandular head 30-45 x 45-60 µm.

Abaxial surface of sepal: Trichomes present throughout, horizontal orientation, glandular, biseriate type, multicellular, 120-135µm, glandular head 45 x 45-60 μm^2

Sepal margin: Trichomes glandular type; present throughout, horizontal orientation, biseriate type, multicellular, 135-150 μm long, glandular head 45-60 x 75 μm.

*No trichomes were found on petal, stamen and carpel.

4.1.2.10B. Venation (Plate 10 D)

Leaf venation: Acrodomous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli district, Bhagwa Basa, 4400m, 31 Aug. 2014, *D.S. Rawat s.n., Acc. No- 891*, G.B. Pant University Herbarium, Pantnagar!

4.1.2.11. *Saxifraga kumaunensis* Engl., in Engl., *Pflanzenr. IV*. 117 (Heft 69): 576. F. 119. 1919; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.11A. Trichomes (Plate 11 A-D, F, G)

Leaf margin: Trichomes glandular type; present along lower half portion of the leaf margin, antrorse orientation, biseriate and multiseriate types, multicellular, 135-180 μm long, glandular head 30-45 x 30-45 μm^2

Pedicel: Trichomes scarce, horizontal orientation, vestiture pubescent, glandular, biseriate type, multicellular, 150 μm, glandular head 15 x 15 μm^2

Sepal margin: Trichomes present throughout but not near apex, antrorse orientation, glandular, multiseriate type, multicellular, 120μm, glandular head 45-60 x 60 μm.

*No trichomes were found on stem, leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.11B. Venation (Plate 11 E)

Leaf venation: Acrodomous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley,Timli, 3800m, 19.6.2012, *D.S. Rawat s.n., Acc. No- 892*, G.B. Pant University Herbarium, Pantnagar.

4.1.2.12. *Saxifraga lilacina* Duthie in Gard. Chron. t. 290. 1904; Harry Sm. in *Bull. Brit. Mus. (Nat. Hist.) Bot.* 2(2): 93. f. 9. 1958.

4.1.2.12A. Trichomes (Plate 12 A-C, E-H)

Stem: Trichomes glandular types; present throughout, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 75-420 µm long, glandular head 30-60 x 45-60 µm.

Adaxial surface of leaf: Trichomes glandular type; present on middle portion of the leaf surface, antrorse orientation, biseriate type, multicellular, 165 µm long, glandular head 60 x 60 µm.

Leaf margin: Trichomes glandular type; present throughout, antrorse orientation, biseriate type, multicellular, 75-255 µm long, glandular head 60-75 x 60-90 µm.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 75-375 µm long, glandular head 15-60 x 30-60 µm.

Abaxial surface of sepal: Trichomes glandular type; present throughout, antrorse orientation, biseriate type, multicellular, 120-450 µm long, glandular head 30-60 x 45-60 µm.

Sepal margin: Trichomes glandular type; present throughout, antrorse orientation, biseriate type, multicellular, 120-450 µm long, glandular head 30-60 x 45-60 µm.

*No trichomes were found on abaxial surface of leaf, petal, stamen and carpel.

4.1.2.12B. Venation (Plate 12 D)

Leaf venation: Eucamptodromous.

Vaucher Specimen: INDIA. Uttarakhand: Kumaon: Pithoragarh District, Kalamuni area, 2500-2650m, 25.4.2013, *D.S. Rawat s.n., Acc. No- 893*, G.B. Pant University Herbarium, Pantnagar.

4.1.2.13. *Saxifraga lychnitis* Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2: 68. 1857; C.B.Clarke in Hook.f., Fl. Brit. India 2: 391. 1878; Griers. in Griers. & Long, Fl. Bhutan 1(3): 504. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 306. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.13A. Trichomes (Plate 13 A-I)

Stem: Trichomes glandular and eglandular type; present throughout, horizontal orientation, vestiture tomentulose; glandular trichomes uniseriate and biseriate types,

multicellular, 255-375 μm long, glandular head 45 x 45 μm; eglandular trichomes biseriate and intermediate types, multicellular, 255-375 μm long.

Abaxial surface of leaf: Trichomes glandular type; present throughout, antrorse orientation, uniseriate and biseriate types, multicellular, 225-450 μm long, glandular head 45 x 45 μm.

Leaf margin: Trichomes glandular and eglandular types; present throughout, antrorse orientation, glandular trichomes uniseriate and biseriate types, multicellular, 225-450 μm long, glandular head 45 x 45 μm; eglandular trichomes scarce, only present at base on either side, biseriate type, multicellular, 900 μm long.

Pedicel: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture tomentulose; glandular trichomes uniseriate and biseriate types, multicellular, 150-240 μm long, glandular head 45 x 45 μm; eglandular trichomes biseriate and intermediate types, multicellular, 150-240 μm long.

Abaxial surface of sepal: Trichomes glandular and eglandular types; present throughout, horizontal orientation; glandular trichomes biseriate type, multicellular, 300 μm long, glandular head 60 x 60 μm; eglandular trichomes biseriate type, multicellular, 255-450 μm long.

Sepal margin: Trichomes glandular and eglandular types; present throughout, horizontal orientation; glandular trichomes biseriate type, multicellular, 300 μm long, glandular head 60 x 60 μm; eglandular trichomes biseriate type, multicellular, 255-450 μm long.

*No trichomes were found on adaxial surface of leaf, petal, stamen and carpel.

4.1.2.13B. Venation (Plate 13J)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA.Uttarakhand: Uttarkashi district, Suralaya, 5000m, July 1996, *D.S. Rawat s.n., Acc. No- 894* (G.B.Pant University Herbarium Pantnagar, Uttarakhand, India).

4.1.2.14. *Saxifraga microphylla* Royle ex Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2: 72. 1857; C.B. Clarke in Hook.f., Fl. Brit. India 2: 395. 1878; Griers. in Griers.

& Long, Fl. Bhutan 1(3): 515. 1987; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.14A. Trichomes (Plate 14 A-H)

Stem: Trichomes eglandular types; present throughout, antrorse and retrorse orientation, vestiture pilose, intermediate type, multicellular, 285-300 µm long.

Leaf margin: Trichomes eglandular type; scarce, present near base, horizontal orientation, biseriate and intermediate types, multicellular, 60-180 µm long.

Pedicel: Trichomes eglandular type; present throughout, antrorse and retrorse orientation, vestiture pilose, uniseriate and intermediate types, multicellular, 255-315 µm long.

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.14B. Venation (Plate 14 I)

Leaf venation: Acrodomous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand: Garhwal: Chamoli District, on way to Roopkund, 4600-4700m, 2.9.2014, *D.S.Rawat s.n., Acc. No- 895* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.15. *Saxifraga minutissima* D.S.Rawat in *Edinburgh J. Bot.* 69(2): 211. 2012.

4.1.2.15A. Trichomes (Plate 15 A-D, F-H)

Adaxial surface of leaf: Trichomes eglandular type; scarce, present on the middle portion of the leaf surface, antrorse orientation, biseriate type, multicellular, 60 µm long.

Leaf margin: Trichomes glandular and eglandular type; present throughout, antrorse orientation; glandular trichomes scarce, present at base on either side; biseriate trichomes multicellular, 135 µm long, glandular head 30 x 30 µm; eglandular trichomes biseriate type, multicellular, 180 µm long.

Pedicel: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture pubescent; glandular trichomes biseriate type, multicellular, 120

μm long, glandular head 30 x 30 μm; eglandular trichomes biseriate type, multicellular, 90 μm long.

Sepal margin: Trichomes glandular and eglandular types; present throughout but not near apex, retrorse and horizontal orientation; glandular trichomes biseriate type, multicellular, 90 μm long, glandular head 45 x 45 μm; eglandular trichomes biseriate type, multicellular, 105 μm long.

*No trichomes were found on stem, abaxial surface of leaf, sepal surface, petal, stamen and carpel.

4.1.2.15B. Venation (Plate 15 E)

Leaf venation: Acrodomous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area near Kedarnath, 4600-4800m, 10.9.2001, Holotype, *D.S. Rawat s.n., Acc. No- 442* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.16. *Saxifraga moorcroftiana* (Ser.) Wall. Ex Sternb., *Revis. Saxifrag. Suppl.* 2: 28. T.24. 1831; Griers. in Griers. & Long, Fl. Bhutan 1(3): 507. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 301. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.16A. Trichomes (Plate 16 A, B, D-F)

Stem: Trichomes glandular types; scarce, more at nodes, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 495 μm long, glandular head 45 x 75 μm.

Leaf margin: Trichomes glandular type; scarce, present towards base, antrorse orientation, biseriate type, multicellular, 150 μmlong, 75 x 105 μm.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation, vestiture tomentulose, biseriate type, multicellular, 525 μmlong, glandular head 60 x 60 μm.

Sepal margin: Trichomes glandular; present throughout, horizontal orientation, biseriate type, multicellular, 180 μm long, glandular head 105 x 135 μm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.16B. Venation (Plate 16 C)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA, Jammu & Kashmir, Zoji Pass, 10-11000 ft, 30.8.1940, *R.R. Stewart 88659* (DD).

4.1.2.17. *Saxifraga mucronulata* Royle, Ill. Bot. Himal. Mts. 7: 227. 1835; Griers. in Griers. & Long, Fl. Bhutan 1(3): 499. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 336. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

17A. Trichomes (Plate 17 A-H)

Stem: Trichomes glandular type; present throughout, retorse orientation, vestiture pubescent, biseriate type, multicellular, 210 µmlong, glandular head 45 x 45 µm.

Adaxial surface of leaf: Trichomes glandular type; present throughout, horizontal orientation, uniseriate and biseriate types, multicellular, 90-195 µmlong, glandular head 30-45 x 45-60 µm.

Abaxial surface of leaf: Trichomes glandular type; present throughout, horizontal orientation, uniseriate and biseriate types, multicellular, 90-195 µm, glandular head 30-45 x 45-60 µm.

Leaf margin: Trichomes glandulartype; present throughout, horizontal orientation, biseriate and multiseriate types, multicellular, 255-630µmlong, glandular head 45-60 x 45-75 µm.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 330 µmlong, glandular head 45 x 45µm.

Abaxial surface of sepal: Trichomes glandular type; present throughout, horizontal orientation, uniseriate and biseriate types, multicellular, 120-300 µmlong, glandular head 45 x 30-45 µm.

Sepal margin: Trichomes glandular type; present throughout, horizontal orientation, biseriate and multiiseriate types, multicellular, 120-450 µmlong, glandular head 45-75 x 30-90 µm.

*No trichomes were found on petal, stamen and carpel.

4.1.2.17B. Venation (Plate 17 I)

Leaf venation: Acrodomous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area near Kedarnath, 4500-4600m, Sep. 2000, *D.S. Rawat s.n., Acc. No- 896* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.18. *Saxifraga palpebrata* Hook.f. et Thomson in J. Proc. Linn. Soc., Bot. 2: 67. 1857; C.B.Clarke in Hook.f., Fl. Brit. India 2: 391. 1878; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.18A. Trichomes (Plate 18 A-H)

Stem: Trichomes eglandular types; present throughout, horizontal orientation, vestiture villous, biseriate and intermediate types, multicellular, 1800μmlong.

Adaxial surface of leaf: Trichomes eglandular type; present throughout, antrorse orientation, multiseriate type, multicellular, 1380 μmlong.

Leaf margin: Trichomes eglandular type; present throughout, antrorse orientation, multiseriate type, multicellular, 1125 μmlong.

Pedicel: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, multiseriate type, multicellular, 2100 μmlong.

Abaxial surface of sepal: Trichomes scarce, antrorse orientation, eglandular, biseriate type, multicellular, 525 μm

Sepal margin: Trichomes present throughout but not near apex, antrorse orientation, eglandular, biseriate type, multicellular, 225 μm

*No trichomes were found on abaxial surface of leaf, petal, stamen and carpel.

4.1.2.18B. Venation (Plate 18 J)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4600m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 897* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2.19. *Saxifraga parnassifolia* D.Don in *Trans. Linn. Soc. London* 13(2): 405. 1821; Griers. in Griers. & Long, Fl. Bhutan 1(3): 507. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 398. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.19A. Trichomes (Plate 19 A, B, D-F)

Stem: Trichomes glandular type; present throughout, longer trichomes are distinctly seen at nodes, horizontal orientation, vestiture pubescent, multiseriate type, multicellular, 300-1680 µmlong, glandular head 60-120 x 45-120 µm.

Leaf margin: Trichomes glandular type; present along the lower half of the leaf margin, longer trichomes at base, horizontal orientation, multiseriate type, multicellular, 150-1680 µmlong, glandular head 60-75 x 45-90 µm.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation vestiture pubescent, multiseriate type, multicellular, 300 µmlong, glandular head 120 x 120 µm.

Abaxial surface of sepal: Trichomes glandular type; present only at base, antrorse orientation, multiseriate type, multicellular, 300 µmlong, glandular head 90 x 90 µm.

Sepal margin: Trichomes glandular type; present throughout, antrorse orientation, multiseriate type, multicellular, 180 µmlong, glandular head 105 x 150 µm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), petal, stamen and carpel.

4.1.2.19B. Venation (Plate 19 C)

Leaf venation: Campylodromous.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli District, Vedni Bugyal, 3500m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 898* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2.20. *Saxifraga pseudopallida* Engl. & Irmsch., *Bot. Jahrb. Syst.* 50, Beibl. 114: 40.1914; Griers. in Griers. & Long, Fl. Bhutan 1(3): 502. 1987.

4.1.2.20A. Trichomes (Plate 20 A-I)

Stem: Trichomes eglandular type; present throughout, dense at node, horizontal orientation, vestiture pubescent, biseriate and intermediate types, multicellular, 330-435 µmlong.

Adaxial surface of leaf: Trichomes eglandular type; present throughout, horizontal orientation, biseriate and multiseriate types, multicellular, 375 µmlong.

Abaxial surface of leaf: Trichomes eglandular type; present throughout, horizontal orientation, biseriate and multiseriate types, multicellular, 420-675 µmlong.

Leaf margin: Trichomes eglandular type; present throughout but not near apex, horizontal orientation, biseriate and multiseriate types, multicellular, 600-630 µmlong.

Petiole: Trichomes eglandular type; present throughout, horizontal orientation, vestiture pubescent, biseriate and multiseriate types, multicellular, 780-900 µmlong.

Pedicel: Trichomes eglandular type; present throughout, horizontal orientation, vestiture pubescent, biseriate and intermediate types, multicellular, 330-435 µmlong.

*No trichomes were found on sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.20B. Venation (Plate 20 J)

Leaf venation: Palinactinodromous

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli district, Kalu Vinayak, 4300m, Aug. 2014, *D.S. Rawat s.n., Acc. No- 899* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2.21. *Saxifraga pulvinaria* Harry Sm. in *Bull. Brit. Mus. (Nat. Hist.) Bot.* 2: 105. Pl. 4. fig. m. 1958; Griers. in Griers. & Long. Fl. Bhutan 1(3): 498. 1987; Pan *et al.* in Wu *et al.* Fl. China 8: 346. 2001; Akiyama & Gornall in Watson *et al.* Fl. Nepal Saxifragaceae 10. 2012. *S. imbricata* Royle, C.B.Clarke in Hook.f., Fl. Brit. India 2: 394. 1878.

4.1.2.21A. Trichomes (Plate 21 A, B, D)

Leaf margin: Trichomes eglandular type; present sparsely along the margin but absent near apex, antrorse (upper trichomes) and retrorse (lower trichomes) orientations, multiseriate type, multicellular, 75-150 µm long.

Pedicel: Trichomes eglandular only; scarce, horizontal orientation, vestiture pubescent, multiseriate, multicellular, 75-150 µm long.

*No trichomes were found on stem, leaf surfaces (adaxial and abaxial), sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.21B. Venation (Plate 21 C)

Leaf venation: Hyphodromous.

Vaucher Specimen: INDIA. Uttarakhand, Kumaon: Bageshwar District, Sunderdhunga Valley, 3800m, 18.6. 2012, *D.S.Rawat s.n., Acc. No- 900* (G.B. Pant University Herbarium, Pantnagar)

4.1.2.22. *Saxifraga saginoides* Hook.f. & Thomson, *J. Proc. Linn. Soc., Bot.* 2:68. 1857; C.B.Clarke in Hook.f., Fl. Brit. India 2: 392. 1878; Griers. in Griers. & Long, Fl. Bhutan. 1(3): 513. 1987; Pan *et al.* in Wu *et al.,* Fl. China 8: 317. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.22A. Trichomes (Plate 22 A-C, E-G)

Stem: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, multiseriate type, multicellular, 1500 µm long.

Leaf margin: Trichomes eglandular type; present throughout, antrorse orientation, biseriate and multiseriate types, multicellular, 1050-1500 µm long.

Pedicel: Trichomes eglandular type; present throughout, horizontal orientation, vestiture tomentose, multiseriate type, multicellular, 1470µmlong.

Sepal margin: Trichomes glandular type; present throughout, antrorse orientation, biseriate type, multicellular, 120-195 µmlong, glandular head 30-45 x 45 µm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.22B. Venation (Plate 22 D)

Leaf venation: Acrodomous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Chamoli District, Bhagwa Basa, 4600m, Aug. 2014, *D.S.Rawat s.n., Acc. No- 901* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2.23. *Saxifraga stella-aurea* Hook.f.et Thomson in *J. Proc. Linn. Soc., Bot.* 2: 72. 1857; Griers. in Griers. & Long, Fl. Bhutan 1(3): 513. 1987; Pan *et al.* in Wu *et al.,* Fl.

China 8: 324. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.23A. Trichomes (Plate 23 A-H)

Stem: Trichomes glandular type; present throughout, horizontal orientation, vestiture pubescent, uniseriate and biseriate types, multicellular, 105-120 µmlong, glandular head 30 x 30 µm.

Adaxial surface of leaf: Trichomes eglandular type; present throughout, antrorse orientation, uniseriate and biseriate types, multicellular, 105-120 µm.

Leaf margin: Trichomes glandular and eglandular types; present throughout but not near apex, antrorse orientation, biseriate type, multicellular, 105 µm, glandular head 30 x 30 µm; eglandular, uniseriate and biseriate types, multicellular, 105-120 µm long.

Pedicel: Trichomes glandular type; present throughout, horizontal orientation, vestiture pubescent, uniseriate and biseriate types, multicellular, 165-225 µmlong, glandular head 45 x 45 µm.

Abaxial surface of sepal: Trichomes glandular type; present throughout, usually at base, antrorse orientation, biseriate type, multicellular, 105 µmlong, glandular head 60 x 60 µm.

*No trichomes were found on abaxial surface of leaf, sepal margin, petal, stamen and carpel.

4.1.2.23B. Venation (Plate 23 I)

Leaf venation: Acrodromous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Uttarkashi District, Chaturangi Glacier Valley, Suralaya on way to Kalindi Pass, 5000m, July 1996, *D.S. Rawat s.n., Acc. No- 902* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.24. *Saxifraga stenophylla* Royle, Ill. Bot. Himal. Mts. 7: 227. t. 50. f. 1. 1835; Pan *et al.* in Wu *et al.,* Fl. China 8: 335. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.24A. Trichomes (Plate 24 A-N)

Stem: Trichomes glandular and eglandular type; present throughout, antrorse orientation, vestiture pubescent; glandular biseriate and multiseriate types, multicellular, 270-330 µm long, glandular head 45-75 x 60-75 µm; eglandular uniseriate, biseriate and multiseriate types, multicellular, 90-150 µm long.

Adaxial surface of leaf: Trichomes glandular and eglandular types; present only near base, antrorse orientation; glandular multiseriate type, multicellular, 210-675 µmlong, glandular head 45-60 x 60-75 µm; eglandular multiseriate type, multicellular, 450 µmlong.

Abaxial surface of leaf: Trichomes glandular & eglandular types; present only near base, antrorse orientation; glandular multiseriate type, multicellular, 210-675 µmlong, glandular head 45-60 x 60-75 µm; eglandular multiseriate type, multicellular, 450 µmlong.

Leaf margin: Trichomes glandular and eglandular types; present throughout, antrorse orientation; glandular present towards base, multiseriate type, multicellular, 210-675 µmlong, glandular head 45-60 x 60-75 µm; eglandular present towards apex, multiseriate type, multicellular, 450 µm long.

Pedicel: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture pubescent; glandular biseriate, intermediate and multiseriate types, multicellular, 195-360 µmlong, glandular head 30-45 x 45-60 µm; eglandular uniseriate and biseriate types, multicellular, 90-120 µmlong.

Abaxial surface of sepal: Trichomes glandular type; present throughout, antrorse orientation, biseriate and multiseriate types, multicellular, 225-285 µm long, glandular head 45-60 x 60 µm.

Sepal margin: Trichomes glandular types; present throughout, antrorse orientation, biseriate and multiseriate types, multicellular, 225-285 µmlong, glandular head 45-60 x 60 µm.

*No trichomes were found on petal, stamen and carpel.

4.1.2.24B. Venation (Plate 24 0)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: Rudraprayag District, Vasuki Tal area, 4600m, Sept. 2000, *D.S. Rawat s.n., Acc. No- 903* (G.B. Pant University Herbarium, Pantnagar!)

4.1.2.25. *Saxifraga wallichiana* Sternb. in *Revis. Saxifrag. Suppl*. 2: 21. Pl. 22. 1831; Pan *et al.* in Wu *et al.,* Fl. China 8: 320. 2001; Akiyama & Gornall in Watson *et al.,* Fl. Nepal Saxifragaceae 10. 2012.

4.1.2.25A. Trichomes (Plate 25 A-C, E-G)

Stem: Trichomes glandular only; present at nodes, horizontal orientation, vestiture pubescent, biseriate type, multicellular, 255 µm long, glandular head 90 x 90 µm.

Leaf margin: Trichome glandular only; present throughout, antrorse orientation, multiseriate type, multicellular, 195 µm long, glandular head 90 x 75 µm.

Pedicel: Trichomes glandular only; present throughout, antrorse orientation, vestiture pubescent, biseriate type, multicellular, 150-300 µm long, glandular head 75 x 90 µm.

Sepal margin: Trichomes glandular only; present throughout, antrorse orientation, biseriate type, multicellular, 105-195 µm long, glandular head 60 x 75 µm.

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.25B. Venation (Plate 25 D)

Leaf venation: Acrodromous, perfect, basal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Chamoli, Kuari Pass area, 3600m, Aug. 2006, *D.S. Rawat s.n., Acc. No- 904* (G.B. Pant University Herbarium, Pantnagar)

4.1.2.26. *Saxifraga* species A

4.1.2.26A. Trichomes (Plate 26 A, B, D, E)

Stem: Trichomes present throughout, horizontal orientation, vestiture pubescent, glandular, biseriate type, multicellular, 75-180 µm, glandular head 45-75 x 45-75 μm^2

Pedicel: Trichomes present throughout, horizontal orientation, vestiture pubescent, glandular, biseriate type, multicellular, 75-180 µm, glandular head 45-75 x 45-75 μm^2

*No trichomes were found on leaf surfaces (adaxial and abaxial), leaf margin, sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.26B. Venation (Plate 26 C)

Leaf venation: Campylodromous

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Chamoli, Bhagwabasa area, 4600m, Aug. 2014, *D.S.Rawat s.n., Acc. No- 905* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.27. *Saxifraga* species B

4.1.2.27A. Trichomes (Plate 27 A-F)

Stem: Trichomes present throughout, horizontal orientation, vestiture tomentose, glandular, biseriate type, multicellular, 2475 μm, glandular head 45 x 30 μm^2

Leaf margin: Trichomes present throughout, horizontal orientation, eglandular, biseriate type, multicellular, 1500 μm

Pedicel: Trichomes present throughout, horizontal orientation, vestiture tomentose, glandular, biseriate type, multicellular, 750-1800 μm, glandular head 45 x 60 μm^2

Sepal margin: Trichomes present throughout, horizontal orientation, glandular, biseriate type, multicellular, 75-450 μm, glandular head 60 x 45 μm^2

*No trichomes were found on leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.27B. Venation (Plate 27 G)

Leaf venation: Acrodomous (Perfect, Basal)

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Chamoli,Bhagwabasa area, 4500m, Aug. 1993, *D.S.Rawat s.n., Acc. No- 906* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.28. *Saxifraga* species C

4.1.2.28A. Trichomes

*No trichomes were found on stem, pedicel, leaf surfaces (adaxial and abaxial), leaf margin, sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.28B. Venation (Plate 28 A)

Leaf venation: Acrodomous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Rudraprayag, Vasuki Tal area, 4700m, Aug. 2000, *D.S.Rawat s.n., Acc. No- 907* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.29. *Saxifraga* Species D

4.1.2.29A. Trichomes (Plate 29 A-E)

Stem: Trichomes eglandular type; scarce, horizontal orientation, vestiture pubescent, biseriate and multiseriate types, multicellular, 195-600 μmlong.

Leaf margin: Trichomes eglandular type; present throughout, antrorse orientation, biseriate and multiseriate types, multicellular, 450-720 μmlong.

*No trichomes were found on leaf surfaces (adaxial and abaxial), pedicel, sepal surface, sepal margin, petal, stamen and carpel.

4.1.2.29B. Venation (Plate 29 F)

Leaf venation: Acrodromous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Chamoli, Homkundi area, 4000m, Sept. 2014, *D.S.Rawat s.n., Acc. No- 908* (G.B. Pant University Herbarium, Pantnagar).

4.1.2.30. *Saxifraga* Species E

4.1.2.30A. Trichomes (Plate 30 A-D, F, G)

Leaf margin: Trichomes eglandular type; present only near apex, horizontal orientation, multiseriate type, multicellular, 300 μm long.

Pedicel: Trichomes glandular and eglandular types; present throughout, horizontal orientation, vestiture pubescent; glandular biseriate type, multicellular, 105 μmlong, glandular head 30 x 30 μm; eglandular uniseriate type, multicellular, 75 μm long.

Sepal margin: Trichomes eglandular type; present only near apex, horizontal orientation, multiseriate type, multicellular, 255 μm long.

*No trichomes were found on stem, leaf surfaces (adaxial and abaxial), sepal surface, petal, stamen and carpel.

4.1.2.30B. Venation (Plate 30 E)

Leaf venation: Acrodromous, perfect, suprabasal.

Vaucher Specimen: INDIA. Uttarakhand, Garhwal: District Chamoli, Roopkund area, 4600-4700m, Sept. 2014, *D.S.Rawat s.n., Acc. No- 909* (G.B. Pant University Herbarium, Pantnagar).

4.2. Discussion

4.2.1. Compilation of Checklist

The present work is the study on the species of *Saxifraga* L. *sensu lato* genus (Saxifragaceae) found in Western Himalaya, India. *Saxifraga* L. is the largest genus in the family Saxifragaceae consisting of 450 species worldwide **(The Plant List, 2013).** The plants dwell in arctic-alpine ecosystems. These plants are widely used as ornamentals in alpine gardens. It is found mostly in the cold rocky terrains of Europe, North America and the Sino-Himalayan region. Sino-Himalayan region is one of the important diversity centres of the genus, particularly the section *Ciliatae* is highly diversified in the area. In the Indian Himalaya 64 species, 4 subspecies and 5 varieties of *Saxifraga* are recently reported by **Agnihotri & Husain (2013).**

The present study includes the compilation of checklist of species of *Saxifraga* L. in Western Himalaya, India. Different herbaria were consulted for the study of the species like G.B. Pant University Herbarium, Botanical Survey of India Herbarium, Dehradun (BSD), Forest Research Institute Herbarium, Dehradun (DD) and Kew Herbarium Catalogue. Some of the species were not found in the herbaria consulted and thus included on the basis of earlier works by **Stewart (1972), Ghazanfar (1977), Dhar & Kachroo (1983), Pan *et al.* (2001), Uniyal *et al.* (2007), Akiyama & Gornall (2012), Klimes & Dickore (http://www.butbn.cas.cz/klimes/desert.html**) and **Pusalkar & Singh (2013)**.

The present checklist includes, currently accepted name, floras cited, province, locality, date of collection, elevation, collector name, collection number and name of the herbarium. The plant species are present at altitude between 2500m-5000m above sea level. They are found usually in the alpine zone in Western Himalaya. Altitudinal distribution of the species indicates increase in the number of species with increase in elevation.

Saxifraga nutans Hook.f.& Thomson (=***Saxifraga nigroglandulifera*** Balakr.) was reported from Himachal Pradesh by **Chowdhery & Wadhwa (1984)** but **Aswal & Mehrotra (1994)** have mentioned that the only specimen from Himachal Pradesh in DD is wrongly identified as *S. nutans*. It is in fact *S. parnassifolia*. Obviously, the presence of *S. nutans* in Himachal Pradesh was based on a wrong identification. Based on this the species is not included in this checklist.

Saxifraga lycopodioides Duthie was mentioned by **Duthie (1906)** from Kuti Valley and Lebung Pass in Pithoragarh District of Uttarakhand. Since no specimens and literature of its publication are traceable the species is excluded from this list.

The final checklist is given in the **section 4.1.1** and it clearly indicates that Western Himalaya is rich in *Saxifraga* species and sustains 62 species. This large number of species exceeds the recent information by **Agnihotri & Husain (2013)** who have reported only 46 species in Western Himalaya. In the checklist 5 unidentified species are also included based on the specimens in G.B. Pant University herbarium. These specimens do not belong to the already known and listed species (species 1-57 in checklist).

Based on the literature and specimens examined the distribution of these 62 species is shown in **figure-4.1** and **table-4.1.**

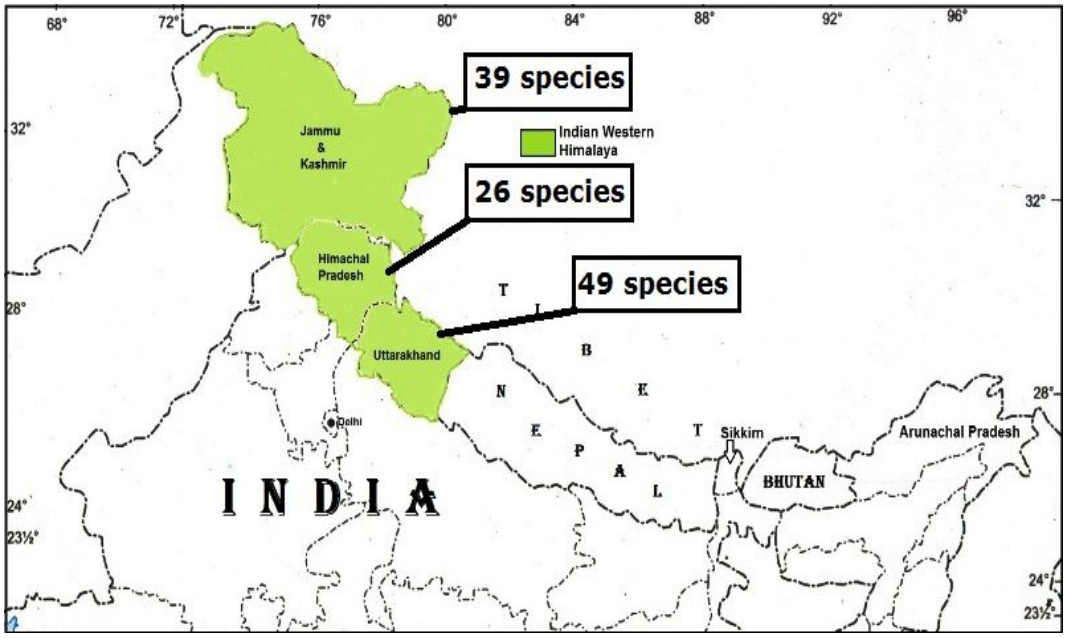


Figure- 4.1 Distribution of *Saxifraga* species in Western Himalaya

Table 4.1: Distribution of *Saxifraga* species in Western Himalaya

Sl. No.	Species	Distribution in Indian Western Himalaya		
		Jammu & Kashmir	**Himachal Pradesh**	**Uttarakhand**
1.	***Saxifraga afghanica*** Aitch. & Hemsl.	+	-	-
2.	***Saxifraga andersonii*** Engl.	-	-	+
3.	***Saxifraga androsacea*** L.	+	-	-
4.	***Saxifraga aristulata*** Hook.f. & Thomson	-	-	+
5.	***Saxifraga asarifolia*** Sternb.	+	+	+
6.	***Saxifraga brachypoda*** D.Don	-	-	+
7.	***Saxifraga brunoniana*** Wall. ex Ser.	+	+	+
8.	***Saxifraga cernua*** L.	+	+	+
9.	***Saxifraga chadwellii*** Wadhwa	+E	-	-
10.	***Saxifraga ciliatopetala*** (Engl. & Irmsch.) J.T.Pan	+	-	-
11.	***Saxifraga coarctata***W.W.Sm.	+	?	?
12.	***Saxifraga corymbosa*** Hook.f. & Thomson	-	+	+
13.	***Saxifraga diversifolia*** Wall. ex Ser.	+	+	+
14.	***Saxifraga duthiei*** Gand.	+E	-	-
15.	***Saxifraga elliptica*** Engl. & Irmsch.	+	-	-
16.	***Saxifraga filicaulis*** Wall. ex Ser.	-	+	+
17.	***Saxifraga flagellaris*** Willd. ex Sternb.	+	+	+
18.	***Saxifraga giraldiana*** Engl. ex Diels	-	+	-
19.	***Saxifraga granulifera*** Harry Sm.	-	-	+
20.	***Saxifraga hemisphaerica*** Hook.f. & Thomson	-	-	+

21.	***Saxifraga hirculoides*** Decne.	+	+	+
22.	***Saxifraga hirculus*** L.	+	+	+
23.	***Saxifraga hispidula*** D.Don.	-	-	+
24.	***Saxifraga jacquemontiana*** Decne.	+	+	+
25.	***Saxifraga kashmeriana*** U.Dhar & Kachroo	+ E	-	-
26.	***Saxifraga kumaunensis*** Engl.	-	-	+
27.	***Saxifraga lepida*** Harry Sm.	-	-	+
28.	***Saxifraga lilacina*** Duthie	+	-	+
29.	***Saxifraga lychnitis*** Hook.f. & Thomson	+	+	+
30.	***Saxifraga meeboldii*** Engl. & Irmsch.	+	-	-
31.	****Saxifraga melanocentra*** Franch.	+	-	+
32.	***Saxifraga microphylla*** Royle ex Hook.f. & Thomson	+	-	+
33.	***Saxifraga minutissima*** D.S.Rawat	-	-	+ E
34.	***Saxifraga moorcroftiana*** (Ser.) Wall. ex Sternb.	+	+	+
35.	***Saxifraga mucronulata*** Royle	+	+	+
36.	***Saxifraga nakaoi*** Kitam.	+	-	+
37.	***Saxifraga nanella*** Engl. & Irmsch.	+	-	-
38.	***Saxifraga oppositifolia*** L.	+	-	+
39.	****Saxifraga pallida*** Wall. ex Ser.	+	+	+
40.	***Saxifraga palpebrata*** Hook.f. et Thomson	-	+	+
41.	***Saxifraga parnassifolia*** D.Don	-	+	+
42.	***Saxifraga poluniniana*** Harry Sm. var. ***mucronata*** U.C.Bhattach. & M.V.Viswan.	-	-	+ E

43.	***Saxifraga pseudopallida** Engl. & Irmsch.	+	+	+
44.	***Saxifraga pulvinaria*** Harry Sm.	+	+	+
45.	***Saxifraga ramulosa*** Wall. & Ser.	+	+	+
46.	***Saxifraga roylei*** Harry Sm.	-	-	+
47.	***Saxifraga saginoides*** Hook.f. & Thomson	+	+	+
48.	***Saxifraga sibirica*** L.	+	+	+
49.	***Saxifraga sinomontana*** J.T.Pan & Gornall	+	+	+
50.	***Saxifraga stella-aurea*** Hook. f. et Thomson	+	+	+
51.	***Saxifraga stenophylla*** Royle	+	+	+
52.	***Saxifraga stolitzkae*** Duthie ex Engl. & Irmsch.			+
53.	***Saxifraga strigosa*** Wall. & Ser.	-	-	+
54.	***Saxifraga subspathulata*** Engl. & Irmsch.			+
55.	***Saxifraga tangutica*** Engl.	+	-	-
56.	***Saxifraga viscidula*** Hook.f. & Thomson	?	?	?
57.	***Saxifraga wallichiana*** Sternb.		+	+
58.	***Saxifraga*** species A*	-	-	+
59.	***Saxifraga*** species B*	-	-	+
60.	***Saxifraga*** species C*	-	-	+
61.	***Saxifraga*** species D*	-	-	+
62.	***Saxifraga*** species E*	-	-	+
Total Species		**39**	**26**	**49**

E= Endemic, *identity yet not determined but certainly different from species 1-57.

The **table-4.1** and **figure-4.1** clearly depict that in spite of smaller area Uttarakhand is richest in *Saxifraga* species with 49 species. This number is even higher than the **Uniyal *et al.* (2007)** in which only 39 species are listed. Jammu and Kashmir sustain 39 species and second richest state and Himachal Pradesh has only 26 species. However, this low number in Himachal Pradesh may also be due to fewer collections from alpine areas as compared to the Uttarakhand. Three species, namely - *Saxifraga chadwellii* Wadhwa, *Saxifraga duthiei* Gand. and *Saxifraga kashmeriana* U.Dhar & Kachroo are endemic to Jammu & Kashmir while one species *Saxifraga minutissima* D.S.Rawat and one variety *Saxifraga poluniniana* Harry Sm. var. *mucronata* U.C.Bhattach. & M.V.Viswan. are endemic to Uttarakhand. No endemic species is known in Himachal Pradesh.

The distribution of *Saxifraga* L. in Iran – Sinohimalayan states/countries is shown in **figure-4.2.** There is a general trend of decrease in the number of species of *Saxifraga* L. from east to west. The highest diversity of *Saxifraga* genus is found in China (**Pan *et al.*, 2001**) consisting of 216 species. It is followed by Nepal with 91 species (**Akiyama & Gornall, 2011**) and Bhutan (**Grierson, 1987**) with 61 species reported. In Indian Himalayan Region, highest diversity is recorded from Sikkim (54 species) in Eastern Himalaya. The western Himalayan states follows up with 49 species in Uttarakhand, 26 species in Himachal Pradesh and 36 species in Jammu & Kashmir. The number of species still lowers moving westward, i.e. 19 species found in Pakistan and only 10 species found in Iran.

Perusal of Indian Red Data Book (**Nayar & Sastry, 1987-90**) indicates that no species of *Saxifraga* found in Western Himalaya is threatened in Indian territories. Though, *Saxifraga jacquemontii* is listed in '1997 IUCN Redlist of Threatened Vascular Plant Species in India' (**Rao *et al.*, 2003**) as Endangered (E) and mentioned as growing only in Jammu & Kashmir. However, this herbarium and literature study clearly indicates that *S. jacquemontii* is a widespread species in Western Himalaya and collected several times from different areas, thus contradicting the Endangered status. The recent IUCN Redlist for Indian plants is available in eflorapantnagar (**Rawat & Rao 2015**) and its perusal shows that no *Saxifraga* species is threatened in India, though it also indicates that no species has been assessed for threat status according to IUCN criteria.

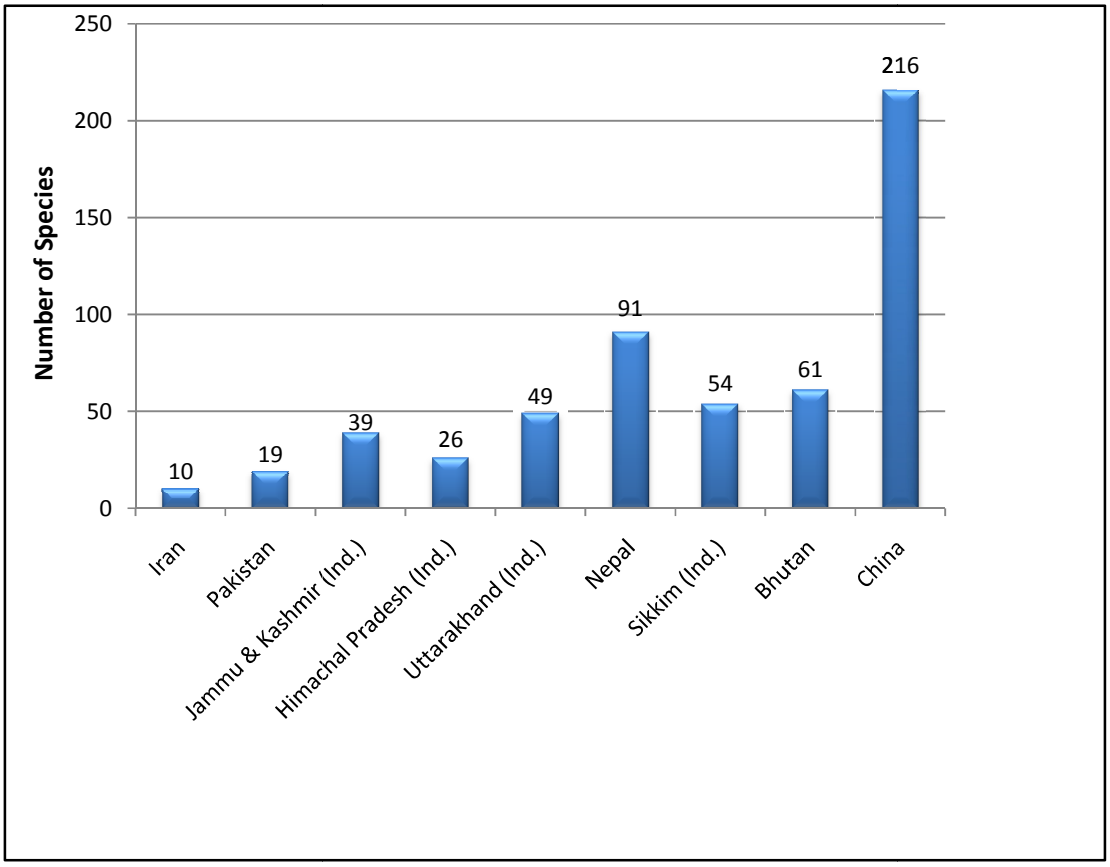


Figure 4.2: Distribution of *Saxifraga* genus in Iran – Sinohimalayan States/Countries

4.3.2. Position of *Saxifraga* Species in Sections of the Genus

Saxifraga is a large genus with high diversity in morphology. Many infra-generic classifications of this genus have been published by different authors. Distribution of species in different sections of *Saxifraga* L. as given by **Gornall (1987)** and partially modified by **Zhang (2013)**, in different areas of Sino-Himalayan region is shown in **Table-4.2.** *Saxifraga* sect. *Ciliatae* comprises of maximum number of species in all three areas, i.e. Western Himalaya, Nepal and China. China has the highest number of species (166 species; **Pan *et al.*, 2001**) followed by Nepal (65 species; **Akiyama & Gornall, 2011**) and Western Himalaya (39 species). This section is followed by section *Porphyrion* with China having maximum number of species (25 species; **Pan *et al.*, 2001**), Nepal having 18 species (**Akiyama & Gornall, 2011**) and

Western Himalaya with 14 species. *Saxifraga* sect. *Micranthes* have 13 species in China (**Pan *et al.*, 2001**), 5 species in Bhutan (**Grierson, 1987**), 4 species in Nepal (**Akiyama & Gornall, 2011**) and 3 species in Western Himalaya. In these larger sections a clear trend of decreasing number of species from east to west is seen as also seen in the number of species.

All the three areas share same number of species (3 species) belonging to section *Mesogyne.* Section *Saxifraga* includes 1 species in China, 1 species in Nepal and 2 species in Western Himalaya. Section *Irregulares* and section *Trachyphyllum* include 1 species each in China. No species belonging to these sections is found in Nepal and Western Himalaya. Western Himalaya possesses 1 species belonging to section *Odontophyllae* but this section is completely absent from China and Nepal.

Table 4.2: Distribution of species in different sections of *Saxifraga* L. genus in Western Himalaya, Nepal and China

S. No.	Section	W. Himalaya	Nepal	China
1.	*Ciliatae*	39	65	166
2.	*Micranthes*	3	4	13
3.	*Irregulares*	0	0	7
4.	*Porphyrion*	14	18	25
5.	*Trachyphyllum*	0	0	1
6.	*Odontophyllae*	1	0	0
7.	*Mesogyne*	3	3	3
8.	*Saxifraga*	2	1	1

Listing of species of *Saxifraga* L. of Western Himalaya under different sections as given by **Gornall (1987)** is shown in **Table-4.3.** Highest diversity is found in *Saxifraga* sect. *Ciliatae* having 39 species in total. *Saxifraga* sect. *Ciliatae* subsect. *Hirculoideae* has the highest number of species, i.e. 21 species. Other subsections of sect. *Ciliatae* found in Western Himalaya are subsects. *Gemmiparae* (7 species),

Rosulares (4 species), *Serpyllifoliae* (1 species), *Flagellares* (4 species) and *Hemispaericae* (2 species).

The second highest diversity of the genus is found in *S.* sect. *Porphyrion* possessing 13 species. *Saxifraga* sect. *Porphyrion* subsect. *Kabschia* includes 9 species, subsect. *Engleria* has 1 species and subsect. *Oppositifoliae* has 3 species present in Western Himalayan region.

Saxifraga sect. *Micranthes* comprises of 3 species belonging to subsect. *Cuneifoliatae*. *Saxifraga* sect. *Mesogyne* also has 3 species occurring in Western Himalaya.

Saxifraga sect. *Saxifraga* possess 2 species, both belonging to subsect. *Holophyllae.* One species belonging to *S.* sect. *Odontophyllae* is also found in Western Himalayan region.

Table 4.3: Listing of species of Western Himalayan Species of *Saxifraga* L. in different sections, subsections and series as recognized by Gornall (1987)

S. No.	Sections	Subsections	Species
1.	*Ciliatae* Haw.	*Hirculoideae* Engl. & Irmscher	*S. parnassifolia* *S. hirculus* *S. saginoides* *S. palpebrata* *S. hirculoides* *S. moorcroftiana* *S. diversifolia* *S. nakaoi* *S. subspathulata* *S. giraldiana* *S. aristulata* *S. ciliatopetala* *S. chadwelli* *S. elliptica* *S. lepida* *S. sinomontana*

			S. tangutica *S. lychnitis* *S. viscidula* *S. kashmeriana* *Saxifraga* species A *Saxifraga* species B
		Gemmiparae Engl. & Irmscher	*S. brachypoda* *S. hispidula* *S. filicaulis* *S. strigosa* *S. wallichiana* *Saxifraga* species D
		Rosulares Gornall	*S. microphylla* *S. jacquemontiana* *S. stella-aurea* *S. nanella*
		Serpyllifoliae Gornall	*S. minutissima*
		Flagellares (C.B. Clarke) Engl. & Irmscher	*S. brunoniana* *S. stenophylla* *S. mucronulata* *S. flagellaris*
		Hemisphaericae (Engl. & Irmscher) Gornall	*S. hemisphaerica* *Saxifraga* species E

2.	*Micranthes* (Haw.) D.Don	*Cuneifoliatae* A.M. Johnson	*S. pseudopallida* *S. pallida* *S. melanocentra*
3.	*Porphyrion* Tausch	*Kabschia* (Engl.) Rouy & Camus	*S. afghanica* *S. andersonii* *S. pulvinaria* *S. kumaunensis* *S. lilacina* *S. stolitzkae* *S. meeboldii* *S. poluniniana* var. *mucronata* *S. ramulosa*
		Engleria (Sündermann) Gornall	*S. corymbosa*
		Oppositifoliae Hayek	*S. duthiei* *S. oppositifolia* *S. roylei* *Saxifraga* species C
4.	*Odontophyllae* Gornall		*S. asarifolia*
5.	*Mesogyne* Sternb.		*S. cernua* *S. granulifera* *S. sibirica*
6.	*Saxifraga* LT	*Holophyllae* (Engl. & Irmscher) Pflanzenr.	*S. androsacea* *S. coarctata*

Tkach *et al.* (2015) gave a revised classification of *Saxifraga* genus excluding *S.* sect. *Micranthes*. They proposed 13 sections and 9 subsections under the genus. The number of species of *Saxifraga* L. in Western Himalaya on the basis of the classification by **Tkach *et al.* (2015)** is given in **Table-4.4.**

Table 4.4: Sectional Position of *Saxifraga* species of Western Himalaya on the basis of the classification of Tkach *et al.* (2015)

S. No.	Section	Species
1.	*Ciliatae*	39
2.	*Mesogyne*	3
3.	*Porphyrion*	14
4.	*Saxifraga*	2

Highest number of the *Saxifraga* species (39 species) in Western Himalaya belongs to *S.* sect. *Ciliatae*, followed by *S.* sect. *Porphyrion* having 14 species, *S.* sect. *Mesogyne* with 3 species and lastly *S.* sect. *Saxifraga* possessing 2 species. Three species, namely *S. pseudopallida, S. pallida* and *S. melanocentra,* are treated under a separate genus *Micranthes*. *Saxifraga asarifolia* was not placed under any section and was listed as *'incertae sedis'*.

4.3.3 Trichome Study

The variability of trichomes in the species of *Saxifraga* L. has been used as reliable character in delimitation and differentiation of these species. **Gornall (1986)** examined trichomes on leaves and pedicels in 213 species of the genera *Saxifraga*, *Zahlbrucknera, Saxifragella, Saxifragodes,* and *Saxifragosis*. He found mainly following four types of trichomes in the genus *Saxifraga*:

1. Multiseriate glandular type (occurring in 4 series of *Saxifraga* sect. *Micranthes*, part of sect. *Gymnopera*, and in sects. *Ciliatae*, *Trachyphyllum, Xanthizoon, Ligulatae, Porophyllum, Porphyrion* and *Irregulares*)
2. Uniseriate glandular type (occuring in 5 series of *Saxifraga* sect. *Micranthes,* part of sects. *Gymnopera* and *Irregulares*, and in sects. *Miscopetalum, Cymbalaria, Tridactylites, Saxifraga* and *Stoloniferae*)
3. Eglandular multicellular type (occurring in sects. *Xanthizoon, Porophyllum* and *Porphyrion,* occasionally in sects. *Micranthes, Gymnopera*, *Ciliatae* and *Ligulatae*)

4. Sessile glandular type (occurring in some species of sect. *Stoloniferae*).

In the present study, 30 species of *Saxifraga* genus available in G.B. Pant University Herbarium, Pantnagar were studied for trichome types and distribution. The plants were examined for presence/absence of trichomes on different plant parts, types of trichomes present and types of vestiture found on stem and pedicel of the plant. Out of these 30 species examined, the trichome diversity in 18 species was not studied by **Gornall (1986)**. These species are *Saxifraga andersonii, S. hirculoides, S. kumaunensis, S. lilacina, S. microphylla, S. minutissima, S. moorcroftiana, S. mucronulata, S. palpebrata, S. parnassifolia, S. stella-aurea, S. stenophylla* and *Saxifraga* species A, B, C, D and E.

Among the 30 species studied for the trichome diversity and distribution, 29 species possess trichomes at least on one plant part while 1 species (*Saxifraga* species C) is totally glabrous. Trichomes are found on stem, pedicel, petiole, adaxial and abaxial surfaces of leaf, leaf margin, abaxial surface of sepal and sepal margin. No trichomes are present on petal, stamen and carpel of any of the examined plant species. The trichomes observed are all of multicellular type. Mainly 8 types of trichomes are recorded in the studied specimens **(Table-4.5)**.

Trichomes observed in this study are of following types and are shown in **Plate-33**:

1. Glandular uniseriate type
2. Glandular biseriate type
3. Glandular intermediate type
4. Glandular multiseriate type
5. Eglandular uniseriate type
6. Eglandular biseriate type
7. Eglandular intermediate type
8. Eglandular multiseriate type

Table 4.5: Trichome diversity and distribution in different species of *Saxifraga* L. found in Western Himalaya

S. No.	Species	Stem	Pedicel	Sepal		Leaf			Petiole
				Surface	Margin	Adaxial	Abaxial	Margin	
1.	*Saxifraga andersonii*	Glandular, biseriate, intermediate	Eglandular, uniseriate Glandular, uniseriate, biseriate, multiseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate, multiseriate	Glandular, biseriate, multiseriate	Glandular, biseriate, intermediate, multiseriate	
2.	*S. aristulata*	Glandular, biseriate	Glandular, biseriate	-	Glandular, biseriate	-	-	-	
3.	*S. brachypoda*	-	Glandular, multiseriate	Glandular, biseriate	Glandular, biseriate	-	-	Eglandular, multiseriate	
4.	*S. brunoniana*	Glandular, biseriate	Glandular, biseriate	-	-	-	-	Glandular, multiseriate	
5.	*S. cernua*	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate	Glandular, uniseriate
6.	*S. filicaulis*	Eglandular, uniseriate, biseriate, intermediate Glandular, biseriate	Eglandular, uniseriate, biseriate, intermediate Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	-	-	Glandular, biseriate	

7.	*S. hirculoides*	Eglandular, uniseriate	Eglandular, uniseriate	-	Eglandular, uniseriate	Eglandular, uniseriate	Eglandular, uniseriate	Eglandular, uniseriate	Eglandular, uniseriate
8.	*S. hirculus*	Eglandular, uniseriate, intermediate	Eglandular, uniseriate, intermediate		Eglandular, uniseriate, intermediate				Eglandular, uniseriate, intermediate
9.	*S. hispidula*	Eglandular, uniseriate, intermediate Glandular, uniseriate	Eglandular, uniseriate, intermediate Glandular, biseriate	Eglandular, multiseriate Glandular, biseriate	Eglandular, multiseriate	Eglandular, uniseriate, intermediate, multiseriate Glandular, intermediate	Eglandular, uniseriate, intermediate, multiseriate	Eglandular, uniseriate, intermediate, multiseriate	
10.	*S. jacquemontiana*	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	
11.	*S. kumaunensis*	-	Glandular, biseriate	-	Glandular, multiseriate	-	-	Glandular, biseriate, multiseriate	
12.	*S. lilacina*	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	Glandular, biseriate	-	Glandular, biseriate	
13.	*S. lychnitis*	Eglandular, biseriate, intermediate Glandular, uniseriate, biseriate	Eglandular, biseriate, intermediate Glandular, uniseriate, biseriate	Eglandular, biseriate Glandular, biseriate	Eglandular, biseriate Glandular, biseriate	-	Glandular, uniseriate, biseriate	Eglandular, biseriate Glandular, uniseriate, biseriate	

14.	*S. microphylla*	Eglandular, intermediate	Eglandular, uniseriate, intermediate	-	-	-	-	Eglandular, biseriate, intermediate	
15.	*S. minutissima*	-	Eglandular, biseriate Glandular, biseriate	-	Eglandular, biseriate Glandular, biseriate	Eglandular, biseriate	-	Eglandular, biseriate Glandular, biseriate	
16.	*S. moorcroftiana*	Glandular, biseriate	Glandular, biseriate	-	Glandular, biseriate	-	-	Glandular, biseriate	
17.	*S. mucronulata*	Glandular, biseriate	Glandular, biseriate	Glandular, uniseriate, biseriate	Glandular, biseriate, multiseriate	Glandular, uniseriate, biseriate	Glandular, uniseriate, biseriate	Glandular, biseriate, multiseriate	
18.	*S. palpebrata*	Eglandular, biseriate, intermediate	Eglandular, multiseriate	Eglandular, biseriate	Eglandular, biseriate	Eglandular, multiseriate	-	Eglandular, multiseriate	
19.	*S. parnassifolia*	Glandular, multiseriate	Glandular, multiseriate	Glandular, multiseriate	Glandular, multiseriate	-	-	Glandular, multiseriate	
20.	*S. pseudopallida*	Eglandular, biseriate, intermediate	Eglandular, biseriate, intermediate	-	-	Eglandular, biseriate, multiseriate	Eglandular, biseriate, multiseriate	Eglandular, biseriate, multiseriate	Eglandular, biseriate, multiseriate
21.	*S. pulvinaria*	-	Eglandular, multiseriate	-	-	-	-	Eglandular, multiseriate	
22.	*S. saginoides*	Eglandular, multiseriate	Eglandular, multiseriate	-	Glandular, biseriate	-	-	Eglandular, biseriate, multiseriate	
23.	*S. stella-aurea*	Glandular, uniseriate, biseriate	Glandular, uniseriate, biseriate	Glandular, biseriate	-	Eglandular, uniseriate, biseriate	-	Eglandular, uniseriate, biseriate Glandular,	

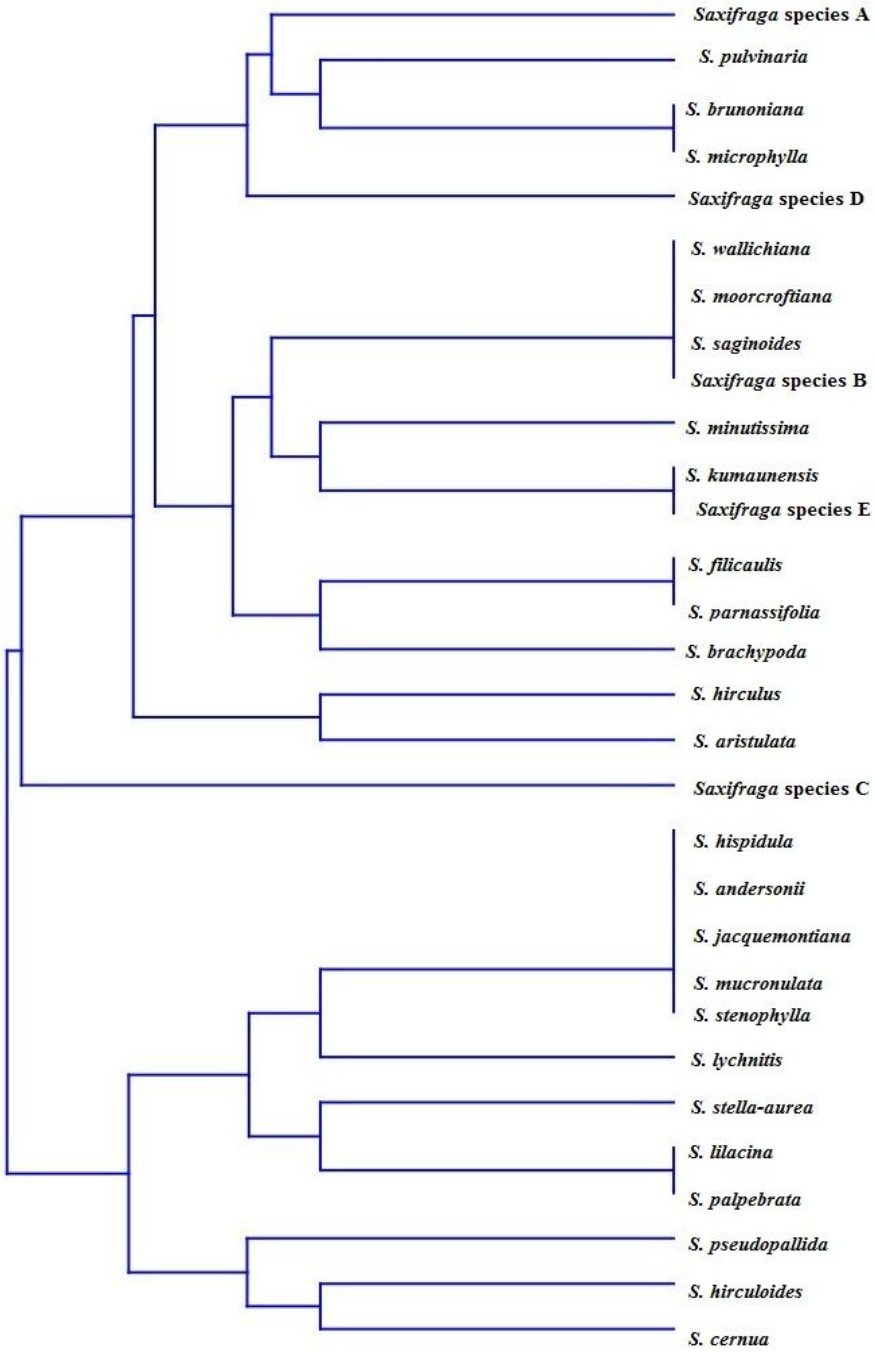
								biseriate	
24.	*S. stenophylla*	Eglandular, uniseriate, biseriate, multiseriate Glandular, biseriate, multiseriate	Eglandular, uniseriate, biseriate Glandular, biseriate, intermediate, multiseriate	Glandular, biseriate, multiseriate	Glandular, biseriate, multiseriate	Eglandular, multiseriate Glandular, multiseriate	Eglandular, multiseriate Glandular, multiseriate	Eglandular, multiseriate Glandular, multiseriate	
25.	*S. wallichiana*	Glandular, biseriate	Glandular, biseriate	-	Glandular, biseriate	-	-	Glandular, biseriate	-
26.	*Saxifraga* species A	Glandular, biseriate	Glandular, biseriate	-	-	-	-	-	
27.	*Saxifraga* species B	Glandular, biseriate	Glandular, biseriate	-	Glandular, biseriate	-	-	Eglandular, biseriate	
28.	*Saxifraga* species C	-	-	-	-	-	-	-	
29.	*Saxifraga* species D	Eglandular, biseriate, multiseriate	-	-	-	-	-	Glandular, biseriate, multiseriate	
30.	*Saxifraga* species E	-	Eglandular, uniseriate Glandular, biseriate	-	Eglandular, multiseriate	-	-	Eglandular, multiseriate	

In **Figure-4.3,** classification of the examined species is done based on the presence of trichomes on different parts of the plant. Broadly, the species are divided into 2 groups. The first group has trichomes all over its body except one or two parts of the plant. This group is further divided into 2 categories based on the presence/absence of trichomes on petiole. *Saxifraga pseudopallida, S. hirculoides* and *S. cernua* have trichomes on petiole, whereas *S. hispidula, S. andersonii, S. jacquemontiana, S. mucronulata, S. stenophylla, S. lychnitis, S. stella-aurea, S. lilacina* and *S. palpebrata* don't have trichomes on petiole.

The second group consists of those species which have trichomes missing from more than two parts of their plant body. *Saxifraga* species C is separated from the rest of the species of this group since no trichome is found in any part of this plant. The other species are further sub-divided into two categories on the basis of presence/absence of trichomes on leaf. *Saxifraga hirculus* and *S. aristulata* doesn't have trichomes on their leaves, neither on the adaxial and abaxial surfaces of the leaf nor on the leaf margin.

The second set, comprising of *S. pulvinaria, S. brunoniana, S. microphylla, Saxifraga* species D, *S. wallichiana, S. moorcroftiana, S. saginoides, Saxifraga* species B, *S. minutissima, S. kumaunensis, Saxifraga* species E, *S. filicaulis, S. parnassifolia* and *S. brachypoda,* have trichome on leaf, whether on one of its surfaces or on its margin. *Saxifraga* species A, which exceptionally doesn't have trichomes on its leaves, comes under this group based on the presence of trichomes only on stem and pedicel.

From further studying the cladogram, it was found that the distribution of trichomes on different plant parts of *Saxifraga* species doesn't have any significance in the infrageneric classification of the genus.



Figur -4.3: Grouping of *Saxifraga* species studied on the basis of distribution of trichomes on different plant parts

Trichome cover on stem and pedicel of the plant specimens is also examined and resulted in 5 types of vestiture (**Table-4.6**). The types of vestiture found are as follows:

1. Pubescent
2. Tomentose
3. Tomentulose
4. Villous
5. Pilose

Table 4.6: Different types of vestiture present on stem and pedicel of the examined species

S. No.	Species	Vestiture	
		Stem	**Pedicel**
1.	*Saxifraga andersonii*	Villous	Villous
2.	*S. aristulata*	Pubescent	Pubescent
3.	*S. brachypoda*	-	Pubescent
4.	*S. brunoniana*	Pubescent	Pubescent
5.	*S. cernua*	Pubescent	Pubescent
6.	*S. filicaulis*	Pubescent	Pubescent
7.	*S. hirculoides*	Tomentose	Tomentose
8.	*S. hirculus*	Tomentose	Tomentose
9.	*S. hispidula*	Pubescent	Pubescent
10.	*S. jacquemontiana*	Pubescent	Pubescent
11.	*S. kumaunensis*	-	Pubescent
12.	*S. lilacina*	Pubescent	Pubescent
13.	*S. lychnitis*	Tomentulose	Tomentulose
14.	*S. microphylla*	Pilose	Pilose
15.	*S. minutissima*	-	Pubescent
16.	*S. moorcroftiana*	Pubescent	Tomentulose
17.	*S. mucronulata*	Pubescent	Pubescent
18.	*S. palpebrata*	Villous	Tomentose
19.	*S. parnassifolia*	Pubescent	Pubescent

20.	*S. pseudopallida*	Pubescent	Pubescent
21.	*S. pulvinaria*	-	Pubescent
22.	*S. saginoides*	Tomentose	Tomentose
23.	*S. stella-aurea*	Pubescent	Pubescent
24.	*S. stenophylla*	Pubescent	Pubescent
25.	*S. wallichiana*	Pubescent	Pubescent
26.	*Saxifraga* species A	Pubescent	Pubescent
27.	*Saxifraga* species B	Tomentose	Tomentose
28.	*Saxifraga* species C	-	-
29.	*Saxifraga* species D	Pubescent	-
30.	*Saxifraga* species E	-	Pubescent

In **Figure-4.4,** classification of the species is done based on the presence of different types of vestiture on stem. Four different groups can be derived. The first group consists of 6 species with glabrous stem. These species are *Saxifraga minutissima, S. brachypoda, S. pulvinaria, S. kumaunensis, Saxifraga* species C and *Saxifraga* species E.

Majority of species (15 species) have pubescent type of trichome cover on stem and hence form the second group, i.e. *S. aristulata, S. brunoniana, S. cernua, S. filicaulis, S. hispidula, S. jacquemontiana, S. lilacina, S. moorcroftiana, S. mucronulata, S. parnassifolia, S. pseudopallida, S. stella-aurea, S. stenophylla, Saxifraga* species A and *Saxifraga* species D.

The third group comprises of 5 species, namely *S. wallichiana, S. hirculoides, S. hirculus, S. saginoides* and *Saxifraga* species B, having tomentose type of vestiture.

Villous type of trichome cover is present in 2 species, *S. andersonii* and *S. palpebrata.* These 2 species form the fourth group. The rest two species, *Saxifraga lychnitis* and *S. microphylla,* are separated from the other groups due to the presence of uncommon types of vestiture, i.e. tomentulose and pilose respectively.

Saxifraga sect. *Ciliatae* possesses all the 6 types of vestiture found in the study; sect. *Porphyrion* has 2 types of vestiture (pubescent and villous); sect. *Mesogyne* and sect. *Micranthes* have pubescent type of vestiture on stem. Glabrous stem is present in 3 species of the sect. *Ciliatae* and 3 species of the sect. *Porphyrion.* Since *Saxifraga*

sects. *Porphyrion, Mesogyne* and *Micranthes* have insufficient number of species examined in the present study, in future more number of species are needed to be studied for a better knowledge.

From the data collected in this study we can conclude that the presence of different types of vestiture in *Saxifraga* sp. is not a reliable character for infrageneric classification of the genus.

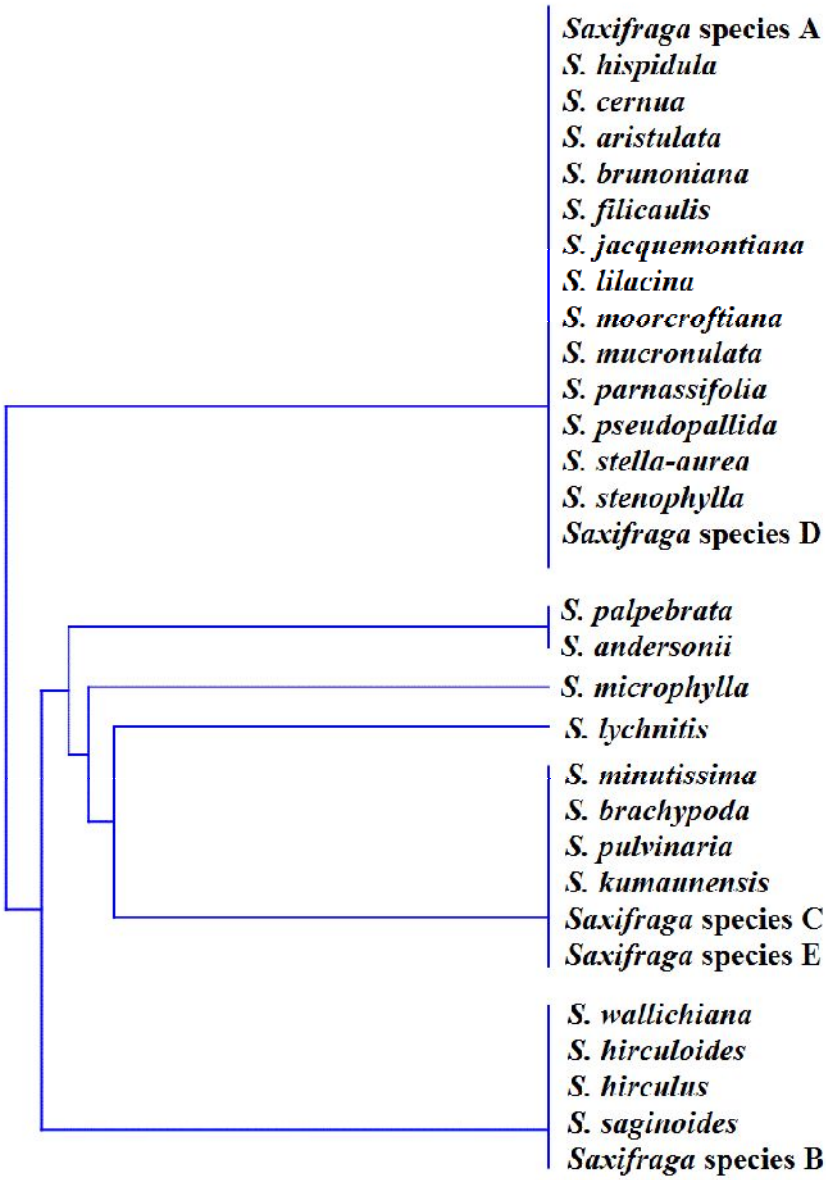


Figure 4.4: Grouping of *Saxifraga* species studied on the basis of presence of different types of vestiture

4.3.4 Leaf venation study

Venation is considered as an important character for plant taxonomy. **Zhang *et al.* (2015)** have investigated leaf venation patterns in 150 species of *Saxifraga* genus from 13 sections of the genus. Three main types of venation patterns in the genus were reported as acrodromous, camptodromous and palinactinodromous. The study concluded that palinactinodromous type of leaf venation pattern may be the ancestral venation in *Saxifraga* genus.The venation types found in different sections of the genus are as follows:

1. Acrodomous – *Saxifraga* sects. *Bronchiales, Trachyphyllum, Saxifraga* and *Ciliatae*
2. Camptodromous – *Saxifraga* sects. *Ligulatae* and *Porphyrion*
3. Palinactinodromous type – *Saxifraga* sects. *Heterisia, Irregulares, Cymbalaria, Cotylea* and *Mesogyne,* in lobed-leaves species of sects. *Bronchiales, Trachyphyllum* and *Saxifraga*
4. *Saxifraga* sect. *Porphyrion* subsect. *Oppositifoliae* and sect. *Xanthizoon* have intermediate between acrodomous and camptodromous types
5. *Saxifraga* sect. *Gymnopera* has venation intermediate between palinactinodromous and camptodromous types

In the present study, 30 species of *Saxifraga* are also studied for the type of leaf venation pattern present in them. Out of these 30 species, the leaf venation in 20 species was not studied by Zhang *et al.* (2015). These species are *Saxifraga andersonii, S. brachypoda, S. hirculoides, S. kumaunensis, S. lilacina, S. microphylla, S. moorcroftiana, S. mucronulata, S. palpebrata, S. parnassifolia, S. pseudopallida, S. pulvinaria, S. ssaginoides, S. stella-aurea, S. stenophylla,* and *Saxifraga* species A, B, C, D, and E.

In total 7 types of leaf venation patterns are found **(Table-4.7)**. These leaf venation types are:

1. Acrodomous (Perfect, Basal)
2. Acrodomous (Perfect, Suprabasal)
3. Acrodomous (Imperfect, Suprabasal)
4. Palinactinodromous

5. Campylodromous
6. Eucamptodromous
7. Hyphodromous

Table 4.7: Types of leaf venation found in the examined species of *Saxifraga* L.

S.No.	Species	Leaf Venation
1.	*Saxifraga andersonii*	Acrodomous (Imperfect, Suprabasal)
2.	*S. aristulata*	Acrodomous (Perfect, Basal)
3.	*S. brachypoda*	Campylodromous
4.	*S. brunoniana*	Acrodomous (Perfect, Suprabasal)
5.	*S. cernua*	Acrodomous (Perfect, Basal), Palinactinodromous
6.	*S. filicaulis*	Acrodomous (Perfect, Basal)
7.	*S. hirculoides*	Acrodomous (Perfect, Basal)
8.	*S. hirculus*	Acrodomous (Perfect, Basal)
9.	*S. hispidula*	Acrodomous (Perfect, Basal)
10.	*S. jacquemontiana*	Acrodomous (Perfect, Suprabasal)
11.	*S. kumaunensis*	Acrodomous (Perfect, Suprabasal)
12.	*S. lilacina*	Eucamptodromous
13.	*S. lychnitis*	Acrodomous (Perfect, Basal)
14.	*S. microphylla*	Acrodomous (Perfect, Suprabasal)
15.	*S. minutissima*	Acrodomous (Perfect, Suprabasal)
16.	*S. moorcroftiana*	Acrodomous (Perfect, Basal)
17.	*S. mucronulata*	Acrodomous (Perfect, Basal)
18.	*S. palpebrata*	Acrodomous (Perfect, Basal)
19.	*S. parnassifolia*	Campylodromous
20.	*S. pseudopallida*	Palinactinodromous
21.	*S. pulvinaria*	Hyphodromous
22.	*S. saginoides*	Acrodomous (Perfect, Basal)
23.	*S. stella-aurea*	Acrodomous (Perfect, Suprabasal)
24.	*S. stenophylla*	Acrodomous (Perfect, Basal)
25.	*S. wallichiana*	Acrodomous (Perfect, Basal)
26.	*Saxifraga* species A	Campylodromous
27.	*Saxifraga* species B	Acrodomous (Perfect, Basal)
28.	*Saxifraga* species C	Acrodomous (Perfect, Suprabasal)
29.	*Saxifraga* species D	Acrodomous (Perfect, Suprabasal)
30.	*Saxifraga* species E	Acrodomous (Perfect, Suprabasal)

In **figure-4.5**, the plants are classified on the basis of type of leaf venation pattern observed in them. The plants can be categorized into five groups. The first group is comprised of maximum number of species (12 species) possessing acrodomous (perfect, basal) type of leaf venation. These species are *Saxifraga aristulata, S. filicaulis, S. hirculoides, S. hirculus, S. hispidula, S. lychnitis, S. mucronulata, S. palpebrata, S. saginoides, S. stenophylla, S. wallichiana* and *Saxifraga* species B.

The second group includes 9 species, i.e. *S. brunoniana, S. jacquemontiana, S. kumaunensis, S. microphylla, S. minutissima, S. stella-aurea, Saxifraga* species C, *Saxifraga* species D and *Saxifraga* species E. This group consists of acrodomous (perfect, suprabasal) type of leaf venation.

The third group is having campylodromous leaf venation and is consisted of 4 species. These species are *S. brachypoda, S. parnassifolia, S. moorcroftiana* and *Saxifraga* species A.

The fourth group is of palinactinodromous type of leaf venation pattern which is found in 2 species, i.e. *S. cernua* and *S. pseudopallida. Saxifraga cernua* differs from *S. pseudopallida* in that having an additional type of leaf venation pattern, i.e. acrodomous (perfect, basal) found in young leaves.

The following three species are separated out from rest of the species since they have other types of leaf venation patterns - *Saxifraga lilacina* has eucamptodromous type; *S. pulvinaria* has hyphodromous type; *S. andersonii* has acrodomous (imperfect, suprabasal) type of leaf venation.

From the above data we can conclude that the presence of different types of leaf venation in different species of *Saxifraga* is reliable and can be used for the infrageneric classification at sectional level. Species from *Saxifraga* sect. *Ciliatae* has three types of leaf venation – Acrodomous (perfect, basal) (12 species), Acrodomous (perfect, suprabasal) (7 species) and Campylodromous (5 species). Species belonging to *Saxifraga* sect. *Porphyrion* possess 4 different types of leaf venation –Acrodomous (perfect, suprabasal) (2 species), Acrodomous (imperfect, suprabasal) (1 species), Eucamptodromous (1 species) and Hyphodromous (1 species). Among the 30 species studied, one species belongs to *Saxifraga* sect. *Micranthes* and possess

Palinactinodromous type of leaf venation. *Saxifraga cernua* belonging to the sect. *Mesogyne* has 2 types of leaf venation patterns – Acrodomous (perfect, basal) type in young leaves and Actinodromous (perfect, marginal, basal) type in mature leaves.

1. **Acrodomous (Perfect, Basal) type –** *Saxifraga* sect. *Ciliatae,* in young leaves of *S. cernua* belonging to the sect. *Mesogyne*
2. **Acrodomous (Perfect, Suprabasal) type –***Saxifraga* sects. *Ciliatae* and *Porphyrion*
3. **Acrodomous (Imperfect, Suprabasal) type –** *Saxifraga* sect. *Porphyrion*
4. **Palinactinodromous type –***Saxifraga* sect. *Micranthes,* in mature leaves of the sect. *Mesogyne*
5. **Campylodromous type –***Saxifraga* sect. *Ciliatae*
6. **Eucamptodromous type –***Saxifraga* sect. *Porphyrion*
7. **Hyphodromous type –***Saxifraga* sect. *Porphyrion*

Number of species was too low for the sects. *Porphyrion, Mesogyne* and *Micranthes* in the present study. For further conclusion more species needed to be observed.

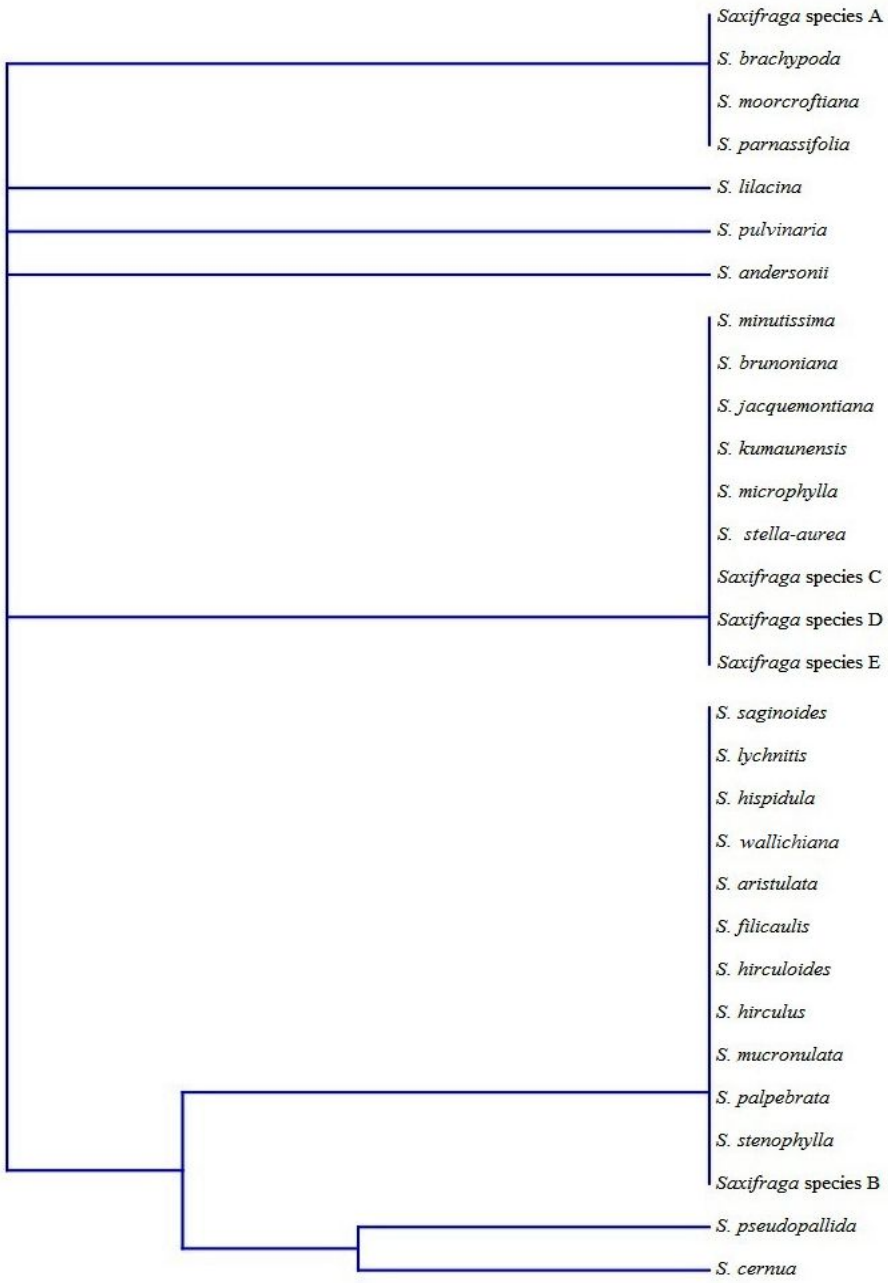
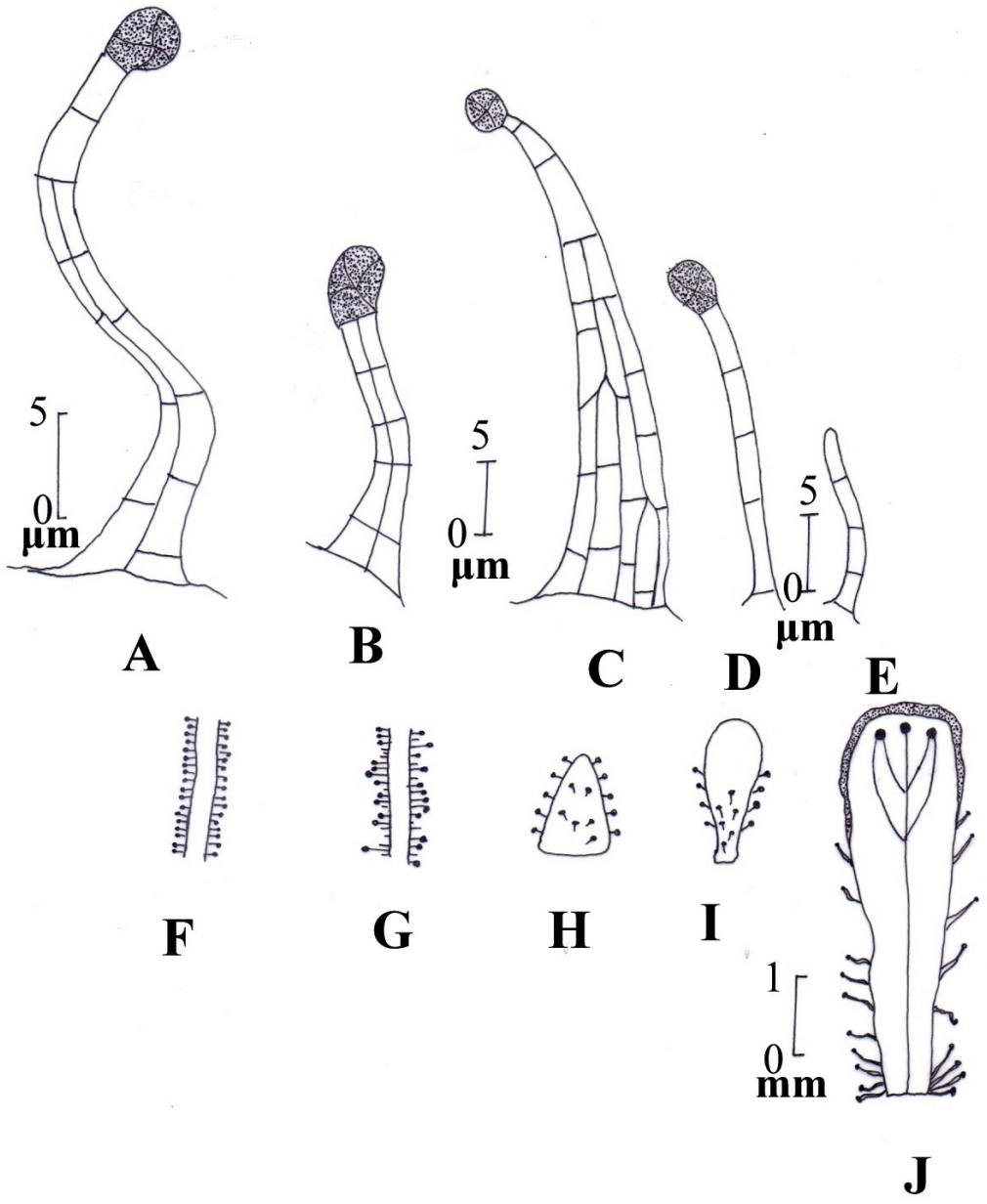


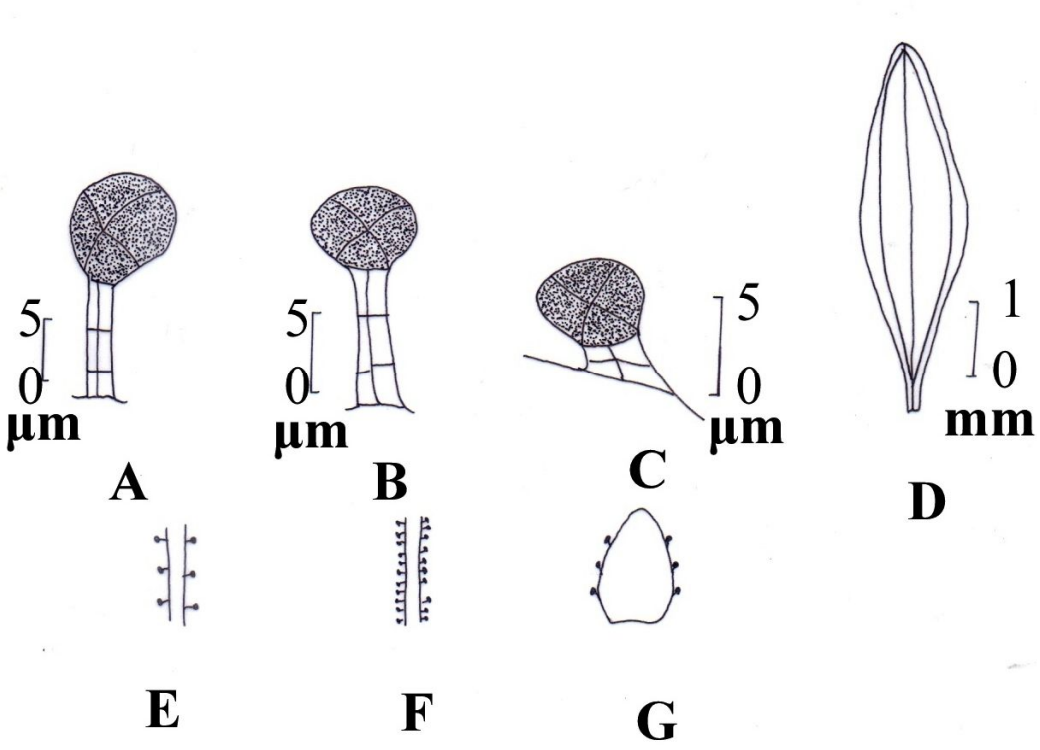
Figure 4.5: Classification of *Saxifraga* species studied on the basis of presence of types of leaf venation

Plates



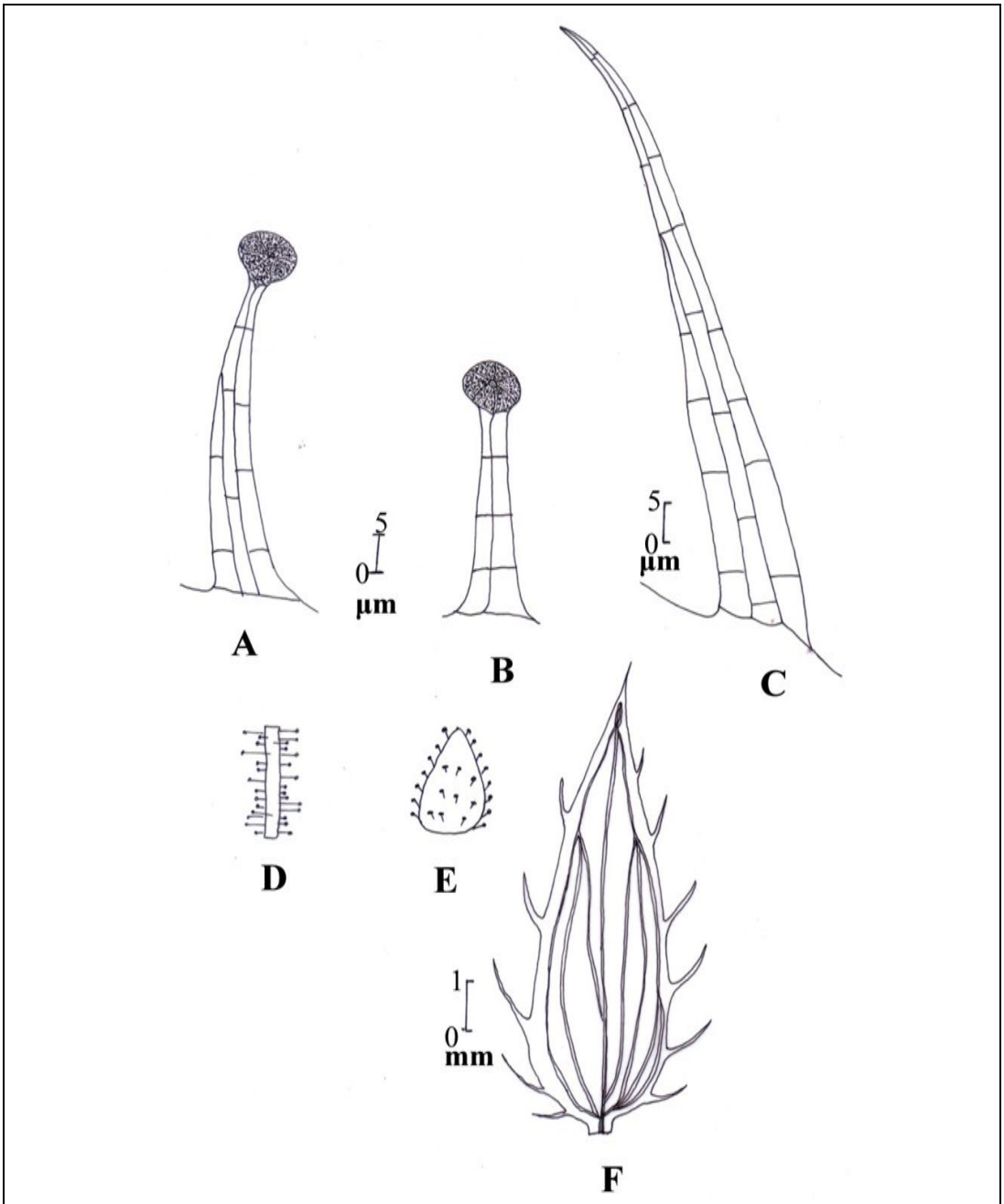
A- Trichome on stem and leaf margin; **B-** Trichome on stem, pedicel, abaxial surface of sepal, sepal margin, adaxial and abaxial surfaces of leaf and leaf margin; **C-** Trichome on pedicel, adaxial and abaxial surfaces of leaf and leaf margin; **D & E-** Trichomes on pedicel; **F-** Pubescence on stem; **G-** Pubescence on pedicel; **H-** Pubescence on sepal; **I-** Pubescence on leaf; **J-** Leaf venation

Plate-1. Trichomes, pubescence and leaf venation in *Saxifraga andersonii*



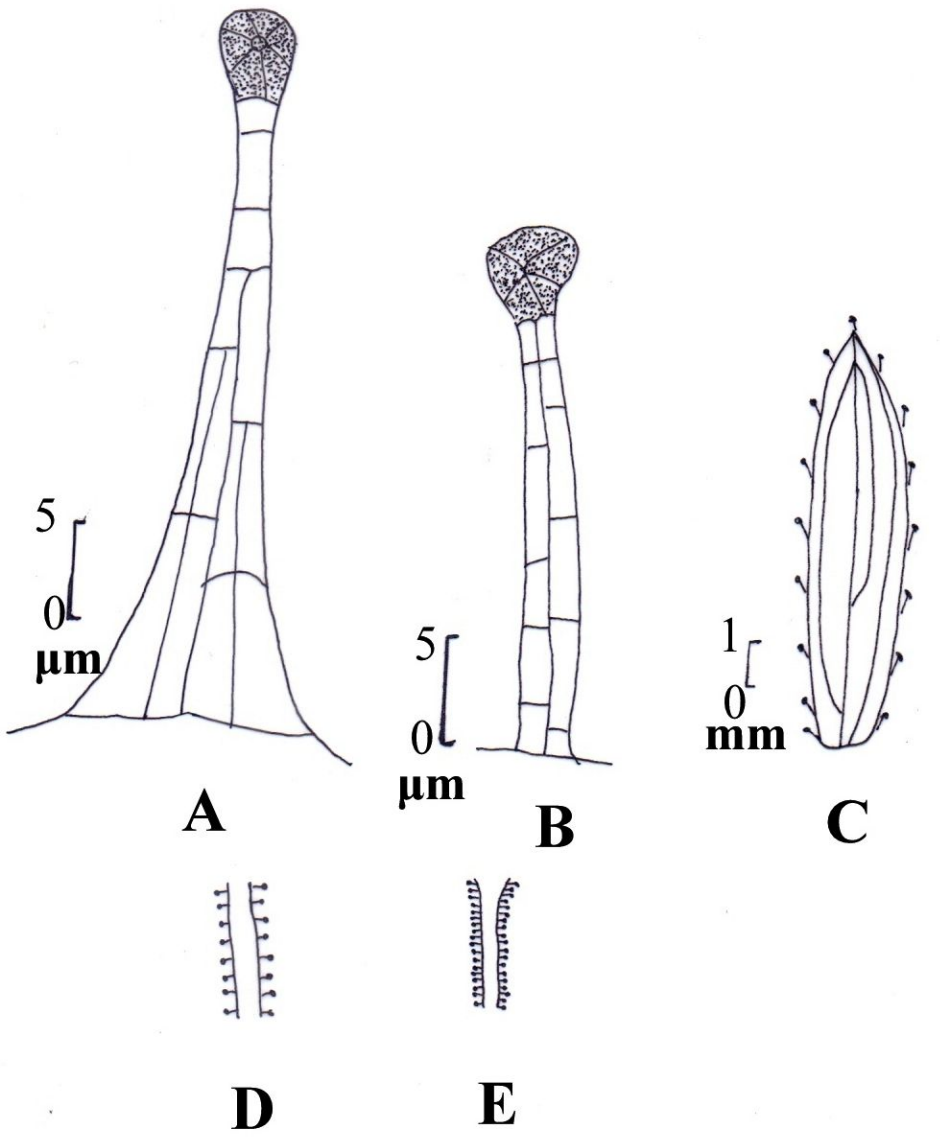
A- Trichome on stem; **B-** Trichome on pedicel; **C-** Trichome on sepal margin; **D-** Leaf venation; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on sepal

Plate-2. Trichomes, pubescence and leaf venation in *Saxifraga aristulata*



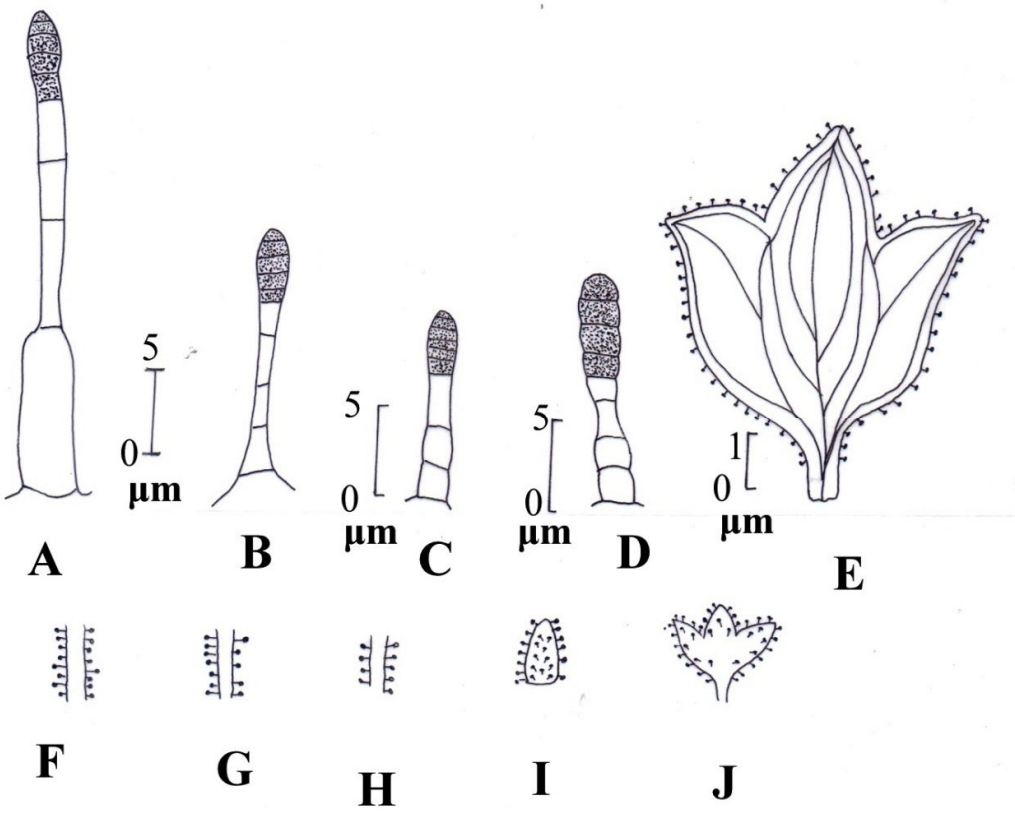
A- Trichome on pedicel; **B-** Trichome on abaxial surface of sepal and sepal margin; **G-** Trichome on leaf margin; **D-** Pubescence on pedicel; **E-** Pubescence on sepal; **F-** Leaf venation

Plate-3. Trichomes, pubescence and leaf venation in *Saxifraga brachypoda*



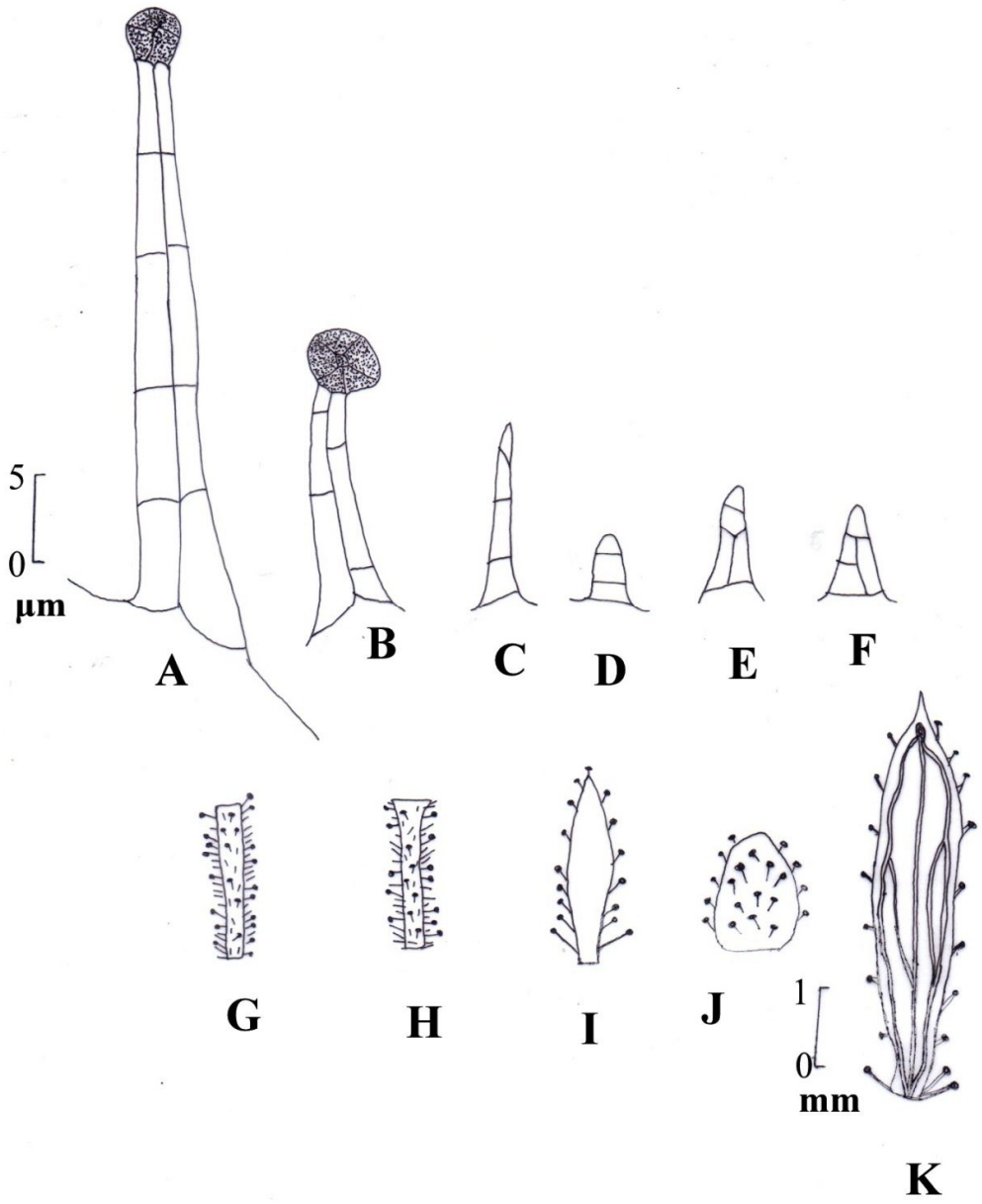
A- Trichome on stem and pedicel; **B-** Trichome on leaf margin; **C-** Leaf venation; **D-** Pubescence on stem; **E-** Pubescence on pedicel

Plate-4. Trichomes, pubescence and leaf venation in *Saxifraga brunoniana*



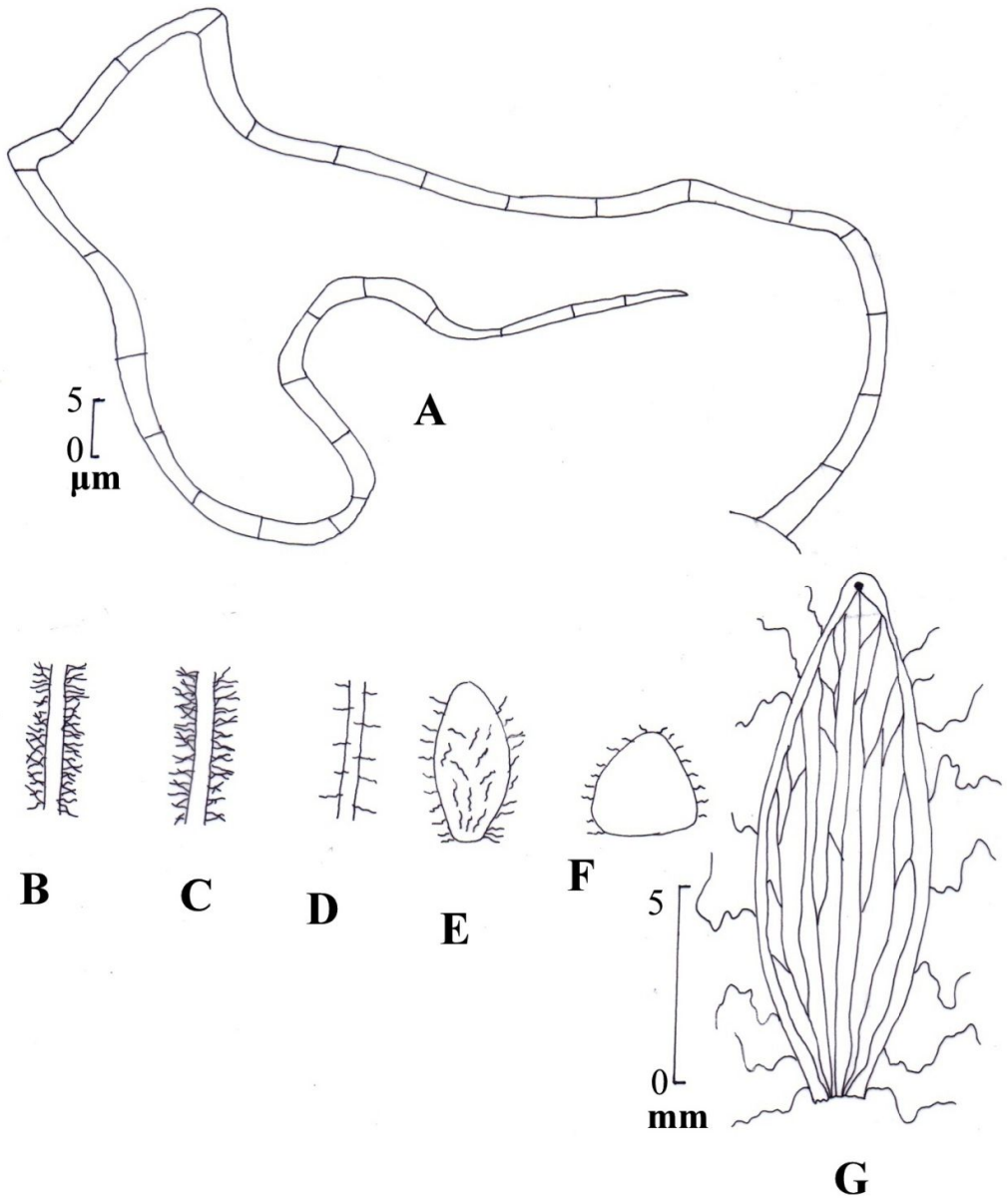
A- Trichome on stem; **B, C & D-** Trichomes on pedicel, abaxial surface of sepal, sepal margin, adaxial and abaxial surface of leaf, leaf margin and petiole; **E-** Leaf venation; **F-**Pubescence on stem; **G-** Pubescence on pedicel; **H-** Pubescence on petiole; **I-** Pubescence on sepal; **J-** Pubescence on leaf

Plate-5. Trichomes, pubescence and leaf venation in *Saxifraga cernua*



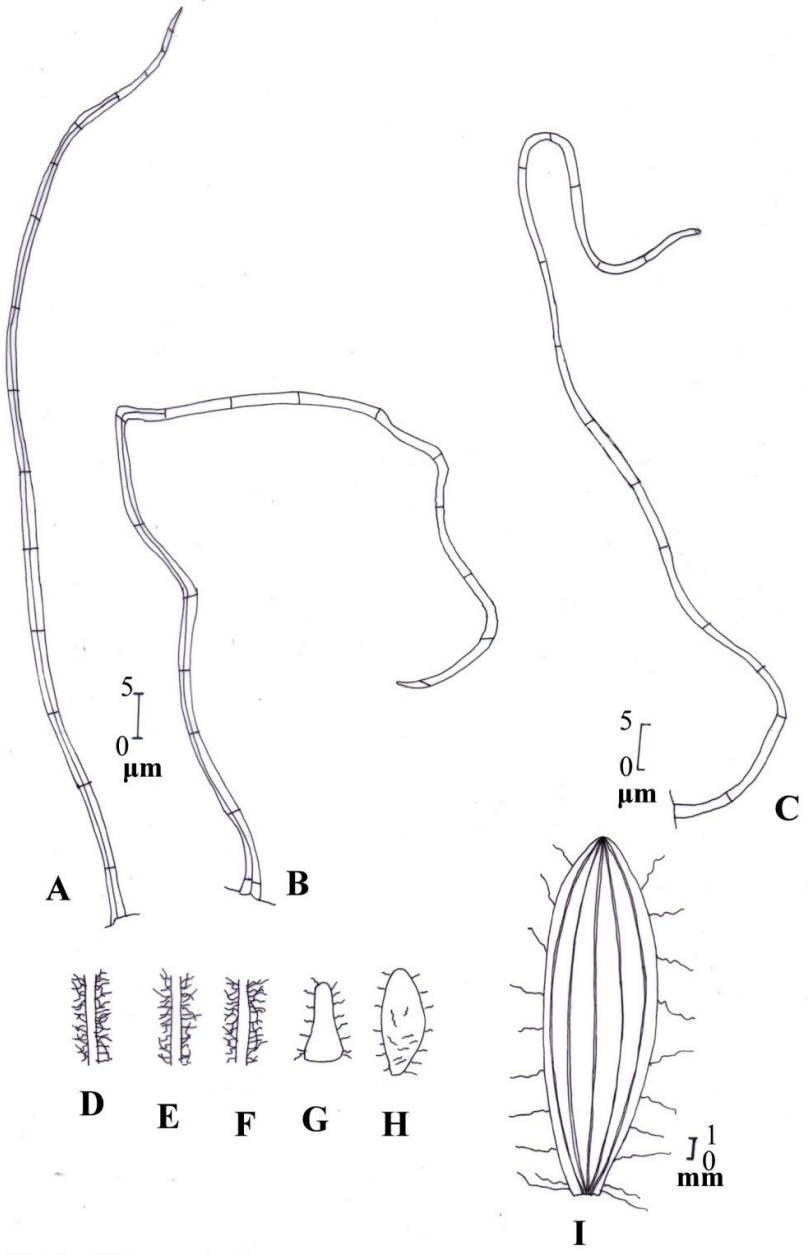
A- Trichome on leaf margin; **B-** Trichome on stem, pedicel, abaxial surface of sepal, sepal margin and leaf margin; **C, D, E & F-** Trichomes on stem and pedicel; **G-** Pubescence on stem; **H-** Pubescence on pedicel; **I-** Pubescence on leaf, **J-** Pubescence on sepal; **K-** Leaf venation

Plate-6. Trichomes, pubescence and leaf venation in *Saxifraga filicaulis*



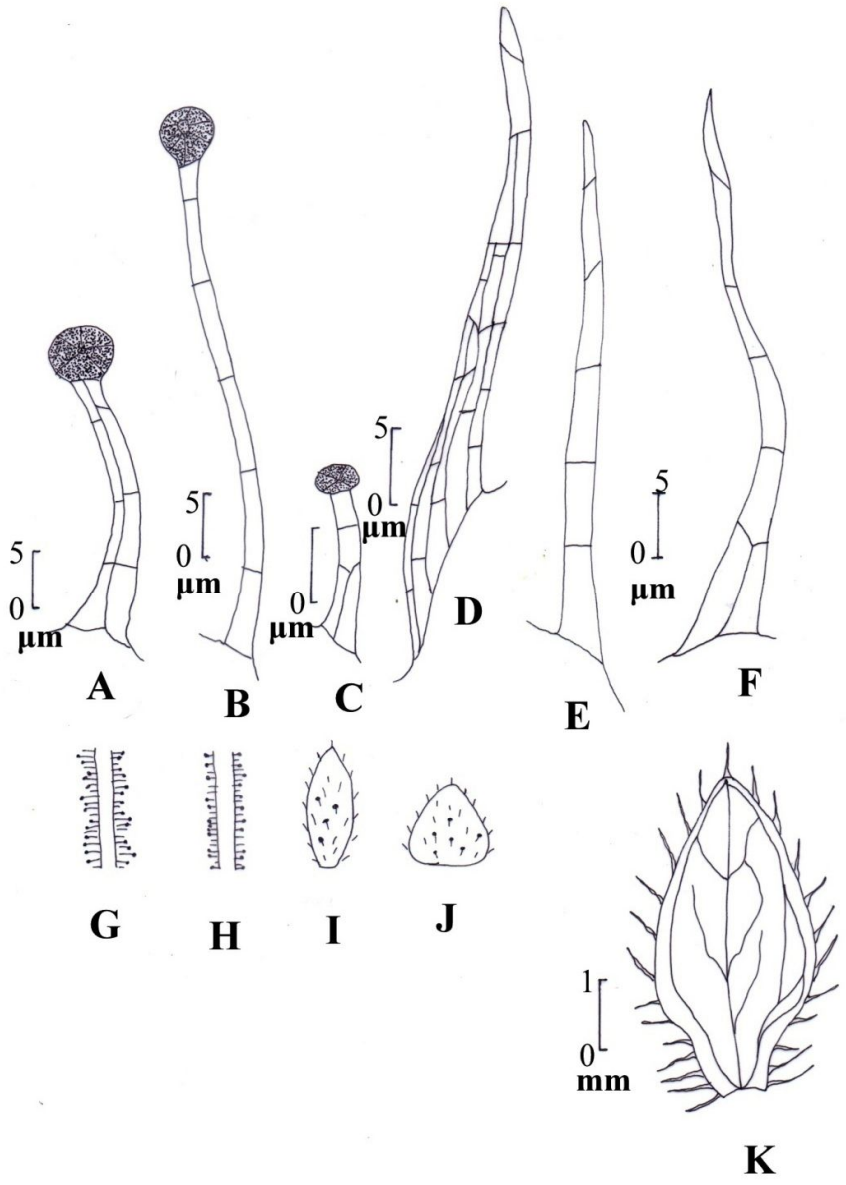
A- Trichome on stem, pedicel, sepal margin, adaxial and abaxial surfaces of leaf, leaf margin and petiole; **B-** Pubescence on stem; **C-** Pubescence on pedicel; **D-** Pubescence on petiole; **E-** Pubescence on leaf, **F-** Pubescence on sepal; **G-** Leaf venation

Plate-7. Trichomes, pubescence and leaf venation in *Saxifraga hirculoides*



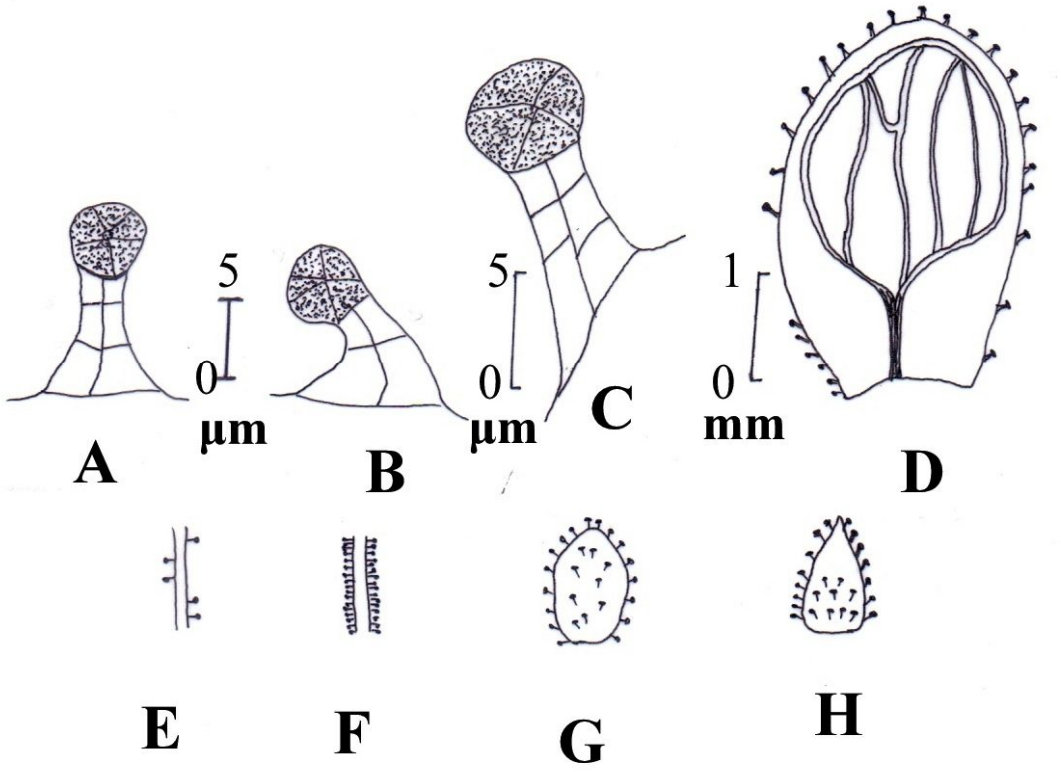
A, B & C- Trichomes on stem, pedicel, sepal margin and petiole; **D-** Pubescence on stem; **E-** Pubescence on pedicel; **F-** Pubescence on petiole; **G-** Pubescence on sepal; **H-** Pubescence on leaf; **I-** Leaf venation

Plate-8. Trichomes, pubescence and leaf venation in *Saxifraga hirculus*



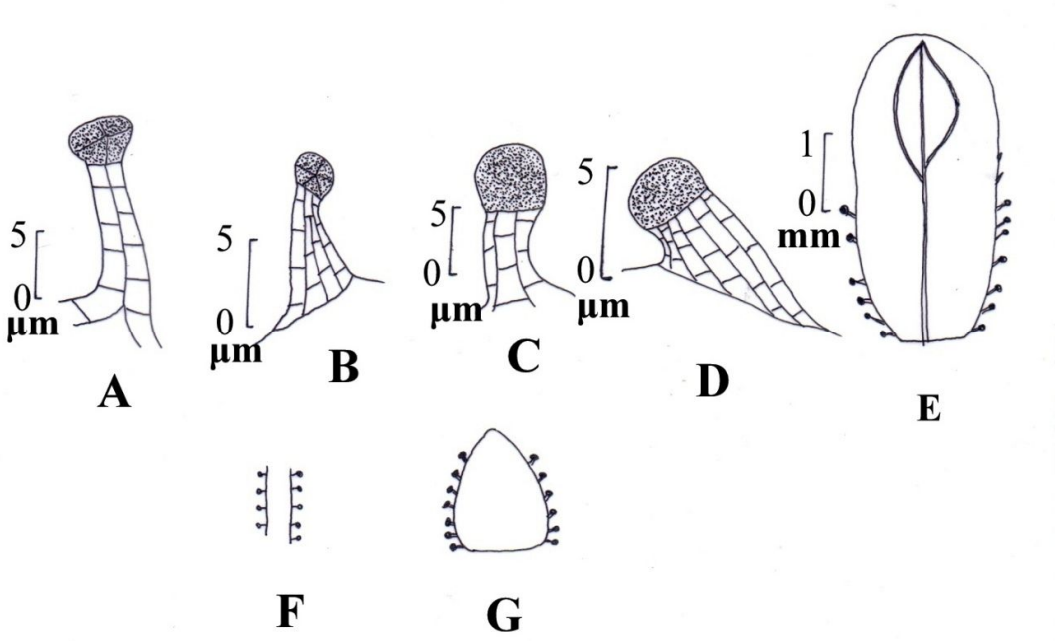
A- Trichome on pedicel and abaxial surface of sepal; **B-** Trichome on stem; **C-** Trichome on adaxial surface of leaf; **D-** Trichome on abaxial surface of sepal, sepal margin, adaxial and abaxial surfaces of leaf and leaf margin; **E & F-** Trichomes on stem, pedicel, adaxial and abaxial surfaces of leaf and leaf margin; **G-** Pubescence on stem; **H-** Pubescence on pedicel; **I-** Pubescence on adaxial surface of leaf; **J-** Pubescence on sepal, **K-** Leaf venation

Plate-9. Trichomes, pubescence and leaf venation in *Saxifraga hispidula*



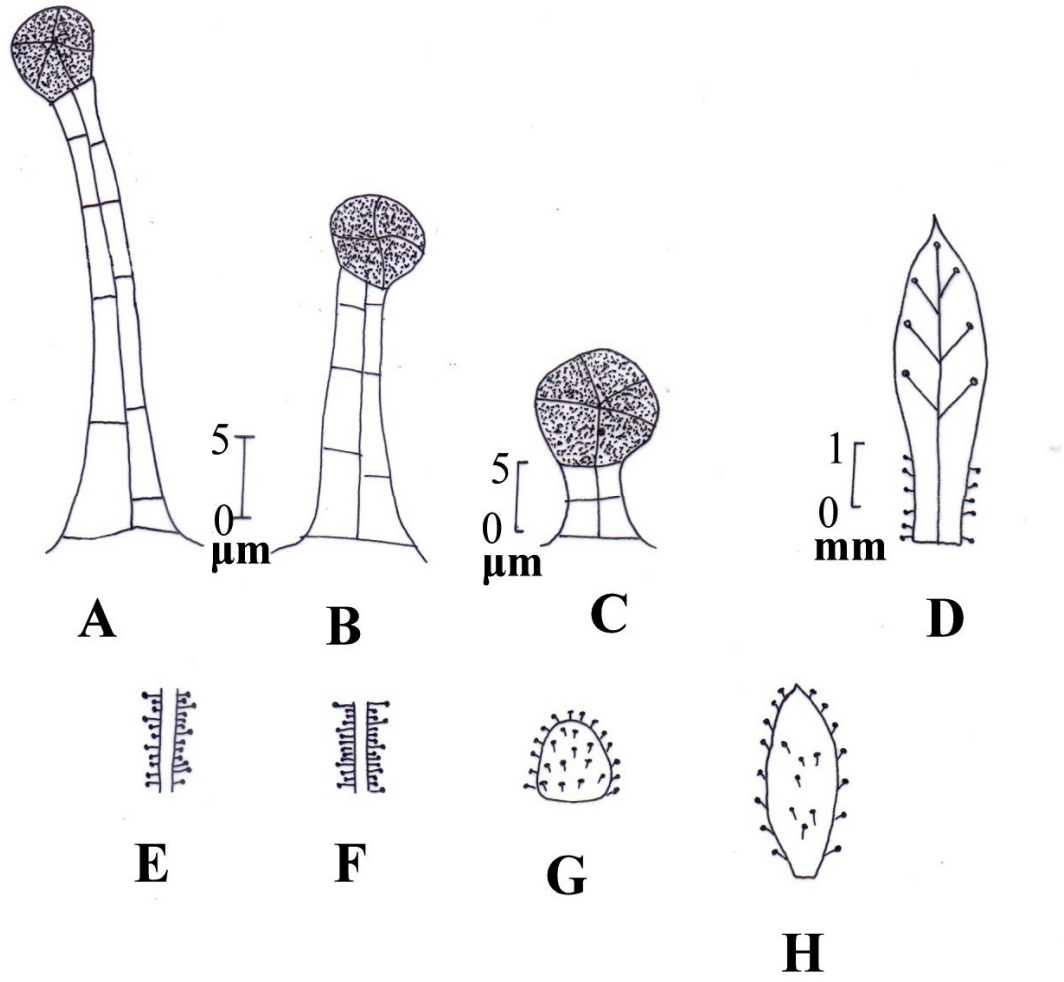
A, B & C- Trichomes on stem, pedicel, abaxial surface of sepal, sepal margin, adaxial and abaxial surfaces of leaf and leaf margin; **D-** Leaf venation; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on leaf; **H-** Pubescence on sepal

Plate-10. Trichomes, pubescence and leaf venation in *Saxifraga jacquemontiana*



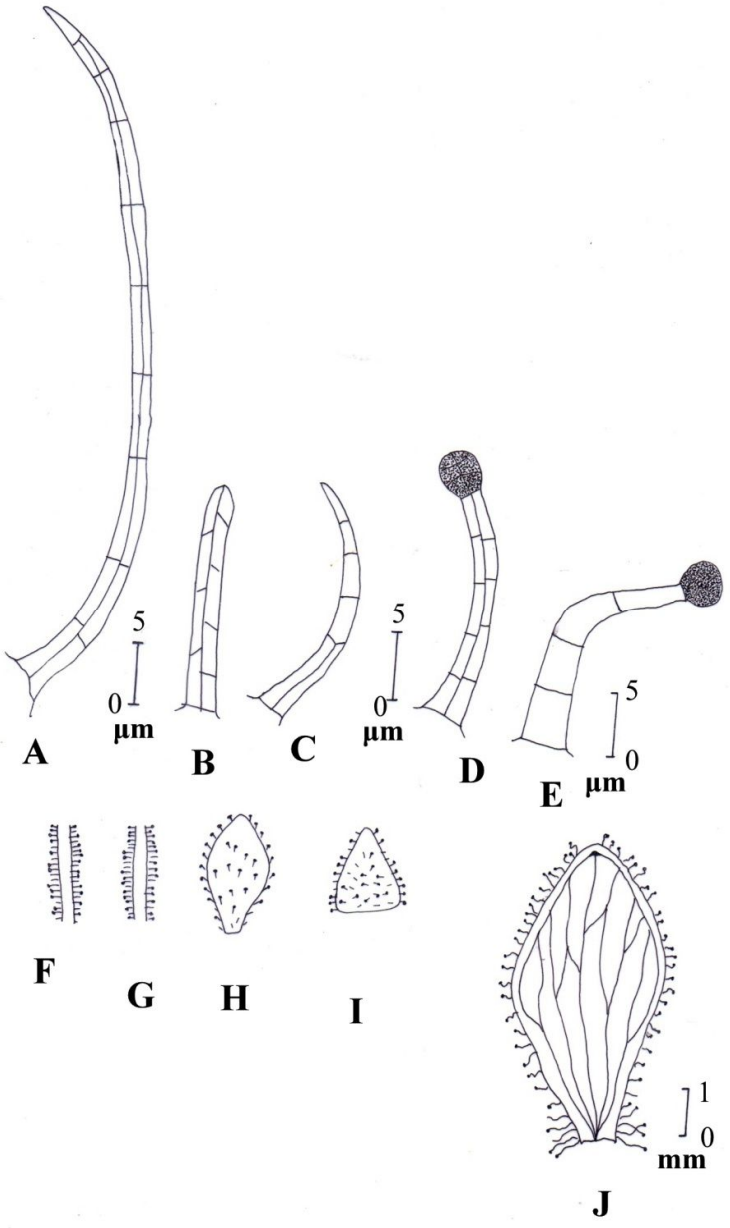
A- Trichome on pedicel and leaf margin; **B, C & D-** Trichomes on sepal margin and leaf margin; **E-** Leaf venation; **F-** Pubescence on pedicel; **G-** Pubescence on sepal

Plate-11. Trichomes, pubescence and leaf venation in *Saxifraga kumaunensis*



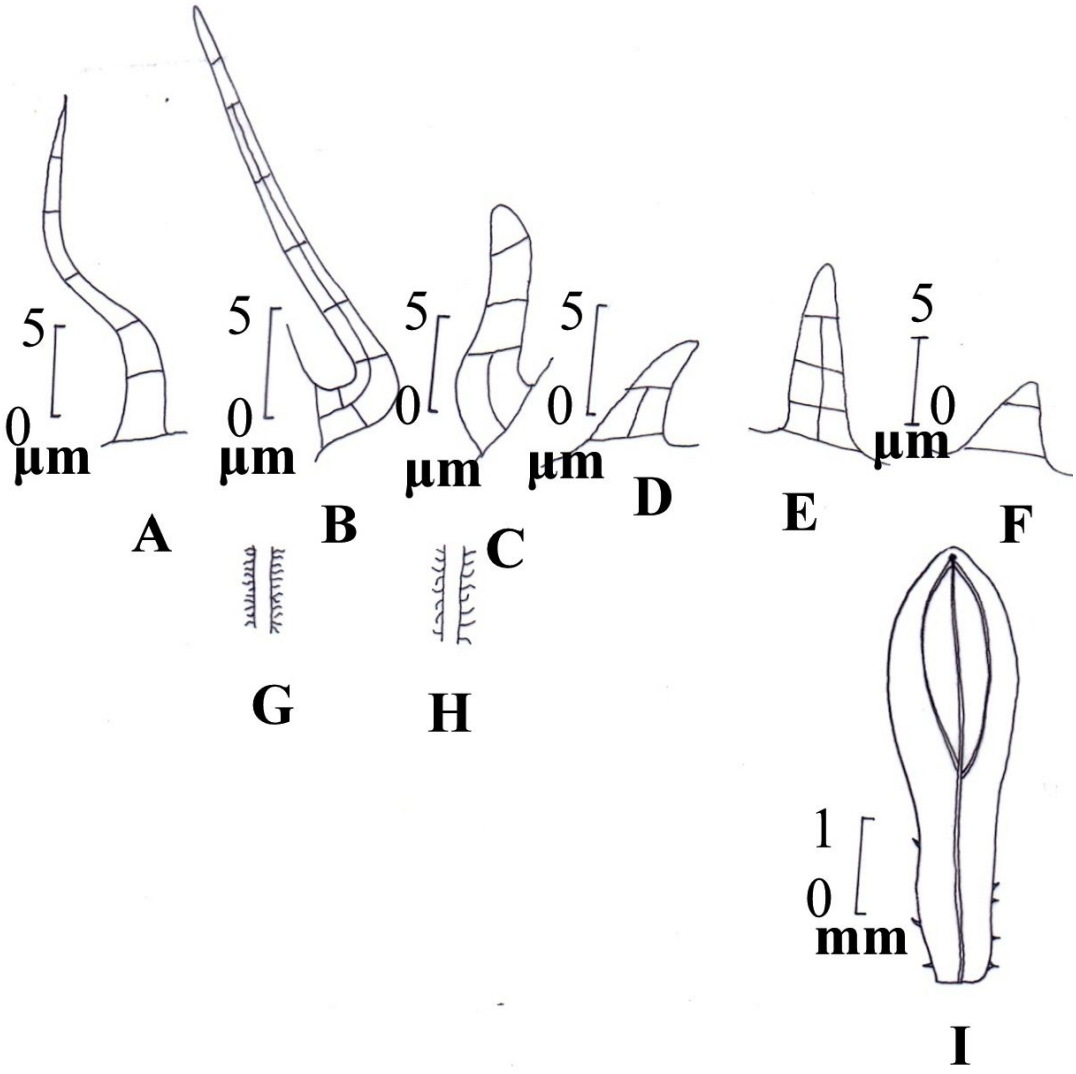
A, B & C- Trichomes on stem, pedicel, abaxial surface of sepal, sepal margin, adaxial surface of leaf and leaf margin; **D-** Leaf venation; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on sepal; **H-** Pubescence on adaxial surface of leaf

Plate-12. Trichomes, pubescence and leaf venation in *Saxifraga lilacina*



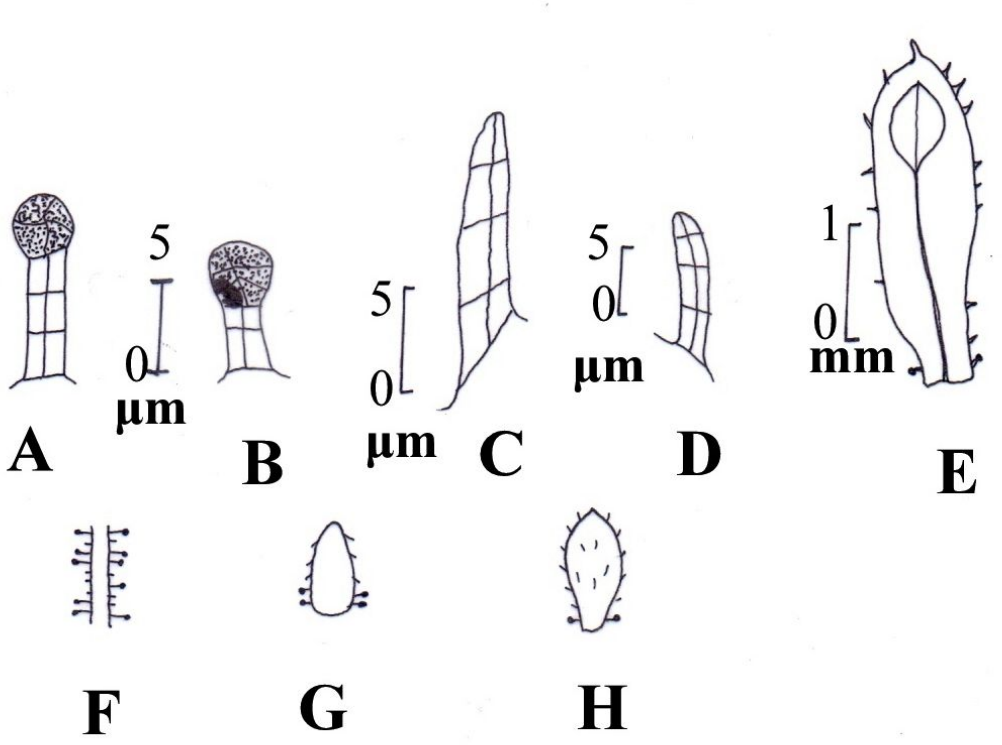
A & B- Trichomes on stem and pedicel; **C-** Trichome on stem, pedicel, abaxial surface of sepal, sepal margin and leaf margin; **D-** Trichome on stem, pedicel, abaxial surface of sepal, sepal margin, abaxial surface of leaf and leaf margin; **E-** Trichome on stem, pedicel, abaxial surface of leaf and leaf margin; **F-** Pubescence on stem; **G-** Pubescence on pedicel; **H-** Pubescence on abaxial surface of leaf; **I-** Pubescence on sepal; **J-** Leaf venation

Plate-13. Trichomes, pubescence and leaf venation in *Saxifraga lychnitis*



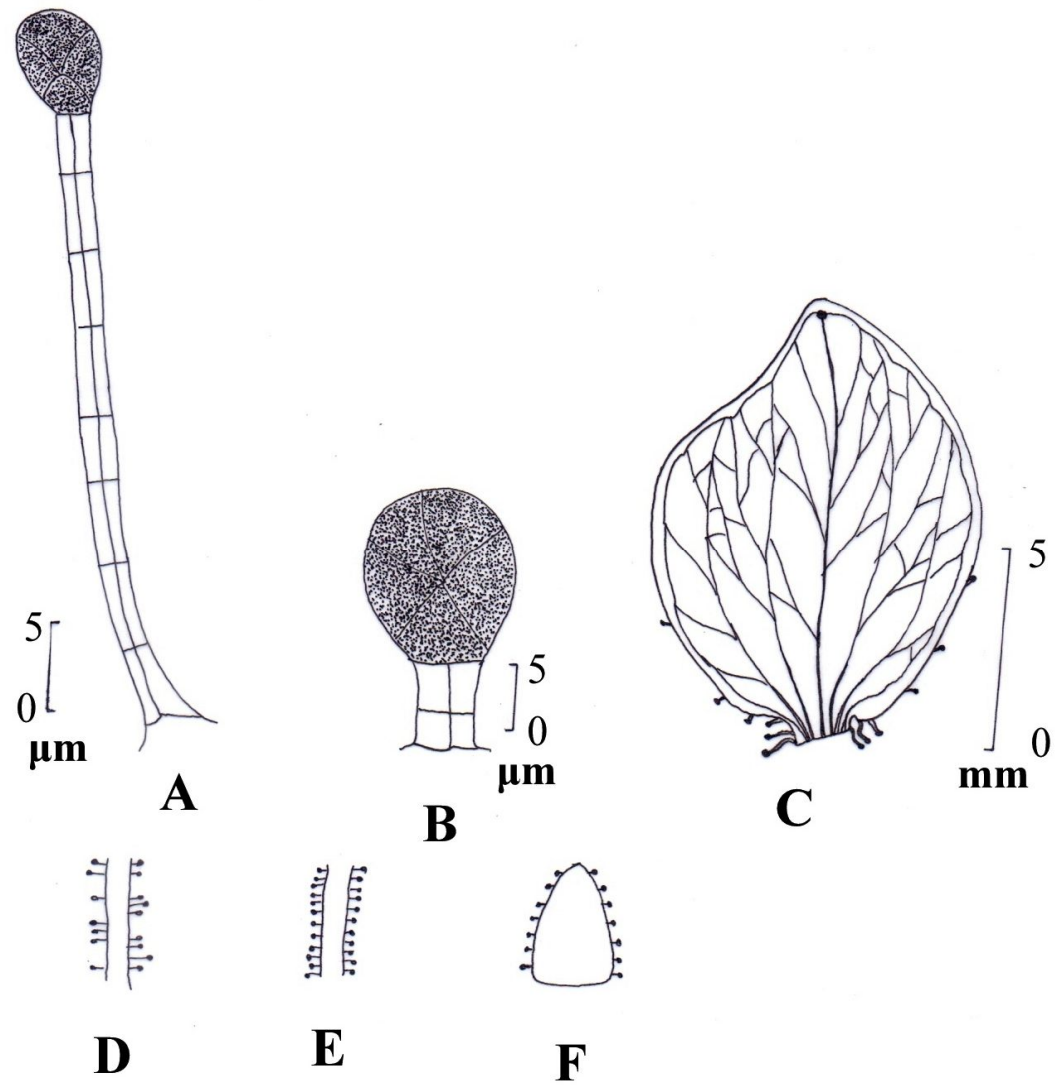
A, B & F- Trichomes on stem and pedicel; **C, D & E-** Trichomes on leaf margin; **G-** Pubescence on pedicel; **H-** Pubescence on stem; **I-** Leaf venation

Plate-14. Trichomes, pubescence and leaf venation in *Saxifraga microphylla*



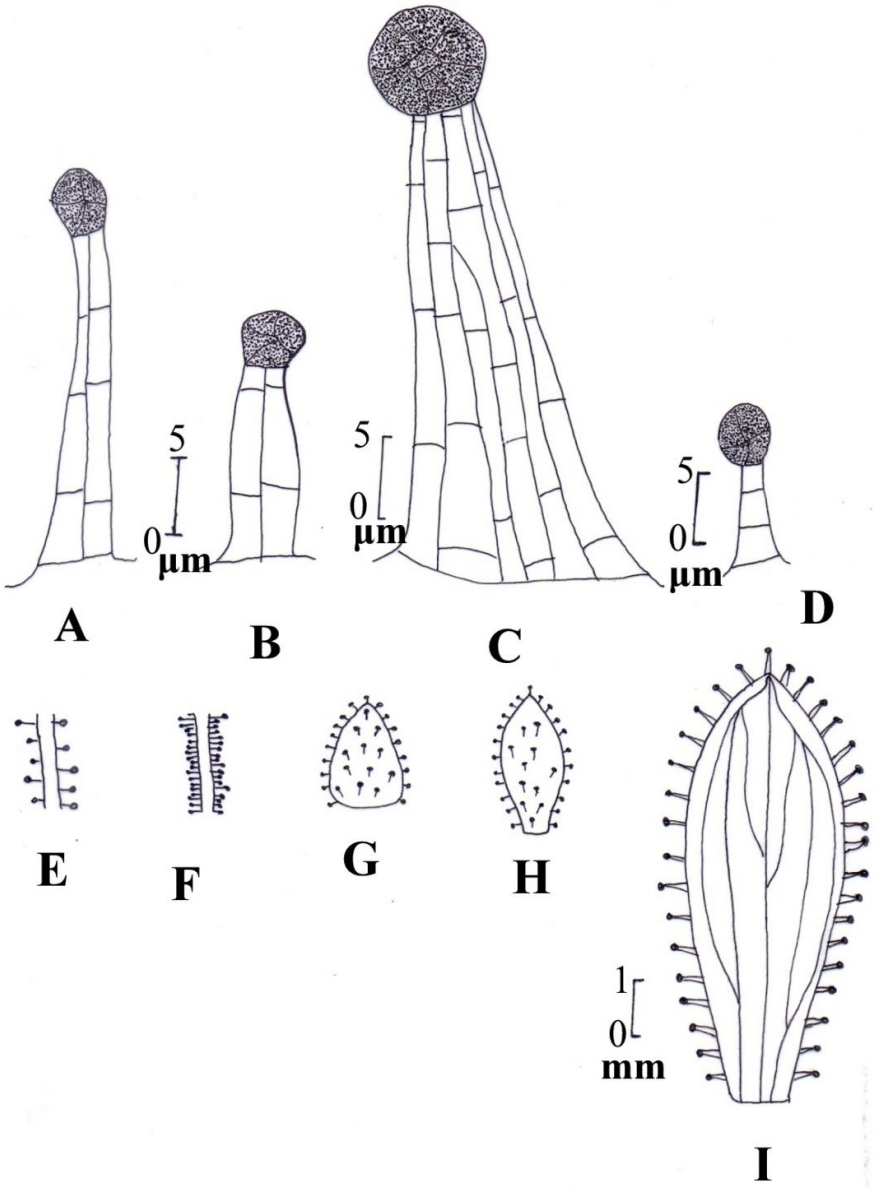
A & B- Trichomes on pedicel, sepal margin and leaf margin; **C & D-** Trichomes on pedicel, sepal margin, adaxial surface of leaf and leaf margin; **E-** Leaf venation; **F-** Pubescence on pedicel; **G-** Pubescence on sepal; **H-** Pubescence on adaxial surface of leaf

Plate-15. Trichomes, pubescence and leaf venation in *Saxifraga minutissima*



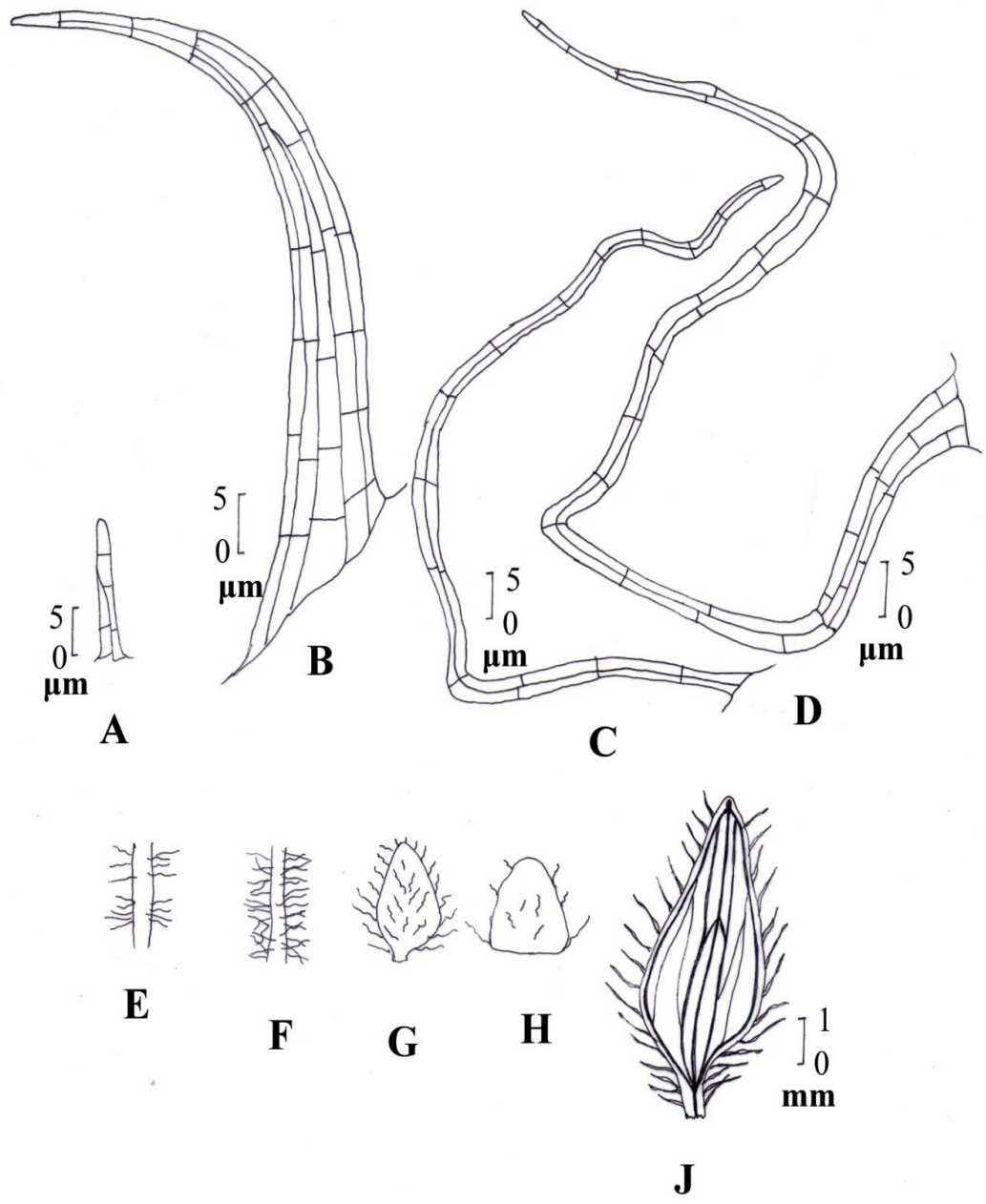
A- Trichome on stem and pedicel; **B-** Trichome on sepal margin and leaf margin; **C-** Leaf venation; **D-** Pubescence on stem; **E-** Pubescence on pedicel; **F-** Pubescence on sepal

Plate-16. Trichomes, pubescence and leaf venation in *Saxifraga moorcroftiana*



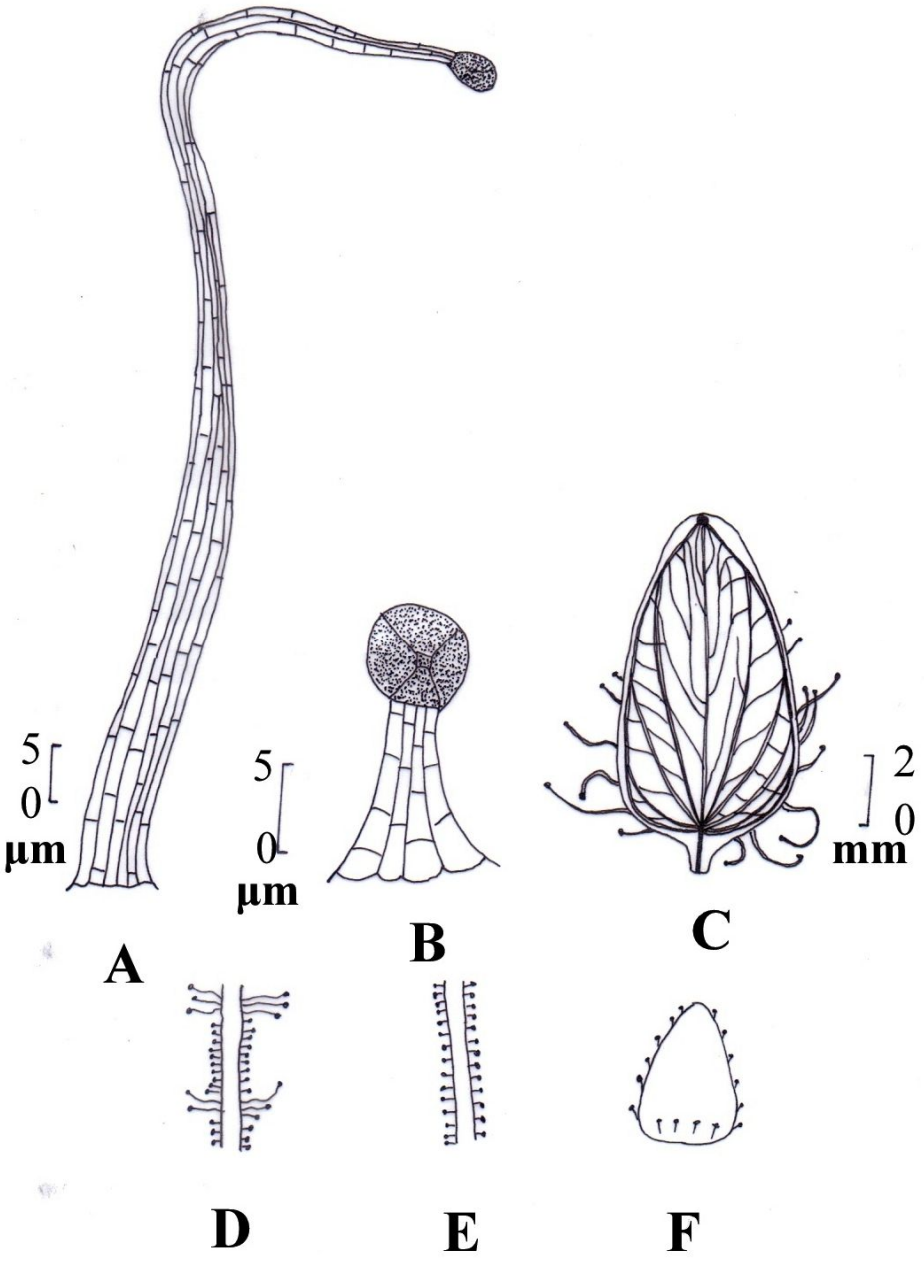
A- Trichome on pedicel, abaxial surface of sepal and sepal margin; **B-** Trichome on stem, adaxial and abaxial surfaces of leaf and leaf margin; **C-** Trichome on sepal margin and leaf margin; **D-** Trichome on abaxial surface of sepal and adaxial and abaxial surfaces of leaf; **E-** Pubescence ob stem; **F-** Pubescence on pedicel; **G-** Pubescence on sepal; **H-** Pubescence on leaf; **I-** Leaf venation

Plate-17. Trichomes, pubescence and leaf venation in *Saxifraga mucronulata*



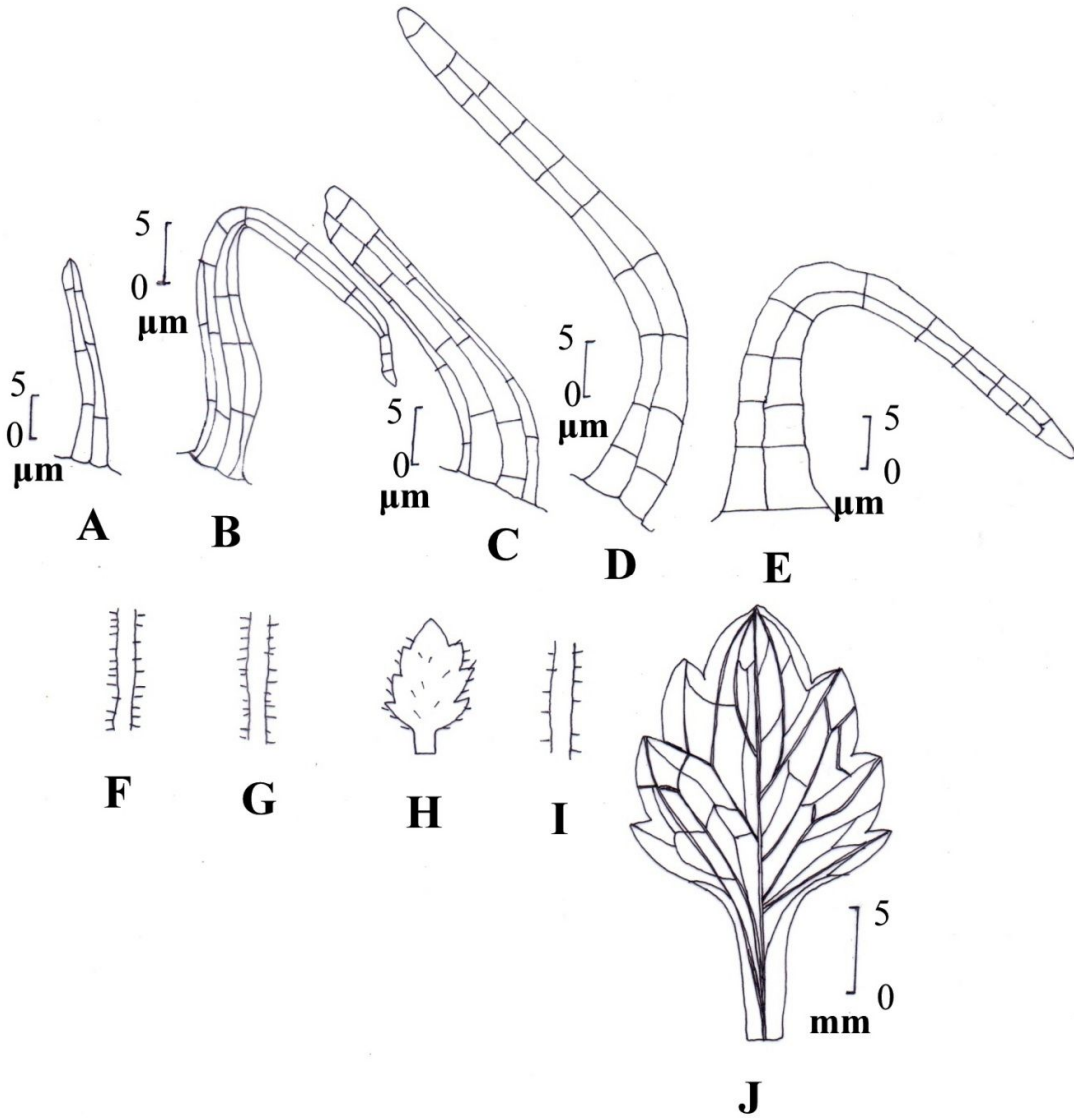
A- Trichome on abaxial surface of sepal and sepal margin; **B-** Trichome on adaxial surface of leaf and leaf margin; **C-** Trichome on stem; **D-** Trichome on pedicel; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on adaxial surface of leaf; **H-** Pubescence on sepal; **I-**Leaf venation

Plate-18. Trichomes, pubescence and leaf venation in *Saxifraga palpebrata*



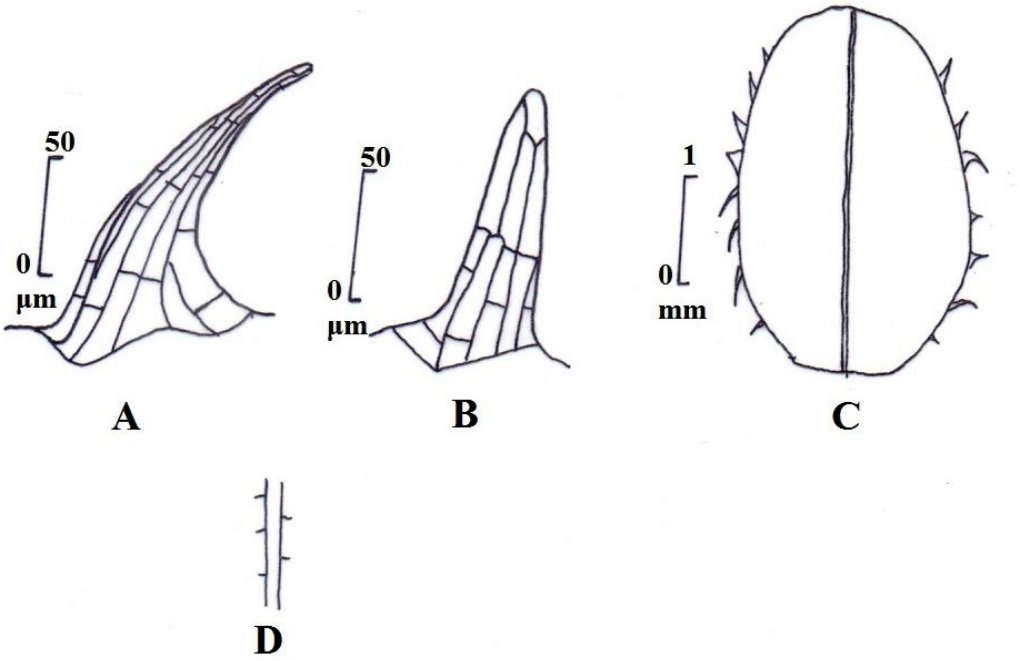
A- Trichome on leaf margin; **B-** Trichome on stem, pedicel, abaxial surface of sepal, sepal margin and leaf margin; **C-** Leaf venation; **D-** Pubescence on stem; **E-** Pubescence on pedicel; **F-** Pubescence on sepal

Plate-19. Trichomes, pubescence and leaf venation in *Saxifraga parnassifolia*



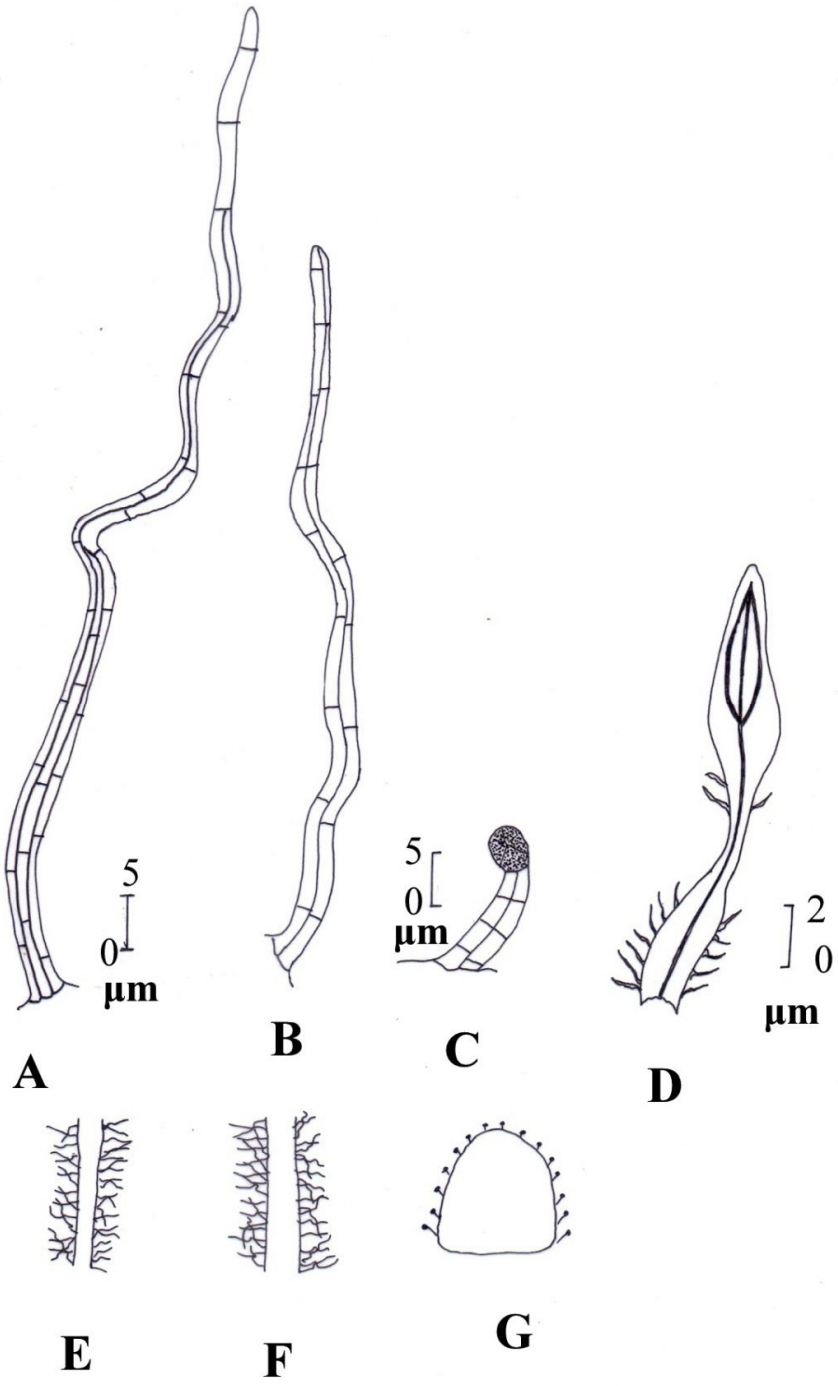
A- Trichome on stem, pedicel and petiole; **B & C-** Trichomes on adaxial and abaxial surfaces of leaf, leaf margin and petiole; **D-** Trichomes on stem and pedicel; **E-** Trichome on petiole; **F-** Pubescence on stem; **G-** Pubescence on pedicel; **H-** Pubescence on leaf; **I-** Pubescence on petiole; **J-** Leaf venation

Plate-20. Trichomes, pubescence and leaf venation in *Saxifraga pseudopallida*



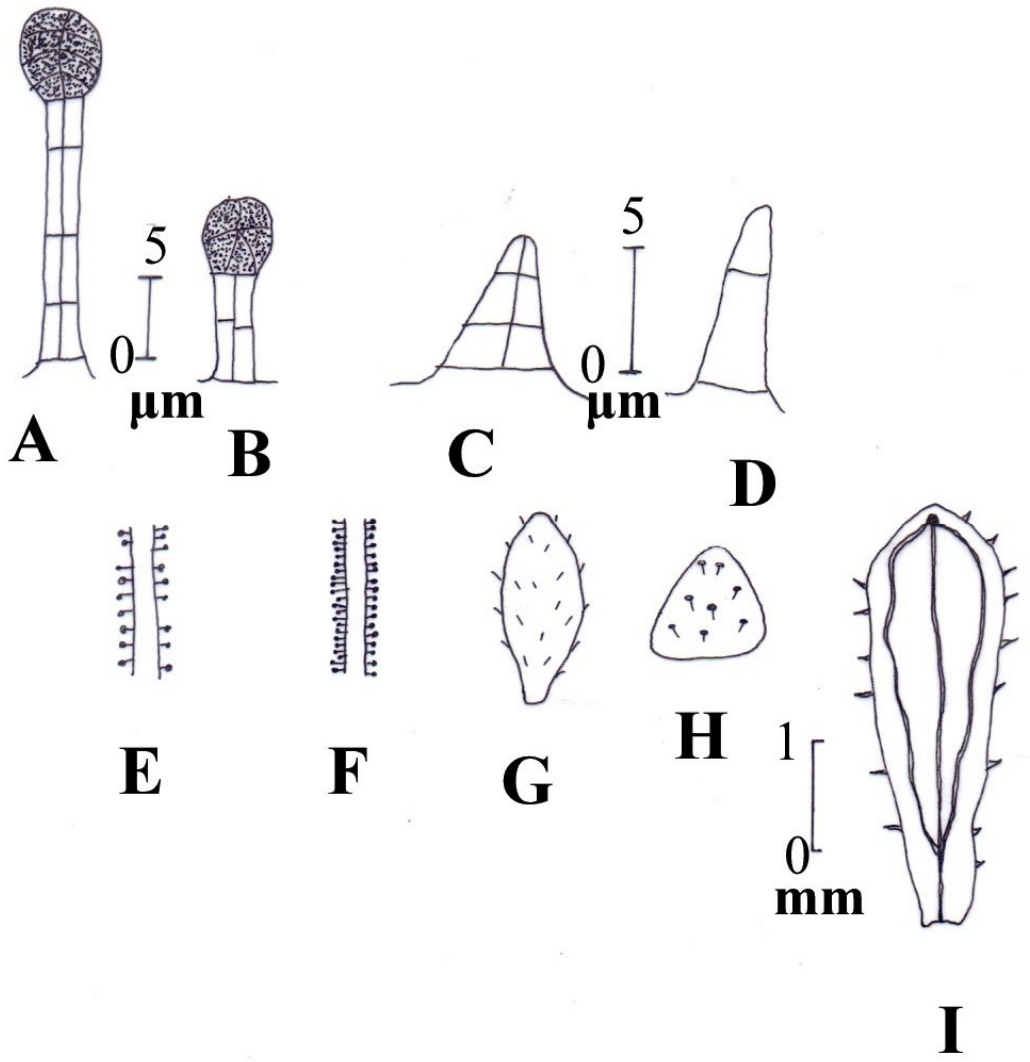
A & B- Trichomes on pedicel and leaf margin; **C-** Leaf venation; **D-** Pubescence on pedicel

Plate-21. Trichomes, pubescence and leaf venation in *Saxifraga pulvinaria*



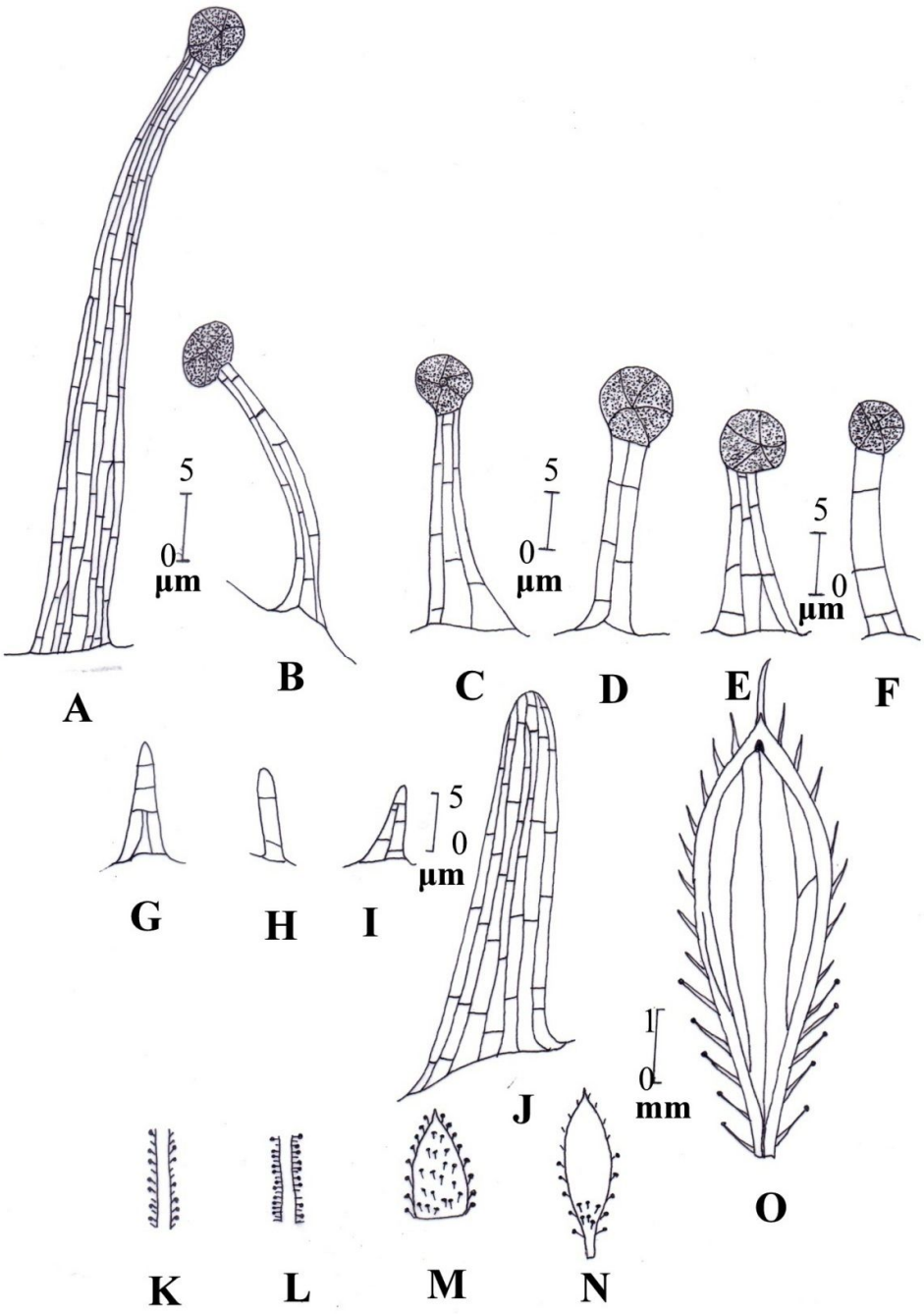
A- Trichome on stem, pedicel and leaf margin; **B-** Trichome on leaf margin; **C-** Trichome on sepal margin; **D-** Leaf venation; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on sepal

Plate-22. Trichomes, pubescence and leaf venation in *Saxifraga saginoides*



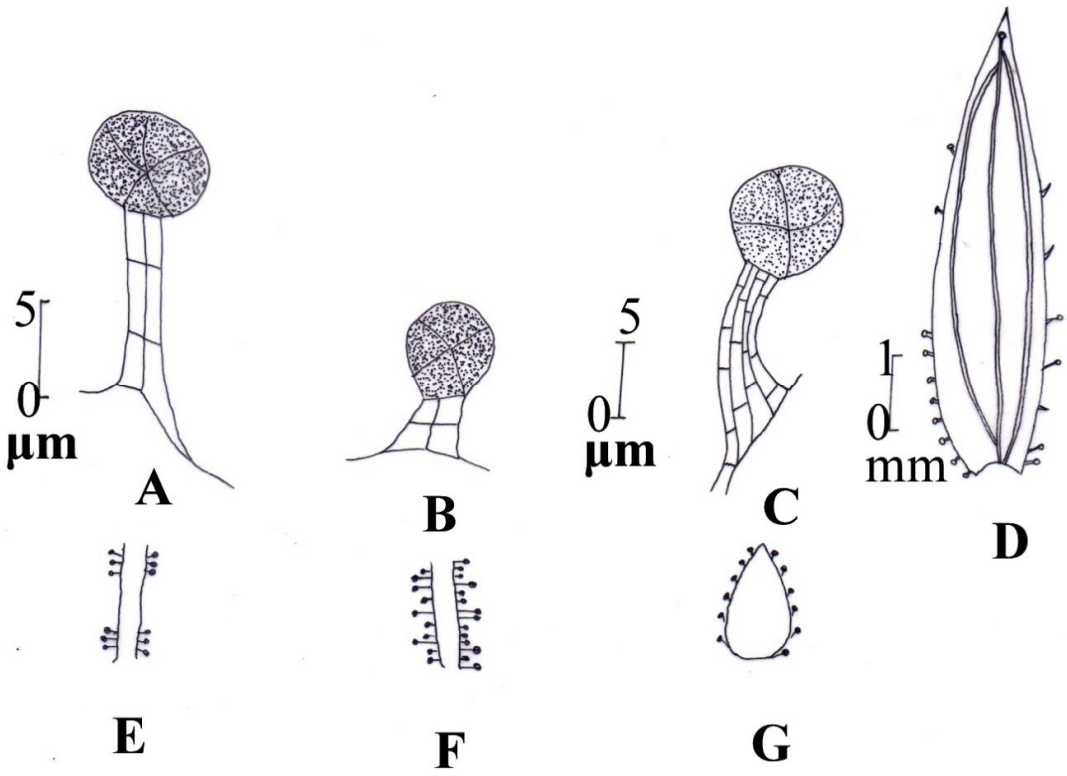
A- Trichome on pedicel; **B-** Trichome on stem, pedicel, abaxial surface of sepal and leaf margin, **C-** Trichome on adaxial surface of leaf and leaf margin; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on adaxial surface of leaf; **H-** Pubescence on sepal; **I-** Leaf venation

Plate-23. Trichomes, pubescence and leaf venation in *Saxifraga stella-aurea*



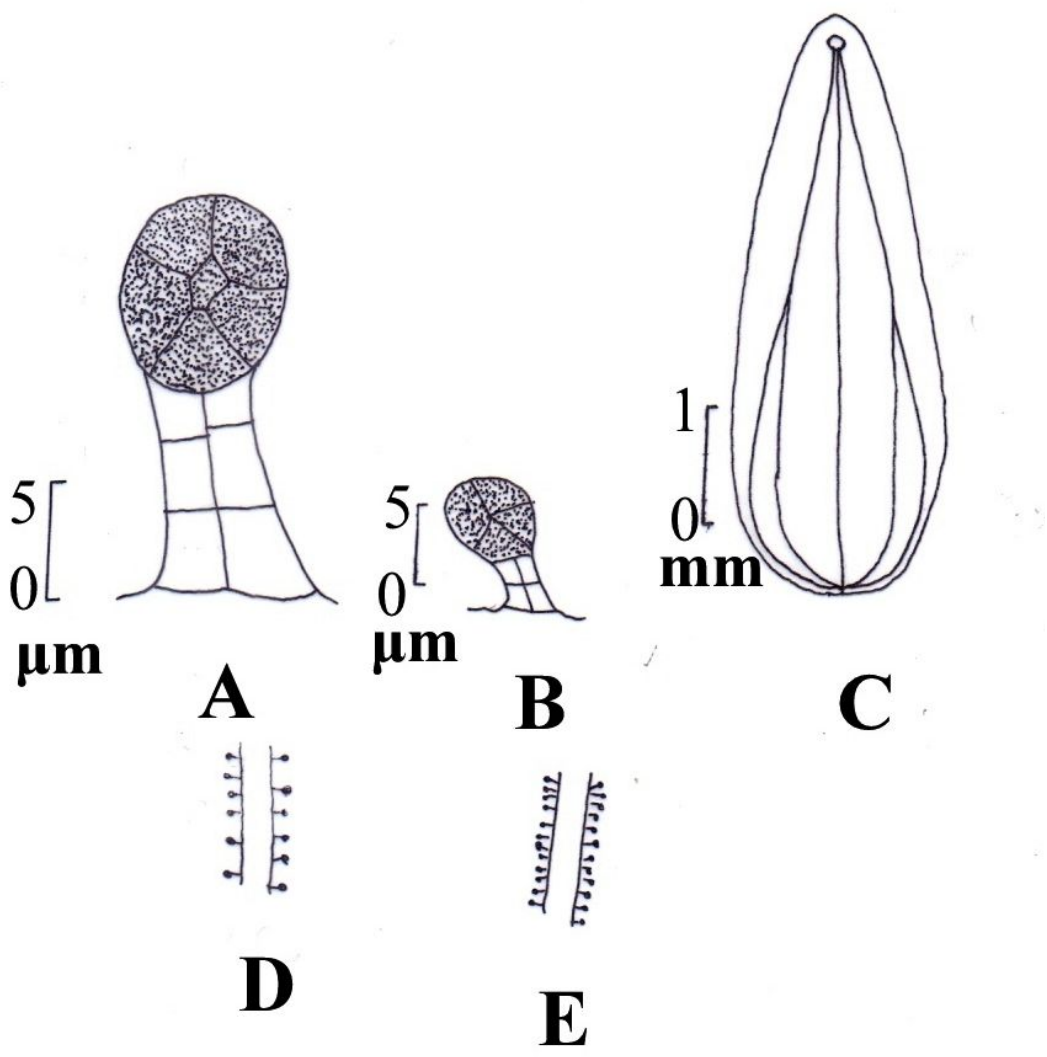
A- Trichome on abaxial surface of leaf; **B, H & I-** Trichome on stem and pedicel; **C & E-** Trichomes on abaxial surface of sepal, sepal margin, adaxial and abaxial surfaces of leaf and leaf margin; **D-** Trichome on stem, pedicel, abaxial surface of sepal and sepal margin; **F-** Trichom on pedicel; **G-** Trichome on stem, adaxial and abaxial surfaces of leaf and leaf margin; **J-** Trichome on adaxial surface of leaf; **K-** Pubescence on stem; **L-** Pubescence on pedicel,; **M-** Pubescence on sepal; **N-** Pubescence on leaf; **O-** Leaf venation

Plate-24. Trichomes, pubescence and leaf venation in *Saxifraga stenophylla*



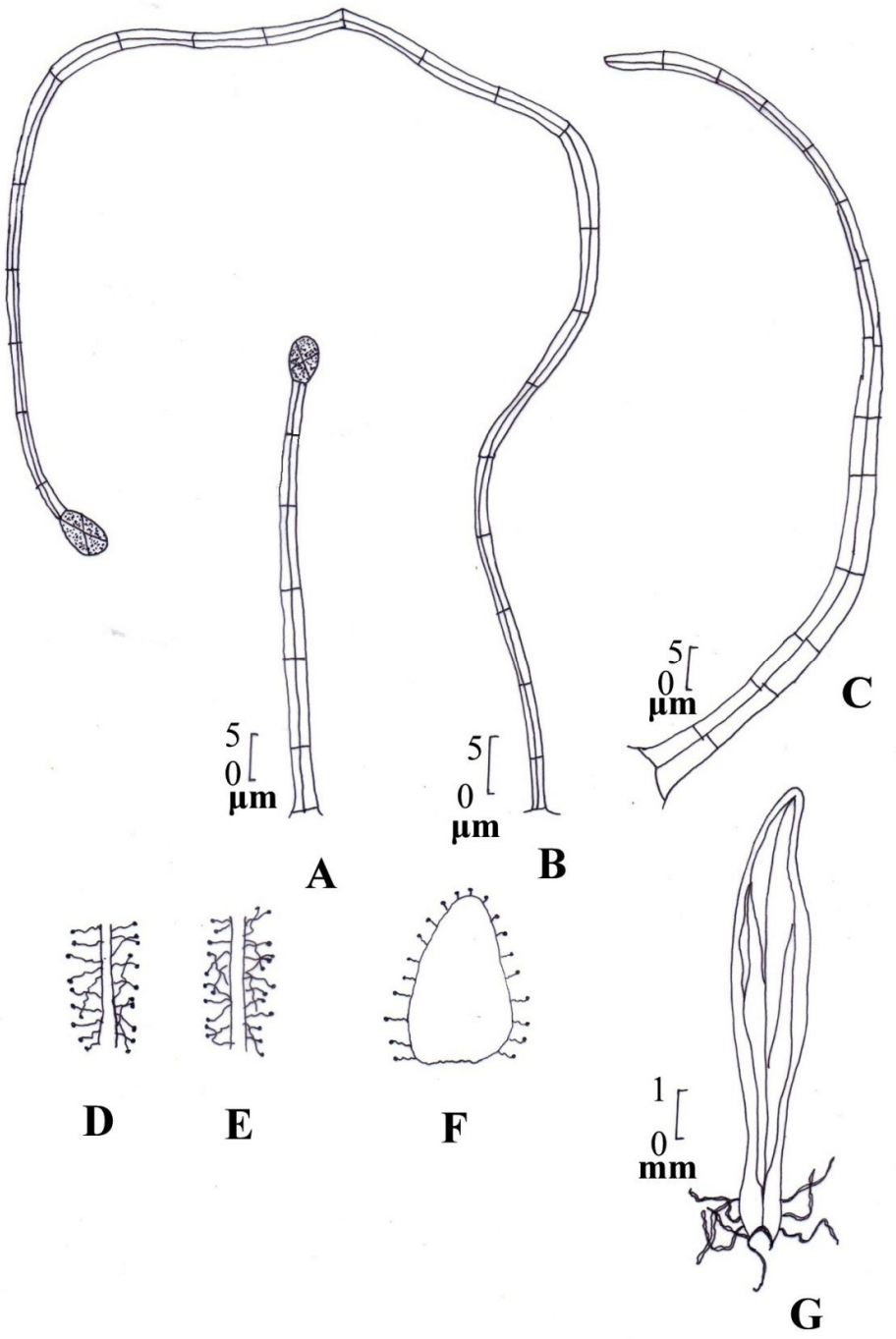
A- Trichome on stem and pedicel; **B-** Trichome on sepal margin; **C-** Trichome on leaf margin; **D-** Leaf venation; **E-** Pubescence on stem; **F-** Pubescence on pedicel; **G-** Pubescence on sepal

Plate-25. Trichomes, pubescence and leaf venation in *Saxifraga wallichiana*



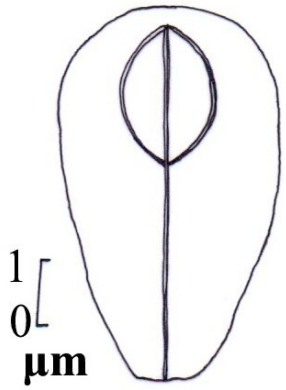
A-Trichome on stem; **B-** Trichome on pedicel; **C-** Leaf venation; **D-** Pubescence on stem; **E-** Pubescence on pedicel

Plate-26. Trichomes, pubescence and leaf venation in *Saxifraga* species A



A- Trichome on pedicel and sepal margin; **B-** Trichome on stem; **C-** Trichome on leaf margin; **D-** Pubescence on stem; **E-** Pubescence on pedicel; **F-** Pubescence on sepal; **G-** Leaf venation

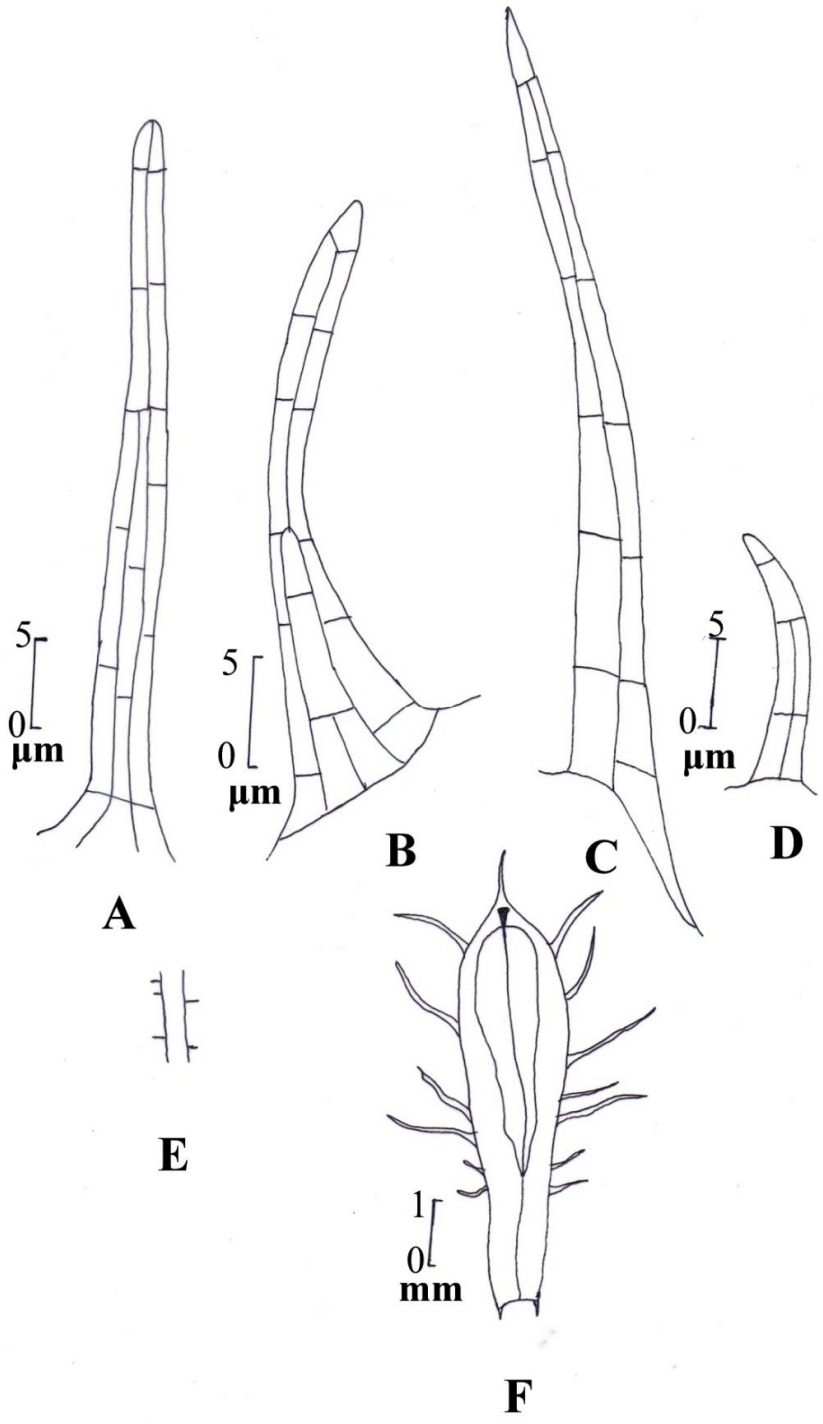
Plate-27. Trichomes, pubescence and leaf venation in *Saxifraga* species B



A

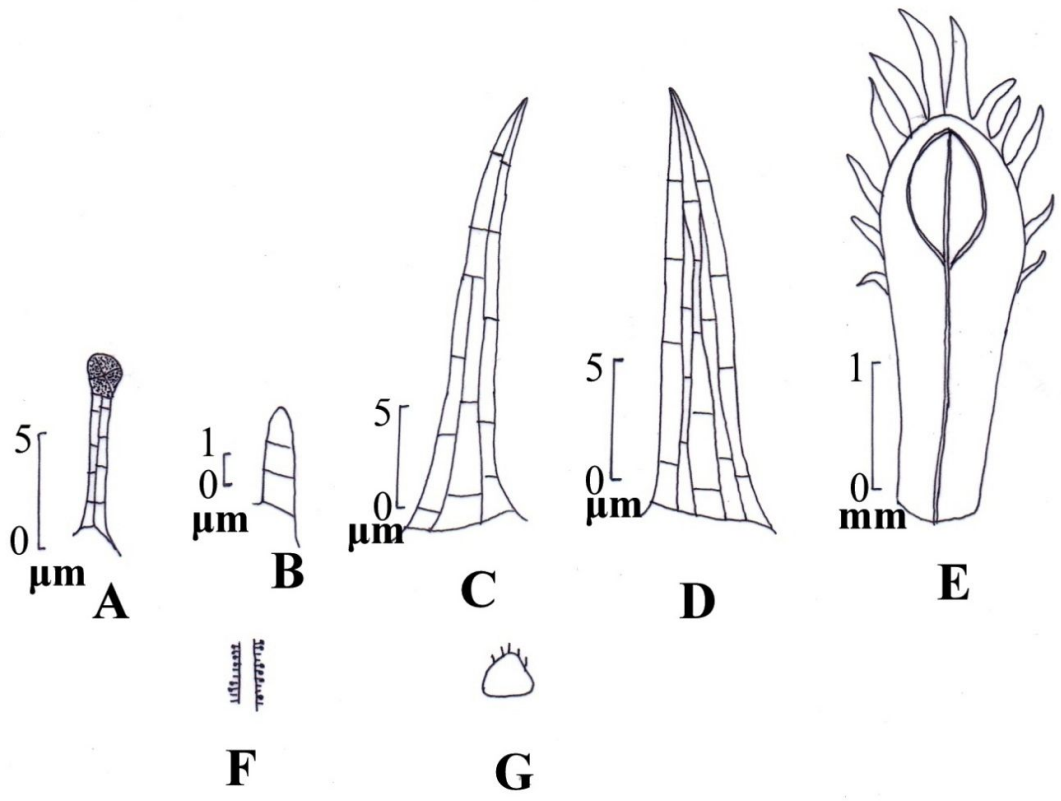
A- Leaf venation
*Plant is completely glabrous.

Plate-28. Trichomes, pubescence and leaf venation in *Saxifraga* species C



A & D- Trichomes on stem; **B & C-** Trichomes on leaf margin; **E-** Pubescence on stem; **F-** Leaf venation

Plate-29. Trichomes, pubescence and leaf venation in *Saxifraga* species D



A & B- Trichomes on pedicel; **C-** Trichome on leaf margin; **D-** Trichome on sepal margin; **E-** Leaf venation; **F-** Pubescence on pedicel; **G-** Pubescence on sepal

Plate-30. Trichomes, pubescence and leaf venation in *Saxifraga* species E

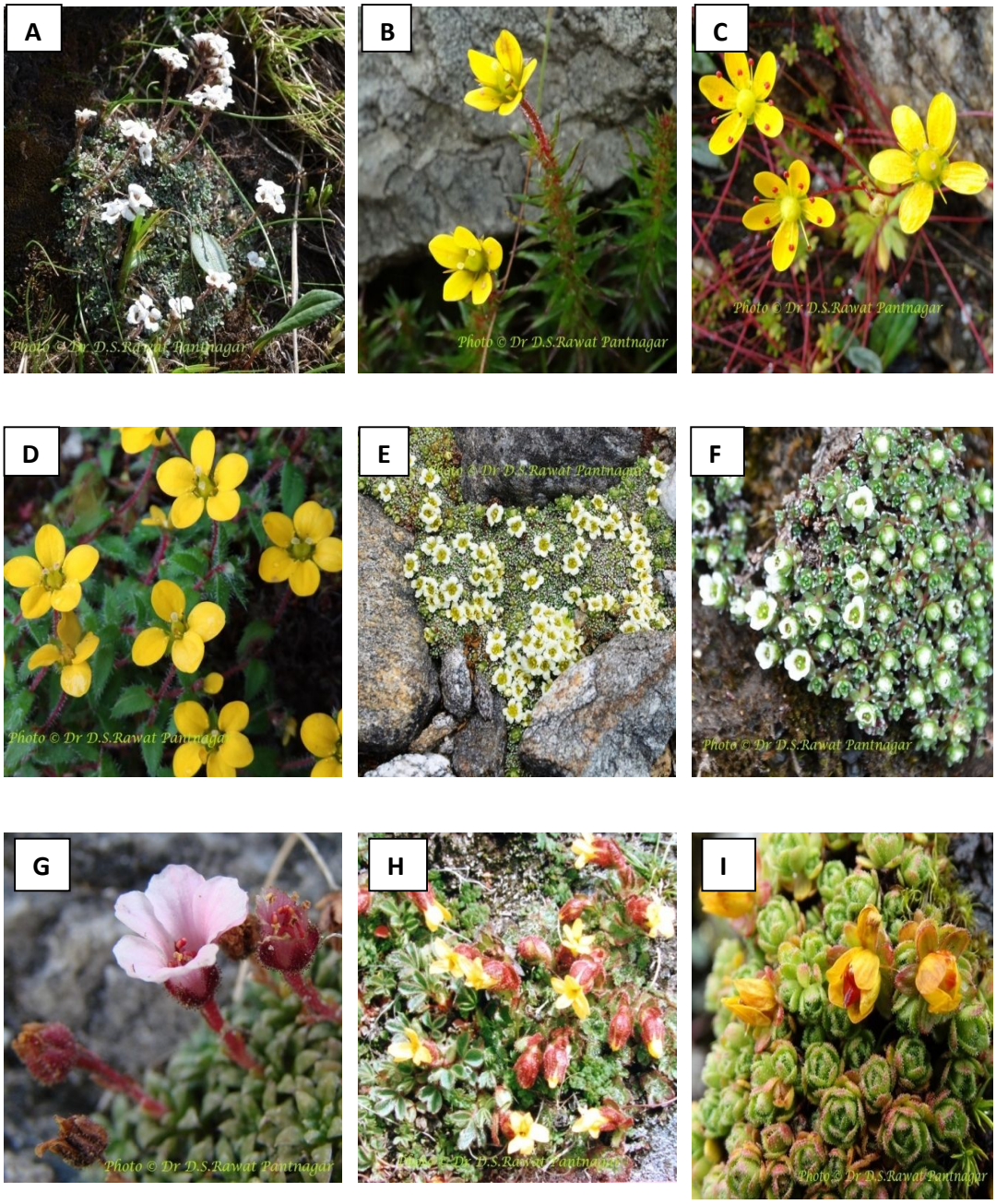


Plate 31. ***Saxifraga*** **species of Western Himalaya**. **A-** *Saxifraga andersonii*; **B-** *Saxifraga brachypoda*; **C-** *Saxifraga brunoniana*; **D-** *Saxifraga hispidula*; **E-** *Saxifraga pulvinaria*; **F-** *Saxifraga kumaunensis*; **G-** *Saxifraga lilacina*; **H-** *Saxifraga lychnitis*; **I-** *Saxifraga jacquemontiana*. [All images © Dr.D.S.Rawat Pantnagar]

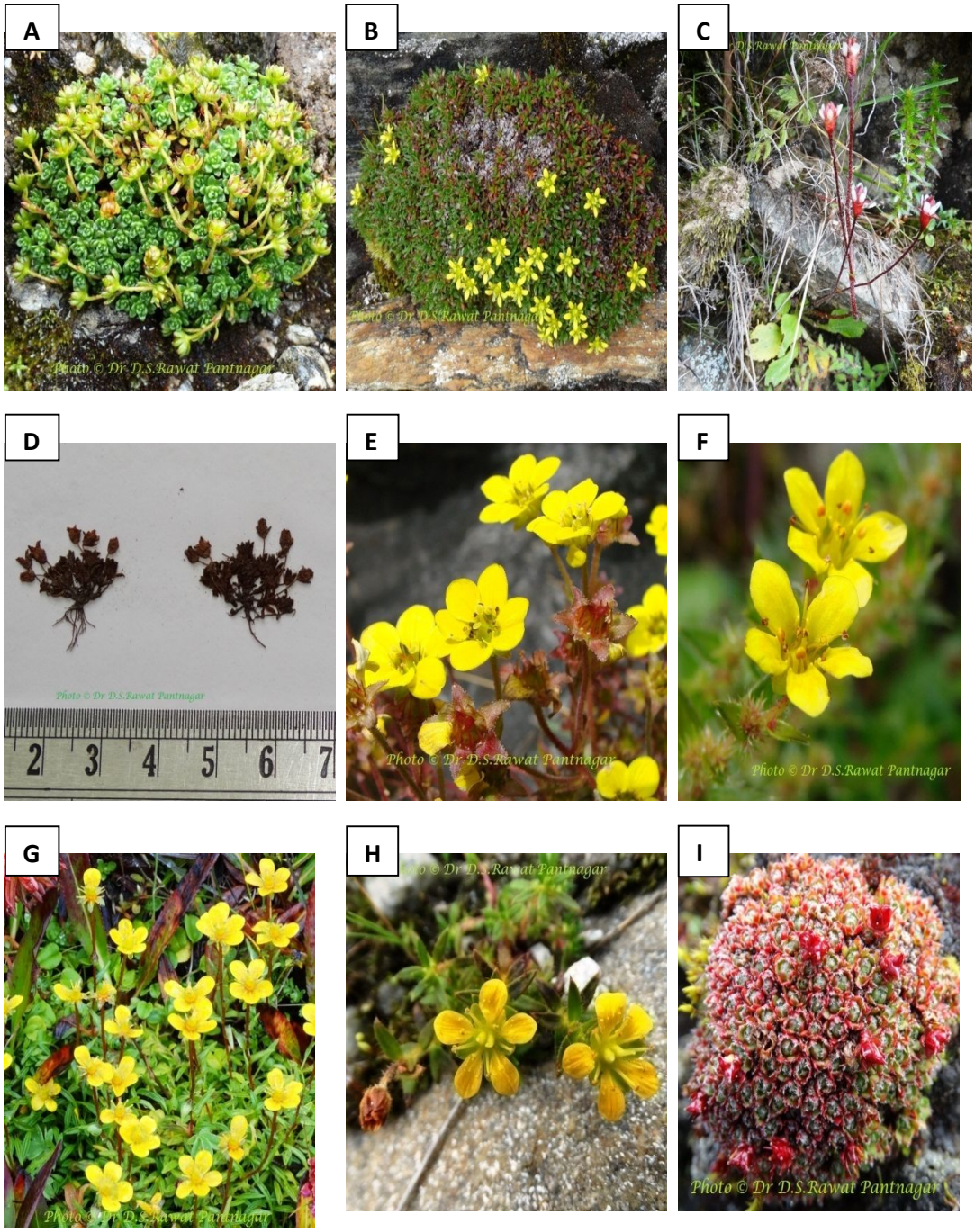
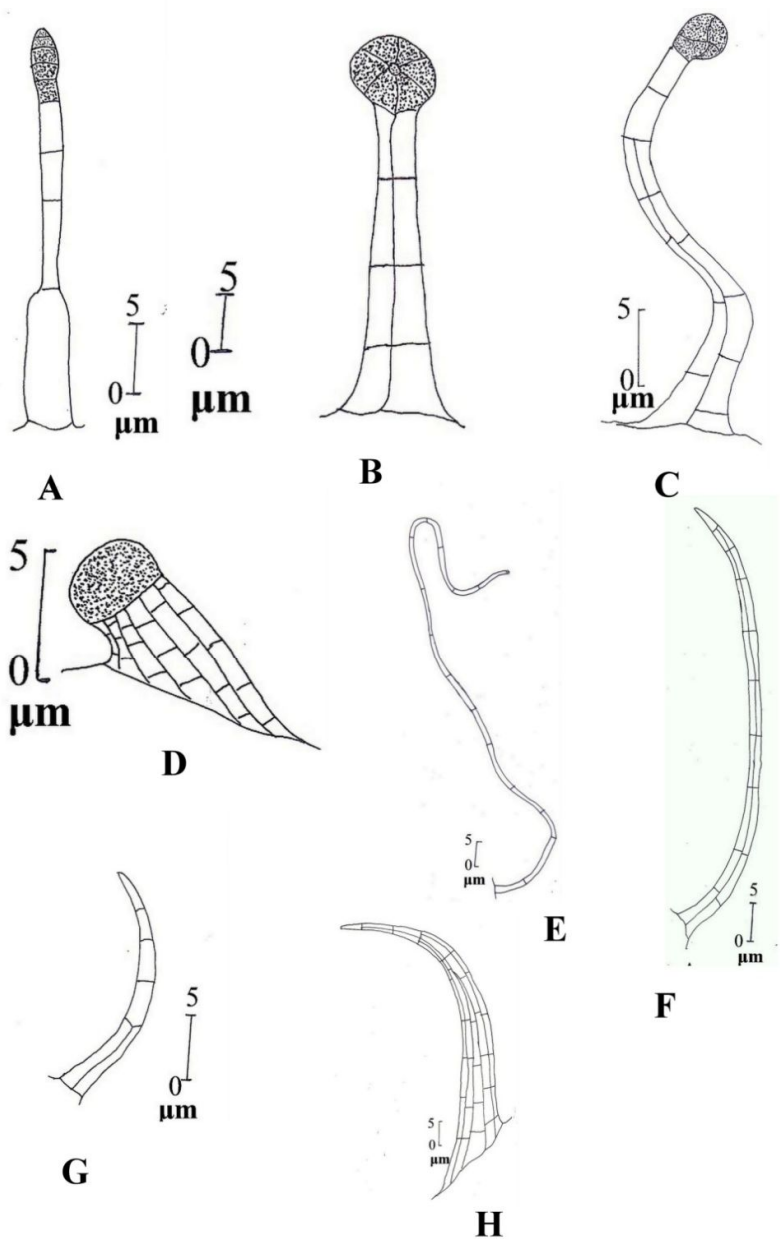


Plate 32. ***Saxifraga*** **species of Western Himalaya**. **A-** *Saxifraga microphylla*; **B-** *Saxifraga saginoides*: **C-** *Saxifraga pseudo-pallida*; **D-** *Saxifraga minutissima*; **E-** *Saxifraga parnassifolia*; **F-** *Saxifraga wallichiana*; **G-** *Saxifraga* species A; **H-** *Saxifraga* species D;

I- *Saxifraga* species E. [All images © Dr.D.S.Rawat Pantnagar]



A- Glandular uniseriate, **B**- Glandular biseriate, **C**- Glandular intermediate, **D**- Glandular multiseriate, **E**- Eglandular uniseriate, **F**- Eglandular biseriate, **G**- Eglandular intermediate, **H**- Eglandular multiseriate

Plate-33. Trichomes in *Saxifraga* species

Summary &Conclusion

Chapter 5 SUMMARY AND CONCLUSION

Saxifraga L., the largest genus in the family Saxifragaceae, is found mostly in the cold rocky terrains of Europe, North America and the Sino-Himalayan region. The plants dwell in arctic-alpine ecosystems. In Western Himalayan region, the members of this genus are found in the elevation range of 2000-5500 m above sea level. The Indian Himalayan region adjacent to China sustains a considerable number of *Saxifraga* being 64 species, 4 subspecies and 5 varieties. Nearly 30% (19 taxa) of the total *Saxifraga* species are endemic with 23 species confined to Western Himalaya and 17 species confined to Eastern Himalaya. However, correct information on West Himalayan species is yet not available in the literature.

Trichomes are fine epidermal outgrowths or appendages on the surface of a plant. They may be unicellular or multicellular, branched or unbranched, and are either glandular, consisting of a stalk with a terminal glandular head, or non-glandular, consisting of elongated tapering end. A plant may have more than one type of trichome on its surface, on one or different locations. These structures have been one of the important micro-morphological features in plant taxonomy and thus have been used for the present study on *Saxifraga* genus.

Leaf venation refers to the pattern of veins and vein branching in a leaf. Patterns of veins can be used as fingerprints to characterize plant taxa. This character was also investigated in the 30 species of *Saxifraga*.

The study area of the present work is the land area covered by the Western Himalaya within the political boundaries of India. The Western Himalayas comprises of three Indian states – Jammu & Kashmir, Himachal Pradesh and Uttarakhand. Covering a geographical area of 331,392 km^2, the Western Himalaya is featured with great mountain peaks, precipitous slopes, gorges, glaciers, rivers, great river valleys, innumerable lakes, exotic flora and fauna etc.

Plant specimens of *Saxifraga* species were examined in different herbaria of the state, i.e. G.B. Pant University Herbarium, Botanical Survey of India Herbarium, Dehradun (BSD) and Forest Research Institute Herbarium, Dehradun (DD). A checklist of *Saxifraga* species is compiled in this work based on herbarium study and perusal of

authentic literature only. Virtual herbarium of Kew was also checked for digital images of herbarium specimens from Western Himalaya.

Key findings of the present study are summarized as follows:

- The checklist prepared in this work indicates that there are 61 species and 1 variety of *Saxifraga* L. in Western Himalaya, India. Some of the species (13 species), i.e. *S. afghanica, S. ciliatopetala, S. coarctata, S. duthei, S. elliptica, S. kashmeriana, S. meeboldii, S. melanocentra, S. nakaoi, S. nanella, S. roylei, S. strigosa* and *S. viscidula*, are included based on earlier literature since their specimens were not found in the herbaria consulted.

- ***Saxifraga nigroglandulifera*** Balakr. (=*Saxifraga nutans* Hook.f. & Thomson) was reported from Himachal Pradesh by **Chowdhery & Wadhwa (1984)** but **Aswal & Melhotra (1994)** have mentioned that the only specimen from Himachal Pradesh in DD is wrongly identified as *S. nutans*. It is in fact *S. parnassifolia*. Obviously, the presence of *S. nutans* in Himachal Pradesh was based on a wrong identification. Based on this the species is not included in this checklist.

- ***Saxifraga lycopodioides*** Duthie was mentioned by Duthie (1906) from Kuti Valley and Lebung Pass in Pithoragarh District of Uttarakhand. Since no specimens and literature of its publication are traceable the species is excluded from this list.

- In the checklist 5 unidentified species are also included based on the specimens in G.B. Pant University herbarium. Out of these five species, four species (*Saxifraga* species A, *Saxifraga* species B, *Saxifraga* species D, *Saxifraga* species E) belongs to the sect. *Ciliatae,* and one species (*Saxifraga* species C) belongs to the sect. *Porphyrion.*

- In Western Himalaya, the genus is represented by 6 sections – *Saxifraga* sects. *Ciliatae* (39 species)*, Porphyrion* (14 species)*, Micranthes* (3 species)*, Mesogyne* (3 species)*, Saxifraga* (2 species) and *Odontophyllae* (1 species).

- The genus is represented by 216 species in China, 91 species in Nepal, 61 species in Bhutan, 54 species in Sikkim, 49 species in Uttarakhand, 26 species

in Himachal Pradesh, 39 species in Jammu & Kashmir, 19 species in Pakistan and 10 species in Iran. There is a general trend of decrease in the number of species of *Saxifraga* L. from Eastern Himalayas to Western Himalayas and further westward. Accordingly, the number of species of *Saxifraga* decreases from Nepal to Kashmir in Western Himalaya and further westward to Pakistan and Iran.

- Elevational distribution of the species indicates that all *Saxifraga* species occur in an elevation range of 2000-5500m.
- No *Saxifraga* species mentioned in the compiled checklist is listed in any threat category in 'Red Data Book of Indian Plants'. *Saxifraga jacquemontiana* Decne is listed as Endangered (E) species in the 'IUCN Redlist of Threatened Vascular Plant Species in India'. However, the current IUCN Red List has not listed any *Saxifraga* species of Western Himalaya as threatened species.
- 4 species of Western Himalaya (*Saxifraga chadwelli*, *S. duthiei, S. kashmiriana, S. minutissima*) and 1 variety (*S. polluniniana* var. *mucronulata*) are endemic elements in Western Himalaya.
- Trichome diversity of 30 species of the genus *Saxifraga* was studied during present work. Trichomes are present on all the species examined except in *Saxifraga* species 'C' which is completely glabrous.
- Eight types of trichomes were found on stem, pedicel, sepal surface (abaxial), sepal margin, leaf surface (adaxial and abaxial), leaf margin and petiole. No trichomes were found on petal, stamen and carpel. The different types of trichomes found are glandular uniseriate, glandular biseriate, glandular intermediate, glandular multiseriate, eglandular uniseriate, eglandular biseriate, eglandular intermediate and eglandular multiseriate types. Though trichome types are helpful in differentiating the species this character alone cannot be used for infra-generic classification.
- Plants were also studied for the types of vestiture present on stem and pedicel. Mainly five types of trichome cover occur, i.e. pubescent, tomentose, tomentulose, pilose and villous.

- Leaf venation patterns on the leaves of the available species of *Saxifraga* L. were also studied. In total seven types of leaf venation are found – acrodromous (perfect, basal), acrodromous (perfect, suprabasal), acrodromous (imperfect, suprabasal), palinactinodroous, campylodromous, eucamptodromous and hyphodromous.
- *Saxifraga cernua* have 2 types of leaf venation types – young leaves possess acrodromous (perfect, basal) type of leaf venation and mature leaves have palinactinodromous type of leaf venation.
- A cladogram was prepared based on the presence of types of leaf venation patterns in the available 30 *Saxifraga* species of Western Himalaya. It can be conclude that the presence of different types of leaf venation in different species of *Saxifraga* is reliable and can be used for the infrageneric classification at sectional level.

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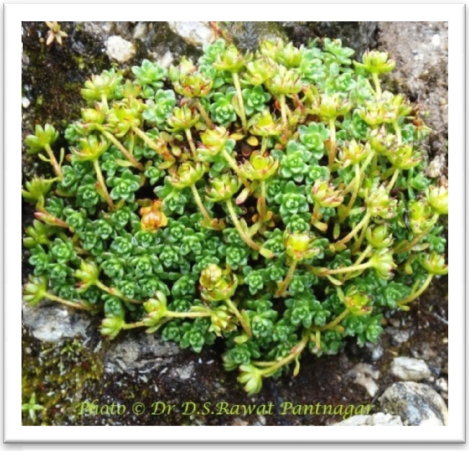

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ABSTRACT

Saxifraga L., the largest genus in the family Saxifragaceae, is found mostly in the cold rocky terrains of Europe, North America and the Sino-Himalayan region. The present study was aimed to prepare checklist of the species of *Saxifraga* L. found in Western Himalaya (Jammu & Kashmir, Himachal Pradesh and Uttarakhand), and study of trichomes and leaf venation patterns in the available 30 species. The checklist indicates presence of 61 species and 1 variety of *Saxifraga* L. in the area. Five unidentified species (*Saxifraga* species A, B, C, D and E) are also included based on the specimens in G.B. Pant University herbarium. State wise Uttarakhand has highest number of *Saxifraga* species (49 species) followed by Jammu and Kashmir (39 species) and Himachal Pradesh (26 species). *Saxifraga chadwellii*, *Saxifraga duthiei* and *Saxifraga kashmeriana* are endemic to Jammu & Kashmir while one species *Saxifraga minutissima* and one variety *Saxifraga poluniniana* var. *mucronata* are endemic to Uttarakhand. The genus is represented by 6 sections in this region. These are *Saxifraga* sects. *Ciliatae* (39 species), *Porphyrion* (14 spp.), *Micranthes* (3 spp.), *Mesogyne* (3 spp.), *Saxifraga* (2 spp.) and *Odontophyllae* (1 spp.). Among the 30 studied species, trichomes were present on all the species except in *Saxifraga* species 'C'. Trichomes were found generally on sepal, pedicel, stem and leaves and were completely absent on petal, stamens and carpels. Eight types of trichomes found were glandular uniseriate, glandular biseriate, glandular intermediate, glandular multiseriate, eglandular uniseriate, eglandular biseriate, eglandular intermediate and eglandular multiseriate. The types of vestiture present on stem and pedicel are pubescent, tomentose, tomentulose, pilose and villous. Seven types of leaf venation patterns are- acrodromous (perfect, basal), acrodromous (perfect, suprabasal), acrodromous (imperfect, suprabasal), palinactinodromous, campylodromous, eucamptodromous and hyphodromous. Based on this feature, a cladogram was prepared depicting its importance in the infrageneric classification of the genus.

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शोध शीर्षक :''पश्चिमी हिमालय, भारत में सैक्सीफ्रैगा एल. वंश का अध्ययन''

सलाहकार : डॉ0 डी0 एस0 रावत

सारांश

सैक्सीफ्रैगा एल. जो कि सैक्सीफैगेसी कुल का सबसे बड़ा वंश है, मुख्यतः यूरोप, उत्तरी अमेरिका और चीनी –हिमालयी क्षेत्र के ठण्डे पथरीले भूभाग में पाया जाता है। वर्तमान अध्ययन का उद्देश्य पश्चिमी हिमालय (जम्मू कश्मीर, हिमाचल प्रदेश और उत्तराखण्ड) में पाई जाने वाली सैक्सीफ्रैगा एल. की जातियों की जाँचसूची तैयार करना तथा 30 उपलब्ध जातियों के रोम एवं पत्ती शिरा विन्यास का अध्ययन करना था। ये जाँचसूची इस क्षेत्र में सैक्सीफ्रैगा एल. की 61 जातियाँ और 1 वैराइटी की उपस्थिति को दर्शाती है। पाँच अज्ञात जातियाँ (सैक्सीफ्रैगा जाति ए,बी,सी,डी,ई) भी जी.बी. पंत विश्वविश्वद्यालय हरबैरियम में उपलब्ध पादप नमूनों के आधार पर सम्मिलित की गई हैं। राज्यों में सैक्सीफ्रैगा की सर्वाधिक जातियाँ (49 जातियाँ) उत्तराखण्ड में पाई जाती हैं, जिसके बाद जम्मू और कश्मीर (39 जातियॉ) और हिमाचल प्रदेश (26 जातियाँ) आते हैं। सैक्सीफ्रैगा चेडवेलाई, सैक्सीफ्रैगा डुथी एवं सैक्सीफ्रैगा कश्मीरियाना जम्मू कश्मीर की तथा सैक्सीफ्रैगा माइन्यूटिसिमा एवं सैक्सीफ्रैगा पोलुनिनियाना वैराइटी म्यूकरोनेटा उत्तराखण्ड की स्थानिक जातियाँ हैं। इस क्षेत्र में इस वंश का प्रतिनिधित्व 6 अनुभागों द्वारा है जो सिलिएटी (39 प्रजातियॅा), पोरफायरियोन (14 प्रजातियाँ), माइक्रेन्थीस (3 प्रजातियाँ), मीसोगाइनी (3 प्रजातियाँ), सैक्सीफ्रैगा (2 प्रजातियाँ) और ओडोन्टोफिली (एक प्रजाति) हैं। 30 जातियों में से सैक्सीफ्रैगा जाति ''सी'' को छोड़कर सभी में रोम पाए गए हैं। रोम मुख्यतः उनके ब्राहयदल, पर्णवृंत, तने और पत्तियों पर पाए गए और दल पर पूर्णतया अनुपस्थित थे। 8 प्रकार के रोम पाए गए जो कि क्रमशः ग्लैन्डुलर यूनिसीरियेट, ग्लैन्डुलर बाईसीरियेट, ग्लैन्डुलर इन्टरमीडिएट, ग्लैन्डुलर मल्टीसीरियेट, ईग्लैन्डुलर यूनिसीरियेट, इग्लैन्डुलर बाईसीरियेट, इग्लैन्डुलर इन्टरमीडिएट एवं ईग्लैन्डुलर मल्टीसीरियेट हैं। तने तथा पुष्पवृंत पर उपस्थित रोमिलताएं प्यूबेसेन्ट टोमेन्टोज़, टोमेन्टुलोज़, पाइलोज तथा विलस हैं। पत्तियों में सात प्रकार के शिरा विन्यास, एक्रोड्रोमस (परफेक्ट बेसल), एक्रोड्रोमस (परफेक्ट, सुपराबेसल), एक्रोड्रोमस (इम्परफेक्ट, सुपराबेसल), एक्टिनोड्रोमस, कैम्पाइलोड्रोमस, युकैम्पटोड्रोमस एवं हाइफोड्रोमस, हैं। इनके आधार पर एक क्लैड्रोग्राम बनाया गया जो कि अन्तः वंशीय वर्गीकरण में इसके महत्व को प्रदर्शित करता है।

(डी0 एस0 रावत)
सलाहकार

(प्रियंका उनियाल)
लेखिका