Studies on Systematics of some members of Polygonaceae A. Jussieu in West Bengal, India

Thesis submitted to the University of North Bengal
for the Award of Doctor of Philosophy in Botany

Submitted by
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November, 2019

Dedicated to my beloved Teacher

Late Dr. Madhur Pramanik

Declaration

*I, Payel Paul hereby declare that the work embodied in my thesis entitled "**Studies on Systematics of some members of Polygonaceae A. Jussieu in West Bengal, India**" has been carried out by me under the supervision of **Dr. Monoranjan Chowdhury**, Assistant Professor, Department of Botany, University of North Bengal for the award of the degree of Doctor of Philosophy in Botany. I also declare that, this thesis or any part thereof has not been submitted for any other degree/diploma either to this or other University.*

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TO WHOM IT MAY CONCERN

This is to certify that the thesis entitled, ***"Studies on Systematics of some members of Polygonaceae A. Jussieu in West Bengal, India"*** *submitted by Ms. Payel Paul for the award of the degree of Doctor of Philisophy in Botany is based on the results of experiments carried out by her. She has worked under my supervision at Department of Botany, University of North Bengal. I am forwarding her thesis for the Ph. D. degree (Science) in Botany of the University of North Bengal. She has fulfilled all requirements according to the rules of the University of North Bengal regarding the works embodied in her thesis. This thesis or any part thereof has not been submitted for any other degree/Diploma either to this or other University.*

She bears good moral character and I wish her best for her future.

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ABSTRACT

The family Polygonaceae comprises a group of flowering plants integrated in the order Polygonales in the Magnoliophyta of the kingdom Plantae. The Angiosperm Phylogeny Group classification (APG IV) placed Polygonaceae in Caryophyllales under the clade Superasterids, one of the major clades of Core Eudicot.

Polygonaceae is prevalent in temperate regions throughout the world. They have an extensive array of distribution in India stretching from the coastal plains to the subtropical temperate regions and almost to the sub alpine regions. Very little floristics and systematics works were reported on various members of this family from West Bengal that shares significant areas under 'The Himalaya' biodiversity hotspot. Through literature survey even comprehensive floristic database of Polygonaceae of this region was not obtained. Since the study on Polygonaceae has not yet completed in this highly diverse region, so there were still some confusions about taxonomic revision of this family, hence, this study will sustain the taxonomic illumination of this family.

Some members of Polygonaceae are economically important mainly because of medicinal resources. Most of the species are utilised in various purposes like aromatic, edible, spice and many being used in a range of household and as well as industrial uses. These economically important species of Polygonaceae remains inadequately predictable and quite complicated to identify as morphologically the taxa are more or less similar. Therefore different parameters like, leaf architecture, palynology and molecular documentation have been use to resolve the problem.

The thorough taxonomic study of the complex family Polygonaceae A. Jussieu has been carried during 2014-2019. Materials for morphological, palynological and molecular studies were obtained through random sampling in three pre-dominant seasons for five successive years, 2014 to 2019. Thirty five taxa belonging to nine genera, Antigonon Endl., Bistorta (L.) Scopoli, Homalocladium (F. Mueller) L .H. Bailey, Fagopyrum Mill., Fallopia Adans., Persicaria Mill., Polygonum L. Rheum L. and Rumex L. were morphologically reviewed in detail, original observations being supplemented by and compared with formerly published literature. One variety of Persicaria chinensis was reported first time in this account from the boundary of West Bengal.

Leaf architecture studies have been conducted for all the collected taxa of the family and observations were prepared through conventional light microscopy. It is a fresh work which has covenant with comprehensive qualitative and quantitative foliar macro & micro

morphological investigations in the taxa of Polygonaceae from West Bengal. The study uncovered some distinctive and unique features on both the surface of lamina such as epidermal cells outline, type of stomata and presence or absence of trichomes. The shapes of the epidermal cells are found to be variable; six different stomatal patterns have been examined, variations among gland of trichomes were also observed. Glandular trichomes were of peltate, capitate spheroidal and stellate types. The analyzed characteristics attributes have great systematic value but they were probably to be constant at specific and/or below rank level therefore not much helpful in generic delimitation.

Pollen morphological characters have been investigated by both light microscope (LM) and scanning electron microscope (SEM). Both qualitative and quantitative attributes including aperture number, pollen shape, size in polar and equatorial view, colpi length, exine thickness have been observed. The studied characters have been proved to be beneficial in classification of the cosmopolitan family Polygonaceae into different genera. On the basis of aperture type and exine sculpturing pattern in SEM, 3 main pollen types and 12 subtypes have been identified. These different pollen types are useful to establish the evolutionary and phylogenetic relationship among the different taxa of the family Polygonaceae.

To scrutinize the inter and intra relationship and high resolution phylogeny among taxa of all the seven recorded genera, based on three chloroplast DNA region viz., rbcL, matK and trnL-F were made. Moreover, phylogenetic analysis of many less known members of Himalayan Polygonaceae, including Persicaria strigosa, P. glabra, P. tenella, P. lanigera and P. lapathifolia var. lanata had been made for the first time. The present study focused on new findings based on extended taxon sampling and ML and BI analyses of three chloroplast markers, which can be useful for the systematic positioning of different taxa of Polygonaceae. Molecular differences were detected among the species although these were not differentiated at the morphological level. The current study shows that uniting Persicaria with Polygonum sensu stricto is unnatural. Their apparent resemblance can only be linked by their more distant affinities within the family Polygonaceae. From the phylogenetic study it was also observed that most of the members of the family are monophyletic in origin whereas the origin of genus Polygonum is found polyphylic.

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Abbreviations

°C	Degree centigrade
AHC	Agglomerative Hierarchical Clustering
ANOVA	Analysis of Variance
APG	Angiosperm Phylogeny Group
BI	Bayesian phylogenetic inference
CAL	Central National Herbariyum
conc.	Concentrated
DNA	De-oxyribonucleic acid
DPX	Dibutyl Phathalate Xylene
FAA	Formaldehyde: Acetic Acid: Alcohol
IPNI	International Plant Names Index
IUCN	The International Union for Conservation of Nature and Natural Resources
ML	Maximum likelihood analysis
NADPH	Nicotinamide-adanine dinucleotide phosphate
NBU	North Bengal University
PCA	Principal Component Analysis

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1. INTRODUCTION

1.1. Polygonaceae A. L. Jussieu

Polygonaceae is cosmopolite to temperate region (Tackholm 1974) *i.e.*, geographically dispersed from the tropical region to the arctic, from montane to lowland and from arid to aquatic condition although majority of the taxa are confined to the northern temperate region. The name of the family "Polygonaceae" is based on its type genus *Polygonum*. It is a large family comprising around 48 genera and 1200 species (Freeman and Reveal 2005; Sanchez and Kron 2008).

Polygonaceae is morphologically diverse and habit ranges from trees, shrubs, vines, lianas to herb. The presence of membranous or hyaline sheath uniting the stipules is the characteristic feature of the family. The sheath more precisely the ochreae are present in majority of the genera except in the largest genus, *Eriogonum* Michaux., *Antigonon* Endl. and *Fallopia* Adans. In various genera the stem is typically swollen at the nodes. Assimilating stems with rudimentary leaves are observed in *Calligonum* and *Muehlenbeckia* but in *Muehlenbeckia platyclada* striate flattened cladodes are present. Phyllotaxy is typically alternate but in some taxa they can be opposite (e.g. *Pterostegia* Fischer & C. A. Meyer., some species of *Polygonum* L. and *Eriogonum* Michaux.). The flowers are habitually actinomorphic with two to six uniform tepals, often in two whorls of three, persistent in fruit, ovule is predominantly orthotropus, fruit is trigonous nut and seeds have excentric copious endosperm (Cronquist 1981).

1.2. Distribution of Polygonaceae

The utmost diversity of Polygonaceae is seen in the northern temperate region which is the most favoured habitat of the family. But some taxa are also dominating the vegetation at sub alpine region. Nevertheless, it is universally found in temperate region of America and Asia. Polygonaceae are broadly distributed from China to Japan in Northern Asia while in south, it occurs in Afganistan, Bhutan, Nepal, Pakistan and India. The family distributed in most part of the Kazakhstan, Korea, Kyrgyzstan, Mongolia, Myanmar, New guinea, Pakistan, Philippines, Tajikistan, Thailand, Turkmenistan, Uzbekistan, Vietnam, North Africa, Australia, Europe,

North America. In India Polygonaceae has extensive range of distribution stretching from the Eastern Himalayan region including Kashmir, the subtropical and temperate to coastal region. Majority of the species are confined to various altitudes of Himalaya and North East India (Assam, Meghalaya, Nagaland and Manipur). The data about the number of the species and their distribution in the Eastern and Western Himalaya are gradually increased since the time of Hooker (1886). Srivastava (2014) reported 121 species and 29 varieties belonging to 12 genera of Polygonaceae from India. The checklist has been made based on the available herbarium specimen of different herbaria of India. Darjeeling-Kalimpong Himalaya and Terai-Duars region of West Bengal forms a fundamental part of the Eastern Himalayan region. Polygonaceae widely distributed from the Darjeeling-Kalimpong Himalaya to the Terai- Duars and also in the Gangetic Delta of West Bengal. Unfortunately through literature survey, no complete floristic database of Polygonaceae was obtained from this region. As the study on Polygonaceae has not yet done from this tremendously rich and diverse vegetation, so there are still some confusions about the phylogeny and affinity of some taxa which are widely distributed in this region and their uncertain positioning and inter relationship are still remains unsolved. Hence, the present study will aiming to clarify the taxonomic repositioning and will enrich the floristic and systematic database of family for this entire region.

1.3. Taxonomic delimitation of Polygonaceae

The family Polygonaceae is a very interesting family, especially regarding their most diverse morphological variations (Ronse Decraene and Akeroyd 1988; Brandbyge 1993). To describe the species and their systematic positions, various authors were frequently segregating this family into subfamilies or tribes in different times based on some selected morphological characters. Jussieu (1789) accepted the distinctiveness of the family as a natural group. Arnott (1832) was published subfamily Eriogonoideae and then subfamily Polygonoideae (Eaton 1836) while third subfamily Coccoloboideae was suggested by Luerssen (1882).

Bentham and Hooker (1880) were directly classifying the family into three tribes: Coccolobeae, Eupolygoneae and Rumiceae based on their morphological characteristic features. Dammer (1893) on the basis of morphological evidences

divided it into three subfamilies like Polygonoideae, Rumicoideae and Coccoloboideae, where he included Eriogonoideae as a tribe under the subfamily Polygonoideae. Gross (1913) proposed Eriogonoideae, Coccoloboideae and Polygonoideae as subfamilies and considered Rumicoideae as a tribe under Polygonoideae.

Jaretzky (1925) recognized two subfamilies in the family Polygonaceae based on their foliar and floral morphological evidences *i.e.*, Eriogonoideae and Polygonoideae and proposed Coccolobeae as a tribe in Polygonoideae. Buchinger (1957) suggested three subfamilies: Polygonoideae, Rumicoideae and Eriogonoideae of Polygonaceae. Polygoneae and Coccolobeae were the tribes under Polygonoideae while Rumiceae placed under Rumicoideae.

On the basis of the morphological evidences Roberty and Vautier (1964) postulated that Polygonaceae can be divided into three subfamilies such as Calligonoideae, Eriogonoideae and Polygonoideae and the sub-family Polygonoideae was also segregated into four tribes *i.e.,* Coccolobeae, Polygoneae, Rumiceae and Rheae.

Haraldson (1978) based on anatomy of vegetative parts first time attempted to divide the family Polygonaceae into two subfamilies Eriogonoideae and Polygonoideae. She further divided Eriogonoideae into two tribes: Eriogoneae and Pterostegieae while Polygonoideae into five tribes Polygoneae, Persicarieae, Rumiceae, Coccolobeae and Triplareae.

The most recent and generally accepted consensus is to recognize two subfamilies, Eriogonoideae Arnott and Polygonoideae Eaton (Brandbyge 1993; Sanchez and Kron 2008) with different circumscription.

1.4. Taxonomic convolution of the Genus *Persicaria* and *Polygonum*

Polygonum, had been presented a great taxonomic challenge over the years. Various classification systems had been proposed to resolve the problem and sometimes same names had been suggested to moderately different groups and at different taxonomic hierarchial ranks (Haraldson 1978). Therefore nearly every botanist was contented to evade the underlying issues by suggesting *Polygonum sensu lato*.

In the first edition of 'Species Plantarum' (1753) Linnaeus described the genus *Polygonum* where he included seven different genera as its species viz., *Aconogonon* (Meisn.) Reichb., *Bistorta* (L.) Scop., *Fagopyrum* Mill., *Fallopia* Adans., *Persicaria* Mill., *Polygonum s.s.*, and *Reynoutria* Haraldson. The first attempt to divide the genus *Polygonum* was done by Meisner (1826) who segregated the genus into eight sections such as *Amblyogonon, Aconogonon, Avicularia, Cephalophilon, Fagopyrum, Persicaria, Bistorta,* and *Tiniaria*. Later in 1857 he added the section *Echinocaulon* and *Tephis* in his studies and distinguished *Echinocaulon* and *Cephalophilon* from *Persicaria* due to capitate inflorescence. Meisner's delimitation into section became the preliminary point for many various workers who wish to subdivide the complex genus *Polygonum*. Moreover, Bentham and Hooker (1880) predominantly followed Meisner's sectional division with addition of some new sections (*Pleuropterus, Pseudopolygonella* and *Pseudomollia*).

Gross (1913) also tried to resolve the confusion among *Polygonum* and *Persicaria* based on the gross morphology and palynology. He retained few of the Meisner's sections and also removed 7 genera from *Polygonum*. He distinguished the genus *Persicaria* Mill. from *Polygonum* L. and suggested *Aconogonon, Amblygonon, Cephalophilon, Echinocaulon* and *Tovara* as sections of *Persicaria* and separated the genus *Fagopyrum* Mill. into two sections (*Tiniaria* and *Eufagopyrum*).

Subsequently, Jaretzky (1925) on the basis of presence or absence of anthraquinones proposed five genera viz., *Avicularia, Polygonum, Polygonella, Persicaria* and *Fagopyrum* which had previously been considered as sections of *Polygonum*. He also supported Bentham and Hooker's (1880) classification *i.e.*, *Pleuropterus* and *Tiniaria* as the sections of *Polygonum* and *Typhis* as the sections of *Avicularia*. On the basis of pollen morphology Hedgeberg (1946) suggested that *Persicaria* is a separate genus. He established eight genera from *Polygonum s.l.* (*Koenigia, Fagopyrum, Bistorta, Persicaria, Polygonum s.s., Pleuropteropyrum* and *Tiniaria*).

Clapham et al. (1962) accepted in the genus *viz., Polygonum*. They proposed this based on a combination of plant habit, leaves shape, perianth segments and stamen number. Roberty and Vautier (1964) also suggested *Persicaria* as a section and divided the genus based on their structural variation in stigmas and propagules into nine sections *viz., Typhis, Avicularia, Persicaria, Polygonum, Bistorta, Aconogonon,*

Cephalophilon, *Echinocaulon* and *Eleutherosperma* and three genera: *Bilderdykia*, *Reynoutria* and *Antenoron*. Webb and Chater (1964) further abridged the number of sections and treated the genus containing four sections (*Aconogonon*, *Bistorta*, *Polygonum*, and *Persicaria*). Graham and Wood (1965) also recommended *Persicaria* as the sections of *Polygonum* along with *Tiniaria*, *Cephalophilon* and *Echinocaulon* whereas *Fagopyrum* and *Polygonella* were considered to be separate genera.

Hara (1966) based on the morphological characteristics proposed that *Persicaria* along with *Aconogonon*, *Antenoron*, *Bistorta*, *Bilderdykia*, *Fagopyrum*, *Koenigia* were not the section of *Polygonum s.l.* but also treated as the separate genera. Haraldson (1978) after thoroughly reviewed the existing data and with the additional support from anatomy of the vegetative character suggested that *Polygonum s.l.* should be separated into two tribes (Polygoneae and Persicarieae) and she placed *Polygonum*, *Fagopyrum*, *Polygonella*, *Fallopia*, *Reynoutria* in the tribe Polygoneae while *Bistorta*, *Aconogonon* and *Persicaria* in Tribe Persicarieae. She also retained sectional division of *Polygonum* (*Duravia*, *Polygonum* and *Tephis*). Ronse Decraene and Akeroyd (1988) also supported the division of *Polygonum* L. *s.l.* into two tribes as anticipated by Haraldson (1978). On the basis of the morphology of floral characters of *Polygonum* and related genera of Polygonaceae they proposed that the tribe Polygoneae should contain *Polygonum* L. *s.s.*, *Fallopia* Adans., *Oxygonum* Burch., *Pteropyrum* Jaub. and Spach., *Atraphaxis* L. *and Calligonum* L. while *Fagopyrum* Mill., *Harpagocarpus* Hutch. and Dandy, *Persicaria* Mill. and *Koenigia* L. were included in the tribe Persicarieae. Li *et al*. (2003) investigated the genus *Polygonum* from China and documented two tribes for the taxa of *Polygonum viz*., Polygoneae and Persicarieae. While studying Polygonaceae for the flora of North America, Freeman and Reveal (2005) suggested *Persicaria* Mill as separate genera and *Polygonum* L. segregated into two sections (*Polygonum* and *Duravia*).

1.5. Taxonomic tool for resolving the systematic position of Polygonaceae

Flora is the most priceless gift of nature which provides all kinds of fundamental requirements for our continued existence, including food, medicine, fuel, fodder, timber, resins, oils etc. Natural assets investigation like floristic study plays imperative role in the economic up gradation of developing country (Ganorkar and

Kshirsagar 2013). Beside this, floristic survey of a particular province is also generating the whole information on different family, genus and species, dominant taxa and major life-forms occupying a particular habitat (Sasidharan 2002). Therefore, floristic study is one of the most important provisions from the taxonomic point of view. In recent years there has been a reinforcement of interest in floristic studies from different regions in India, as it is one of the seventeen mega diversity countries of the world. Till now, large number new taxa have been reported from various parts of the country (Eshuo and Chaturvedi 2011; Chowdhury *et al*. 2013; Paul and Chowdhury 2016; Mondal and Chowdhury 2019). This is due to insufficient previous documentation, progress in processes of evolution and changes of floristic elements of vegetation with time. Exotic species of a flora have some impact that in most cases it becomes offensive for the local taxa. However, several exotics are progressively naturalizing (Chowdhury *et al*. 2013). Conversely many inhabitant species are slowly but surely becoming endangered and even getting extinct from the different floristically rich regions. As the result number and the identity of taxa included in earlier floras are now changing hurriedly so, it is necessary to explore the flora in regular interval. Other than that numerous floristically important regions are not yet explored rather under explored. Therefore, floristic study is one of the most important provisions from the taxonomic point of view. West Bengal is the major part of IUCN recognized 'Himalaya Biodiversity Hotspot' (Conservation International 2005). However, Darjeeling - Kalimpong Himalaya, Terai and Duars are forming a proximate and comprehensive part of the prosperous vegetation of the Eastern Himalaya. Extensive survey through available literature covering the flora of East Himalayan region shows that Polygonaceae is one of the dominant families in this region (Hooker 1886; Prain 1906; Maiti and Sikdar 1985; Chowdhury 2013). Regrettably, there is no comprehensive floristic work accessible on these important plants occurring West Bengal. Thus, in the present study an endeavour has been made to investigate the distribution of Polygonaceae in this region.

From the primitive time recognition and reconstruction of relationships between plants have been based mainly on characteristic features of their reproductive organs. The floral characters have recognized very helpful for identification (Wilkinson 1979), but sometimes these organs are not easily accessible for study.

Therefore, fossils record viz., leaf impression and compression are the most recurrent macroscopic residues of extinct plants, but they are generally not attached to other plant organs when those are excavated. Because of their profusion and impenetrable strata graphic occurrence, fossil leaves can provide massive information about the composition and diversity of primordial floras. Leaves are very important as those are extremely polymorphic organs and provide sets of diverse features. The term "leaf architecture" was coined by Hickey (1973) to denote the placement and outline of those elements constituting the outward expression and lamina structure, as well as leaf shape, size, blade class, venation pattern, marginal configuration and gland position etc. Venation is the vasculature formed by veins and veinlets. Hence, venation patterns are significant characteristics attribute used to resolve many controversies in plant systematics (Larano and Buot 2010). So, leaf architecture like venation pattern were studied in different families viz., Asteraceae (Banerjee and Deshpande 1973), Berberidaceae (Singh *et al.* 1978), Betulaceae (Frank 1979), Euphorbiaceae (Sehgal and Paliwal 1974), Bignoniaceae (Jain 1978), Labiatae (Tyagi and Kumar 1978), Rosaceae (Merrill 1978), Solanaceae (Inamdar and Murthy 1978) and Scrophulariaceae (Varghese 1969), Hydrocharitaceae, Taccaceae, Dioscoreaceae, Smilacaceae, Araceae, Alismataceae, Aponogetonaceae (Inamdar *et al.* 1983), Lauraceae (Chowdhury 2015).

Alongside venation, stomata and epidermal cells also provide taxonomically imperative diagnostic features, such as the occurrence of stomata on the adaxial or abaxial surface of lamina and arrangement of epidermal cells adjoining to the guard cells (Tripathi and Mondal 2012). Usually, the small openings in the epidermal layers which involve with gaseous exchange among intercellular spaces and the atmosphere are known as stomata. These are surrounded by guard cells, which organize the pore size. The morphology of the stoma was first studied by Stresburger (1866) followed by various workers such as Vesque (1989) who reported four basic types of stomata based on the presence and arrangement of subsidiary cells along with their mode of development namely Rannanculaceous, Cruciferous, Rubiaceous and Caryophyllaceous. Metcalfe and Chalk in 1950 described main four types of stomata, i.e. Anisocytic, Anomocytic, Diacytic and Paracytic whereas Stace (1980) observed 31 different types of stomata among dicotyledonous plants.

One more fundamental character of foliar micro morphology is indumentums and it plays a noteworthy role in plant systematics, especially of particular groups at generic and specific levels (Hardin 1979). The presence or absence of peltate hairs and their shape, size could be used as distinguishing features of different genera and species (Cooper 1931; Spring 2000). Undoubtedly in recent studies advancement of approaches like bioinformatics, biotechnology, biochemistry, biomolecular etc. are necessary, but the conventional morphological disciplines should not be neglected. Now a day, leaf architecture is also a neglected feature. Conversely, importance of leaf architectural data like other countless parameters remains unquestionable. Therefore in the present study comprehensive account of leaf architectural data is undertaken as one of the parameter for resolving the confusion about the systematic position of Polygonaceae.

The floral character plays an important role in angiosperm taxonomy. The vegetative parts of the plant may differ in different climate conditions, geographical location and various biotic and abiotic stresses. In these cases, the floral parts or the floral formula can play an incredibly significant role in the authentic identification at the species level. The great Swedish botanist Linnaeus was first introduced the term pollen (Knox 1984). Pollen refers to the highly reduced male gametophyte enclosed within the microspore wall of seed plants or flowering plants. It is the most vital unit of the angiosperm flower, both with regard to form and function, and represents the sole medium through which the entire male genetic attributes are transmitted to the next generation; and thereby, it enters the perpetuation of species (Erdtman 1952; Nair 1970). The term Palynology was coined by Hyde and Williams (1944) who refer to the study of external morphological features of mature pollen grains. The term palynology has been derived from the word palymein, meaning ‘to scatter’ as pollens are often spread by wind, and logos meaning study. Comparative studies of pollen morphology have provided constructive attributes for resolving the inter-relationships and delimiting genera and species. Palynology is diverse and widely accepted to reflect phylogenetic relationships (Lee *et al*. 2011). Unique morphological features of pollen grains were moderately conserved and recurrently used in solving taxonomic inconvenience at family, genus, species and varietal rank since long and have become part of the multidisciplinary and mutual approach in plant systematic and evolution (Carlo *et al*. 2004; Giveyrel *et al*. 2000; Persson

1996). Constant exine ornamentation and aperture features of pollen grains are appreciably recognizable for parent genera or species (Harris 1955; Moore *et al.* 1978). Different researchers from different parts of the world have worked on the pollen morphology of Polygonaceae but very little work was done on this family from this part of the world. Present study reports detailed morphology of pollen grains of the Polygonaceae from West Bengal using LM (Light microscopy) and SEM (Scanning Electron Microscopy).

In recent years, the understanding of phylogenetic relationship among angiosperms has significantly increased with the coalescence of molecular data accumulated through different conventional techniques. Large-scale barcoding projects through molecular data coupled with the rapid expansion of bioinformatics tools, recommended a unique circumstance for species delimitations (Monaghan *et al*. 2009; Fujita *et al*. 2012). The chloroplast genome of terrestrial plants typically harbours a conserved set of approximately 120 genes in a 120–160 kb pair genome (Kaneko *et al*. 1996). Although chloroplast genomes contain highly conserved indispensable genes for the growth and development of plant, they also contain variable regions, *i.e*., intergenic regions and structural variations. In addition, they restrain one of the few sets of characters that can exceed the life history of green plants and hence produce important evolutionary information. Therefore, chloroplast genome sequences can be used for comparative evolutionary studies within and between different groups of plants (Timmis *et al*. 2004; Greiner and Bock 2013). Among molecular markers, the *rbcL* gene has been extensively used for systematics at higher levels (Olmstead *et al.* 1992; Chase *et al*. 1993; Qiu *et al*. 1993; Nickrent *et al.* 2002).

Taking this into consideration the present study deals with the sequencing of *rbcL*, *matK* and *trnL-F* region of chloroplast genome of some members of Polygonaceae that were not sequenced earlier.

1.6. Research Objectives

The objectives of the present research work:

- Floristic survey to understand the present status of different taxa of Polygonaceae from West Bengal along with their habitat types and recognition of economically important taxa.
- Construction of distribution map of those taxa of Polygonaceae
- To Record the exact flowering and fruiting periods for different recorded taxa of Polygonaceae in study area.
- To study and analyze the macro and foliar micro-morphological characters of collected taxa.
- To study and analyze the ultra-morphology of pollen grains of recorded taxa.
- To assess inter and intraspecific relationship in selected taxa of Polygonaceae through barcode primers (*matK, trnL-F, rbcL*) of chloroplast genome.
- Analysis and draw a significant phylogeny among the taxa using both Phenetic and molecular taxonomic attributes and easy identification key were made and it helps to reduce the confusion at least at species level of Polygonaceae.

2. LITERATURE REVIEW

2.1. Taxonomic treatments

Family Polygonaceae was established and published by A. L. Jussieu (1789) in Genera Plantarum. Around 1200 species representing 48 genera are geographically distributed from the tropics to the arctic, although most species are concentrated in the northern temperate region (Heywood 1978; Freeman and Reveal 2005; Sanchez and Kron 2008). Polygonaceae Jussieu commonly known as the Buckwheat, Smartweed or Knotweed family is one of the complex group among the class Magnoliopsida regarding its identification. The family name was derived from Greek word "*Polygonon*", "***Polys***" meaning many and "***gonon***" meaning Knee referring to the prominent nodes of many species (Komarov 1970).

Bentham and Hooker (1880) placed Polygonaceae Jussieu in their classification as follows:

Kingdom: Phanerogamia
Class: Dicotyledonae
Sub class: Monochlamydae
Series: Curvembryae
Family: Polygonaceae

Cronquist (1981) placed Polygonaceae in his classification as follows:

Division: Magnoliophyta
Class: Magnoliopsida
Sub class: Caryophyllidae
Order: Polygonales
Family: Polygonaceae

Takhtajan (1997) placed Polygonaceae in his classification as follows:

Division: Magnoliophyta

Class: Magnoliopsida

Subclass: Caryophyllidae

Order: Polygonales

Family: Polygonaceae

APG IV (2016) placed Polygonaceae in the classification as follows

Kingdom: Plantae

Clade: Core Eudicots

Clade: Superasterids

Superorder: Asterids

Order: Caryophyllales

Family: Polygonaceae

Type genus: *Polygonum* Linnaeus

2.2. General characteristics

Polygonaceae is a very complex family due it's most diverse and peculiar morphological features. Members of the Polygonaceae are showing variable habit range from annual or perennial herbs, shrubs to lianas and some trees. The most distinctive feature of the family is the presence of membranous or hyaline sheath uniting the stipules (except *Antigonon* Endl., *Eriogonum* Michx. etc). Leaves are simple usually alternate but in some cases they can be opposite (*Pterostegia* Fisch. and C. A. Mey., some species of *Polygonum* L. and *Eriogonum* Michx.). Nectary discs are usually present and the nodes are typically swollen (Hutchinson and Dalziel 1954). The flowers are usually perfect and actinomorphic with a perianth of three to six sepals, often in two whorls of three or one whorl of five. After flowering sometimes the sepals become enlarged around the developing fruit. Flowers lack corolla and in some taxa the sepals are petal-like and colorful. Androecium is composed of three to eight stamens that are normally free or united at base (Jones and Luchsinger 1979). Three united carpels of ovary forms a single locule, which in turn produces only one ovule. Superior ovary with basal or free central placentation

is the unique feature of the family. Gynoecium terminates 1–3 styles, each of which ends in a single stigma. Ovule is mostly orthotropus, fruit is trigonous nut and seeds have copious endosperm (Cronquist 1981). Seeds are erect, testa membranous, albumen floury or horny. Embryo is various, radicle superior (Maiti and Sikdar 1985).

2.3. Economic importance

Most of the species of the family Polygonaceae were growing in waste areas as weeds. But, few genera of Polygonaceae were reported as economically important for their widespread uses (Steward 1930). However, Cardoso *et al.* (2006) studied and analyzed the medicinal and chemical properties from different species Polygonaceae. The complex genus *Polygonum* L. has some economic importance. *P. aviculare* L. is an accepted widely in international pharmaceutical market, sold in German drug stores as Homeriana Tea; it contains 2–2.5% sugar, traces of essential oil, tannin, resin and wax. Its seeds are cathartic and emetic (Bamber 1916). It is also popular as good fodder plant and its roots yield a blue dye (Komarov 1970). It is a bad weed, resistant to herbicide (Mabberley 1987). It is used as an astringent, tonic, antipyretic, diuretic and extract is given against dysentery. *P. plebium* R. Br. was reported as medicine used to cure pneumonia (Agarwal 1997). The leaves of *P. arenastrum* Boreau. contains tannins and is used as medicine (Zohary 1966). Its aerial parts has haemostatic action (Joachimovits 1959) used as antiseptic (Gupta 1995) and internally as antihaemorrhoidal, astringent and antirheumatic (Mors *et al.* 2000). The plant is also famous for its antifertility properties (Garg *et al.* 1978; Sarma and Mahanta 2000). Infusions and decoctions are made from *P. lapathifolium* L. and used as cathartic and emetic drugs. The infusion of *P. persicaria* L. leaves is used to relieve stomach pains and its decoction is used in the treatment of rheumatism (Moerman 1998). Fleshy roots of *P. viviparum* L. are cooked because of its almond flavour and also used as a substitute for nuts and raisins (Szczawinski and Hardy 1972).

Some species of *Persicaria* are economically important worldwide such as *P. capitata* (Buch-Ham. *ex* D. Don) H. Gross and *P. orientalis* (L.) Spach are used as ornamental plants in China (Lorenzi and Souza 1999). Root of *P. chinensis* (L.) H. Gross (Mountain knotweed or Chinese knotweed) is used for the treatment of fluxes,

antihelminthic and neutralizes scorpion poisoning. Extract of *P. minor* (Huds.) Opiz is mixed with rice powder and used on affected area to cure sprains and body aches. The plant is also used as an antidote for dyspepsia in children (Wiart 2006). Watery sap obtained from the roots of *P. barbata* (L.) H. Hara is used as an antiseptic (Watt and Breyer-Brandwijk 1962).

The rhizome of *Bistorta amplexicaulis* (D. Don) Green is used for making tea and decoction (Qaiser 2001).

Fagopyrum Mill. (Buckwheat) is reported to be economically important genus (Campbell 1995). In China, *F. dibotrys* (D. Don) Hara is used for the treatment of lung diseases, including lung tumor (Liu *et al.*, 1981). In India, its seeds are used for the treatment of colic, choleraic diarrhoea and abdominal blockage troubles (Samaiya and Saxena 1989). Its leaves are used as vegetable and crushed grains given against the stomach disorders (Qaiser 2001). Polyphenols like rutin and quercetin have been isolated from *F. esculentum* Moench. has anti-inflammatory and anticarcinogenic properties (Oomah and Mazza 1996). Leaves are edible and nectar famous for the production of honey that is used for the treatment of various blood diseases (Campbell 1997; Erlund *et al.* 2000; Qaiser 2001). In China, Japan, Korea it is use as non poaceous alternative human crop, famous for its nutritious qualities (Wijngaard and Arendt 2006). *F. tataricum* (L.) Gaertn. (Tatary buckwheat) used for the treatment of bleeding gums and the people who used tatary buckwheat flour for brushing their teeth and gargling showed 62% recovery in their gum diseases (Song and Zhou 1992). It is an important crop in Himalayan hills and mountain regions of southern areas of China (Tsuji and Ohnishi 2001).

High proportion of anthraquinones is present in the genus *Rumex* L. and the roots of *R. dentatus* L. are used as an astringent and for dyeing purposes because of high percentage of tannin (Hongo 1986; Watt and Breyer-Brandwijk 1962). The leafy juice of *R. vesicarius* L. produces cooling effect in snake bite (Qaiser 2001).

2.4. Genus under Polygonaceae

Different authors documented 30 to 59 genera under the family Polygonaceae. The major genera are *Eriogonum* (240 species), *Rumex* (200 species), *Coccoloba* (120 species), *Persicaria* (100 species) and *Calligonum* (80 species) (Freeman and

Reveal 2005). According to Cronquist (1981) the family is represented by 30 genera, where as Freeman and Reveal (2005) reported 48 genera for Polygonaceae. Brandbyge (1993) distinguished the Polygonaceae family with 43 genera (Table 1) while according to Plantlist (www.plantlist.org) the family comprises 59 genera.

Table 1: Genera under the family Polygonceae (Brandbyge, 1993)

Sl. No.	Genera	Sl. No.	Genera
1.	*Antigonon* Endl.	**23.**	*Millspaughia* Robins.
2.	*Aristocapsa* Reveal and Hardham	**24.**	*Mucronea* Benth.
3.	*Atraphaxis* L.	**25.**	*Muehlenbeckia* Meisn.
4.	*Brunnichia* Banks *ex* Gaertn.	**26.**	*Neomillspaughia* S. F. Blake
5.	*Calligonum* L.	**27.**	*Oxygonum* Burch. *ex* Campd.
6.	*Centrostegia* A. Gray *ex* Benth.	**28.**	*Oxyria* Hill
7.	*Chorizanthe* R. Br. *ex* Benth.	**29.**	*Oxytheca* Nutt.
8.	*Coccoloba* P. Browne	**30.**	*Persicaria* (L.) Mill.
9.	*Dedeckera* Reveal and J. T. Howell	**31.**	*Podopterus* Humb. and Bonpl.
10.	*Dodecahema* Reveal and Hardham	**32.**	*Polygonella* Michx.
11.	*Emex* Neck. *ex* Campd.	**33.**	*Polygonum* L.
12.	*Eriogonum* Michx.	**34.**	*Pteropyrum* Jaub. and Spach
13.	*Fagopyrum* Mill.	**35.**	*Pterostegia* Fisch. and C. A. Mey.
14.	*Fallopia* L.	**36.**	*Reynoutria* Houtt.
15.	*Gilmania* Coville	**37.**	*Rheum* L.
16.	*Goodmania* Reveal and Ertter	**38.**	*Rumex* L.
17.	*Gymnopodium* Rolfe	**39.**	*Ruprechtia* C. A. Mey.
18.	*Harfordia* Greene and Parry	**40.**	*Stenogonum* Nutt.
19.	*Hollisteria* S. Watson	**41.**	*Symmeria* Benth.
20.	*Koenigia* L.	**42.**	*Systenotheca* Reveal and Hardham
21.	*Lastarriaea* Remy	**43.**	*Triplaris* Loefl. *ex* L.
22.	*Leptogonum* Benth.		

2.5. Geographical distribution

The family containing approximately 59 genera and about 1384 species (www.theplantlist.org) geographically distributed from the tropics to arctic, although most species are concentrated in the northern temperate region (Heywood 1978). Many of the members of this family are confined to Himalayan regions of which West Bengal occupies the prominent position. India is represented by 121 species and 29 varieties belonging to 12 genera of Polygonaceae (Srivastava 2014). Most of the species of *Polygonum sensu lato* were distributed primarily in the Himalayan region, with a few species in tropical regions (Fig 1).

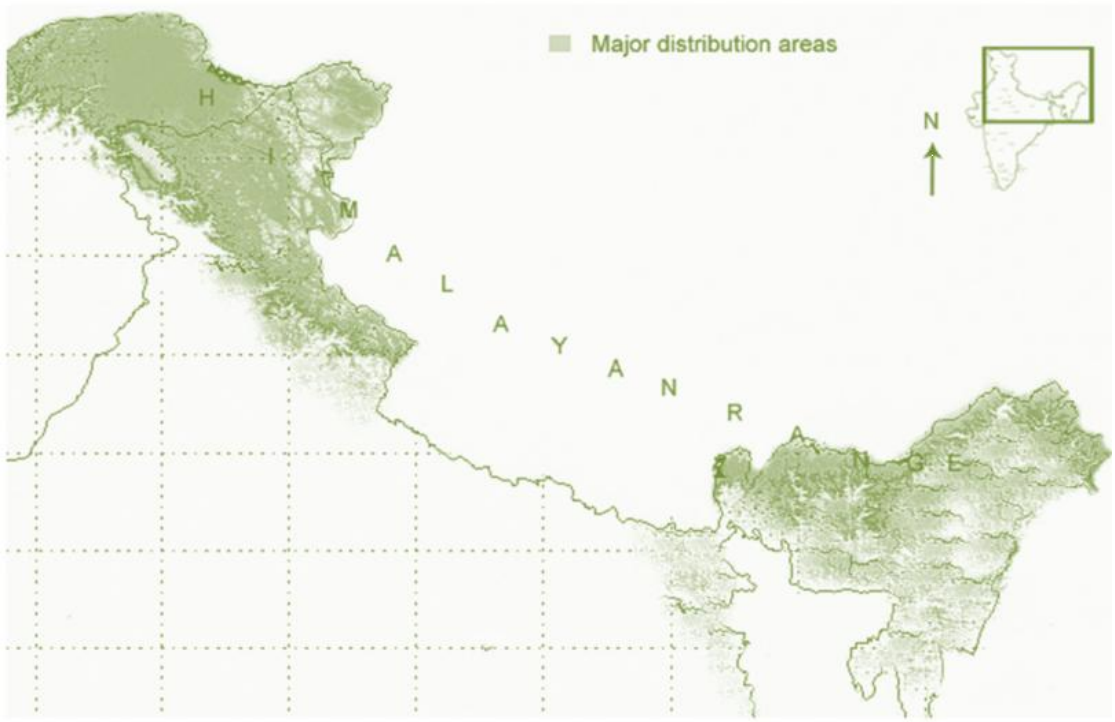

Fig. 1: Major distribution areas of *Polygonum sensu lato* in India (Choudhary *et al.* 2012)

The following table shows the distribution of some species of Polygonaceae in West Bengal, India and Worldwide.

Table 2: Distribution ranges of some species of Polygonaceae grow in Himalayas (Maiti & Sikder 1985; Rai 2007; Lepcha 2011; Srivastava 2014)

SL NO.	TAXA	DISTRIBUTION		
		West Bengal	**India**	**Global**
01.	***Aconogonon molle*** (D. Don) H.Hara	Darjeeling, Kalimpong	Sikkim (Kupup, Jelepa 3050-4200), Meghalaya	Nepal, Bhutan, Indo-China, Malaysia
02.	***Bistorta emodii*** (Meisn.) H.Hara	Darjeeling	Sikkim (Rachela peak) to Simla	W. China
03.	***Bistorta macrophylla*** (D. Don) Soják	-	Sikkim (Zuluk, Kyongnosla), Himachal Pradesh, Uttarakhand	Nepal, Bhutan, China
04.	***Bistorta vaccinifolia*** (Wall. *ex* Meisn.) Greene	-	Sikkim (Zuluk, Kupup 2800-4000), Kashmir, Manipur	Pakistan, Nepal, Bhutan, W. Tibet
05.	***Polygonum assamicum*** Meisn.	Jalpaiguri	Assam, Meghalaya, Nagaland	Myanmar, China
06.	***Polygonum humile*** Meisn.	Darjeeling, Kalimpong	Sikkim, Himachal Pradesh, Uttarakhand	Nepal
07.	***Polygonum plebeium*** R. Br.	Throughout West Bengal	Throughout tropical India,	N. Africa, Kazakhstan, Nepal, Myanmar, Thailand, Indonesia, Australia, Philippines, China, Japan, Russia

08.	***Polygonum microcephalum*** D. Don	Darjeeling, Kalimpong	Sikkim, Eastern Himalaya, N. E. India [Assam, Meghalaya (Khasi Hills)], Nagaland	Nepal, Bhutan, Bangladesh, China
09.	***Polygonum posumbu*** Buch.-Ham. *ex* D. Don	Darjeeling, Jalpaiguri	Sikkim, Assam, Meghalaya, Arunachal Pradesh, Manipur, Nagaland	Nepal, Bangladesh, China, Japan
10.	***Polygonum thunbergii*** Siebold & Zucc.	-	Sikkim (Baba mandir, Changu, Zuluk)	Pakistan, Nepal, Bhutan, Bangladesh, Indonesia, ‚Japan, Korea, China
11.	***Polygonum viscosum*** Buch.-Ham. *ex* D. Don	Jalpaiguri, Burdwan	Assam, Meghalaya, Nagaland	Nepal, Bhutan
12.	***Polygonum runcinatum*** Buch.-Ham. *ex* D. Don	Darjeeling, Kalimpong, Jalpaiguri	Sikkim, Jammu &Kashmir, Assam, Nagaland, Tamilnadu (Nilgiri Hills),	Nepal, Bhutan, Myanmar, Thailand, W. & C. China, Malaysia, Indonesia (Sumatra), Philippines
13.	***Polygonum pubescens*** Blume	Throughout West Bengal	Throughout India	N. Africa, Europe, Nepal, Bhutan Japan, N. America
14.	***Polygonum perfoliatum*** L.	Darjeeling, Coochbehar	Sikkim, Jammu & Kashmir, Arunachal Pradesh, Himachal Pradesh, Uttarakhand	New Guinea, Russia, Japan, Korea, China, Nepal, Bhutan, Bangladesh, Malaysia, Thailand, Vietnam, Indonesia, Philippines, S. W. Asia, N. America
15.	***Polygonum kawagoeanum*** Makino	Darjeeling, Jalpaiguri	Sikkim, Jammu & Kashmir (Gulmarg), N. E. India (Assam, Manipur, Meghalaya), Himachal Pradesh, Uttarakhand	Europe, Pakistan, China, Japan, Nepal, Bangladesh, Myanmar, Malaysia
16.	***Polygonum filicaule*** Wall. *ex* Meisn.	Darjeeling	Kashmir to Sikkim (Panglakha, Rachela peak, Trijunction)	Tibet and Formosa in Taiban

17.	***Polygonum delicatulum*** Meisn.	Darjeeling	Sikkim, Jammu & Kashmir, Himachal Pradesh, Uttarakhand	Pakistan, Nepal, China, Tibet, Bhutan
18.	***Polygonum hastatosagittatum*** Makino	Jalpaiguri	Meghalaya (Khasi Hills at Myrung, Shillong), Manipur (Myang Khong Valley), Himachal Pradesh (Kulu), Uttarakhand (Kumaon)	Russia, Japan, Korea, Mongolia, N. America.
19.	***Rheum acuminatum*** Hook. *f.* & Thomson	-	Sikkim (Manju lake, Serathang 3400-4100m)	China, Nepal, Myanmar
20.	***Rheum australe*** D. Don	-	Sikkim (Manju lake, Serathang 3400-4100m) Himachal Pradesh (Kinnaur , Lahul , Spiti)	Pakistan, Nepal, Bhutan, Myanmar
21.	***Rheum nobile*** Hook. *f.* & Thomson	Darjeeling	Sikkim (Top hill of baba mandir upto 5000m), Eastern Himalaya.	Afghanistan, Pakistan, Nepal, China, Myanmar
22.	***Rheum spiciforme*** Royle	-	Sikkim (Alpine hillsides, 4250m), Jammu & Kashmir, Himachal Pradesh (Lahul & Spiti), Uttarakhand	Afghanistan, Pakistan, China, Bhutan
23.	***Rheum globulosum*** Gage	-	Sikkim (Lungnak, Grassy mountain slopes, 3960-5200m.)	China
24.	***Persicaria barbata*** (L.) H. Hara	Darjeeling, Kalimpong, Jalpaiguri, Malda, Bankura, Howrah,	Throughout India	Africa, Afghanistan, China, Japan, Malaysia
25.	***Persicaria capitata*** (Buch.-Ham. *ex* D.Don) H. Gross	Darjeeling, Kalimpong, Jalpaiguri	Sikkim, Assam, Meghalaya, Arunachal Pradesh, Punjub	W. China, Tibet, Indo-China, Bhutan, North Myanmar
26.	***Persicaria chinensis*** (L.) H. Gross	Throughout West Bengal	Subtropical and temperate Himalaya	Nepal, China, Bhutan, Malaysia, Japan

27.	***Persicaria hydropiper*** (L.) Delarbre	Throughout West Bengal	N. E. India (Meghalaya), N. W. and South India	North Africa , Europe, Japan, N. America
28.	***Persicaria glabra*** (Willd.) M.Gómez	Throughout West Bengal	N. E. region (Assam) to Uttarakhand (Garhwal).	Africa, Tropical Asia, America
29.	***Persicaria limbata*** (Meisn.) H. Hara	Burdwan, Purulia	Bihar, Karnataka, Uttarakhand (Garhwal), Uttar Pradesh,	Tropical Africa
30.	***Persicaria nepalensis*** (Meisn.) Miyabe	Darjeeling, Kalimpong, Jalpaiguri	Sikkim (Alubari, Rechila middle),	Nepal, China, Bhutan, Sri Lanka, Korea, Japan, N. America
31.	***Persicaria orientalis*** (L.) Spach	Throughout West Bengal	Throughout India	Japan, Bangladesh, Australia
32.	***Persicaria polystachya*** Opiz	Darjeeling	Sikkim, Jammu & Kashmir	Afghanistan, Pakistan, Nepal, Bhutan, Myanmar
33.	***Persicaria strigosa*** (R.Br.) Nakai	Darjeeling, Kalimpong, Jalpaiguri	Tropical parts of India	Malaysia, Myanmar, Sri Lanka
34.	***Persicaria campanulata*** (Hook. *f.*) Ronse Decr.	Darjeeling	Sikkim (Rachela peak, Panglakha 2200-3100 m)	W. China, S. Tibet
35.	***Persicaria amplexicaulis*** (D. Don) Ronse Decr.	Darjeeling	Sikkim (Kupup, Tinsimana, Panglakha 2800-3050 m), Nepal, Bhutan	Afghanistan, W. and C. China,
36.	***Persicaria lanigera*** (R. Br.) Soják	Darjeeling (Siliguri), N & S Dinajpur, Malda	Assam, Himachal Pradesh (Shimla), Uttarakhand (Dehradun), Rajasthan (Mt.Abu)	Myanmar

37.	***Persicaria lapathifolia*** (L.) Delarbre	Darjeeling, Jalpaiguri	Sikkim, Jammu & Kashmir (throughout Plains of Kashmir), Assam, Himachal Pradesh, Uttarakhand	N. Africa, New guinea, Turkmenistan, Uzbekistan, Kazakhstan, Korea, Kyrgyzstan, Tajikistan, Pakistan, Nepal, Mongolia, Japan, China, Bangladesh, Myanmar, Indonesia, Philippines, Thailand, Vietnam, Australia, N. America
38.	***Persicaria dichotoma*** (Blume) Masam.	Darjeeling	Assam, Nagaland, Tamilnadu (Nilgiri Hills)	Laos, Indonesia, Thailand, Malaysia, Philippines, Vietnam, Japan (Ryukyu Islands), Australia
39.	***Persicaria decipiens*** (R. Br.) K. L. Wilson	Hooghly, Howrah, Purulia	Assam, N. India	Africa, South Europe, Australia, America
40.	***Persicaria stagnina*** **(**Buch.-Ham. *ex* Meisn.) Qaiser	North Bengal, Malda,	Throughout hotter parts of the Country.	Pakistan, Bangladesh, Myanmar
41.	***Fagopyrum acutatum*** (Lehm.) Mansf. *ex* K. Hammer	Darjeeling	Kashmir to N. E. India (old Assam), Himachal Pradesh,	N. Europe & N. Asia
42.	***Fagopyrum esculentum*** Moench	Darjeeling, Jalpaiguri	Jammu & Kashmir, Himachal Pradesh	China, Tibet
43.	***Rumex acetosella*** L.	Darjeeling, Malda, 24-Parganas	Jammu & Kashmir, Himachal Pradesh	Kazakhstan, China, Mongolia, Japan, Korea, Russia, Europe, North America.
44.	***Rumex dentatus*** L.	Malda, 24-Parganas, Burdwan, Howrah	Jammu & Kashmir to Sikkim	N. Africa, Kazakhstan, Afghanistan, Nepal, China, Russia, S. E. Europe

45.	***Rumex maritimus*** L.	Darjeeling, Jalpaiguri, 24-Parganas, Burdwan	N. E. Region	Kazakhstan, Myanmar, Russia, Mongolia, Europe, North America.
46.	***Rumex napalensis*** Meisn.	Darjeeling, Jalpaiguri	Sikkim, Himachal Pradesh	Tajikistan, Afghanistan, S.W. Asia, Pakistan, Nepal, Vietnam, Bhutan, Indonesia, Myanmar , China, Japan
47.	***Rumex nigricans*** Hook. *f.*	North Bengal	Jammu & Kashmir	Kazakhstan, Kyrgyzstan, Tajikistan, Mongolia, Russia, Europe
48.	***Rumex vesicarius*** L.	Howrah	N.E. Region, Uttar Pradesh (cultivated), Western Punjab,	Pakistan
49.	***Homalocladium platycladum*** (F. Muell.) L. H. Bailey	Howrah	Planted (in sandy alluvial soils) in Botanical Gardens almost throughout India.	Native of Solomon Islands
50.	***Antigonon leptopus*** Hook. & Arn.	Burdwan, Howrah, Hooghly, Bankura	Throughout plains	Mexico

2.6. Affinity with Plumbaginaceae

Plumbaginaceae are group of plants with diverse habitat such as shrubs, climbers or herbs (rarely), mostly living in brackish regions or cool alpine areas world-wide (Chant 1993). The family consists of 27 genera and 650 species (Kubitzki 1993). Most of the taxa have restricted distribution, mostly concentrated in subtropical and tropical Africa and Eurasia. Plumbaginaceae are usually regarded as monophyletic in origin on the basis of floral characteristics. The presence of circinotropous ovule and endotrophic transmitting tissue are quite significant and unique (De Laet *et al.* 1995).

Polygonaceae and Plumbaginaceae placed together in single order Plumbaginales close to Primulales (Bedell and Reveal 1982). This close relationship to Primulales was due to the presence of united, imbricate petals, epipetalous stamens and superior unilocular ovary with free basal placentation (Bentham and Hooker 1876; Hutchinson 1959). Nevertheless, palynological investigations showed that Primulaceae can be isolated from Polygonaceae and Plumbaginaceae (Nowicke and Skvarla 1977). According to Brummitt (1992) Polygonaceae and Plumbaginaceae were placed in Polygonales and Plumbaginales, respectively. These monotypic orders were strongly related to Caryophyllales from which they differ by the absence of Betalains (also lacking in Caryophyllaceae and Molluginaceae of Caryophyllales) and *p-type* sieve tube plastids. Rodman's (1994) macromorphological cladistic analysis revealed sister relationship between family Polygonaceae and Plumbaginaceae. Based on wood anatomical studies, both families share several characters such as vessel restriction patterns, nonbordered perforation plates, septate fibres and presence of silica bodies (Carlquist and Boggs 1996; Carlquist 2003).

Monophyly of Polygonaceae and Plumbaginaceae is strongly supported by the *rbcL* analysis. Thus, both families could be grouped in a single order, Plumbaginales (Bedell and Reveal 1982; Chase *et al.* 1993). Downie *et al.* (1997) analysed the partial chloroplast DNA ORG2280 homologue sequences and recognized sister relationship between Polygonaceae and Plumbaginaceae.

2.7. Foliar macro & micro morphology

Anatomical studies of vegetative part of angiosperm are quite important and it gives several unique characters that can helps taxonomist during the species identification and solving their taxonomic delimitations. Foliar epidermal anatomy of Polygonaceae has been investigated by many previous workers worldwide. Metcalfe and Chalk (1950) observed during leaf anatomical study that stomata are nearly always anomocytic type, rarely paracytic and dicytic type in Polygonaceae.

Inamdar (1969) investigated foliar epidermal anatomy and stomatal development in 19 species of Centrospermae and two species of Polygonales from India. He observed those elongated, isodiametric and polygonal epidermal cells, eleven types of glandular and non-glandular trichomes and various stomata types (anomocytic, paracytic, diacytic, anisocytic and many intermediate forms between diacytic and paracytic type) in different species.

Inamdar (1971) described epidermal structures and development of stomata in 15 species of Polygonaceae. He noticed the diversity of trichomes and epidermal cells filled with calcium oxalate crystals. The stomata were mostly anisocytic, anomocytic and paracytic types in Polygonaceae. Anisocytic and paracytic stomata were found to be monocyclic or amphicyclic while anomocytic stomata were incompletely monocyclic. Paired stomata were seen only in *Polygonum plebium*.

Kapoor *et al.* (1971) investigated the epidermal features and venation pattern of leaves in ten species of *Polygonum* L. which belong to five sections *viz.*, *P. recumbens* Royle *ex* Bab. (Sect. *Avicularia* Meisn.), *P. affine* D. Don, *P. amplexicaule* D. Don, *P.vaccinifolium* Wall. *ex* Meisn. (Sect. *Bistorta* Tourn.); *P. glabrum* Willd., *P. lapathifolium* L., *P. serrulatum* Lagase. (Sect. *Persicaria* Meissn); *P. chinense* L., *P. nepalense* Meisn. (Sect. *Cephalophilon*) and *P. rumicifolium* Royle *ex* Bab. (Sect. *Aconogonon* Meisn.).

Mitchell (1971) described systematic studies on leaf morphology and anatomy of native, aquatic *Polygonum* species including members of section *Persicaria,* two species of *Bistorta* and one member of section *Echinocaulon*. Analyzing 40 major and minor leaf characters he was able to distinguish different sections of American species of *Polygonum*. Valvate chambers were shown to be constant characteristic of

the *P. punctatum* Ell. whereas unicellular idioblasts were present in the upper epidermal surface of all *Persicaria* species. The plate-like multicellular glands were present frequently in *P. opelousanum* Ridd. but occasionally in *P. hydropiperoides* Michx. He separated the section *Bistorta* from *Persicaria* based on reticulate leaf venation and unicellular glandular trichomes.

Lersten and Curtis (1992) examined the foliar anatomy of 153 species of *Polygonum* L. (Polygonaceae) and described several anatomical features, their variation in the leaves. Their comprehensive study included a good number of characters of glandular and eglandular trichomes, specialized parenchyma, nodules, stomatal apparatus, internal cavities, crystals, laticiferous cells, nodules and sub epidermal fibres. According to them none of the anatomical characteristics appear to be identifying characters, either by their presence or absence in any taxonomic section of *Polygonum* L. They found some characters like laticiferous cells, epidermal and internal nodules, resin cups, enlarged crystal cells, epidermal and sub epidermal cavities which are limited in distribution and may have taxonomic importance. This investigation has uncovered the wealth of anatomical characters.

Ayodele and Olowokudejo (2006) investigated foliar epidermal anatomy of family Polygonaceae in West Africa. They observed epidermal cell shape, anticlinal wall pattern, stomata and trichome type. The leaf epidermal cells were generally isodiametric, polygonal to irregular in outline. Mostly irregular shaped cells were found on abaxial surface while they occur on the adaxial surfaces in a few species. Sometimes irregular cells were intermixed with polygonal cells. The polygonal epidermal cells usually had straight to curved anticlinal walls while irregular cells had undulate anticlinal walls. Striated epidermal cells were noted only in few species, such as. *Polygonum plebeium* R. Br., *Oxygonum sinuatum* (Meisn.) Dammer., *Persicaria nepalensis* (Meisn.) Gross. and *Harpagocarpus snowdenii* Hutch. and Dandy. Six different types of stomata (paracytic, anisocytic, cyclocytic, diacytic, anomocytic and parallelocytic) were observed by him. Most common type of stomata was paracytic. More than one type of stomata was also seen on same leaf surface. Non glandular trichomes (unicellular or multicellular) were significant in the identification of *Persicaria* Mill. species except in *P. senegalensis* (Meisn.) Sojak *forma albotomentosa,* where uniseriate flagelliform eglandular trichomes were observed and an easy identification keys were prepared on the basis of foliar

epidermal characters. They suggested that these anatomical characters have taxonomical implications and can be used for the species identification when applied in combination with morphological characters.

Mosaferi and Keshavarzi (2011) examined macro and micro morphological features of tepal epidermis, dorsal leaf epidermis, achene surface and pollen grains of some taxa of Polygonaceae from Iran. They observed that tepal epidermis consists of rectangular to elongated cell with different outline. In most of taxa leaf epidermis irregular and short cells with undulating cell wall. They observed three different type of achenes or nut. In the genus *Persicaria*, nuts were biconvex, biconcave and trigonous, while in *Polygonum spp.* it was triangular in shape and in *Rumex spp.* the nuts were conspicuous with reticulate surface.

2.8. Pollen morphology

Palynology is concern with the study of pollen grains and spore both living and fossils. The term *Palynology* was proposed by Hyde and Williams (1944). They used the term palynology to refer to the study of external morphological features of mature pollen grains. The term palynology has been derived from the word *palymein*, meaning 'to scatter' as pollens are often spread by wind, and *logos* meaning study. Palynological informations are useful for systematic studies and in making taxonomic suggestions (Huang 1972; Tomsovic 1997).

The family Polygonaceae is a distinctly eurypalynous family with a wide range of pollen morphological characters. The shape of the grains varies from sub-oblate to prolate. Most of the pollens are zonoaperturate some are panto-aperturate. The numbers of colpi are generally 3, but 2-colpate and 4-colpate pollen grains are also found. The colpi are mostly long, narrow slit-like and short in panto- colpate type. The ora vary from lalongate to lolongate. The exine patterns in the Polygonaceae are varied from psilate to reticulate (Mondal 1997).

Wodehouse (1931) carried out extensive work on pollen morphology of Polygonaceae identified different types of pollen grains .On the basis of those palynological characters, identification keys were prepared and proved through illustrations that how tricolporate pollen with thick walls and broad furrow might

have given rise to many pored pollen grain with thin walls and narrow or reduced furrow. He regarded Polygonaceae as transitional family.

Hedgeberg (1946) studied pollen morphology of *Polygonum* L. *sensu lato*, under light microscope reported ten different types of pollen (*Aconogonon, Avicularia, Bistorta, Cephalophilon*, *Duravia*, *Fagopyrum*, *Koenigia*, *Persicaria*, *Tiniaria* and *Tovara*) and classified the genus into seven genera on the basis of pollen morphology.

Hong and Hedgeberg (1990) observed the evolution of number and arrangement of apertures of pollen grains between *Koenigia*, *Persicaria* and *Aconogonon* by using LM (light microscope) and SEM (scanning electron microscope).

Perveen (1993) studied pollen morphological characters of 5 species belonging to 4 genera of Polygonaceae from Pakistan by LM and SEM. She observed considerable variation in apertures, pollen size and exine ornamentation and regarded the family as a eurypalynous family as suggested earlier by previous workers (Wodehouse, 1931; Hedgeberg, 1946, Nowicke and Skvarla, 1979).

Among the different genus under the family Polygonaceae the genus *Polygonum* was widely studied by different workers in different period of time from China. Wang and Feng (1994) observed different shapes and variable number of apertures, exine ornamentation on studying pollen structure of 44 species and two varieties of the genus *Polygonum* and divided the ten pollen types in to ten groups viz. *Aconogonon* type, *Amphibium* type *Avicularia* type, *Bistorta* type, *Cephalophilon* type, *Convolvulus* type, *Fagopyrum* type, *Persicaria* type, *Sibiricum* type and *Tiniaria* type. Zhang and Zhou (1998) while worked on pollen types in Polygonaceae on the basis of distribution centre, pattern and the means of pollen dispersal recognized five genera in Polygoneae and twelve sections in *Polygonum* and suggested the division of genus *Rumex* into two sections namely *Acetosa* and *Aquaticus*. In the following year, Zhou *et al.* 1999 reported the study of pollen morphology of 111 species under the family Polygonaceae, describing 28 pollen types and arranged them in six parallel evolutionary lines. They considered 3-zonocolpate *Aconogonon* type as a basic type from which other types of the pollen have originated along parallel direction. Zhou *et al.* (2000) reported great variability in exine sculpturing viz. smooth, granulate, perforate, translucently or densely

reticulate when pollen ultrastucture of 15 species belonging to 6 genera of Polygonaceae were studied under scanning electron microscope and transmission electron microscope. TEM observations showed stratification of exine (tectum, columella, foot layer and endexine) which is the characteristic feature of dicots.The ornamentation and sculpturing pattern of exine under scanning electron grouped pollen grains into five types Viz. *Aconogonon, Campanulatum, Forrestii, Polystachyum and Sibricum*.

Hong *et al.* (2005) investigated the pollen morphology of 27 species, one subspecies and two varieties in two genera (*Polygonum and Polygonella*) from the herbarium specimen of LV, NY, S and UPS herbaria by light microscope (LM) and scanning electron microscope (SEM) while some species were also examined with transmission electron microscope (TEM). In equatorial view pollen are prolate to subprolate while in polar view circular, With regard to apertures, typically the pollen is tricolporate, occasionally pantocolporate or hexocolporate. Three types of pollen are recognized on the basis of wall ornamentation *viz., Avicularia*- Type, with smooth exine and spinules, *Pseudomollia*-Type, with verrucose exine and *Duravia*-type, with semitectate or rugulate/reticulate exine. Pollen grains of *Polygonum molliaeforme* Boiss. are found to be intermediate between the *Avicularia*-type and the *Duravia*-type. Few species were also examined with TEM, some pollen wall structures like ektexine, endexine and columella appeared as variable characters and can be used for generic differentiation.

Yasmin *et al.* (2010) examined pollen morphology of 12 species of *Polygonum* L., (Polygonaceae) from Pakistan by both light and scanning electron microscopy and they observed four different types of exine ornamentation under scanning electron microscope. Based on this exine ultrastructure they distinguish four pollen types (*Patulum* type, *Plebijum* type, *Cognatum* type and *Avicularia* type).They also concluded that *Polygonum* L., is a eurypalynous genus. Pollen morphology proved to be constructive for the specific delimitation within the genus.

Soleimani *et al.* (2014) studied anatomical and palynological characters of Rumex species from N.E. Iran. In palynological study, the pollen were extracted from anther, acetolysed and observed by SEM. The palynological findings showed,

pantoporate, tricolporate, tetracolporate, granulate, microechinate and punctate type of pollen grains in studied species.

Yasmin *et al.* (2015) to understand systematic characters of *Aconogonon* from Pakistan studied pollen morphology in three (*A. alpinum*, *A. rumicifolium* and *A. tortuosum*) species using light microscopy and scanning electron microscopy. They observed that *Aconogonon* is characterized by tricolpate pollen with microspinulose type of exine ornamentation. On the basis of aperture number and exine ornamentation under SEM only one unique pollen grain type was documented. In this study diagnostic identification keys for the three taxa were also provided on the basis of the analyses.

2.9. Molecular phylogeny

In recent years, the understanding of phylogenetic relationship among angiosperms has significantly increased, particularly as a result of analysis of molecular data accumulated through different conventional techniques.

Chase *et al.* (1993) investigated the phylogenetics of seed plants by analyzing nucleotide sequences from plastid genes *rbcL* and proposed that the family Polygonaceae is monophyletic in origin.

Lamb Frye and Kron (2003) established phylogenetic relationship within Polygonaceae, particularly in *Polygonum* L., *Emex* Necker *ex* Campdera., *Persicaria* Mill. and *Polygonella* Michaux., by using chloroplast gene *rbcL*. They suggested that presently accepted two subfamilies *i.e.*, Polygonoideae and Eriogonoideae are not monophyletic.

Kim and Donoghue (2008) examined relationships within the Polygonaceae using rbcL sequences, with an emphasis on *Polygonum* and its segregates. Specifically, they focus on inferring the relationships of *Eupersicaria* (*Polygonum* sect. *Persicaria* in many prior treatments), by means of the chloroplast genes *rbcL*, *trnL-F*, *trnK intron-matK* and *psbA-trnH IGS*, and nuclear ribosomal ITS sequences. According to them, *Eupersicaria* is monophyletic and most closely related to *Tovara* and *Echinocaulon*. The clade is most closely related to *Cephalophilon*. The sister group of this entire *Persicaria* clade contains *Bistorta* and a clade together with *Aconogonon* and *Koenigia*, which supports the monophyletic origin of the Persicarieae. Within *Eupersicaria* there appears to be a deep split between *P.*

amphibia and the left over species, and there is strong divergence regarding the position of *P. punctata*. These results set the stage for a more detailed phylogenetic analysis of *Eupersicaria.*

Sanchez and Kron (2008) made comprehensive studies on phylogenetics of Polygonaceae with particular interest on Eriogonoideae. Three Choloroplast region (*rbcL, matK,* and *ndhF*) analyses showed that subfamily Polygonoideae is polyphyletic while Eriogonoideae is monophyletic. They observed that the subfamilies *i.e.*, Polygonoideae consisting of 11 genera (*Polygonum* L, *Atraphaxis* L., *Emex* Campd., *Fagopyrum* Mill., *Fallopia* Adans., *Koenigia* L., *Muehlenbeckia* Meisn., *Oxyria* Hill., *Persicaria* (L.) Mill., *Rheum* L., and *Rumex* L.) in 3 tribes (Persicarieae, Polygoneae and Rumiceae) and Eriogonoideae contains *Antigonon* Endl., *Brunnichia* Banks. *ex* Gaertn.,*Coccoloba* L., *Ruprechtia* C. A. Mey. and *Triplaris* Loefl. *ex* L. They suggested that many changes in classification of *Polygonum* L. are necessary.

Sanchez *et al.* (2009) investigated 75 taxa of Polygonaceae to identify clades within different and to provide a global approximation of phylogenetic relationships in this extremely diverse and cosmopolitan group. They use three chloroplast genome regions (*rbcL, matK,* and *ndhF*) and the ribosomal internal transcribed spacer to recognize the phylogenetic relationships within Polygonaceae. They observed *Symmeria* is the sister group. *Afrobrunnichia* branches next but has only moderate support. They suggested that the family Polygonaceae was consisted two large clade (Fig. 2).

Schuster *et al.* (2011) examined the molecular data from five chloroplast regions (*matK, ndhF, 39rps16-59trnK, trnL-trnF, 39trnV-ndhC*) and two nuclear gene regions (second intron of LEAFY, internal transcribed spacer) of 22 species of *Muehlenbeckia* and representatives of *Atraphaxis, Fallopia* (including *Reynoutria*), *Polygonella* and *Polygonum*. They suggested neither *Fallopia n*or *Muehlenbeckia* is monophyletic, with most species of *Muehlenbeckia* related to Fallopia. As a result of this study four clades are named: *Duma, Fallopia, Muehlenbeckia,* and *Reynoutria*.

Choudhury *et al.* (2012) were examined the nuclear ribosomal DNA internal transcribed spacer (ITS) sequences from 44 Indian *Polygonum* taxa to investigate relationships among various sections. The relationships among different sections were largely congruent with those inferred from morphological characters as

described by Hooker (1886). Also, the treatment of the *Persicaria* recommended by Haraldson (1978) on the basis of anatomical characters proved to be virtually in line with that based on their molecular data. They provide a high resolution of phylogeny of the Himalayan *Polygonum sensu lato* and sustained the grouping of the section *Amblygonon* in the section *Persicaria*. Moreover, they made the first phylogenetic analysis of many of the less known Himalayan *Polygonum*, including *Polygonum microcephalum*, *P. assamicum*, *P. recumbens*, and *P. effusum.*

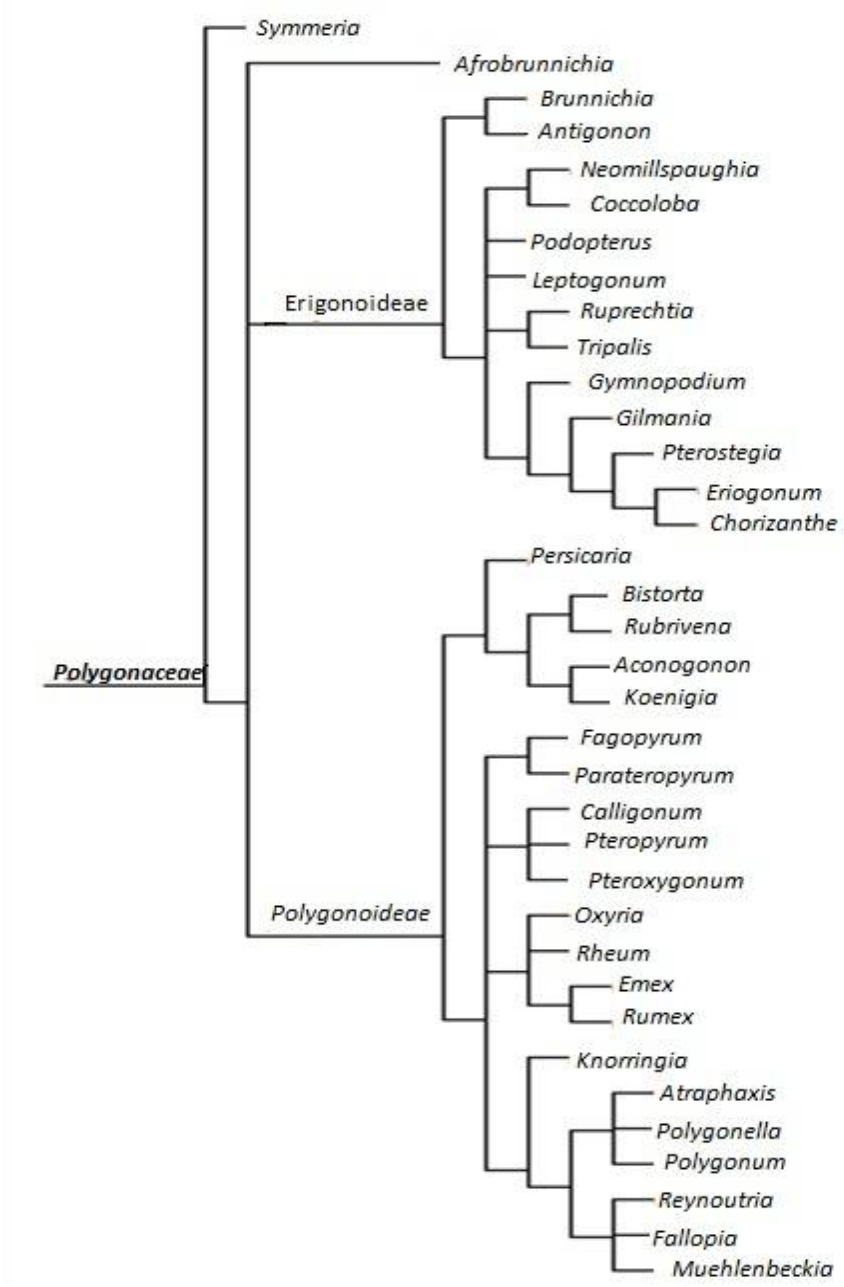

Fig. 2: Phylogenetic tree of family Polygonaceae (Sanchez *et al.* 2009)

Fan *et al.* (2013) examined the sequences of nuclear ITS and four plastid regions (*trnL-F*, *atpB-rbcL*, *rbcL*, and *rpl32-trnL* (UAG)) for the study of phylogenetic relationships among 43 species of *Koenigia* and closely related taxa (e.g., *Aconogonon*, *Bistorta*, and *Persicaria*). Phylogenetic analyses showed that *Koenigia* is paraphyletic in origin and that the basal species *K. delicatula* should be treated as a new and separate genus.

Schuster *et al.* (2015) examined the relationships of *Aconogonon*, *Emex*, *Fallopia*, *Koenigia*, *Oxygonum*, *Polygonum* and *Rumex*. In this study the evolutionary history of Polygonoideae was observed by building on an existing molecular dataset (*nrITS*, *matK*, *trnL-trnF*) analysed with maximum likelihood and Bayesian methods. In this study, they observed that that the African *Oxygonum* is an isolated lineage likely sister to all other members of Polygonoideae, the two species of *Emex* are nested in the *Rumex* clade, *Fallopia* and *Koenigia* are polyphyletic with *Aconogonon* and *Koenigia* forming a clade, and *Fallopia denticulata* and *F. cilinodis* are separate from the Fallopia s.str. clade.

From the above mentioned various data sources like macro, micro, pollen and molecular aspects, may generates a huge number of characters of different species of Polygonaceae. All those characters, after analyzing gives a clear idea about the inter-relationship among the members of the family including their degree of closeness through phonetically as well as phylogenetically. These huge data also help us to proper identification of plants at their species or below ranks and also clarifying the confusion among the phenotypic or ecotypically variable individuals.

3. STUDY AREA

India holds 7th position in terms of area distribution among 195 countries presently existed in world geography, covering an area of 3,287,263 km^2. The political geography divides the vast area of India into 28 states and 9 union territories with Delhi as National Capital. Due to wide diversity in land forms, India is divided into seven geographical regions, namely-the northern mountains including the Himalayas and the northeast mountain ranges, Indo-Gangetic plains, Thar Desert, Central Highlands and Deccan Plateau, East Coast, West Coast and Bordering Sea and islands. Among the standing 28 states of India, the 13th largest state located in the eastern part and considered as the land of Royal Bengal Tiger is the West Bengal.

West Bengal comprises peaks of Himalayas and Teesta and Terai alluvial areas in north; Ganges delta in the south; red, lateritic and Gangetic areas in the west; and alluvial areas in the middle. These diverse geographical areas of West Bengal are divided into 23 districts, out of that 8 districts namely Darjeeling, Jalpaiguri, Cooch Behar, Malda, Uttar Dinajpur, Dakshin Dinajpur, Alipurduar and Kalimpong located at the north of river Ganga and remaining 15 districts namely Bankura, Paschim Bardhaman, Purba Bardhaman, Birbhum, Purulia, Murshidabad, Nadia, West Midnapore, Jhargram, East Midnapore, Hooghly, Howrah, Kolkata, North 24 Parganas and South 24 Parganas on the south of river Ganga. The Teesta, Torsa, Jaldhaka, and Mahananda etc. are the major rivers flowing through the northern hills and plains of West Bengal. While toward the south river Ganga and its tributaries flows to reach Bay of Bengal by entering Bengal from Bihar in the west.

3.1. Location and Boundaries

West Bengal is located on eastern part of India at 21°45' – 27°16' N latitude and 85°55' – 89°56' E longitude, covering of an area of 88,752 km^2. West Bengal remains surrounded by international boundaries with three countries, Bangladesh in the east, Bhutan in the north east and Nepal to the North West. Beside this West Bengal form state boundaries with five neighbouring Indian states, Sikkim to the north, Jharkhand and Bihar to the west, Assam to the north east and Orissa to the south west (Fig. 3). The Siliguri corridor of West Bengal forms the bottle neck connecting seven sister and one brother states of north east India namely Arunachal

Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim respectively.

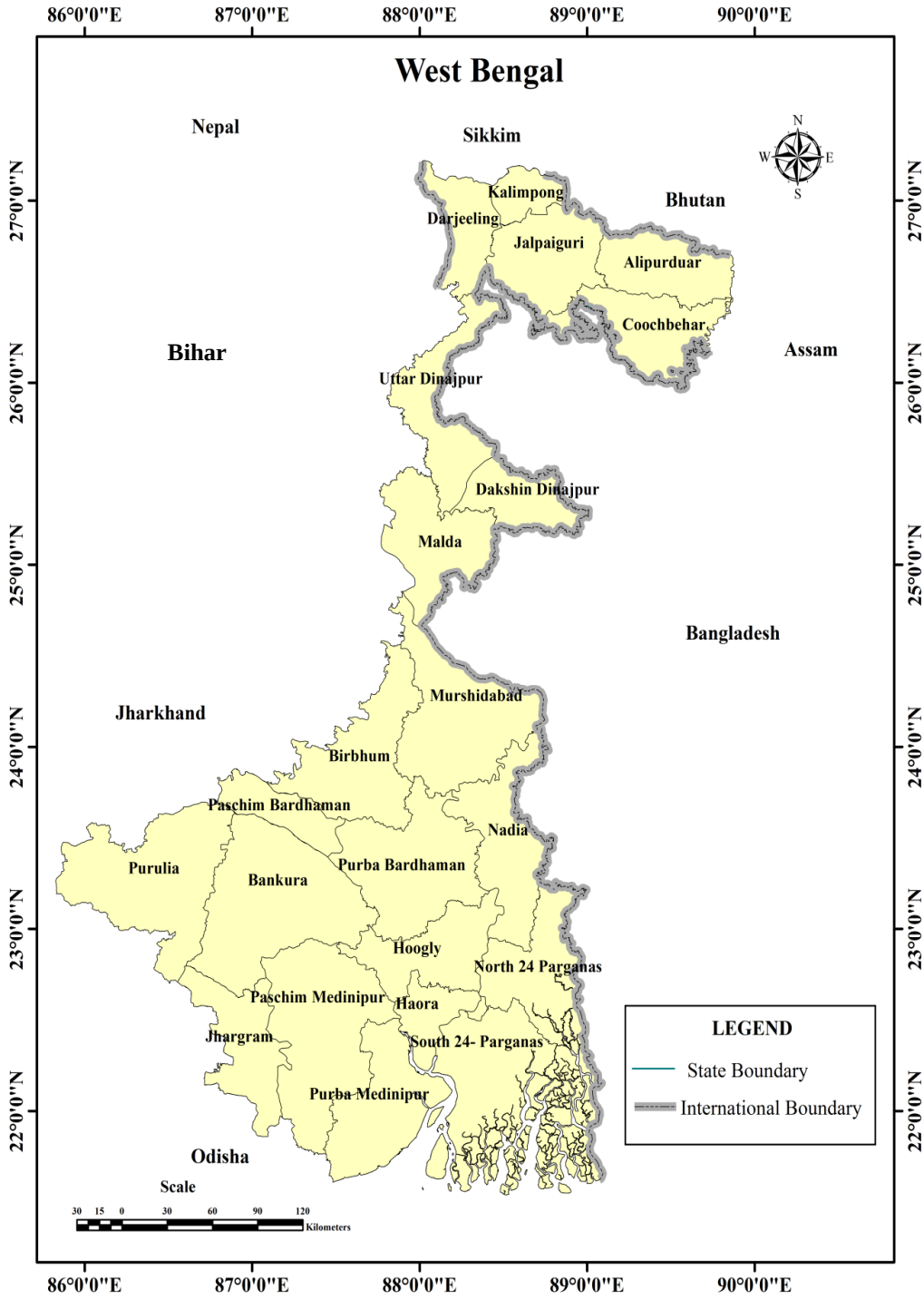

Fig. 3: International and state boundaries making the territory of West Bengal, India

3.2. Topography of West Bengal

On the basis of altitude, soil pattern, river distribution and vegetation the state of West Bengal is divided into five topographic zones namely Darjeeling and Kalimpong Himalaya, Terai and Dooars region, North Bengal and South Bengal Plains, Western undulating highlands and plateaus and Gangetic delta.

Darjeeling and Kalimpong Himalaya resides towards the north-western site. This area is composed of entire Darjeeling and Kalimpong district except Siliguri sub-division. Tiger Hill and Senchal is the notable peak in this region. While Sandakfu, Phalut, Sabargram and Tonglu are the important peaks of Singalila range located in the border of India and Nepal. Sandakfu is located at 3636 m and is considered as highest peak point of West Bengal. Rivers like Mechi, Balason, Rammam, Rangeet, Teesta, and Jaldhaka flows through this region of the state.

At the base of the Himalayan range lays the Terai and Dooars region commonly known as land of savannas. The Terai region contains rich deposition of rock, gravel, and soil that eroded from the Himalayas. This region comprises the district of Alipurduar, Jalpaiguri and plains of Darjeeling district. The marshy wetlands of these regions favour the growth of large savanna grasses, evergreen and deciduous forests. Himalayan rivers like the Teesta, Torsa, Raidak, Jaldhaka, Sankosh flows through this region.

The North Bengal plains composed of parts of the district Jalpaiguri, North Dinajpur, South Dinajpur, Malda, Alipurduar and southern part of Cooch Behar districts. This region limits between south of Terai region to the left bank of the river Ganga. The sediment deposition of the rivers Kalindi, Mahananda, Teesta, Torsa, Raidak, Jaldhaka, Sankosh, Balason, Punarbhaba, Atrai makes this part highly fertile for agricultural practices. Rice, jute and mango cultivation are the major agricultural trade for the peoples of this part of West Bengal.

Western Undulating Highlands and Plateaus cover the western part of Purulia, Bankura, Bardhaman, Birbhum and Paschim Medinipur district. This region is composed of igneous rocks of the Archaean era, coal-bearing mudstone and quartzite rocks of Carboniferous period. The slope of this area is from the west to the east and bears altitudinal ranges from 500 to 100 m. Ajodhya Hills, Panchet,

Baghmundi, Biharinath and Susunia are the major hill slopes in this area, with Ajodhya Hills being the height peak point in this region.

Entire Nadia, Kolkata, North 24 Parganas, and South 24 Parganas districts and the Eastern half of Murshidabad district constitutes the Gangetic delta. Geographically this area is divided in to three parts namely old, mature and active delta on the basis of distribution of river Ganga. Silted rivers, swamps, beels and oxbow lakes of Murshidabad and Nadia and Purulia district forms the old delta. Kolkata and North 24 Parganas lies within mature delta, while South 24 Parganas forms the active Gangetic delta. This delta formation process is still an ongoing process.

3.3. Drainage System

The drainage system of West Bengal is the recipient of three major rivers basins *i.e.*, the Ganga, the Brahmaputra and the Subarnarekha covering 81%, 12% and 4 % of the total area respectively, while remaining 3% was constituted by two small costal basins (Bandyopadhyay *et al*. 2014). The discharges of these river increases during rainy season and culminates into flood. Depending on the origin and the area of flow the rivers of West Bengal was divided into six major categories viz. Himalaya and northern fan rivers, western plateau rivers, western fan rivers, upper Ganga delta rivers, lower Ganga delta rivers and Medinipur coastal rivers (Bandyopadhyay *et al*. 2014). Distribution of major river system of West Bengal was represented in Fig. 4.

The rivers which originate from the Himalaya and draining the northern part of West Bengal are mostly shallow and braided. The Tista, Jaldhaka and Torsa forms the major drainage system of this region draining small and mid-sized hinterland basins of 4–500 km^2 and are extremely responsible for causing storm rainfall in this region. The annual average discharge of the Jaldhaka, Torsa and Tista was reported to be 230, 225 and 608m^3/sec respectively (Starkel *et al*. 2008; ORNL-DAAC 2010). The discharge of the Tista was carry into the Ganga by three Misfit River namely Tangan, Punarbhaba and Atrai (Fergusson 1863).

Western plateau rivers system is distributed in the Chhotanagpur plateau region of Purulia district and in some parts of Bankura districts. The drainage system of this area was formed by tributaries of the Subarnarekha, Kangsabati-Haldi and Dwarakeshwar. Western Fan Rivers system was formed by eight major streams

drain, among which four rivers spread out from the Chhotanagpur plateau and are now largely regulated by controlled release from reservoirs. Mayurakshi-Dwarka, Ajoy, Rupnarayan and Kangsabati-Haldi are the major rivers that drain into the Bhagirathi-Hugli (Rao 1979) contributing annual discharge of 558 m^3/sec.

The river Ganga with an average annual discharge of 11,811 cumecs at Farakka (MoWR-GoI 2014) forms the principal contributor toward the formation of upper Ganga delta rivers bed. Farakka barrage project leads to the distribution of Ganga water to the Bhagirathi-Hugli. The two rivers that fall into the Bhagirathi-Hugli from its east are the Bhairab-Jalangi and the Mathabhanga-Churni. Besides Bhagirathi-Hugli, the Ichhamati that branches off from the Churni flows through India- Bangladesh border and reaches up to the sea. The portion of the Ganga delta that finally flows to Bay of Bengal forms the lower Ganga delta river system. Besides Hugli this drainage system includes the Ichhamati and the Kulti Ganga which drain through the middle part of the upper Ganga delta including Kolkata (Fig. 4).

Four main inlets drainage system forms the Medinipur coastal rivers. The Pichhabani and the Rasulpur are the major contributing rivers of this region. These rivers mostly carry regional drainage of 2,432 km^2 between the Kangsabati-Haldi and the Subarnarekha.

Besides wide distributed rivers and their associated tributaries, wetlands also contribute to the drainage system of West Bengal. Lower Gangetic Plains of West Bengal bears special significance due to the presence of large numbers of large to small wetlands where inland fisheries contributes a major part in state economy. Ministry of Water Resources, River Development and Ganga Rejuventation demarked six important wetlands in the state of West Bengal *viz*. East Kolkata Wetland, Sunderbans, Ahiron Beel, Rasik Beel, Santragachi, Patlakhawa- Rasomati. Out of these major wetlands, East Kolkata Wetland obtained the status of Ramsar site way back on 19th August, 2002 covering an area of 125 km^2. While on 30th January, 2019 Sunderbans Wetland become the 27th Ramsar site of India spending over an area of 4230 km^2. Along with wetlands, lakes like Rabindra Sarobar, Mirik Lake, Sumendu Lake, Sagar Dighi, Senchal Lake, Subhash Sarovar, Lal Bandh forms the major inland water reservoir of West Bengal.

3.4. Soil

On the basis of geographical location and soil texture the soil of West Bengal was divided into seven categories: Brown Red Yellow soil, Laterite soil, Old Alluvium soil, Red Yellow soil, Saline and Deltaic soil, Teri soil and Young Alluvium soil (Fig. 5). Brown Red Yellow soil occur in Darjeeling, Kalimpong and some areas of Jalpaiguri and Alipurduar district; Terai soil remains confined in Jalpaiguri and Alipurduarn district; The soils are brought down by hill rivers like Tista, Torsa, Mahananda, Jaldhaka, etc. and their tributaries, bringing materials from a height of about 3048 m, and have deposited those layer by layer to form the soil of this area. The depth of the soil vary from 0 – 400 cm in different regions, with texture varying from fine sandy, rocky with moderate organic matter and low Phosphate, Potassium, and other micronutrient contents (State Forest Report 2006 – 2007). The pH of the soil of this region is acidic mainly due to heavy rainfall. The pH ranges between 5.6 to 6.5 in some parts and major portion showing highly acidic soil with pH below 5.5.Young Alluvium soil is largely distributed from North to South covering the areas of Jalpaiguri, Coochbehar, Uttar Dinajpur, Dakshin Dinajpur, Malda, Mushidabad, Nadia, North 24 Parganas, Purba Bardhman, Hoogly, Howrah and Purba Midnipur; Old Alluvial soil was reported in some areas of Uttar Dinajpur, Dakshin Dinajpur and in Malda district in northern part, while in southern part this soil type was observed in some areas of Purba Bardhaman, Bankura, Paschim Midnipur, Purba Midnipur and Jhargram district; Laterite soil was abundantly reported from Birbhum, Paschim Bardgman, Bankura, Paschim Midnipur and Jhargram district; Red Yellow soil remains confined in Purulia district while Saline and Deltaic soil remains restricted to the areas of South 24 Parganas, Purba Midnipur and Howrah.

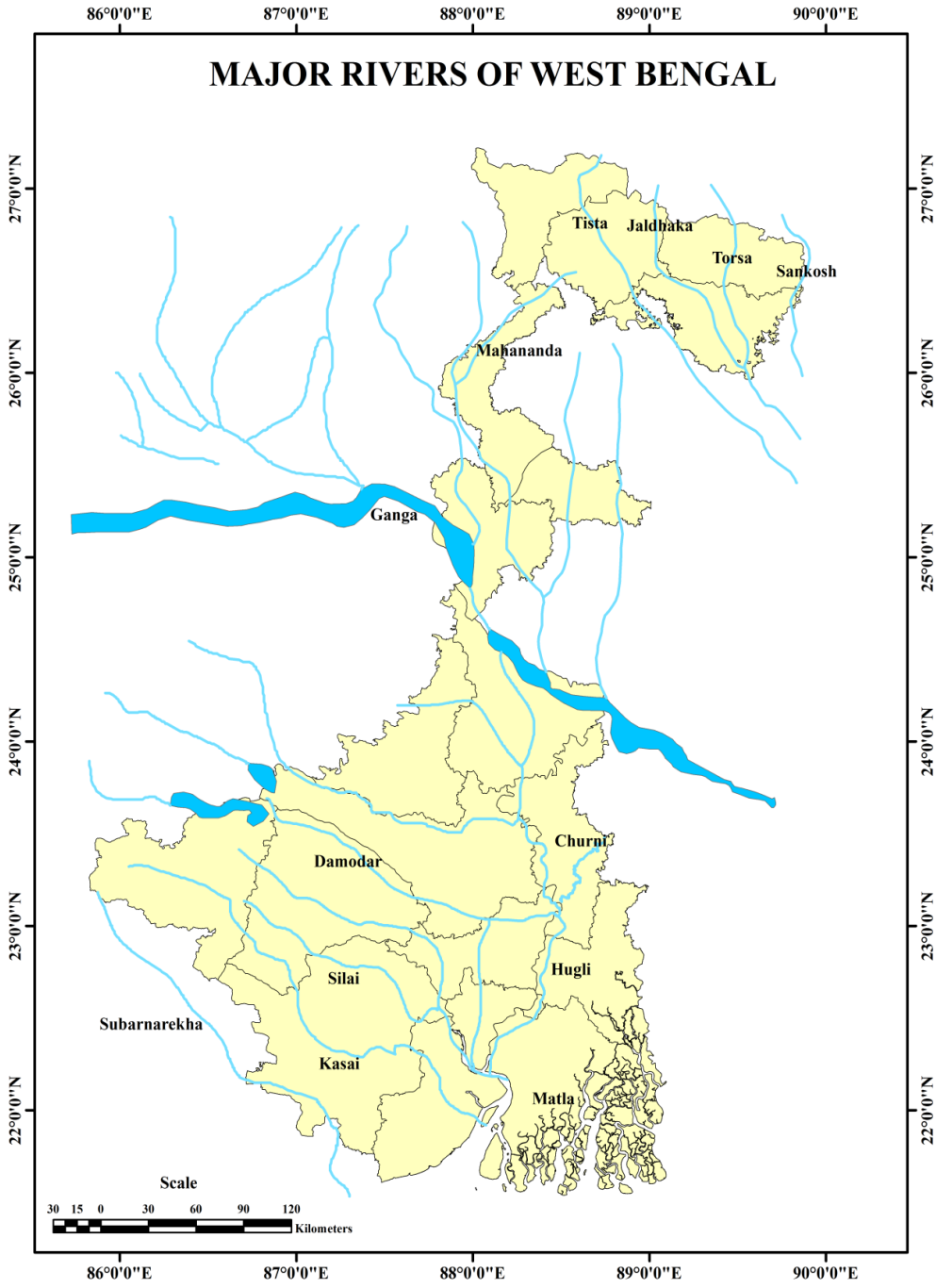

Fig. 4: Major rivers forming the drainage system of West Bengal, India

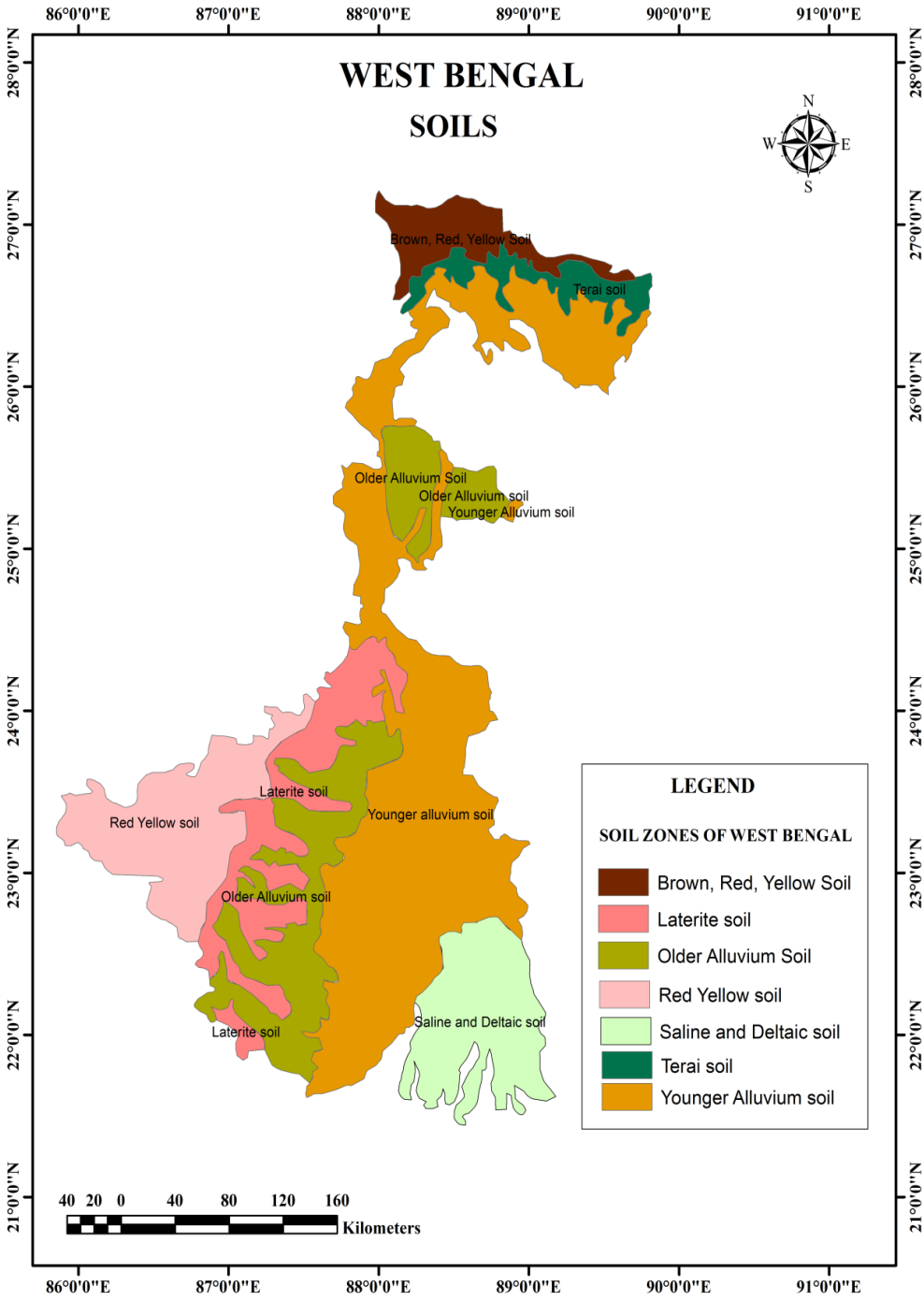

Fig. 5: Soil types covering the state of West Bengal, India

3.5. Precipitation

On the basis of precipitation West Bengal has been divided into two sub-divisions and Gangetic West Bengal. The Sub-Himalayan West Bengal, located in the foot-hills of Himalayas covering the Darjeeling, Jalpaiguri, Coochbehar, Uttar Dinajpur , Dakshin Dinajpur and Malda districts, while Gangetic West Bengal includes districts of Murshidabad, Birbhum, Bardhman, Nadia, Manbhum Purulia, Bankura, Hoogly, Howrah, Purba Midnipur , Paschim Midnipur, North 24 Parganas, South 24 Parganas and Kolkata.

In Sub-Himalayan West Bengal average annual rainfall varies between 2000–4000 mm, of which maximum precipitation was received by Jalpaiguri district (~3871 mm) while Malda district represents minimum rainfall of ~1471 mm. The hilly regions of Darjeeling and Kalimpong district on an average receive 126 days of rainfall in a year with average annual rainfall of ~3092 mm. In Gangetic West Bengal the costal part receives annual rainfall of ~2000 mm, while the central part and the western plateau receive comparatively lesser precipitation of 1500–2000 mm and 1000–1250 mm respectively (Fig. 6). District wise reports suggest that South Pargana district receives highest average annual and seasonal maximum rainfall of 1765 mm and 1328 mm respectively and minimum by Nadia district of 1309 mm and 956 mm respectively (Nandargi and Barman 2018). In Bankura and Purulia district drought condition prevails.

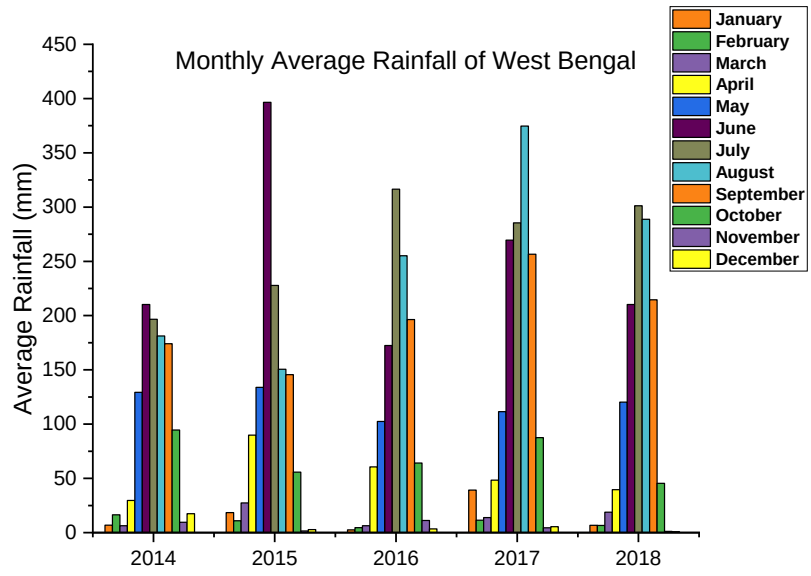

Fig. 6: Average monthly rainfall of West Bengal for the period of 2014 to 2018

Appearance of pre-monsoon thunderstorm activity locally known as ‘Kal Baisakhi’ (northwesters) during March to May plays significant contribution towards the annual average rainfall. July is the height rainfall recorded month throughout the West Bengal which decreases gradually and from October precipitation recorded was negligible.

3.6. Seasons

Within West Bengal five prominent seasonal variations are observed viz. spring, summer, monsoon, autumn and winter. Spring season was prominent in northern part of Bengal in the month of February. Summer starts from first week of March and prevails during June after which monsoon starts and lasts till end of September. Like spring, autumn was also short existing in Bengal, starting in October and prevails till November mid. winter starts from November mid and lasts till February with December last to January mid remains the coldest days of a year.

3.7. Temperature and Humidity

The tropic of Cancer passes 6 km north of Nabadwip, so the northern part of Bengal resides in temperate belt while southern part falls under tropical belt. Variation in temperature and humidity in different seasons of West Bengal leads to the flourish of different vegetation in different region of the state under seasonal fluctuation. During summer the temperature of West Bengal ranges from 28˚C to 45˚C, with average temperature of 30˚C (Fig. 7a; 7b). The delta regions of West Bengal face high humidity during summer time. During rainy season the south-west monsoon carries moisture from Bay of Bengal and distributes it over Bengal. The pleasant southerly cold wind that blows from Bay of Bengal in southern part during night gives relaxation during summer. During winter cold dry wind blows from northern part, decreasing the temperature to average range of 9˚C to 16˚C. The cold wind that blows in this region from November to February substantially decreases the humidity during winter, resulting in dry season (Fig. 8). In the northern hills of Darjeeling and Kalimpong districts seasonal temperature fluctuates from 6˚C to 18˚C with average temperature maxima and minima of 14˚C and 8.9˚C respectively. The humidity of this region is around 65% with wind velocity of 5.5 Km/h.

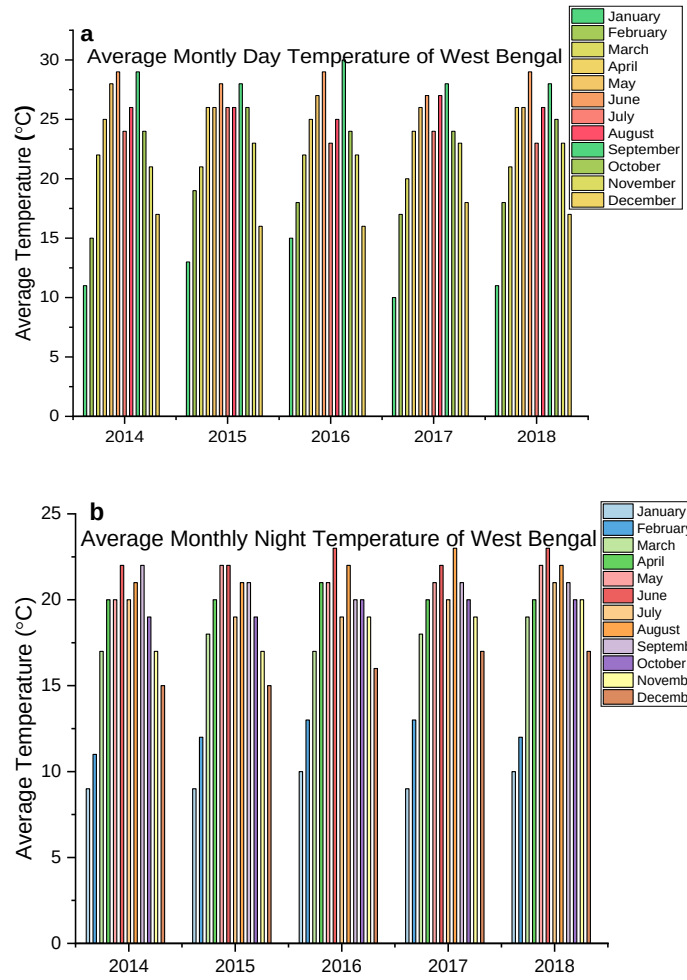

Fig.7: Average monthly day (a) and night (b) temperature of West Bengal for the period of 2014 to 2018

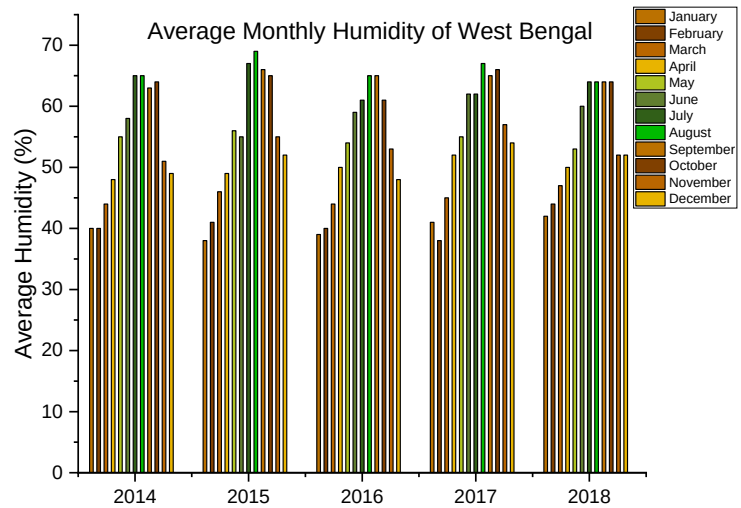

Fig. 8: Average monthly humidity of West Bengal for the period of 2014 to 2018

3.8. Natural Vegetation

Climate is a foremost determinant of different forest types and more precisely, rainfall is key factor though soil, topography, temperature etc plays a prevailing role. Conversely, forests put forth an immense influence on the environment of a country by retaining humidity in the atmosphere. They avoid rapid run-off, by promoting percolation of rainwater. Water that percolates into the soil helps to maintain the flow of rivers in deficient rainfall regions and helps to save moisture in the soil.

The total area of forest in West Bengal was ~16,900 km^2 which is almost 21% of the total area of the State. Several areas are intersected by broad rivers. So the actual forest covering area is only 14% leaving the space occupied by rivers. This is not uniformly distributed throughout the state but concerted in different areas; one of them is the mountains and foothills of North Bengal, another one in the plateau fringe and the other one in the southern part of the State i.e. in the Sundarbans. In the rest of the State, the present picture of the vegetational pattern and forest types is not the same as in the past and has been completely shattered or distorted by intense bio-edaphic factors (Basak and Guha Bakshi 1977).

Four different types of forests exist in the State; these are (a) Mountain temperate forest (b) tropical mixed evergreen forests of the foothills (c) the deciduous forests of the Western undulating highland and plateau and (d) the tidal forests of Sundarbans.

a. Mountain temperate forest

This type of forest is generally associated to high altitude and floristic composition of the mountainous Darjeeling including its plain areas being greatly influenced by the Himalayan elements. Here among 1000 to 1500 metres, subtropical forests are observed while temperate forests take place between 1500 to 3000 metres which include some varieties of oaks and conifers. Silver fern is incredibly widespread above 3000 metres. In the higher altitude alpine meadows, small bushes and flowering plants are found. Thus it is observed that the changes of flora with increasing altitude in the Himalaya are parallel to the changes that take place, as one travels from the tropics to the poles. According to Champion and Seth (1968) the forest type is recognized as East Himalayan moist mixed deciduous forest where

Shorea robusta is habitually found growing along with various other tress and shrub and the bottom is densely covered with grasses. Along with dominating *Shorea robusta* other commonly growing species are *Lagerstroemia parviflora*, *Stereopermum personatum*, *Wrightia tomentosa*, *Stercullia villosa*, *Malotus philippensis*, *Erythrina stricta. Bridelia stipularis*, *Ziziphus rugosa* etc.

b. Tropical and subtropical mixed evergreen forests of the foothills

Tropical and subtropical moist evergreen forests are observed at the foothills of Himalaya. Among 500 to 1000 metres, evergreen forests are observed. This forest is moderately dense. There is much undergrowth of shrubs and bushes. Orchids stick to the trees and giant creepers form a tangled mass of impassable vegetation. Some common species that are growing in this region are *Shorea robusta*, *Terminalia bellirica*, *Stercularia villosa*, *Terminalia alata*, *Syzygium cumini*, *Litsea monopetala*, *Bauhinia vahlii*, *Pterospermum acerifolium* etc.

c. Mixed evergreen forests of Terai and Duars region

Mixed evergreen forests in the Terai regions of Darjeeling, Jalpaiguri and Coch Bihar. *Shorea robusta* (Sal) is the most frequently found tree grown along with other such as *Michelia champaea* (Champa), *Schima wallichii* (Chilauni), *Acacia catechu* (Khair), *Gmelina arborea* (Gamar) which are less frequently observed. Bamboo is also common here. Common associates of this type of forests are: *Lagerstroemia parviflora*, *Sterculia villosa*, *Morinda angustifolia*, *Maesa indica*, *Terminalia bellirica*, *Schima wallichii*, *Earnthemum splendens*, *Strobilanthes capitatus* and others. It is very dense and there is much undergrowth of shrubs and bushes like any other tropical rain forest. Forests of such types are found in small patches near the rivers or streams.

c. Deciduous forests of the Western undulating highland and plateau

The dry deciduous forests of the undulating highland and plateau mainly concentrated in Medinipur, Bankura, Puruliya, Barddhaman and Birbhum districts. Due to porch of the floristically rich hilly plateau of Bihar and Orissa along the western boundary of West Bengal the vegetation in these areas of the bordering districts represents a distinct type of flora related to the adjoining drier areas of the

two States. This forest mainly bears Sal which is different from the Sal bearing forest of the northern region in size, undergrowth and other aspects. Here the dry Sal forest has been mostly kept as fuel jungle in which other fire-resistant varieties such as *Butea forndosa* (Palash), *Bassia latifolia* (Mahua) etc. are also grown. There is also marked dominance of shrubs and thorny bushes.

d. The tidal forests of Sundarbans

The most remarkable and attractive forest vegetation of West Bengal is the Mangrove vegetation of Sundarbans. Here the forests consist of the evergreen trees, shrubs and herbs. The trees are peculiar to the tidal swamps and can thrive well in coastal saline soil. They are characterised by their peculiar root developments which can be seen above the soil when the tide water recedes. Another unique feature of these plants is that they germinate from their seeds when they still in the tree. With the growth of the plant, a stab like root is develops and then falls on the ground at that time stabs attach in the ground. This type germination is known as viviparous germination. Among the trees grown here *Heritiera minor* (Sundri) is widespread and it grows best on the drier lands near the streams where the salinity is moderate. Some other plants which are found in this region are *Avicenuia officinalis* (baen), *Excecaria agollocha* (gengwa), *Phonix palmdosa* (hital), *Soumeratia apatata* (Kaora) and *Rhizophora mueronata* (bhora). Besides, there are various types of bushy plants and creepers which can tolerate a considerable degree of salinity.

Some of the most ideal conditions have rendered this forest a congenial habitat for harnessing the world fame Royal Bengal Tiger in the forest and a Tiger Reserve has been declared by the Govt. for protecting this race in the Sajnakhali Block of the Sundarbans.

4. MATERIALS & METHODS

4.1. Floristic Survey

The Polygonaceae flora of West Bengal have been prepared through indiscriminate sampling in various pre-dominant seasons *viz*., winter, pre-monsoon, monsoon and post-monsoon for four successive years, 2015 to 2019. A good number of species of Polygonaceae were distributed mainly in the marshy areas of Ganga-Brahmaputra flood plains, Himalayas and sub-Himalayan moist areas. Random collection of all the taxa of family Polygonaceae have been done covering all the important habitats starting from the sub-alpine Darjeeling hills, Terai-Duars, North Bengal plains, Gengetic plains, Western plateau (Purulia, Bankura etc), Sunderban mangroves and coastal areas in West Bengal, India. Several Wildlife Sanctuaries and National Parks like Singalilla National park, Mahananda Wildlife Sanctuary, Gorumara National Park, Buxa Tiger Reserve and Jaldapara National Park were visited regularly for the collection of all relevant field data including time of flowering and fruiting, ethnic and medicinal uses etc.

4.1.1. Collection and Preservation of Materials

During frequent field trips throughout the year, mainly healthy twigs with flowers and/or fruits and generally with leaves were collected. The specimens were tagged and field characters were recorded in the Field Note Book. Then collected specimens were cleaned and processed through standard herbarium techniques (Jain and Rao 1977) following drying in blotters (old news prints and blotting papers). After proper drying of specimens were poisoned by soaking with saturated solution of 4–6% Mercuric Chloride ($HgCl_2$) in rectified ethanol and then dried again and mounted on standard herbarium sheets, labelled and housed at NBU Herbarium.

4.1.2. Field Note Book

The Field Note Book contained precise locations, altitude, habit, habitat, availability, date of collections, flower colour and other characteristic features of plants which are not available among the dry and mounted herbarium specimens. The field notes were transferred to herbarium labels for ready reference. After completion of the work, the Field Note Book was deposited at the NBU-Herbarium.

4.1.3. Identification

The processed plant specimens were identified using the relevant taxonomic literatures (Hooker 1886; Prain 1906; Grierson and Long 1983; Chowdhury 2009) and by matching with the reliable specimens housed in various herbaria (CAL, NBU, ASSAM). Identified specimens were deposited at NBU Herbarium against accession number.

4.1.4. Flowering and fruiting calendar

The calendar were equipped by regular monitoring and recording the flowering and fruiting time of different taxa. It was found that the flowering period varies in different taxa with the change of altitude, longitude, latitude and physiography etc. For methodology Panda *et al.* (1992) and Chowdhury (2009) had been followed.

4.1.5. Enumeration and Description

All the recorded taxa were enumerated with genera, species under different genera and also variety under different species in alphabetic order. For each taxa the correct name was followed by basionym if any and available or important synonyms. Proper author citation, protologue references and references to the record in other relevant floras of nearby regions were also cited. This was followed by the local name(s). Detailed description of each taxa had been given. The place of collection with altitude, collector's names, field number and date of collection had been provided independently. Ranges of flowering and fruiting time had been given. Local distributions provided in the enumeration were based both on collected specimens and observation made during the field trips. General distribution had been determined from published literature. Last but not the least, a note was given which mainly focused on the local uses and any other remarkable observation made during the field study.

4.2. Foliar Macro Morphology

4.2.1. Plant samples

The work had been carried out with some fresh specimens collected from their natural habitats of West Bengal. The voucher specimens were deposited in the NBU herbarium [NBU] against specific accession numbers (Table 3).

Table 3: Plant sampling and herbarium depositions

Taxa	Collector	Accession Number	Latitude Longitude	Locality	District
Antigonon leptopus Hook. & Arn.	Payel Paul & M. Chowdhury	NBU – 9861	26º42′38″N; 88º21′20″E	Malda Station Road	Malda
Fagopyrum dibotrys (D. Don) Hara	Payel Paul & M. Chowdhury	NBU – 9858	27º00′18″N; 88º15′35″E	Sukhiapokhri Road	Darjeeling
Fagopyrum esculentum Moench	Payel Paul & M. Chowdhury	NBU – 5657	27º03′33″N; 88º28′00″E	Kalimpong college campus	Kalimpong
Fallopia convolvulus (L.) A. Love	Payel Paul & M. Chowdhury	NBU – 7825	27º03′15″N; 88º15′29″E	Darjeeling Govt. College	Darjeeling
Homalocladium platycladum (F. Muell.) L. H. Bailey	Payel Paul & M. Chowdhury	NBU – 7836	26º42′35″N; 88º21′20″E	NBU campus	Darjeeling
Persicaria barbata (L.) H. Hara	Payel Paul & M. Chowdhury	NBU – 10314	26º42′33″N; 88º21′17″E	Lochka River Bed	Darjeeling
Persicaria campanulata (Hook. *f.*) Ronse Decr.	Payel Paul & M. Chowdhury	NBU – 10312	26º59′50″N; 88º17′41″E	Tiger Hill	Darjeeling
Persicaria capitata (Buch.-Ham. *ex* D. Don) H. Gross	Payel Paul & M. Chowdhury	NBU – 7829	27º00′04″N; 88º14′36″E	Ghoom	Darjeeling

Taxa	Collector	Accession Number	Latitude Longitude	Locality	District
Persicaria chinensis (L.) H. Gross var. *chinensis*	Payel Paul & M. Chowdhury	NBU – 10162	27º02′17″N; 88º27′38″E	Durpin	Kalimpong
Persicaria chinensis (L.) H. Gross var. *hispida* Kantachot	Payel Paul & M. Chowdhury	NBU – 10317	27º02′17″N; 88º27′38″E	Durpin	Kalimpong
Persicaria chinensis (L.) H. Gross var. *ovalifolia* (L.) H. Gross	Payel Paul & M. Chowdhury	NBU – 10313	26º53′41″N; 88º16′55″E	St. Mary's Hill	Darjeeling
Persicaria glabra (Willd.) M. Gómes	Payel Paul & M. Chowdhury	NBU – 10334	26º34′35″N; 88º46′32″E	Domohani beel	Jalpaiguri
Persicaria hydropiper (L.) Delarbre	Payel Paul & M. Chowdhury	NBU – 10332	26º34′35″N; 88º46′32″E	Domohani beel	Jalpaiguri
Persicaria lanigera (R. Br.) Sojak	M. Chowdhury	NBU – 4123	24º53'06"N; 88º11'42"E	Gabgachi-chatral beel	Malda
Persicaria lapathifolia (L.) Delarbre var. *lapathifolia*	PayelPaul & M. Chowdhury	NBU – 10331	26º34′35″N; 88º46′32″E	Domohani beel	Jalpaiguri
Persicaria lapathifolia (L.) Delarbre var. *lanata* (Roxb.) H.Hara	Payel Paul & M. Chowdhury	NBU – 10324	26º34′20″N; 88º49′26″E	Kathambari beel	Jalpaiguri
Persicaria microcephala (D. Don) H. Gross.	Payel Paul & M. Chowdhury	NBU – 10320	27º03′35″N; 88º15′23″E	Singamari	Darjeeling
Persicaria minor (Hud.) Opiz	Payel Paul & M. Chowdhury	NBU – 10190	26º34′35″N; 88º46′32″E	Domohani beel	Jalpaiguri
Persicaria nepalensis (Meissn.)	Payel Paul & M.	NBU – 10311	26º52′19″N; 88º16′01″E	Pankhabari road	Kurseong

Taxa	Collector	Accession Number	Latitude Longitude	Locality	District
H. Gross	Chowdhury				
Persicaria orientalis (L.) Spach	PayelPaul & M. Chowdhury	NBU – 7824	24º58'53"N; 88º11'43"E	Nayagram beel	Malda
Persicaria posumbu (Buch.-Ham. *ex* D. Don) H. Gross	PayelPaul & M. Chowdhury	NBU – 10187	24º58'53"N; 88º11'43"E	Nayagram beel	Malda
Persicaria strigosa (R. Br.) Nakai	Payel Paul & M. Chowdhury	NBU – 9870	26º42′34″N; 88º21′19″E	Kathambari beel	Jalpaiguri
Persicaria tenella (Blume) Hara	Payel Paul & M. Chowdhury	NBU – 5816	26º42′28″N; 88º21′32″E	Lochka River Bed	Darjeeling
Polygonum molle D. Don	Payel Paul & M. Chowdhury	NBU – 10329	27º04′30″N; 88º01′26″E	Tonglu	Darjeeling
Polygonum plebeium R. Br.	Payel Paul & M. Chowdhury	NBU – 5615	26º48′12″N; 88º30′12″E	Sukna	Darjeeling
Polygonum pubescens Blume	Payel Paul & M. Chowdhury	NBU – 10330	27º03′17″N; 88º15′45″E	Lebong Road	Darjeeling
Polygonum runcinatum Buch.-Ham. *ex* D. Don	Payel Paul & M. Chowdhury	NBU – 10326	27º03′15″N; 88º15′29″E	Darjeeling Govt. College	Darjeeling
Polygonum viscosum Buch.-Ham. *ex* D. Don	Payel Paul & M. Chowdhury	NBU – 10319	26º34′35″N; 88º46′32″E	Domohani beel	Jalpaiguri
Rumex acetosella L.	Payel Paul & M. Chowdhury	NBU – 10161	26º42′38″N; 88º21′20″E	Nayagram beel	Malda
Rumex dentatus L.	PayelPaul & M. Chowdhury	NBU – 7018	26º42′38″N; 88º21′20″E	Burdwan	West Burdwan

Taxa	Collector	Accession Number	Latitude Longitude	Locality	District
Rumex maritimus L.	Payel Paul & M. Chowdhury	NBU – 7020	26º42′48″N; 88º21′30″E	Lochka River Bed	Darjeeling
Rumex nepalensis Spren.	Payel Paul & M. Chowdhury	NBU – 10165	27º03′17″N; 88º15′45″E	Lebong Road	Darjeeling
Rheum nobile Hook. *f.* & Thompson	Jambey Tsering	NBU – 10347	27º35′07″N; 91º52′26″E	Nakyo	Twang

4.2.2. Study of Venation

4.2.2.1. Clearing of leaves

For the Details study of leaf venation of each taxa, a good number of mature and healthy leaves were cleared following the very widely used techniques as suggested by Mishra *et al.* (2011). Leaves were engrossed in 80% ethanol for 48–72 h to remove chlorophyll pigments. Then the leaf samples will be washed and treated with 3–5% NaOH at room temperature for 12–18 days. The digested leaf tissue was carefully brushed apart to acquire the leaf skeleton. These will be further hardened by treating with saturated chloral hydrate solution for several days, washed, dehydrated and preserved. But if the leaves remained opaque after clearing it was then boiled with lactic acid to attain the desired level of clearing (Lama 2004). After clearing specimens were stained with 2% saffranin prepared in 70% ethanol. The excess stain was removed with 70% ethanol and finally mounted between two glass plates with DPX (Foster 1952; Chowdhury 2015).

4.2.2.2. Major Venation pattern

At first two orders of veins were recognized. In general major structural veins (primary and secondary veins) of the lamina were effortlessly recognized with naked eye or through a simple magnifying lens. The mid-vein or primary vein was the thickest vein of the lamina and thickness decreases steadily toward the apex. It also includes the study of 2º venation pattern (Hickey 1973).

4.2.2.3. Minor venation pattern

To study minor venation patterns, small bits were cut from the central part of the leaf skeletons (excluding mid rib and marginal parts), stained with saffranin and mounted in DPX. The highest orders of veins were identified up to 4°. Minor venation patterns included several microscopic studies like 3º to 4º vein category, vein course, vein angle variability, marginal ultimate venation etc. For the study of minor venation pattern, stained segments were observed under 5X objective of a compound microscope using a 10X eye piece.

Leaf venation pattern, vein islets, vein terminal etc. for the delicate leaves of each taxa of Polygonaceae of this region was standardized and determined according to the standard methods as suggested by Gupta (1961) and Hickey (1973). Necessary drawing, photography and measurement of each part of every taxa was made carefully for further analysis and use.

4.2.3. Study of Indumentum

For the determination of the position and type of indumentums all the plant parts such as fresh lamina, petioles were observed under the 5X and 10X and then 40X and 45X objectives of compound microscope. The measurements of various types of indumentums (Hickey 1973; Chowdhury 2015) were made to utilizing the ocular micrometer after proper standardization of the microscope. Necessary drawing, photography and measurement of each part of every taxa were made carefully for further analysis and use.

4.2.4. Study of Stomata

Through the stomata diffusion of water takes place from the internal tissue of the aerial parts of the plant body to the atmosphere under the influence of sunlight and air-current. Stomata and associated epidermal cells provide taxonomically important diagnostic characters. Stomata frequency and index are mainly the characters those are important in physiological and ecological studies. Several techniques were followed for stomatal study, *viz*.,

1. A strip of lower epidermis from the middle portion of the leaf was peeled off and mounted in glycerol after staining with saffranin.

2. In impression technique as an impression material colourless nail polish was used. To get the impressions of foliar epidermal cells the nail-polish was smearing on the dorsal surface of the lamina and it was allowed to dry entirely. Then the thin layers were taken out from lamina and placed on glass slides and studied under compound microscope.

3. In case of thick leaves where above mentioned technique were not producing substantial results, then the scrapping technique was used. The upper epidermis and mesophyll tissues were scrapped out with the help of a scalpel or a sharp blade. Then the scrapped pieces were immersed into the FAA solution (formalin, glacial acetic acid and 50% ethanol in 1:1:18 ratio) for 2–5 minutes. Then the pieces were placed on clean glass slide and mounted with 10% glycerine and were studied under the compound microscope (Chinniah and Thiagarajan 2015).

4. In some cases, samples were boiled around 15–20 minutes in 10 ml of 10% aqueous HNO_3 solution. Then the samples were dipped in lactic acid for 2–3 minutes to become transparent and finally a small portion was taken out and mounted with 10% glycerin on glass-slide for observation (Ibrahim and Ayodele 2013).

5. Boiling technique was also done with absolute alcohol till the sample becomes transparent followed by lactic acid treatment for becoming transparent and observed under compound microscope.

Stomatal type, frequency and index (SI) will be determined following Salisbury (1927, 1942). Necessary drawing, photography and measurement of each parts of every species were made carefully for further analysis and use.

Stomatal index (SI) = (S/E+S) x 100,

where S = No. of stomata per vision, E = No. of epidermal cells per vision.

Stomatal frequency = No. of stomata per mm^2 of microscopic field.

4.3. Pollen morphology

Fresh anthers of 28 species and five variety of the subfamily Polygonoidae were collected from their natural habitats.

4.3.1. Preparation of Glycerin Jelly

Glycerin jelly was prepared according to modified method of Ahmad *et al.* (2008) who followed Erdtman (1952). 250 ml of distilled water was taken in a beaker and heated. When water in the beaker attained 70º–80°C temperatures, then 15 gm of gelatin was added and subjected to more heating to become a viscous liquid. Then it was mixed in it with few crystals of phenol. It was stirred continuously until uniform solution appeared. The homogenized mixtures was poured on a petriplate and used for staining of pollen grains.

4.3.2. Sample preparation

4.3.2.1. Light microscopy (LM)

Anthers collected from matured flower buds in fresh for all the plants under study and were used for acetolysis method (Erdtman 1960, 1969) with slight modification.

- Fresh polliniferous materials were crushed on a fine sieve mesh (0.11 sq.mm) resting on a funnel, set on a glass centrifuge tube. After each treatment the brass sieve was burnt on a flame to avoid contamination
- Acetolysis mixture was prepared in a measuring cylinder by gradually adding one part of concentrated sulphuric acid to nine parts of acetic anhydride
- Acetolysis mixture was added in each tube and stirred with clean and dry glass rod. The tubes are placed in water bath at 60º temperature. The mixture turned brown and then it was allowed to cool down
- Then the samples were centrifuged and supernatant decanted
- Distilled water added to sediment and the mixture was centrifuged at 4000 rpm for 5 minutes and decanted
- The washing was repeated twice or thrice
- Few drops of freshly prepared sodium chlorate solution and a few drops of concentrated hydrochloric acid were added and then centrifuged and decanted (Chlorination was avoided for some pollen)
- 50% glycerine was added to each tube, centrifuged at 4000 rpm for 5 minutes and decanted
- The tubes were kept inverted on a piece of blotting paper for overnight.

After acetolysis, each sample was critically studied under light microscope (LM). The pollen grains were mounted in glycerine jelly and studied under OLYMPUS 'Magnus – 1111'light microscope at 40X magnification equipped with digital image capture facility.

4.3.2.2. Scanning electron microscopy (SEM)

Pollen grains suspended in 40% acetic acid were transferred to clean aluminium stubs and allowed to air dry overnight in a desiccator. Then the stubs were coated with carbon. SEM observations were carried out on a ZEISS EVO 40 microscope in GSI, Kolkata, India.

4.3.3. Pollen description

Pollen grains type, shape and length of polar axis (P) and equatorial diameter (E) view, P/E ratio, exine thickness and length of colpi were properly examined. Detailed pollen morphology was based on the average measurement of 30–35 pollen grains. The terminologies used during describing the pollen grains were in accordance to Erdtman (1952), Faegri and Iversen (1964), and Punt *et al.* (1994, 2007), Halbritter *et al.* (2018).

4.4. Statistical analysis

Results were expressed as Mean ± SDEV where n = 30 for all the macro, micro morphological and pollen grains parameters. The data were subjected to analysis of variance (ANOVA) to determine the level of significance of different selected attributes. Pearson correlation test (Pearson 1948) was performed to determine the correlation significance among different attributes under study (XLSTAT 2017). To determine the relationship among different attributes with respect to various selected species by group clustering Principle Component Analysis (PCA) (Pearson 1901) was done using XLSTAT 2017. Agglomerative hierarchical clustering (AHC) was performed following Pearson similarity dendrogram using XLSTAT 2017 to understand the interrelationship among the species.

4.5. Molecular documentation

Genetic diversity of all the collected taxa of Polygonaceae was studied by using barcoding markers (*rbcL*, *matK* and *trnL-F*). For genomic DNA isolation from the

collected plant leaves standard protocol of Bookjans *et al.* (1984), Palmer *et al.* (1986) and Sakaguchi *et al.* (2017) was followed with minor alterations which is summarized below-

4.5.1. Extraction of DNA from leaf

All the following steps were carried out at 0°C if not otherwise stated.

- 2g of leaves were collected and cut into pieces (~1 cm) and homogenized in 12 ml of ice-cold Cold isolation buffer. The homogenate was filtered into centrifuge bottles using two layers of Miracloth (Merck) with softly squeezing the cloth.
- The homogenate was centrifuged at 1000rpm for 5 minutes.
- The chloroplast pellet was resuspended in 4 ml cold isolation buffer, and the chloroplasts were repelleted at 3000 g, 10 min.
- The final chloroplast pellet was resuspended in 2 ml of cold isolation buffer. Chloroplast DNA isolation
- 1/10 volume of 10% CTAB was added to lyse the chloroplasts. It was incubated at 55°C for 1 to 2 hours.
- The supernatant was extracted with an equal volume of saturated phenol and chloroform: isoamylalcohol in the centrifugation of 10000 g 20 min for twice.
- An equal volume of isopropyl alcohol was added to the upper clear aqueous phase. Then the centrifuge bottles were kept in the -20°C for 1 hour or overnight.
- The aqueous phase was centrifuged at 10000 g for 20 min. The cpDNA pellet was washed repeatedly with ethanol (70%, 96%), air-dried, and re-dissolved in 50 µl TE buffer.

4.5.2. Purification of crude DNA

RNA, protein and polysaccharides are the chief contaminants observed in crude DNA which affect the further downstream process. Therefore, removal of these impurities is necessary for purification of crude DNA. Utilization of CTAB helps in elimination of polysaccharides from DNA. Subsequently, phenol: chloroform and RNase treatment make possible in the elimination of RNA and most of proteins to a

large extent from crude DNA. The following procedure of DNA purification is as follows:

- Freshly prepared RNaseA (50µg/ml) was added into the genomic DNA, dissolved in 500 µl of 1X TE buffer (pH 7.4) and incubated at 37 ºC for 1h in a drybath.
- Then the equal volume of chloroform: isoamyl alcohol (24:1) was added and mixed properly and centrifuged at 15,000 g for 15 min at room temperature.
- The upper aqueous phase was then transferred to a fresh micro centrifuge tube and 0.1 volume of 3M sodium acetate (pH 5.2) was then added into the tube followed by double volume of absolute ethyl alcohol for DNA precipitation. In the next step, the tube was centrifuged at 15,000 g for 30 min at 4ºC.
- Finally, the DNA pellet was collected and washed gently with chilled 70% ethyl alcohol, air dried and finally dissolved in 100 µl of 1X TE buffer (pH 7.4).

4.5.3. Quantification of DNA

Proper DNA quantification is required for the amplification of target DNA by polymerase chain reaction. DNA quantification is carried out by spectrophotometric measurements or by agarose gel analysis. Both the methods were used in the study.

4.5.3.1. Spectrophotometric measurement

The quantity of the isolated DNA was checked in UV-VIS spectrophotometer (Vivaspec Biophotometer, Germany). The A_{260}/A_{280} ratio was recorded to check the purity of DNA and A_{260}/A_{280} value close to 1.8 was taken as standard. At first, spectrophotometer was calibrated at 260 nm as well as 280 nm by taking 600 µl 1X TE buffer. The purified DNA (6 µl diluted in 594 µl of 1X TE) was taken, mixed properly and the absorbance was recorded at both 260 nm (A_{260}) and 280 nm (A_{280}).

4.5.3.2. Gel analysis

The quality and quantity of the isolated DNA was checked on 1% agarose gel in a submarine gel electrophoresis system (GeNei, India). For preparation of gel 1% (w/v) agarose was suspended in 1X TAE buffer and allowed to melt in water bath to

obtain a clear solution. Ethidium bromide (1 µg/ml) was added to the solution after cooling (60 $^{\circ}$C), mixed properly, poured carefully into the gel casting tray and allowed to solidify. The gel with tray was then completely submerged in tank containing 1X TAE buffer. Sample DNA (5 µl) was mixed with 1 µl of 6X gel loading dye and was loaded onto the gel. Electrophoresis was done at 5 V/cm for 60 minutes and viewed under under UV-transilluminator.

4.5.4. Chloroplast genome diversity analysis

4.5.4.1. Primer used

Three different sets of primers were used to amplify the three different regions of chloroplast DNA *viz., matK, trnL-F* and *rbcL* (Table 4)

Table 4: Oligonugleotide primers used for the study and their amplicon size

Primers	**Sequences (5′- 3′)**	**Amplicon Size (bp)**	**Reference**
rbcL FP	ATGTCACCACAAACAGAAAC	530	Bruder and Medlin, 2007
rbcL RP	TCGCATGTACCTGCAGTAGC		
matK FP	CGTACAGTACTTTTGTGTTTACGAG	777	Ford *et al.* 2009
matK RP	ACCCAGTCCATCTGGAAATCTTGGTTC		
trnL-F FP	CGAAATCGGTAGACGCTACG	672	Taberlet *et al.* 1991
trnL-F RP	ATTTGAACTGGTGACACGAG		

4.5.4.2. PCR amplification

PCR amplification was done in 20 µl of reaction mixture containing 1X PCR buffer (Kappa, SA); 25 mm $MgCl_2$, 3 mm dNTP mix, 0.25 mm *Taq* DNA polymerase, 10 picomol primer and 50 ng templates DNA (Table 5).

Table 5: PCR components and their volume

PCR components	**Volume (µl)**
Nuclease free water	10.75
10X Reaction buffer with 1.5 mM $MgCl_2$	2.00
dNTP mix (2.5 mM each**)**	2.00
Primer 16S F (5 **picomoles/µl)**	2.00
Primer 16S R (5 **picomoles/µl)**	2.00
Taq DNA polymerase (5U)	0.25
Template DNA (50 ng/µl)	1.00
Total volume	**20.00**

For the primers '*matK* FP - *matK* RP' and '*trnL-F* FP - *trnL-F* RP', PCR condition was initial denaturation at 94 ºC for 2 minutes, followed by 30 cycles of denaturation at 94 ºC for 50 seconds, annealing at 48 ºC for 30 seconds, polymerization at 72 ºC for 1 minutes 30 seconds, and final extension at 72 ºC for 6 minutes. For the primers '*rbcL* FP - *rbcL* RP', PCR condition was initial denaturation at 94 ºC for 2 minutes, followed by 30 cycles of denaturation at 94 ºC for 30 seconds, annealing at 54 ºC for 45 seconds, polymerization at 72 ºC for 1 minutes 30 seconds, and final extension at 72ºC for 10 minutes. All the PCR products were run on 1% agarose gel electrophoresis system, visualized under UV-transilluminator and stored at 4ºC for future use.

4.5.5. Sequencing of amplified products

All the PCR amplicons were sent to Credora Inc. Pvt. Ltd., Bangalore, India for sequencing. A total of 19 taxa were subjected for DNA sequencing purposes using *rbcL*, *matK* and *TrnL-F* genes that are not available in the GenBank. Amongst these taxa, *Persicaria lanigera*, *Persicaria lapathifolia* var. *lanata*, *Persicaria glabra*, *Persicaria strigosa* and *Persicaria tenella* were selected for the sequencing of all the three regions as no reports on sequences of these three genes were available.

4.5.6. Submission of sequence

The raw sequences of all 19 taxa of Polygonaceae were aligned using Clustal W (Thompson *et al.* 1994). The sequences were annotated and submitted to GenBank upon BLASTn analysis (Altschul *et al.* 1997) along with all necessary information viz., definition of the sequence (i.e. the specific region of the genome) and other necessary sequence attributes like- name of the plant species along with its taxonomic position, date and place of collection, tissue type etc.).

4.5.7. Phylogenetic analysis

For phylogenetic analysis several other sequences belonging to 8 genera (*Antigonon*, *Fagopyrum*, *Fallopia*, *Muehlenbeckia*, *Persicaria*, *Polygonum*, *Rheum* and *Rumex*) reported worldwide were used (Appendix 1) and *Oxygonum sinuatum* was taken as outgroup. During phylogenetic analysis maximum likelihood (ML) trees were generated for these three chloroplast DNA regions viz., *matK*, *rbcL* and *trnL-F* using RAxML 7.2.8 (Stamatakis 2006) with 1000 replicates. Bayesian phylogenetic inference (BI) was carried out using MrBayes 3.12 (Ronquist and Huelsenbeck 2003) with Markov chain Monte Carlo simulations (MCMC) algorithm with four cumulative heated chains starting from random trees for 100,000 generations and sampling one out of every 100 generations. The first 25% of the reconstructed trees were cast aside as burn-in (Zhang *et al.* 2017). Colour-coded sequence identity matrix was generated using SDT 1.2 (Muhire *et al.* 2014).

5. RESULT

5.1. FLORISTIC SURVEY

5.1.1. General morphology of Polygonaceae

The members of Polygonaceae are characterized by herbs, shrubs, occasionally trees or climbing habit, leaves generally simple, alternate, stipules united to form a sheath like structure around the stem known as Ochreae, nodes clearly swollen. Ochreae membranous, hyaline, ciliate, fimbriate or tubular. Inflorescences are in spikes, fascicles or panicles. Flowers usually bisexual, rarely unisexual, actinomorphic, pedicel with distinct articulation; perianth biseriate, tepals 3–6, united below and sometimes distended in fruit; stamens 4–9, sporadically up to 16; ovary superior, unilocular, styles 2–4, stigma capitate or fimbriate and ovule 1, basal. Fruit trigonous or biconvex nut, often covered with persistent tepals, brown or black. Seeds with curved embryo.

5.1.2. Enumeration

Polygonaceae comprises about 1384 species and 59 genera worldwide (Sanchez & Kron 2008); 121 species, 29 varieties and 12 genera in India (Srivastava 2014). A Total of 35 taxa of Polygonaceae were collected from different moist and temperate habitats of West Bengal (Fig. 11; 12; 13). Based on considerable reliable and effortlessly conspicuous vegetative, flower and fruit characters artificial dichotomous keys were prepared for the recorded taxa. All the taxa were enumerated below alphabetically accompanied by protologue reference, local names, salient features, exsiccatus, availability status, flowering and fruiting periods, occurrence in West Bengal and world distribution.

Key to the Genera

1a. Phylloclade present .... ***Homalocladium***

1b. Phylloclade absent **2**

2a. Plant climbers; achenes not enclosed by winged perianth .... ***Antigonon***

2b. Plant erect herb or shrubs; achenes enclosed by winged perianth **3**

3a. Perennial herbs; ochreae tubular, acute - aristate, hyaline .... ***Bistorta***

3b. Annual or perennial herbs, sometimes shrubby; ochreae tubular, entire, dentate, acute - acuminate, mostly silvery or brownish **4**

4a. Lower leaves deltoid; inflorescence corymbose; pedicel papillose or pubescent; achenes as long as perianth .... ***Fagopyrum***

4b. Lower leaves variously shaped; inflorescence capitates head or solitary and axillary, raceme, panicle, spike, pedicel glabrous or pubescent or scabrous; achenes shorter than perianth **5**

5a. Mostly twining herbs; tepals keeled .... ***Fallopia***

5b. Prostrate, erect - suberect herbs; tepals not keeled **6**

6a. Inflorescence a spike, raceme ovoid or sub globose or sometimes a capitate head; stamens 4–8 .... ***Persicaria***

6b. Inflorescence solitary, axillary, in few flowered cluster or simple or branched receme; stamens 5 – 6 .... **7**

7a. Ochreae overlapping with leaves; perianth 3–5 partite .... ***Polygonum***

7b. Ochreae not overlapping with leaves; perianth 6 partite, arranged in two whorls, outer 3 small, inner 3 enlarged to form valves .... ***Rumex***

Antigonon **Endlicher**

Gen. Pl. 310.1837; Bentam & Hooker *f.*, Gen. Pl. 3: 103.1883. *Corculum* Stuntz in U.S. Dept. Agr. Bur. Pl. Ind. Bull. 282: 84. 1913.

Climbers. Leaves alternate, simple, lanceolate, cordate or deltoid. Flowers in raceme, cluster; tepals 5, pink; stamens 7–9, connate at base to form a tube; ovary trigonous. Achenes trigonous, tepals persistent.

Genus comprises about 3 species worldwide; native of Central America; 1 species was found in India; one species is recorded from West Bengal.

Antigonon leptopus Hooker & Arnott, Bot. Beechey Voy. 308. 1838; Maiti & Sikdar, Ind. J. Forestry 8(3): 197. 1985; Srivastava, Ind. J. Pl. Sc. 3(2): 113. 2014. *Corculum leptopus* (Hooker & Arnott) Stuntz, U. S. Dept. Agr. Bur. Pl. Ind. 282: 84. 1913. ***'Anantalata'***

Perennial, weak climbers. Stems pentagonal, usually 1.5–3.5 m long; Leaves opposite, lamina 8.5–9.5 × 11.8–14.09 cm, ovate-lanceolate, glabrous, margin ciliate, base truncate, acute. Flowers in axillary cymes; tepals 5, ovate, pink; stamens 7; ovary trigonous, styles reduced or rudimentary or absent, stigma 3, capitates. Achenes trigonous.

Flowering & Fruiting: July to November

Specimen examined: India. West Bengal: Malda District, Besides Malda Station, *Payel Paul & M. Chowdhury 0035*, dated 12.09.2015. Darjeeling District, Siliguri, *Payel Paul & M. Chowdhury 00135*, dated 17.10. 2018

Status: Common in roadside bushes

Distribution: India (Kerala, Karnataka, Rajasthan,Assam, Bihar, West Bengal), West Indies, Africa, N, C and S. America, Australia; native to Mexico; common in roadside bushes of Malda, Mursidabad, Bankura, Burdwan, Hoogly, Medinipur, Howrah (recently naturalized).

Note: The plant is used as ornamental plant worldwide.

Bistorta (Linnaeus) Scopoli

Meth. Pl. 24. 1754; Adans., Fam. 2: 277. 1763; Hara *et al*., Enum. Fl. Pl. Nepal 3: 173. 1982; Grierson & Long, Fl. Bhutan 1(1): 166. 1983; Munshi & Javeid, Syst. Stud. Polygon. Kashm. Himal. 58. 1986.

Perennial herbs or sub-shrubs. Root fibrous, rhizome thick. Stem erect, unbranched, glabrous. Leaves alternate, lower petiolate, upper sessile, linear, lanceolate to elliptic, oblong, acute or obtuse, entire, serrulate, crenate, glabrous usually with narrow margin. Ochreae tubular, thin, membranous, nerved. Inflorescence dense spikes, simple or branched. Flowers bisexual; tepals 5, entire-undulate, acute or obtuse; stamens 5–8, poorly developed, slightly or clearly exserted, anther dorsifixed or basifixed; ovary trigonous; styles 3, stigma minute. Achenes trigonous, ovoid, smooth, shiny and dark brown.

This genus comprises about 40 species in the world; 7 species in India; only 1 species was recorded from West Bengal.

Bistorta emodi (Meisner) H. Hara, FI. East. Himal. 69. 1966; Hara *et al*., Enum. Fl. Pl. Nepal 173. 1982; Grierson & Long, Fl. Bhutan l(1): 167. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 190. 1985. *Polygonum meissneri* Wallich, Cat. 1693. 1829, *nom. nud. Polygonum emodi* Meisner in Wall. Pl. Asia. Rar. 3: 51. 287. 1832; Hooker *f*., Fl. Brit. Ind. 5: 33. 1886; Steward, Contr. Gray Herb. 88: 29. 1930.

Perennial, branched, glabrous, prostrate herbs. Stem branched, 10–15 cm long, woody at base. Lamina 2.5–5 × 1.8–3 cm, lanceolate, acute and sessile. Ochreae 1.5–3 cm long, tubular, ovate, lacuminate or lacerate, membranous. Inflorescence erect, terminal, simple or branched, 3–4 cm. Flowers 1.8–2.9 mm across; tepals 4–5 parted, 4–5 mm long, oblanceolate, obtuse, deep red; stamens 8, filaments long, filiform; ovary 1–2 × 0.5–0.75 mm, trigonous, styles 3, free till middle, stigmas capitate. Achenes trigonous, glabrous, black, shining.

Flowering & Fruiting: July to September

Specimen examined: India. West Bengal: Darjeeling District, Tiger Hill, *Payel Paul & M. Chowdhury 0151*, dated 19.04.2019.

Status: Rarely occurring on the hilly slopes of Darjeeling Himalaya only

Distribution: India (Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Sikkim), Bhutan, W. China; Darjeeling hills (Tiger Hill to Sandakphu) at an antitude from 3500 m to 3636 m.

Fagopyrum Miller

Gard. Dict. Abr., ed. 4. 1754; Hooker *f*., Fl. Brit. Ind. 5: 54. 1886. D. A. Webb in Tutin et al., Fl. Europ. 1: 81. 1964; Hara *et al*., Enum. Fl. Pl. Nepal 3: 174. 1982; Grierson & Long, Fl. Bhutan 1(1): 171. 1983.

Annual or perennial, erect herbs. Stems round, branched, cylindrical. Leaves simple, alternate, petiolate, lamina entire, cordate or ovate, acute or acuminate, base cordate, hastate or deltoid. Ochreae entire, ciliate, oblique. Flowers in dense cyme or spike;

flowers pedicillate, tepals 5, white; stamens 5–8, attached at base; ovary trigonous, style 3, stigma capitates; Achenes trigonous, ovoid.

Genus comprises about 15 species worldwide; 6 species in India; only 2 species were recorded from West Bengal.

Key to the species

1a. Perennial, wild; sparsely pubescent herbs..... .... ***F. dibotrys***

1b. Annual, cultivated; glabrous herbs..... .... ***F. esculentum***

Fagopyrum dibotrys (D. Don) Hara, Fl. E. Himal. 69. 1966; Hara *et al*., Enum. Fl. Pl. Nepal. 3: 174. 1982; Grierson & Long, Fl. Bhutan 1(1): 171. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 197. 1985; Srivastava, Ind. J. Pl. Sc. 3(2): 115. 2014. *Polygonum dibotrys* D. Don, Prod. Fl. Nepal. 73: 1825. *Polygonum cymosum* Treviranus, Nov. Act. Acad. Caes. Leop.-Carol. Nat. Cur. 13: 177. 1826. *Fagopyrum cymosum* (Treviranus) Meisner in Wallich, Pl. As. Rar. 3: 63. 1832. ***'Ban Phappar'***

Perennial herbs. Stem branched, weak, green to brownish in colour. Leaves simple, alternate, petiolate, 0.7–1.8cm long, lamina 2.5–4.1 × 3.7–6.5 cm, deltoid, entire, acute; Ochreae 4.5 × 7.9 mm, brown, membranous; fimbriae present, no of the fimbriae 4, length 145.78µm. Flowers in terminal or axillary cymes, pedunculate; tepals 5, elliptic, white; stamens 8, anthers dorsifixed, bicelled; stigma 3, capitates, ovary trigonous. Achenes trigonous, smooth, black.

Flowering & Fruiting: June to September

Specimen examined: India. West Bengal: Darjeeling District, Lebong Road, *Payel Paul & M. Chowdhury 0081,* dated 21.09.2016; India. Darjeeling District, Tiger Hill Road *Payel Paul & M. Chowdhury 0087,* dated 22.02.2017.

Status: Abundantly found in temperate climates in Darjeeling and Kalimpong hills

Distribution: India (Jammu and Kashmir, Himachal Pradesh, West Bengal), Nepal, Bhutan, China, Tibet, Myanmar, Vietnam; temperate wet forest of Darjeeling upto meghma and tonglu in between the altitude ranges from 1600 m to 3636 m.

Note: Seeds, leaves used for treatment of colic, choleric diarrhoea and abdominal blockage troubles; young leaves used as vegetable.

Fagopyrum esculentum Moench, Meth. 290. 1794; Webb in Tutin *et al*., Fl. Europ. 1: 81. 1964; Grierson & Long, Fl. Bhutan 1(1): 171. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 197. 1985; Munshi & Javeid, Syst. Stud. Polygon. Kashm. Himal. 83. 1986; Srivastava, Ind. J. Pl. Sc. 3(2): 115. 2014. *Polygonum fagopyrum* Linnaeus, Sp. Pl. 1: 364. 1753. *Fagopyrum sagittatum* Gilibert, Exerc. Phyt. 2: 435. 1792. *Polygonum emarginatum* Roth, Catalect. B. 1: 48. 1797. *Fagopyrum vulgare* T. Nees, Gen. Fl. Germ. Monochl. 53. 1835. ***'Meethe Phaper*** or ***Titaphapur'***

Annual, erect herbs. Stems hollow, glabrous, green, nodes swollen. Leaves simple, alternate, petiolate, petiole 0.5–0.9 cm, lamina ovate-cordate, 2–4.8 × 3–5.5 cm. Ochreae funnel shaped, 0.7 × 0.6 cm; fimbriae present, no of the fimbriae 9, length 68.28µm. Flowers in axillary or terminal corymb; tepals 5, ovate, entire, obtuse, white or pink; stamens 8, anthers bicelled, dorsifixed; stigma 3 capitates; ovary trigonous. Achenes trigonous, ovoid, dark brown.

Flowering & Fruiting: May to October

Specimen examined: India. West Bengal: Jalpaiguri District, *Payel Paul & M. Chowdhury 0090*, dated 15.03.2017.

Status: Commonly cultivated species

Distribution: India (Jammu and Kashmir, Himachal Pradesh, West Bengal, Sikkim), Pakistan, Iran, China, Tibet, S Europe, N America; Darjeeling, Kalimpong, Jalpaiguri at an altitude ranges from 140 m to 1784 m.

Note: Leaves used as vegetable.

Fallopia Adans

Fam. 2: 274. 1763; emend. Holub, Folia Geobot. Phytotax. Praha, 6: 171. 1971; Hara *et al*., Enum. Fl. Pl. Nepal 3: 174. 1982; Grierson & Long, Fl. Bhutan 1(1): 169. 1983; Boulos, Fl. Egypt 1: 30. 1999.

Annual or perennial, herbs, Prostrate or twining. Stem branched, angular, ridged, glabrous or papillose. Leaves alternate, petiolate, ovate, base cordate, sagittate or hastate, entire. Ochreae usually tubular, deciduous. Flowers in axillary fascicles, racemes or panicle or spike, ochreolae tubular; tepals 5-parted, unequal, in 2 whorls; stamens 7–8, unequal; ovary trigonous, styles 3, stigmas capitate. Achenes trigonous, smooth or rough.

Genus comprises about 9 species worldwide; 4 species in India; only 1 species was recorded from West Bengal.

Fallopia convolvulus (Linneaus) A. Löve, Taxon. 19: 300. 1970; Holub, Folia Geobot. Phytotax. Praha 6: 176. 1971; Hara *et al*. Enum. Fl. Pl. Nepal 3: 174.1982; Grierson & Long, Fl. Bhutan l (1): 169. 1983; Ronse Decreane & Akeroyd, Bot. J. Linn. Soc. 98: 369. 1988. *Polygonum convolvulus* Linnaeus, Sp. Pl. 464. 1753; Hooker *f*., Fl. Brt. Ind. 5: 53.1886. *Bilderdykia convolvulus* (Linnaeus) Dumortum, Fl. Belg. 18: 1827; D.A.Webb in Tutin et al., Fl. Europ. 1: 81. 1964. *Fagopyrum convolvulus* (Linnaeus) H. Gross, Bull. Geogr. Bot. 23: 21. 1913; *Fagopyrum carinatum* Moench, Meth. 290. 1794. *Tiniaria convolvulus* (Linnaeus) Webb & Moq, Phyt. Canar. 3: 221. 1847.

Annual herbs. Stem twining, branched, angular, striate, slightly hairy, papillose at angles, light brown. Leaves alternate, petiole 1.2–3.0 cm long, lamina ovate or orbicular, 2–4 × 1–2 cm, glabrous-papillose, acute-acuminate, glabrous, midrib and vein network papillate, base cordate-sagitate, entire. Ochreae 2.3 × 4.8 mm long, tubular with slightly incised margins, membranous, glabrous, brown; fimbriae absent. Inflorescence is an axillary spike. Flower 4–5 × 2–2.3 mm, pedicillate; tepals 5, 4–5 × 1.2–1.8 mm, unequal, narrowly elliptic, slightly pubescent, persistent in fruit; stamens 8, unequal, anther bicelled, dorsifixed; ovary 1–3 × 0.6–2 mm, trigonous, styles 3, stigmas capitate. Achenes trigonous, ellipsoid, rough and brown.

Flowering & Fruiting: May to September

Specimen examined: India. West Bengal: Darjeeling District, Near Darjeeling Govt. College, *Payel Paul & M. Chowdhury 0058*, dated 21.06.2016.

Status: Rare occurrence; temperate climate in Darjeeling hills.

Distribution: Afghanistan, Kazakhstan, Pakistan, India (West Bengal, Sikkim), Nepal, Bhutan, Mongolia, Korea, Japan, Russia, Europe, introduced in N. America; Darjeeling and Kalimpong at an antitude from 1200m to 2800m.

Note: Seeds are used as nutritious food.

Homalocladium **(**F. Mueller) L .H. Bailey

Gentes Herb. 2 : 56. 1929.

Undershrubs, striate and glabrous phylloclades. Leaves alternate, lanceolate, entire. Flowers bisexual, sessile clusters at the joints; perianth 5- parted, accrescent in fruit; stamens 8–9, reduced to staminodes or absent in the female flowers; styles 3. stigmas 3, fimbriate; ovary trigonous. Achenes triangular, smooth.

Genus comprises about 23 species worldwide; 2 species in India; only 1 species was recorded from West Bengal.

Homalocladium platycladum (F. Mueller *ex* Hooker) L. H. Bailey, Gentes Herbarum. 2:56. 1929; R. R. Stewart, Ann. Cat. Vasc. Pl. W. Pak. & Kashm. 202. 1972; Maiti & Sikdar, Ind. J. Forestry 8(3): 197. 1985. *Coccoloba platyclada* F. J. Muel. *ex* Hooker, Bot. Mag. 5382. 1863; *Muehlenbeckia platyclada* (F. J. Muel. *ex* Hooker) Meisner, Bot. Zeit. 22: 313. 1865; Parker, For. Fl. Punj. Hazara 424. 1921 (reprint. ed.); Srivastava, Ind. J. Pl. Sc. 3(2): 116. 2014.

Perennial, erect, shrubs with broad, flat, thin, delicately striate, ribbon-like phylloclades. Leaves sessile, 0.9–1.2 × 1.7–2.3 cm, membranous, entire. Ochreae 1–2 mm long, ovate, obtuse. Flowers 1–6, sessile, bracteate, bracts ovate; perianth 5 segments, greenish, oblong, 1–2.3 mm long; stamens 8–9; ovary ovoid, 3-angular; styles 3. Achenes enclosed in the purplish perianth, black, rough.

Flowering & Fruiting: February to May

Specimen examined: India. West Bengal: Darjeeling District, NBU Campus, *Payel Paul & M. Chowdhury 0129*, dated 15.07.2018.

Status: Common; cultivated

General distribution: India (Various Botanical Gardens), Australia, Pacific Islands (New Zealand), America; Darjeeling, Howrah (cultivated)

Note: Entire plants are used for the treatment of anthracia, sores, snake bite, insect bite

Persicaria Miller

Gard. Dict. Abr. ed. 1754; Hooker *f.*, Fl. Brit. Ind. 5: 34. 1886; Grierson & Long, Fl. Bhutan 1(1): 159. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 196. 1985.

Annual or perennial, prostrate-suberect or erect, herbs. Stem herbaceous sometimes woody, simple or branched, round, angular, ridged, glabrous-scabrous or strigose. Leaves alternate, simple, petiolate or sessile or sub sessile, lamina linear-lanceolate or elliptic-ovate, glabrous or hairy, sometime dotted glands. Ochreae tubular, ciliate or sometime eciliate, hyaline, membranous, glabrous or strigose. Flowers in spike, raceme or capitate head; tepals 4–5, divided, occasionally glandular; stamens 5–8; stigmas capitates, ovary biconvex, trigonous. Achenes trigonous, ovoid, glabrous, brown-dark brown or blackish brown, smooth, shiny.

Genus comprises about 131 species worldwide; 56 species in India; 13 species was recorded from West Bengal.

Key to the species:

1a. Flowers on long recemes **2**

1b. Flowers on globose, condense head **3**

2a. Tepals 4; leaves glandular .... ***Persicaria lapathifolia***

2b. Tepals 5; leaves eglandular **4**

3a. Leaves heterophyllous, lamina oblanceolate-rhombate; ochreae glabrous; stamens 5 .. .. ***Persicaria nepalensis***

3b. Leaves homophyllous, lamina ovate; ochreae pubescent; stamens 8 .... ***Persicaria capitata***

4a. Ochreae ciliate **5**

4b. Ochreae not ciliate **6**

5a. Lamina linear - lanceolate; inflorescence terminal or axillary raceme **7**

5b. Lamina elliptic-ovate; inflorescence terminal spicate **8**

6a. Lamina elliptic - ovate **9**

6b. Lamina linear - elliptic **10**

7a. Stamen 6; apex acute - obtuse ..... ***Persicaria hydropiper***

7b. Stamen 8; apex acuminate - caudate ..... ***Persicaria posumbu***

8a. Leaf apex subacute - obtuse; ochreae glabrous; anther basifixed ..... ***Persicaria glabra***

8b. Leaf apex acute-acuminate; ochreae hispidus; anther dorsifixed **11**

9a. Base subcordate; penduncle eglandular; anthers dorsifixed ..... ***Persicaria chinensis***

9b. Base rounded; penduncle glandular; anthers basifixed ..... ***Persicaria campanulata***

10a. Anthers dorsifixed; achenes ellipsoid ..... ***Persicaria minor***

10b. Anthers basifixed; achenes trigonous ..... ***Persicaria tenella***

11a. Ochreae winged, broadly ovate; lamina ovate ..... ***Persicaria orientalis***

11b. Ochreae not winged, tubular; lamina elliptic..... **12**

12a. Lamina base cuneate; stamens 8 ..... ***Persicaria barbata***

12b. Lamina base saggitate; stamens 5–7 ..... ***Persicaria strigosa***

Persicaria barbata (Linnaeus) H. Hara, Fl. E. Himal. 70. 1966; Grierson & Long, Fl. Bhutan 1(1): 162. 1983; Maiti & Sikdar, Ind. J. Forestry 8 (3): 191. 1985. *Polygonum barbatum* Linnaeus, Sp. Pl. 1: 362. 1753; Hooker *f.*, Fl. Brit. Ind. 5: 37. 1886; Prain, Beng. Pl. 2: 663. 1903; Srivastava, Ind. J. Pl. Sc. 3(2): 123. 2014. *Polygonum hispidum* Buchanan-Hamilton *ex* D. Don, Prodr. Fl. Nepal. 71. 1825. ***'Bekh-unjubaz*** or ***Bish'***

Perennial, erect herbs. Stem glabrous, weak, branched, ridged, striated, greenish-brown. Leaves alternate, simple, sessile-subsessile, petiolate, lamina elliptic, 2.9–8.5

× 1.6–3.6 cm, tip acute-acuminate, base cuneate. Ochreae 1.8 × 0.8 cm long, tubular below margin ciliate, densely hispidulous, membranous, brown; fimbriae present, no of the fimbriae 7, length 108.65 µm. Inflorescence terminal, spicate, 2–10 cm long, 1–3 spikes aggregated, pedunculate. Flowers bisexual, glabrous, pedicelate; tepals 5, elliptic, obtuse, entire, unequal in two whorls, 3 outer and 2 inner; stamens 8, anther two celled, dorsifixed; styles 3, filiform, stigmas capitates; ovary broadly ovate, trigonous. Achenes ovoid, trigonous, smooth, shiny, blackish brown.

Flowering & Fruiting: August to October

Specimen examined: India. West Bengal: Darjeeling District, Lochka River Bed, *Payel Paul & M. Chowdhury 0092*, dated 17.03.2017; Jalpaiguri District, Kathambari beel *Payel Paul & M. Chowdhury 0120*, dated 22.05.2017

Status: Very common throughout the plains of West Bengal.

Distribution: Pakistan, India (throughout the temperatrate region), Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, Philippines, China, New Guinea; moist and marshy areas of West Bengal plains.

Note: Watery sap from roots used as antiseptic.

Persicaria campanulata (Hooker *f*.) Ronse Decreane, Bot. J. Linn. Soc. 98: 367. *Aconogonon campanulatum* (Hooker *f*.) H. Hara, FI. East. Himal. 67. 1966; Maiti & Sikdar, Ind. J. Forestry 8 (3): 195. 1985. *Polygonum campanulatum* Hooker *f.* Fl. Brit. Ind. 5: 51. 1886; Srivastava, Ind. J. Pl. Sc. 3 (2): 123. 2014.

Perennial, herbs. Stems glabrous to pilose. Leaves deciduous, alternate, petiolate, lamina elliptic to ovate, 9.83–10.95 × 2.42–3.01 cm, acuminate, base rounded, appressed pilose above, margins entire. Ochreae persistent, tubular, 0.7 × 0.5 cm; fimbriae present, no of the fimbriae 8, length 112.25 µm. Inflorescences terminal, raceme like; peduncle present, glandular. Flowers bisexual; perianth non accrescent, white or pink, rotate, glabrous; tepals 5, connate, petaloid, slightly dimorphic, outer 2 smaller than inner 3; stamens 8, filaments distinct, free, anthers yellow to pink, basifixed; styles 3, erect or spreading, connate proximally, stigmas capitate. Achenes exserted, dark brown, unwinged, trigonous, glabrous

Flowering & Fruiting: July to August

Specimen examined: India. West Bengal: Darjeeling District, Tiger Hill, *Payel Paul & M. Chowdhury 0076,* dated 21.06.2016; Darjeeling, *Payel Paul & M. Chowdhury 0131,* dated 25.07.2018.

Status: Few plants found on the hilly slopes of Darjeeling Himalaya.

Distribution: India (West Bengal, Sikkim), Nepal, Bhutan, Myanmar; Hilly slopes of Darjeeling (Meghma, Tumling upto Sandakphu) at an altitude range from 2590m to 3636m.

Note: The plant is used as ornamental plant.

Persicaria capitata (Buchanan-Hamilton *ex* D. Don) H. Gross, Engl. Bot. Jahrb. 49. 277. 1913; H. Hara, FI. East. Himal. 70. 1966; Grierson & Long, Fl. Bhutan 1(1). 165. 1983; Maiti & Sikdar, Ind. J. Forestry 8 (3): 191. 1985. *Polygonum capitatum* Buchanan-Hamilton *ex* D. Don, Prodr. Fl. Nepal. 73.1825; Hooker *f*., Fl. Brit. Ind. 1: 44. 1886. Srivastava, Ind. J. Pl. Sc. 3 (2): 123. 2014. ***'Ratnyaule jhar'***

Perennial, decumbent herbs. Stem much branched, branches arising from base, reddish brown to black. Leaves alternate, simple, lamina broadly ovate, 2.5–3.14 × 1.21–1.82 cm, petiolate, entire, acute, base cuneate, serrate-undulate, both surfaces glabrous-slightly hairy. Ochreae ovate, tubular, 0.9 × 0.7 cm long, margin ciliate, membranous, pubescent; fimbriae present, no of the fimbriae 8, length 80.26µm. Inflorescence solitary, axillary, capitate head. Flowers pedunculate, hairy; tepals 5, oblanceolate, veins clearly visible, entire, obtuse; stamens 8, anther two celled, dorsifixed; styles 3, long, filiform, connate nearly to the middle, stigmas capitates, ovary trigonous. Achenes trigonous, smooth, black brown and shining

Flowering & Fruiting: May to September

Specimen examined: India. West Bengal: Darjeeling District, Ghoom, *Payel Paul & M. Chowdhury 0029,* dated 21.06.2015; Darjeeling, Lebong road, *Payel Paul & M. Chowdhury 0085,* dated 25.09.2016.

Status: Commonly found throughout the Darjeeling and Kalimpong hills.

Distribution: India (Arunachal Pradesh, Meghalaya, West Bengal, Sikkim), Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia; Darjeeling (Kurseong, Meghma), Kalimpong, at an altitude range from 1247m to 2600m.

Note: Ornamental, whole plant extract used as antidote in snakebite and insect sting.

Persicaria chinensis (Linnaeus) H. Gross, Engl. Bot. Jahrb. 49: 269, 277 & 315. 1913; H. Hara, FI. East. Himal. 70. 1966; Hara *et al*., Enum. Fl. Pl. Nepal 3: 175. 1982; Grierson & Long, Fl. Bhutan 1(1): 163. 1983; Maiti & Sikdar Ind. J. Forestry 8: 191. 1985.

Key to the variety:

1a. Ochreae and both surface of lamina glabrous **2**
1b. Ochreae and both surface of lamina hispidly hairy .... **var. *hispida***
2a. Lamina base truncate or sub-cordate; peduncle eglandular .... **var. *chinensis***
2b. Lamina base cordate; peduncle glandular .. .. **var. *ovalifolia***

Persicaria chinensis (Linnaeus) H. Gross var. ***chinensis*** in Engl. Bot. Jahrb. 49:269. 1913; H. Hara, FI. East. Himal. 70. 1966; Hara *et al*., Enum. Fl. Pl. Nepal 3: 175. 1982; Grierson & Long, Fl. Bhutan 1(1): 163. 1983; Maiti & Sikdar, Ind. J. Forestry 8: 191. 1985. *Polygonum chinense* Linnaeus, Sp. Pl. 1: 363. 1753; Meisnner in DC., Prodr. 14: 130. 1857; Hooker *f.*, Fl. Brit. Ind. 5: 44. 1886. *Ampelygonum chinense* (Linnaeus) Lindley, Bot. Reg. 24. 63. 1838. ***'Kakur thotne'***

Perennial herb or subshrubs, 30–40 cm tall. Stem erect-suberect, somewhat woody, much branched, round, ridged, glabrous, brownish green, internode 3.5–6 cm long. Lamina narrowly ovate-elliptic, lanceolate, 9.5–10.5 × 4.6–5 cm, petiole 5–9 mm long, acute-acuminate, base truncate or sub-cordate, ciliate, revolute, undulate, glabrous. Ochreae 3–4 cm long, glabrous, foliaceous, tubular below, slightly dentate above, lower portion brown and upper whitish in colour, veins clearly visible; fimbriae present, no of the fimbriae 6, length 147.75 µm. Inflorescence terminal or axillary corymb, peduncle eglandular, 3.5–4.5 cm long. Flowers 3–3.8 × 1.3–2.2 mm, pedicel 1 mm long; tepals 5 parted, 3–3.8 × 1–1.6 mm, ovate, entire, acute and glabrous. Stamen 8, filament 2–3 mm, slightly exserted, anther two celled,

dorsifixed; ovary 1.2–1.5 × 0.6–0.8 mm, trigonous, styles 3, 1.3–2 mm long, free above the middle. Nut 1–1.2 × 0.3–0.4 mm, ovoid, trigonous, dark brown.

Flowering & Fruiting: March to September

Specimen examined: India. West Bengal: Kalimpong district, Durpin, *Payel Paul & M. Chowdhury 0022*, dated 03.03.2015; Darjeeling district, Govt. College Road, *Payel Paul & M. Chowdhury 0057*, dated 03.07.2016.

***Status*:** Abundantly found throughout the northern part of the state.

Distribution: India (West Bengal, Sikkim, Karnataka, Kerala, Tamilnadu), Nepal, Bhutan, Sri Lanka, China, Myanmar, Philippines, Vietnam, Japan; introduced in Pakistan; Darjeeling, Kalimpong (Mirik), Jalpaiguri, Alipurduar ditricts in between the altitude ranges from 93 m upto 2042 m.

Note: Root used for fluxes, anthelminthic and neutralizes scorpion poisoning.

Persicaria chinensis (Linneaus) H. Gross var. ***hispida*** Kantachot, Thai. Bull. Bot. 38: 135: 2010. *Polygonum chinense* var. *hispidum* Hooker *f.*, Fl. Brit. Ind. 5: 45. 1886. *Polygonum chinense* var. *scabra* Gage, Rec. Bot. Surv. India 2: 408. 1903; Li *et al*., Fl. China 5. 301. 2003.

Perennial herbs. Stems erect, 84 cm tall, ligneous at base, much branched, striate, retrorsely hispid. Petiole 2 cm, lamina ovate-elliptic, 4–16 × 1.5–8 cm in diameter, apex shortly acuminate, base auriculate, base broadly cordate, both surface hispid, margin entire. Ochreae tubular, 1.2 cm long, membranous, hairy, much veined; fimbriae present, no of the fimbriae 7 – 8, length 156.78 µm. Inflorescence terminal, capitates, 4 mm long, aggregated, hispidly hairy; bract broadly ovate, each 3 flowered. Perianth white, 5-parted, tepals ovate, acrescent in fruit; stamens 8, included; style 3, connate. Achenes included in persistant perianth, black, opaque, broadly ovoid, trigonous, 3 mm long.

Flowering & Fruiting: August to November

Specimen examined: India. West Bengal: Kalimpong district, Durpin, Kalimpong, *Payel Paul & M. Chowdhury*, *0038*, *0040*, *0042*, dated 04. 10. 2015.

Status: Rarely occurring in hilly slopes of Durpin Monastry.

General distribution: India (Khasi Hills of Meghalaya, Kohima of Nagaland) Myanmar, Thailand, China; Kalimpong; Durpin Monastry (New Distributional Record) at an altitude 1372m.

Persicaria chinensis (Linnaeus) H. Gross var. ***ovalifolia*** (Linnaeus) H. Gross, Fl. E. Him. 71. 1966. Maiti & Sikdar, Ind. J. Forestry 8: 192. 1985. *Polygonum chinense* var. *ovalifolium* Meisner, Wall. P1. Asiat. Rar. 3: 60. 1832; Hooker *f*., Fl. Brit. Ind. 5: 45. 1886; Srivastava, Ind. J. Pl. Sc. 3(2): 125. 2014.

Perennial shrubs. Stems erect, much branched, striate, glabrous, and slightly woody. Petiole auriculate at base; lamina ovate, 10–21 × 4.3–9.2 cm, base cordate, margin entire, apex acuminate. Ochreae tubular, 2.7 cm long, glabrous, much veined; fimbriae present, no of the fimbriae 5, length 167.98 µm. Inflorescence terminal, capitates, aggregated penduncle glandular, hispid; Perianth white, 5-parted; tepals ovate, acrescent in fruit; stamens 8, included; style 3, connate. Achenes included in persistant perianth, black, opaque, broadly ovoid, trigonous

Flowering & Fruiting: July to November

Specimen examined: India. West Bengal: Darjeeling district, Kurseong (St Mary Hill), *Payel Paul & M. Chowdhury*, *0051*, *0056*, dated 14. 06. 2016.

Status: Rarely occurring on hilly slopes of Kurseong.

Distribution: India (West Bengal, Sikkim) Malaysia, Myanmar, Nepal, Thailand, S. Japan; Darjeeling (Kurseong) at an altitude of 1371m.

Persicaria glabra (Willdenow) M. Gómes, Ann. Inst. Segunda Ensef. Habana. 2: 278. 1896; Hara *et al*., Enum. Fl. Pl. Nepal. 3: 176. 1982; Grierson & Long, Fl. Bhutan 1(1): 161. 1983; Maiti & Sikdar, Ind. J. Forestry 8 (3): 192. 1985. *Polygonum glabrum* Willdenow, Sp. Pl. 2: 447. 1799; Meisner in DC., Prodr. 14: 115. 1856; Hooker *f*., Fl. Brit. Ind. 5: 34. 1886; Srivastava, Ind. J. Pl. Sc. 3(2): 123. 2014. **'*Bihagni*** or ***Seto Pire'***

Helophytes; perennial, erect herbs. Stem branched, glabrous, nodes swollen, reddish-dark brown. Leaves alternate, simple, petiolate, lamina entire, lanceolate or elliptic-oblong, 6.54–7.36 × 2.02–2.83 cm, acute-acuminate, base cuneate, glabrous on both surfaces. Ochreae tubular, 1.6 × 0.6 mm, margin ciliate, silvery, membranous, glabrous; fimbriae present, no of the fimbriae 9, length 94.96 µm. Inflorescence terminal, axillary, branched raceme. Tepals 5, overlapping, elliptic, entire, acute; stamens 6, anther two celled, basifixed; ovary ovoid, biconvex, styles 2, connate at the base, slightly exserted, stigmas capitate. Achenes biconvex, ovoid, smooth, shiny, brown.

Flowering & Fruiting: March to September

Specimen examined: India. West Bengal: Kalimpong district; Mirik, *Payel Paul & M. Chowdhury 0025*, dated 03.03.2015; Jalpaiguri district, Doumohani Beel, *Payel Paul & M. Chowdhury 0097*, dated 07.04.2017.

Status: Commonly found on the hilly slopes of Darjeeling Kalimpong Himalaya.

Distribution: India (West Bengal, Assam, Arunachal Pradesh), Bhutan, Bangladesh, Sri Lanka, Myanmar, Philippines, Thailand, Vietnam, Africa, Australia, N. and S. America, Pacific Islands; Moist areas throughout West Bengal at an altitudinal range from 9m upto 1495m.

Note: Plant juice and rootstock used in pneumonia, jaundice, fevers. Leaves are antispasmodic and are used for colic.

Persicaria hydropiper (Linnaeus) Spach, Hist. Veg. 10: 536. 1841; H. Hara, FI. East. Himal. 2: 23. 1971; Hara *et al.* Enum. Fl. Pl. Nepal. 3: 176. 1982; Grierson & Long, Fl. Bhutan1(1): 162. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 192. 1985. *Polygonum hydropiper* Linnaeus, Sp. Pl. 1: 361. 1753; Hooker *f.*, Fl. Brit. Ind. 5: 39. 1886; Webb & Chater in Tutin *et al*., Fl. Europ. 1:79. 1964; Srivastava, Ind. J. Pl. Sc. 3(2): 129. 2014. ***'Packur mul*** or ***Pire'***

Hyperhydrate, annual, erect or decumbent herbs. Stem simple or branched from base, glabrous, round, ridged, light brown-dark brown, nodes swollen, base woody. Leaves alternate, simple, petiolate, lamina 6.32–7.01 × 1.62–2.01 cm, lanceolate-

narrowly elliptic, acute-obtuse, ciliate, cuneate, both surfaces glabrous. Ochreae cylindrical, 18 × 9 mm, margin ciliate, cilia shorter than tubular portion, scabrous, fimbriae present, no of the fimbriae 12, length 70.79 µm. Inflorescence terminal spicate; flowers pedunculate. Tepals 5, entire, obtuse, elliptic, obovate; stamens 6, anther two celled, basifixed; styles 3, stigmas capitates, ovary trigonous. Achenes trigonous, dark brown and smooth.

Flowering & Fruiting: April to October

Specimen examined: India. West Bengal: Jalpaiguri district, Doumahoni Beel, *Payel Paul & M. Chowdhury 0050*, dated 02.04.2016; Darjeeling district, Kurseong, *Payel Paul & M. Chowdhury 0061*, dated 22.07.2016.

Status: Abundantly found on moist areas.

Distribution: Pakistan, India, Japan, Temperate Asia, N. and W. Africa, N. America, Europe; throughout marshy lands of West Bengal at an altitudinal range from 9 m to 1098 m (Humalaya).

Note: Seeds, leaves used for treatment of arthritis, bladder stone and cholera.

Persicaria lapathifolia (Linnaeus) S. F. Gray, Nat. Arr. Brit. Pl. 2: 270. 1821.

Key to the variety:

1a. Plant glabrous or sub glabrous, green ....**var. *lapathifolia***
1b. Plant sparsely pubescent, silvery .... **var. *lanata***

Persicaria lapathifolia (Linnaeus) S. F. Gray var. ***lapathifolia*** Nat. Arr. Brit. Pl. 2: 270. 1821; Hara *et al.* Enum. Fl. Pl. Nepal 3: 176. 1982; Grierson & Long, Fl. Bhutan 1(1): 161.1983. *Polygonum lapathifolium* Linnaeus Sp. Pl. 1: 360. 1753; Hooker *f*., Fl. Brit. Ind. 5: 35.1886; Maiti & Sikdar, Ind. J. Forestry 8(3): 189. 1985. Srivastava, Ind. J. Pl. Sc. 3(2): 130. 2014. *Polygonum lanatum* Roxburgh, Fl. Ind. 2: 285. 1832. *Polygonum nutans* Roxburgh, Fl. Ind. 2: 285. 1832.

Helophytes; Annual, erect herbs. Stem erect reddish brown to brown, upper portion leafy and hollow, base woody, round and ridged, swollen, glabrous or pubescent. Leaves alternate, simple, petiolate, lamina lanceolate-narrowly elliptic, 4–12.1 × 0.9–

3.4 cm, glandular, acute-subacute or obtuse, base attenuate-cuneate, entire, ciliate, upper surface glabrous or pubescent. Ochreae tubular, 2.4 × 0.8 cm, ovate, entire, dark brown, glabrous or pubescent; fimbriae present, no of the fimbriae 9, length 132.22 µm. Inflorescence axillary raceme, pedunculate. Tepals 4, in two whorls, whitish, elliptic, 2 tepals with acute apex and 2 obtuse, entire; stamens 6, unequal, filament thin, anther two celled and basifixed; styles 2, filiform, free above connate below, stigmas capitates; ovary biconvex. Achenes broadly ovate, biconvex, shining, blackish brown.

Flowering & Fruiting: March to September

Specimen examined: India. West Bengal: Darjeeling district, Ghoshpukur, *Payel Paul & M. Chowdhury 0045*, dated 20.03.2016; Doumahoni Beel, *Payel Paul & M. Chowdhury 0094*, dated 02.04.2017.

Status: Commonly found throughout the marshy land.

Distribution: India (West Bengal, Assam, Manipur, Tamilnadu), Pakistan, Temperate Asia, Japan, N. and W. Africa, N. America, Europe; throughout marshy lands of West Bengal at an altitudinal range from 9 m to 945 m (Himalaya).

Note: Decoctions from root used as cathartic and emetic drug.

Persicaria lapathifolia (L.) Delarbre var. ***lanata*** (Roxb.) H. Hara, Enum. Fl. Pl. Nepal 3: 176 1982.

Annual, erect herbs. Stem erect reddish brown to brown, upper portion leafy and hollow, base woody, round and ridged, swollen, pubescent. Leaves alternate, simple, petiolate, lamina lanceolate-narrowly elliptic, 8.32–13.5 × 3.5–4.6 cm, entire, glandular, acute-subacute or obtuse, base attenuate-cuneate ciliate, upper surface pubescent. Ochreae tubular, 2.34 × 1.13 cm, ovate, entire, dark brown, glabrous; fimbriae present, no of the fimbriae 5, length 149.87 µm. Inflorescence axillary raceme, pedunculate. Tepals 4, in two whorls, whitish, elliptic, 2 tepals with acute apex and 2 obtuse, entire; stamens 6, unequal, filament thin, anther two celled and basifixed; styles 2, filiform, free above connate below, stigmas capitates; ovary biconvex. Achenes broadly ovate, biconvex, shining, blackish brown.

Flowering & Fruiting: March to November

Specimen examined: India. West Bengal: Jalpaiguri District, Kathambari beel, *Payel Paul & M. Chowdhury 0053*, dated 26.05.2016; Darjeeling district, Siliguri, *Payel Paul & M. Chowdhury 0125*, dated 12.04.2018.

Status: Commonly found throughout the marshy land.

Distribution: India (West Bengal), Pakistan, China, Temperate Asia, Japan, N. America, Europe; throughout marshy lands of West Bengal at an altitudinal range from 89 m upto 140 m.

Persicaria minor (Hudson) Opiz, Seznam 72. 1852; Maiti & Sikdar, Ind. J. Forestry 8(3): 185. 1985. *Peutalis minus* (Hudson) Rafinesque, Fl. Tellur. 3: 14. 1837. *Polygonum minus* Hudson, Fl. Angl. 148. 1762.

Annual, creeping herbs. Stem glabrous. Lamina linear-lanceolate, 12.32–19.78 × 8.5–9.6 cm, scabrid below. Ochrea 7–10 mm long, shortly bristled at mouth. Inflorescence racemes like, 3 cm long, cylindrical, terminal; fimbriae present, no of the fimbriae 3 – 4, length 65.78µm. Flowers closely packed; tepals 5, pink, obtuse, ovate, united at base; stamens 5, anthers bicelled, dorsifixed; stigma capitates. Achenes biconvex, ellipsoid, brown, shining.

Flowering & Fruiting: April to August

Specimen examined: India. West Bengal: Jalpaiguri district, Doumohini beel, *Payel Paul & M. Chowdhury 0129*, dated 10.07.2018.

Status: Few species are found in small water bodies.

Distribution: India (West Bengal, Kerala), Malaysia, Thailand, Vietnam, Indonesia, Australia; throughout marshy lands of North Bengal at an altitude range from 24 m to 89 m.

Note: Young shoot and leaves are edible; Decoctions from leaves has been used in post-natal tonics and for treatment of digestion oil has been used for aromatherapy and in treatments for dandruff.

Persicaria nepalensis (Meisner) H. Gross, Bot. Jahrb. 49(2): 277. 1913; Hara *et al*., Fl. East. Himal. 72. 1966; Grierson & Long, Fl. Bhutan 1(1):164. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985. *Polygonum nepalense* Meisner, Monog. Polyg. 84. 1826; Hooker *f*., Fl. Brit. Ind. 5: 41. 1886; Srivastava, Ind. J. Pl. Sc. 3(2): 132. 2014. *Polygonum punctatum* Buchanan-Hamilton *ex* D. Don, Prodr. Fl. Nepal. 73. 1825. ***'Ratnaaulo*** or ***Priya Ghaans*** or ***Raunne'***

Annual herbs. Stem simple or branched, round, glabrous, sometime upper portion of branches bear hair like structures with glandular tip. Leaves heterophyllous, petiole slightly winged, upper leaves oblanceolate-rhombate, lower leaves broadly ovate-rhomboid, 1.8–5.09 × 1.23–3.5 cm, base auricled, base truncate, margin entire-slightly hairy, gland dots are present. Ochreae tubular, 0.56 × 0.21 cm, truncate, upper portion glabrous, lower strigose, brownish; fimbriae absent. Inflorescence corymbose head, axillary, pedunculate. Flowers shortly pedicellate; tepals 4, obtuse, obovate; stamens 5, filament unequal, anther two celled, basifixed; ovary biconvex, styles 2, united below, stigmas capitate. Achenes biconvex, smooth, shining, light brown to dark enclosed in perianth.

Flowering & Fruiting: June to September

Specimen examined: India. West Bengal: Darjeeling district, Kurseong, *Payel Paul & M. Chowdhury 0065*, dated 22.07.2016; Darjeeeling district, Tumling, *Payel Paul & M. Chowdhury 0121*, dated 15.04.2018.

Status: Commonly found on the hilly slopes of Darjeeling Kalimpong Himalaya.

Distribution: Pakistan, Afghanistan, India (Arunachal Pradesh, Meghalaya, Kashmir to Sikkim), Nepal, Bhutan, China, Japan, Malaysia, Thailand, Indonesia, Philippines, Korea, Russia, New Guinea, Tropical Africa; Darjeeling (Kurseong upto Meghma), Kalimpong at an altitude range from 1250m to 2600m.

Note: Whole plant extract used in the treatment of swelling.

Persicaria orientalis (Linnaeus) Spach, Syst. Veg. 537. 1841; Grierson & Long, Fl. Bhutan 1(1): 161. 1983. *Persicaria orientale* Assenov, FI. Reipubl. Popul. Bulgar. 3: 250. 1966; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985. *Polygonum orientale*

Linnaeus, Sp. Pl. 1: 362. 1753; Hooker *f.*, Fl. Brit. Ind. 5: 30. 1886; Prain, Beng. Pl. 2: 663. 1903; Srivastava, Ind. J. Pl. Sc. 3(2): 133. 2014. *Persicaria pilosum* Roxburgh, Fl. Ind. 2: 286. 1832. *Persicaria tibetica* Rendle, J. Bot. 428. 1900. *Amblyogonum orientale* (Linnaeus) Nakai in Mori., Enum. Pl. Cor. 192. 1922. '***Bishkatala'***

Helophytes; annual, erect herbs. Stem round and ridged, strigose, olive green-brown, nodes clearly swollen, base woody. Leaves alternate, simple, petiolate, densely strigose, lamina broadly ovate, 5.5–14 × 2.9–6.2 cm, acute-acuminate, base truncate, ciliate, entire-undulate. Ochreae tubular, broadly ovate, margin ciliate, strigose. Inflorescence terminal raceme, pedunculate, hirsute. Tepals 5, unequal, gland dotted, lanceolate-ovate, entire, obtuse; stamens 7, filament unequal, anther two celled, basifixed; styles 2, united up to middle, stigmas capitates, ovary biconvex. Achenes trigonous, biconvex, brownish black.

Flowering & Fruiting: May to September

Specimen examined: India. West Bengal: Jalpaiguri district, Doumohini beel, *Payel Paul & M. Chowdhury 0031*, dated 17.07.2015; Malda district, Nayagram beel, *Payel Paul & M. Chowdhury 0101*, dated 16.04.2017.

Status: Abundantly grows on moist areas.

Distribution: India (West Bengal, Asssam, Kerala), China, Japan, Korea, Malaysia, Thailand, Indonesia, Philippines; throughout moist areas of the West Bengal at an altitudinal range from 25m to 142m.

Note: Ornamental; nuts are used in tuberculous swellings and flatulence; decoction of the ripe fruits is used in the treatment of hepatitis, sloughing ulcers, tympanites and cancer.

Persicaria posumbu (Buchanon-Hamilton *ex* D. Don) H. Gross, Engl. Bot. Jahrb. 49: 313. 1913; H. Hara, FI. East. Himal. 73. 1966; Hara *et al*., Enum. Fl. Pl. Nepal 3: 177. 1982; Grierson & Long, Fl. Bhutan 1(1): 162. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985. *Polygonum posumbu* Buchanon-Hamilton *ex* D. Don, Fl. Nepal. 71. 1825; Hooker *f.*, Fl. Brit. Ind. 5: 38. 1886; R. R. Stewart, Ann. Cat. Vasc.

Pl. W. Pak. & Kashm. 211. 1972; Srivastava, Ind. J. Pl. Sc. 3(2): 136. 2014. *Polygonum caespitosum* Blume, Bijdr. 532. 1826; *Polygonum donii* var. *tenerum* Meisn. in Wall. Pl. As. Rar. 3: 58. 1832.

Perennial, herbs. Stem erect, decumbent, angular, ridged, glabrous, light brown. Leaves alternate, petiolate, slightly pubescent, lamina narrowly ovate or elliptic - lanceolate, 1.7–4.5 × 1.2–1.5 cm, acuminate-caudate, base cuneate, entire, pubescent, on upper surface midrib vein network sparsely strigose. Ochreae 1.8–3.1 cm, hyaline, membranous, tubular below, ciliate, cilia shorter, glabrous; fimbriae present, no of the fimbriae 6–7, length 81.38 µm. Inflorescence axillary or terminal, raceme with variable number of flowers, pedunclate, glabrous. Tepals 5-parted, 2–3 × 1.9–2.3 mm, obtuse, slightly undulate; stamens 8, unequal, exserted, filament long, anther to celled and basifixed; ovary trigonous, oblong with 3 styles which are united below, stigmas capitate. Achenes trigonous, ovoid, blackish brown, smooth and shiny.

Flowering & Fruiting: May to October

Specimen examined: India. West Bengal: Malda district, Nayagram beel, *Payel Paul & M. Chowdhury 0140*, dated 21.08.2018.

Status: Commonly occurring in marshy land.

Distribution: India (West Bengal, Sikkim, Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland), Nepal, Bhutan, China, Bangladesh, Malaysia; Marshy areas of North Bengal plains at an altitudinal range from 17m to 1560 m.

Note: Decoction is used in the treatment of dysentery, enteritis, boils and abscesses; aromatic leaves are added to other vegetables for flavor.

Persicaria strigosa (R. Brown) Nakai, Rigakkwai 24: 299 1926; Maiti & Sikdar, Ind. J. Forestry 8(3): 194. 1985. *Polygonum bodinieri* H. Léveille & Vaniot, Bull. Acad. Int. Géogr. Bot. 11: 343 1902. *Polygonum strigosum* R. Brown, Prodr. Fl. Nov. Holl. 420 1810; Hooker *f.*, Fl. Brit. Ind. 5: 47. 1886; Prain, Beng. Pl. 2: 664. 1903; Srivastava, Ind. J. Pl. Sc. 3(2): 139. 2014. *Tracaulon strigosum* (R. Brown) Greene, Leafl. Bot. Observ. Crit. 1: 22 1904.

Hyperhydrate; annual, erect or decumbent herbs. Stems branched, angulate. Leaves alternate, simple, petiolate, laminaelliptic or lanceolate, 17– 23.34 × 4.2–8.5 cm, glabrous or sparsely strigose adaxially, acuminate or acute, base sub sagittate or hastate margin ciliate. Ochreae tubular, 1.7 × 0.6 cm, membranous, with dense strigose at base, apex truncate, long ciliate; fimbriae present, no of the fimbriae 8, length 132.85 µm. Inflorescence spicate; peduncle branched, 2 or 3-flowered, densely pubescent, sparsely glandular hairy; bracts elliptic or ovate, usually strigose. Tepals 5-parted, elliptic, pinkish; stamens 5–7; styles 2–3, stigmas capitate. Achenes biconvex or trigonous, perianth persistent, dark brown, dull, nearly orbicular.

Flowering & Fruiting: May to October

Specimen examined: India. West Bengal: Darjeeling district, Ghoom, *Payel Paul & M. Chowdhury 0037*, dated 15.07.2015; Jalpaiguri district, Kathambari beel, *Payel Paul & M. Chowdhury 0091*, dated 15.03.2017.

Status: Commonly found on moist places.

Distribution: India (West Bengal, Himalchal Pradesh, Uttarakhand) Nepal, Bhutan, Bangladesh, Myanmar, Malaysia, Thailand, Indonesia, Vietnam, Australia, New Guinea; Darjeeling (Kurseong, Tiger hill), marshy areas of Jalpaiguri at an altitudinal range from 89m to 3260m.

Note: Tender roasted shoots are used for the dysentery of cattles

Persicaria tenella (Blume) Hara, J. Jap. Bot. 44: 375. 1969; Hara *et al.*, Fl. E. Himal. 2: 23. 1971; Grierson & Long, Fl. Bhutan 1(1): 163. 1983. *Polygonum tenellum* Blume, Bijdr. 530. 1825. *Polygonum minus* Hooker *f.*, Fl. Brit. Ind. 5: 36. 1886. *Polygonum kawagoeanum* Makino, Bot. Mag. Tokyo 28: 115. 1914; Srivastava, Ind. J. Pl. Sc. 3(2): 130. 2014. *Persicaria kawagoeana* (Makino) Nakai, Rigakukai 24: 12. 1926; Prain, Beng. Pl. 2: 663. 1903; Munshi & Javeid, Polygon. Syst. Stud. Kashm. Himal. 64. 1986; Maiti & Sikdar, Ind. J. Forestry 8(3): 192. 1985. *Polygonum tenellum* var. *kawagoeanum* (Makino) Murata, Acta Physt. Geobot. 26: 88. 1974.

Helophytes; annual, erect-ascending herbs. Stem, terete, ridged, reddish, internode. Leaves alternate, simple, sessile-subsessile, lamina linear-lanceolate, oblong, 1.5–6.9 × 0.3–1.4 cm, subacute-obtuse, base attenuate, ciliate, glabrous above and below. Ochreae tubular, 0.5 × 0.6 cm, membranous, papery, margin shortly ciliate; fimbriae present, no of the fimbriae 10, length 104.85 µm. Inflorescence axillary or terminal raceme, pedunculate. Tepals 5, unequal, oblanceolate, acute, entire; stamens 5, anthers two celled, basifixed; style 3, connate below stigmas capitates; ovary orbicular. Achenes biconvex, trigonous, smooth, shining, dark brown.

Flowering & Fruiting: March to September

Specimen examined: India, West Bengal: Kalimpong district, Kalimpong College campus, *Payel Paul & M. Chowdhury 0033*, Dated 17.07.2015; Darjeeling district, Lochka River Bed, *Payel Paul & M. Chowdhury 0043*, Dated 08.03.2016.

Status: Abundantly grows on moist land.

Distribution: India (Himachal Pradesh, Jammu and Kashmir, N. E. India specially Assam, Manipur, Meghalaya, Sikkim, Uttarakhand, Tamilnadu), Pakistan, Nepal, China, Japan, Bangladesh, Myanmar, Malaysia, Europe; throughout the moist lands of North Bengal plains at an altitude range from 65m to 1750m.

Polygonum Linnaeus

Sp. Pl. 359. 1753; Hooker *f*., Fl. Brit. Ind. 5:23. 1886.

Marshland, annual or perennial, prostrate-erect, sometimes shrubby, simple or branched herbs. Stem branched from base with procumbent or decumbent branches, round or angular, smooth or ridged, glabrous or scabrous with variable colours. Leaves small, sessile or subsessile, lamina linear, lanceolate, elliptic – oblong, acute or acuminate-aristate or obtuse, cuneate, entire, revolute, undulate, pubescent or scabrous. Ochreae small, silvery or whitish, hyaline, membranous, tubular, lacerate, sometimes so numerous giving the whole plant whitish appearance. Inflorescence axillary, solitary or in few flowered cluster. Tepals 5–6, elliptic-ovate, lanceolate or of variable shape, may be unequal in size; stamens 5–6 or 8, filaments short, may be unequal, dilated at the base, anther two celled, dorsifixed or basifixed; 2–3 styles

with capitate stigmas; ovary ovate, trigonous,. Nuts biconvex, ovate, trigonous, dark brown, black, shining, smooth, striated, sometimes hairy.

Genus comprises about 60 species worldwide; 38 species in India; 7 species was recorded from West Bengal.

Key to the species:

1a. Lamina pinnatified, runcinate..... .... ***Polygonum runcinatum***
1b. Lamina not pinnatified, elliptic – lanceolate or ovate – oblong **2**
2a. Ochreae glabrous **3**
2b. Ochreae pubescent **4**
3a. Stem retrosely prickled; lamina triangular, peltate .... ***Polygonum perfoliatum***
3b. Stem glabrous; lamina elliptic – lanceolate **5**
4a. Aromatic; hairs glandular, viscous; bracts pubescent…….. ……. ……... ..... ***Polygonum viscosum***
4b. Non aromatic; hairs non glandular, bracts glabrous .... …… ……. ……. …..... ***Polygonum pubescens***
5a. Petioles winged, not auriculate; lamina base cordate ..... …….. ……... ***Polygonum microcephalum***
5b. Petioles not winged, auriculate; lamina base cuneate **6**
6a. Flowers on axillary fascicles; prostrate small herbs.... ... . ……. ……... ……..... ***Polygonum plebeium***
6b. Flowers on panicle; erect, large bushy shrubs .... ***Polygonum molle***

Polygonum microcephalum D. Don, Prodr. Fl. Nepal. 72. 1825; Hooker *f.*, Fl. Brit. Ind. 5:42. 1886; Srivastava, Ind. J. Pl. Sc. 3(2): 131. 2014. *Persicaria microcephala* (D. Don) H. Gross in Engler, Bot. Jahrb. 49: 277. 1913; Hara *et al.*, FI. East. Himal. 72. 1966; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985.

Perennial, erect or decumbent herbs. Rhizomes stout. Stems angulate, branched. Leaves alternate, simple, petiole winged, lamina broadly ovate or triangular-ovate, 18.5–23.33 × 5.02–7.67 cm, both surfaces glabrous-pilose, acuminate, base subrounded, decurrent along petiole forming a wing, margin entire, ciliate. Ochreae tubular, 1.8 × 0.4 cm, pubescent, apex truncate, ciliate; fimbriae present, no of the fimbriae 7, length 89.25 µm. Inflorescence terminal, usually geminate, capitates;

peduncle glabrous or glandular hairy; bracts ovate, apex acute. Tepals 5-parted, white or pinkish, elliptic; stamens 8; styles 3, connate to below middle; stigmas capitate. Achenes black-brown, opaque, broadly ovoid, trigonous, punctuate.

Flowering & Fruiting: April to October

Specimen examined India. West Bengal: Darjeeling district, Govt. College road, *Payel Paul & M. Chowdhury 0073*, dated 21.06.2016; Darjeeling district, Singamari, *Payel Paul & M. Chowdhury 0133*, dated 25.07.2018.

Status: Rarely occuring on the hilly slopes of Darjeeling - Kalimpong Himalaya.

Distribution: India (Assam, Meghalaya, Nagaland, Sikkim), Nepal, Bhutan, China, Bangladesh; Temperate hilly areas of Darjeeling, Kalimpong at an altitude range from 1260 m to 3456 m.

Note: Young shoot and seeds are used as vegetable and condiment respectively.

Polygonum molle D. Don Prodr. Fl. Nepal. 72. 1825; Hooker *f*., Fl. Brit. Ind. 5: 50. 1886; Maiti & Sikdar, Ind. J. Forestry 8(3): 195. 1985; Srivastava, Ind. J. Pl. Sc. 3(2): 132. 2014. *Aconogonum molle* (D. Don) H. Hara, Fl. E. Himal. 68. 1966. *Persicaria mollis* (D. Don) H. Gross, Bull. Géogr. Bot. 23: 31. 1913. *Polygonum molle* var. *frondosum* (Meisner) A. J. Li, Fl. Xizangica. 1: 622. 1983. ***'Tuknu*** or ***Patusua'***

Annual, erect or sometimes ascending, bushy subshrubs. Stems much branched, retrorsely hirsute or glabrous. Leaves alternate, simple, petiolate, densely pubescent or glabrous, lamina elliptic or elliptic-lanceolate, 19.87–23.36 × 15.33–16.09 cm, acuminate, base cuneate, entire, both surfaces glabrous. Ochreae dark brown, 0.7 × 0.4 cm, tubular, membranous, oblique, glabrous; fimbriae present, no of the fimbriae 8, length 116.87 µm. Inflorescence spreading, paniculate. Tepal 5-parted, white, elliptic, accrescent and fleshy in fruit, darkened; stamens 8; styles 3, free, stigmas capitate. Achenes trigonous, ovoid, slightly exceeding perianth, black, shiny.

Flowering & Fruiting: August to November

Specimen examined: India. West Bengal: Kalimpong district, Durpin, *Payel Paul & M. Chowdhury 0024*, dated 03.03.2015; Darjeeling district, Kurseong, *Payel Paul & M. Chowdhury 0066*, dated 22.07.2016; Darjeeling district, Sandhakphu, *Payel Paul & M. Chowdhury 0122*, dated: 15.04.2018.

Status: Abundantly grown on the temperate hilly region.

Distribution: India (Arunachal Pradesh, Sikkim), Nepal, Bhutan, N Myanmar, Thailand, Indonesia; throughout the temperate hilly areas of Darjeeling (Kurseong, Tumling, Meghma upto Sandakphu), Kalimpong at an altitude range from 1267 m to 3636 m.

Note: The whole plant used as astringent; young shoot, leaves and seeds are edible

Polygonum perfoliatum Linnaeus, Syst. Nat., ed. 10, 2:1006. 1759; Hooker *f*., Fl. Brit. India 5: 46. 1886; Prain, Beng. Pl. 2: 664. 1903; Srivastava, Ind. J Pl. Sc. 3(2): 134. 2014. *Persicaria perfoliata* (L.) H. Gross in Engl., Bot. Jahrb. 49: 275. 1913; Hara *et al*., FI. East. Himal. 72. 1966; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985. *Ampelygonum perfoliatum* (Linnaeus) Roberty & Vautier, Boissiera 10: 31. 1964. *Fagopyrum perfoliatum* (Linnaeus) Raffinose, Fl. Tellur. 3: 10. 1837. *Truellum perfoliatum* (Linnaeus) Soják, Preslia 46: 148. 1974.

Annual, weak, large marshland herbs. Stems trailing, branched, angulate, with retrorse prickles along angles, red-brown. Leaves alternate, simple, petiolate, sparsely retrorsely prickly, lamina triangular-peltate, 3.5–5.49 × 1.3–2.97 cm, abaxially usually sparsely retrorsely prickly along veins, adaxially glabrous, subacute, base truncate or subcordate. Ochreae tubular, 1.34 × 0.63 cm, with green herbaceous orbicular wing at apex; fimbriae present, no of the fimbriae 3, length 62.59 µm. Inflorescence terminal or axillary, spicate, bracts ovate-orbicular, each 2–4 flowered. Tepals 5-parted, elliptic, white or pinkish, in fruit dark blue, accrescent, fleshy; stamens 8, in 2 whorls, included; styles 3, connate at middle. Achenes with persistent perianth, black, shiny, globose

Flowering & Fruiting: June to October

Specimen examined: India. West Bengal: Alipurduar district, Palasbari, *Payel Paul & M. Chowdhury 0126*, dated 13.06.2018.

Status: Rarely occurring.

Distribution: India (Himachal Pradesh, Jammu and Kashmir, Uttarakhand West Bengal, Sikkim, Arunachal Pradesh), Nepal, Bhutan, China, Japan, Korea, Bangladesh, Vietnam, Malaysia, Thailand, Indonesia, Philippines, New Guinea, Russia, N. America; Darjeeling Himalaya, Coochbeher at an altitude range 48 m upto 2080 m.

Note: Tender leaves, shoots and fruit are edible; whole plant is depurative, diuretic, febrifuge and also used to stimulate blood circulation; decoction is used in the treatment of dysentery, enteritis, boils and abscesses, poisonous snake bites, haematuria, cloudy urine and traumatic injuries.

Polygonum plebeium R. Brown, Prodr. Fl. Nov. Holl. 420. 1810; Hooker *f*., Fl. Brit. Ind. 5: 27. 1886; Prain, Beng. Pl. 2: 662 1903; Hara *et al*., FI. East. Himal.75. 1966; Maiti & Sikdar, Ind. J. Forestry 8(3): 189. 1985; Srivastava, Ind. J. Pl. Sc. 3(2): 132. 2014. *Avicularia indica* Didrichs, Bot. Not. 1850: 187. 1850. *Polygonum changii* Kitagawa, J. Jap. Bot. 40(2): 54. 1965. *Polygonum herniarioides* Sprengel, Syst. Veg. 2: 256. 1825. *Polygonum roxburghii* Meisner, Prodr. 14: 93. 1856. ***'Chemti sag*** or ***Bethe'***

Annual, prostrate herbs. Stems much branched at base. Leaves alternate, simple, sessile or sub-sessile, lamina narrowly elliptic or oblanceolate, 0.5–1.0 × 0.1–0.2 cm, entire, obtuse or acute, base narrowly cuneate. Ochreae white, 0.5 × 0.8 cm, membranous, apex lacerate; fimbriae present, no of the fimbriae 11, length 68.41 µm. Flowers in axillary fascicles; bracts membranous; tepals 5-parted, narrowly elliptic, abaxially with prominent veins; stamens 5, filaments included; styles 3, rarely 2, very short, stigmas capitates. Achenes broadly ovoid, trigonous or biconvex, smooth, persistent perianth, black-brown, shiny.

Flowering & Fruiting: May to August

Specimen examined: India. West Bengal: Darjeeling district, Sukna forest, *Payel Paul & M. Chowdhury 0063, 0064*, dated 15.07.2016.

Status: Commonly found throughout the plains.

Distribution: Kazakhstan, India (Andhra Pradesh, Assam, Daman, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, West Bengal), Nepal, Myanmar, Philippines, Indonesia, Thailand, Japan, N. Africa, Australia, Russia, Europe (introduced); throughout the plains of West Bengal at an altitude ranges from 20 m upto 140 m.

Note: Leaves used for the treatment of pneumonia and young leaves are used as vegetable; roots are used in treatment of baldness.

Polygonum pubescens Blume, Bijdr. F1. Ned. Ind. 532. 1826. *Polygonum flaccidum* Meisner, Prodr. 14(1): 107. 1856; Hooker *f.*, Fl. Brit. Ind. 5: 39.1886; Prain, Beng. Pl. 2: 664. 1903; Srivastava, Ind. J. Pl. Sc. 3(2): 136. 2014. *Persicaria pubescens* (Blume) H. Hara, J. Jap. Bot. 17(6): 335. 1941; Maiti & Sikdar, Ind. J. Forestry 8(3): 193. 1985. *Polygonum hydropiper* var. *flaccidum* (Meisner) Steward, Contr. Gray Herb. 88: 59 1930.*Polygonum hydropiper* var. *hispidum* (Buchanan-Hamilton *ex* D. Don) Steward, Contr. Gray Herb.88: 60 1930.

Annual, erect, marshland herbs. Stems erect, sparsely hispid, branched above, swollen at nodes. Leaves, alternate, simple, petiolate, lamina ovate-lanceolate or broadly lanceolate, 21.32–23.0×8.76–9.58 cm, apex acuminate-acute, base broadly cuneate, both surfaces densely hispidulous, margin ciliate. Ochreae tubular, 1.1 × 0.8 cm, membranous, hispid, apex truncate, stoutly long ciliate; fimbriae present, no of the fimbriae 5, length 109.87 µm. Inflorescence terminal or axillary spicate, interrupted below; bracts green, funnel-shaped, margin sub membranous, ciliate, each 3- or 4-flowered; pedicels longer than bracts, slender. Tepals 5-parted, green, red above, glandular punctuate, elliptic; stamens 8; styles 3, connate to below middle. Achenes ovoid, trigonous, persistent perianth, black.

Flowering & Fruiting: August to November

Specimen examined: India. West Bengal: Darjeeling district, Lochka River Bed, *Payel Paul & M. Chowdhury 036*, dated 12.09.2015; Darjeeling district, Lebong road, *Payel Paul & M. Chowdhury 0100*, dated 22.04.2017.

Status: Few plants occur on the moist places.

Distribution: India (West Bengal, Kashmir, Himachal Pradesh), Bhutan, Indonesia, Japan, Korea; throughout moist areas of West Bengal at altitude range of 10 m to 3125 m.

Note: Leaves and seeds are edible; decoction of the plant, combined with onion, is used as a styptic; bruised plant is applied locally to blistered and swollen feet.

Polygonum runcinatum Buchanan-Hamilton *ex* D. Don, Prodr. Fl. Nepal. 73 1825; Hooker *f.*, Fl. Brit. Ind. 5:43.1886; Srivastava, Ind. J. Pl. Sc. 3(2): 138. 2014. *Persicaria runcinata* (Buchanan-Hamilton *ex* D. Don) H. Gross in Englar, Bot. Jahrb. 49: 277. 1913; Hara *et al*., FI. East. Himal. 74. 1966; Maiti & Sikdar, Ind. J. Forestry 8(3): 194. 1985. *Polygonum panduriforme* H. Léveilli & Vaniot, Bull. Acad. Int. Géogr. Bot. 11: 343. 1902. ***'Seto pire'***

Perennial, suberect or ascending herbs. Rhizomes stout. Stems angulate, pilose or subglabrous, usually nodes retrorsely appressed hispid. Leaves simple, alternate, petiolate, narrowly winged, base auriculate, lamina pinnatifid, terminal lobe triangular, large, 18.76–23.34×11.76–15.58 cm, apex acuminate, lateral lobes smaller, margin shortly ciliate, both surfaces sparsely strigose or glabrous. Ochreae tubular, 0.6 × 0.3 cm, membranous, pubescent, apex truncate, ciliate; fimbriae absent. Inflorescence terminal, corymbose or paniculate, peduncle glandular hairy; bracts narrowly ovate, margin membranous; pedicels shorter than bracts, slender. Tepals 5-parted, pinkish or white; narrowly ovate; stamens usually 8; anthers purple; styles 3. Achenes ovoid, trigonous, persistent perianth, black-brown, opaque.

Flowering & Fruiting: July to September

Specimen examined: India. West Bengal: Darjeeling district, Lebong Road, *Payel Paul & M. Chowdhury 0069*, dated 27.07.2016; Darjeeling district, Govt. College Road, *0139*, dated 19.07.2018

Status: Commonly found on temperate hilly slopes.

Distribution: India (Jammu and Kashmir, Nagaland, Sikkim, Assam, Tamilnadu), Nepal, Myanmar, Malaysia, Philippines, Thailand, Indonesia (Sumatra); Temperate parts of Darjeeling (Kurseong), Kalimpong (Mirik) at an altitude range from 1540 m to 3437 m.

Note: Leaves are edible.

Polygonum viscosum Buchanan-Hamilton *ex* D. Don, Prodr. Fl. Nepal. 71. 1825; Hooker *f.*, Fl. Brit. India 5: 36. 1886; Prain, Beng. Pl. 2: 663. 1903; Srivastava, Ind. J. Pl. Sc. 3(2): 141. 2014. *Persicaria viscosa* (Buchanan-Hamilton *ex* D. Don) Nakai, Rigakkai 24: 300. 1926; Hara, Fl. East. Himal. 24. 1971; Maiti & Sikdar, Ind. J. Forestry 8(3): 194. 1985. *Polygonum kuekenthalii* H. Léveilli, Cat. Pl. Yun-Nan. 207. 1916. ***'Bishkatali'***

Annual, erect or ascending, herbs. Stems much branched, densely hirsute and glandular hairy. Leaves alternate, simple, seseelie or sub-sessile, lamina ovate-lanceolate or elliptical-lanceolate, 25.65 – 29.87× 11.87 – 14.09 cm, both surfaces hispid, densely so along veins, margin entire, densely shortly ciliate. Ochreae tubular, 1.9 × 0.6 cm, membranous, densely glandular hairy and hirsute, apex truncate, long ciliate; fimbriae present, no of the fimbriae 10, length 112.22 µm. Inflorescence terminal or axillary spicate, usually several spikes aggregated and panicle-like; peduncles densely hirsute and glandular hairy; bracts funnel-shaped, hirsute and glandular hairy, margin sparsely long ciliate, each 3–5 flowered; pedicels longer than bracts; tepals 5-parted, pinkish, elliptic; stamens 8, styles 3, connate to below middle. Achenes broadly ovoid, trigonous, persistent perianth, black-brown, shiny.

Flowering & Fruiting: July to October

Specimen examined: India. West Bengal: Jalpaiguri district, Doumohani Beel, *Payel Paul & M. Chowdhury 0077*, dated 16.09.2016.

Status: Commonly found on moist places.

Distribution: India (West Bengal, Assam) Nepal, Japan, Korea, Russia; moist areas of plains of Darjeeling, Jalpaiguri, Burdwan at an altitude range from 30 m to 1020 m.

Note: Aerial parts have antiHIV1, anticholinergic, analgesic and CNS depressant activities and significant cytotoxicity against the ovarian cancer cell line.

Rumex Linnaeus

Sp. Pl. 1: 333. 1753; Gen. Pl. ed. 5: 156. 1754.

Annual or perennial herb, rarely shrubs; Root rhizomatous. Stem erect, branched. Leaves simple, alternate, cauline, undulate. Ochreae tubular. Flowers in terminal or axillary, raceme or panicle; tepals 6, in two whorls, persistent, margin entire often dentate; stamens 6, anthers basifixed; style 3, ovary trigonous, stigma penicillate. Achenes trigonous; embryo lateral, straight.

Genus comprises about 200 species worldwide; 22 species in India; 5 species were recorded from West Bengal.

Key to the species

1a. Flowers unisexual .... ***Rumex acetosella***
1b. Flowers bisexual **2**
2a. Fruiting perianth margin entire, smooth **3**
2b. Fruiting perianth margin toothed **4**
3a. Perennial shrubs..... .... ***Rumex hastatus***
3b. Annual herbs .... ***Rumex maritimus***
4a. Lamina oblong to elliptic, leaf base truncate or subcordate; annual .....
……. ……. ……. ..……... ***Rumex dentatus***
4b. Lamina ovate, leaf base cordate; perennial .... ***Rumex nepalensis***

Rumex acetosella Linnaeus, Sp. Pl. 1: 338. 1753; Hooker *f.*, Fl. Brit. India 5: 61. 1886; Grierson & Long, Fl. Bhutan 1(1): 174. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 196. 1985; Srivastava, Ind. J. Pl. Sc. 3(2): 144. 2014. *Acetosella acetosella* (Linnaeus) Small, Man. S. E. Fl. 446. 1933. *Acetosella vulgaris* Fourreau Ann. Soc. Linn. Lyon ser. 2, 17: 145. 1869. *Acetosa hastata* Moench, Methodus. 357. 1794. ***'Tok Palong'*** or ***'Hale'***

Perennial, dioecious herbs. Rhizome horizontal. Stem weak, slender, greenish to reddish, glabrous. Leaves alternate, simple, lamina glabrous, trilobed, terminal lobe lanceolate, 5.6–14.6 × 0.6–2.5 cm, lateral lobe small, margin entire, base cordate, acute to obtuse; Ochreae membranous, greenish, 1.2 cm × 0.7 cm. Flowers in terminal panicle; unisexual, pedicillate; *Male flower*: tepals 6, in two whorl, outer tepals small, inner tepals elliptic; stamen 6, filament short; *Female flower:* tepals 6, outer tepals lanceolate, inner tepals enlarged in fruit; stigma 3, stellate. Achenes trigonous, brown

Flowering & Fruiting: January to April

Specimen examined: India. West Bengal: Malda district, Nayagram beel, *Payel Paul & M. Chowdhury 0088*, dated 30.03.2017.

Status: Commonly cultivated.

Distribution: India, Kazakhstan, China, Japan, Korea, Mongolia, Russia, Europe, N. America; Darjeeling, Jalpaiguri, Malda at an altitude ranges between 25 m to 140 m.

Note: Leaves used as vegetable.

Rumex dentatus Linnaeus, Mant. Pl. Altera. 226. 1771; Hooker *f.*, Fl. Brit. Ind. 5: 59. 1886; Prain, Beng. Pl. 2: 665. 1903; Rechinger *f.* in Tutin *et al.*, Fl. Europ. 1: 88.1964; Maiti & Sikdar, Ind. J. Forestry. 8(3): 196. 1985; Munshi & Javeid, Syst. Stud. Polygon. Kashm. Himal. 96. 1987; Srivastava, Ind. J. Pl. Sc. 3(2): 147. 2014. *Rumex klotzschianus* Meisnner, Prodr. 14: 1856. *Rumex dentatussensu* Hooker *f.*, Fl. Brit. Ind. 5: 59. 1890; Forbes, J. Linn. Soc. 26: 356. 1891. *Rumex nipponicus* Franch & Savat, Pl. Japan 2: 471. 1879. *Rumex dentatus* subsp. *halacsyi* (Rechinger) Rechinger *f.*, Beih. Bot. Centralbl. 49(2): 18 1932. ***'Ban Pate* or *Ban Palungo'***

Annual, erect herbs. Stem greenish to brown, glabrous. Leaves alternate, simple, petiolate, lamina oblong to elliptic, 4.3–12.2 × 1–3.1 cm, glabrous, acute, base sub cordate, entire to slightly undulate. Ochreae tubular, 0.6 × 0.4 cm, glabrous, brown. Flowers in axillary or terminal panicle; bisexual, pedicelate; tepals 6, in two whorls, 3 outer tepals elliptic, entire, acute, 3 inner longer than outer tepals, in fruiting stage, valves are enlarged, broadly ovate, triangular, membranous, finely reticulate, acute,

base rounded, each margin with 2–4 teeth; stamens 6, anther two celled, basifixed; styles 3, stigmas penicillate, ovary trigonous. Achenes ovoid, trigonous with narrow base and acute apex, broadest in the middle, smooth, shiny and blackish.

Flowering & Fruiting: May to August

Specimen examined: India. West Bengal: West Burdwan district, *Payel Paul & M. Chowdhury 0049*, dated 24.05.2016.

Status: Very few species grows on moist places.

Distribution: India (Jammu and Kashmir to Sikkim), Afghanistan, Kazakhstan, Nepal, Russia, N. Africa, S. E. Europe; Darjeeling, Jalpaiguri, Malda, Burdwan, Howrah, Hoogly at an altitude ranges from 7 m upto 140 m.

Note: Root extract used as an astringent and dye.

Rumex hastatus D. Don, Prodr. Fl. Nepal. 74. 1825; Meisnner in DC., Prodr. 14: 72. 1856; Hooker *f*., Fl. Brit. Ind. 5: 60. 1886; Rech. *f*., Candollea 12: 21. 1949; Kitamura, Fl. Afgh. 95. 1960; Hara *et al*., Enum. Fl. Pl. Nepal 3: 179. 1982. Srivastava, Ind. J. Pl. Sc. 3 (2): 147. 2014. *Acetosa hastiformis* Love & Kapoor, Taxon 16: 521. 1967. *Acetosa hastata* Moench, Meth. 357. 1794.

Perennial shrubs. Stem erect, much branched, glabrous, round, woody, nodes swollen, light brown. Leaves petiolate, glabrous sometimes glandular, deltoid, hastate with three lobes, 0.6–3.2 × 0.3–2.7 cm, entire or slightly wavy, revolute, whitish or papillate. Ochreae, fugacious, tubular, brown and glabrous. Inflorescence terminally branched, paniculate, 2–7 flowers in each axil. Flower bisexual; tepals 6 arranged in two whorls of three each, elliptic - ovate, obtuse, reflexed back in fruits; stamens 6, in two whorls of 3 each, filament very short, anther bicelled, basifixed; ovary trigonous, styles 3, free above connate below, stigmas very small. Achenes triquetrous, apex and base pointed, broad below the middle, smooth and dark brown.

Flowering & Fruiting: June to October

Specimen examined: India. West Bengal: Jalpaiguri District, Kathambari beel, *Payel Paul & M. Chowdhury 0142, 0145*, dated 03.09.2018.

Status: Few plants are growing in small water bodies.

Distribution: India (Kashmir, Uttarakhand, Chandigarh, Himachal Pradesh), Kazakhstan, Kyrgyzstan, Mongolia, Russia, Tajikistan, Europe; throughout the North Bengal plains at an altitude ranges from 35 m to 876 m.

Note: Leaf extract applied on wounds and cuts to check bleeding and for nettle sting; root is laxative and anti rheumatic and also be used in skin disease.

Rumex maritimus Linnaeus, Sp. Pl. 1: 335. 1753; Hooker *f*., Fl. Brit. Ind. 5: 59. 1886; Prain, Beng. Pl. 2: 665. 1903; Maiti & Sikdar, Ind. J. Forestry 8(3): 196. 1985; Srivastava, Ind. J. Pl. Sc. 3 (2): 147. 2014. *Rumex maritimus* var. *persicarioides* (Linnaeus) R. S. Mitch, Brittonia 30(2): 295. 1978. *Rumex maritimus* var. *fueginus* (Philippe) Dusén, Svensk. Exp. Mag. 3(5): 194. 1900. ***'Bunpalung'***

Annual herbs. Stems erect, branched below middle, grooved, glabrous or weakly shortly papillose. Leaves alternate, simple, lamina lanceolate or lanceolate-oblong, 4–19.2 × 0.5–7.5 cm, acute, base cuneate, both surfaces glabrous or shortly papillose below, entire, smooth, occasionally slightly undulate. Ochreae fugacious, 0.75 × 0.38 cm, membranous; fimbriae present, no of the fimbriae 6, length 116.23 µm. Flowers in panicle; bisexual, pedicelate; outer tepals elliptic, inner tepals enlarged in fruit base; stamens 6, anther two celled, basifixed; styles 3, stigmas capitates, ovary trigonous. Achenes yellow brown, shiny, ellipsoid, sharply trigonous.

Flowering & Fruiting: May to July

Specimen examined: India. West Bengal: Darjeeling district, Lochka River Bed, *Payel Paul & M. Chowdhury 0044*, dated 05.06.2016; Kalimpong district, Durpin, *Payel Paul & M. Chowdhury 0154*, dated 21.04.2019.

Status: Commonly found on marshy places.

Distribution: India (West Bengal, Assam, Kerala), Kazakhstan, Myanmar, Mongolia, Russia, Europe, N. America; Darjeeling, Jalpaiguri, Burdwan, Howrah at an altitude ranges from 7 m upto 550 m.

Note: Leaves are applied externally to burns; leaves and seed extract are also used as aphrodisiac, astringent and carminative.

Rumex nepalensis Sprengel, Syst. 2: 159. 1825; Hooker *f.*, Fl. Brit. Ind. 5: 60. 1886; Hara *et al.*, Fl. Pl. Nepal. 3: 179. 1982; Grierson & Long, Fl. Bhutan 1(1): 173. 1983; Maiti & Sikdar, Ind. J. Forestry 8(3): 196. 1985; Munshi & Javeid, Syst. Stud. Polygon. Kashm. Himal. 95. 1986; Srivastava, Ind. J. Pl. Sc. 3(2): 148. 2014. *Rumex peregrinus* Boissier, Diagn. Pl. Or. Nov. Ser. 1(5): 46. 1844. ***'Pahari palang* or *Halahale* or *Jangali Palak'***

Perennial herbs. Stem erect, stout or leafy, branched above, deeply grooved, glabrous, slightly papillose just beneath node, sometimes lower internodes papillose at ridges, nodes clearly swollen, reddish brown-brown or olive green. Leaves alternate, simple, basal leaves dimorphic, upper broadly ovate, 5.5–17.1 × 2.2–8.7 cm, petiolate, glabrous-papillose, acute-sub acute, base cordate-sub cordate, undulate-dentate, basal lamina oblong, obtuse, truncate, slightly undulate, cauline leaves shortly petiolate, lamina lanceolate, acute-acuminate, truncate-cuneate. Ochreae tubular, 1.8 × 0.6 cm, membranous, fugacious; fimbriae present, no of the fimbriae 7, length 114.56 µm. Flowers in panicle; bisexual, pedicelate; tepals 6, in two whorls, outer tepals elliptic, entire, acute, valves oblong-ovate, acute-attenuate, truncate, finely reticulate, circinately curled inward at their apices; stamens 6, anther two celled, basifixed; styles 3, stigma penecilliate, ovary trigonous. Nut trigonous, shiny, blackish brown, apex acute with narrow base, broadest below.

Flowering & Fruiting: September to March

Specimen examined: India. West Bengal, Kalimpong district, Durpin monastry road, *Payel Paul & M. Chowdhury 0015*, dated 03.03.2015; Darjeeling district, hilly slopes of Tumling *Payel Paul & M. Chowdhury 0123*, dated 15.04.2018.

Status: Very common in Darjeeling and Kalimpong Himalaya.

Distribution: S.W. Asia, Pakistan, Afghanistan, Tajikistan, India (Assam, Kashmir, Meghalaya, Khasmir), Nepal, Bhutan, Myanmar, Indonesia, Vietnam, Japan (introduced); Darjeeling (Sandakphu, Meghma, Tumling Kurseong), Kalimpong at an altitude ranges from 1540 m upto 3636 m.

Note: Leaves used for treatment of colic, headache and body pain.

5.1.3. Phytogeographical distribution of Polygonaceae

Phytogeographically there are 5 major floristic zones in West Bengal *viz.,* The Darjeeling Himalaya, Terai-Duars Region, North Bengal and South Bengal plains, Western undulating highland and plateau and the Gangetic Delta with diversified vegetation types. Members of Polygonaceae are mostly moist loving species and found to grow near by marshy and wet areas especially in plains. The high altitude species were widely growing in moist forests.

Most of the recorded taxa were primarily distributed in The Darjeeling Himalaya and Terai-Duars Region. Few taxa are uniformly distribution throughout the 5 floristic zones of the state. Least number of taxa is found in the Western undulating highland and plateau (Table 6). All the recorded taxa of Polygonaceae along with their distribution area within the boundary of West Bengal were mentioned in table 6 and district wise species distribution map (Fig. 9) were constructed for easy understading of their distributions pattern within the state.

Table 6: Phytogeographical distribution of different taxa of Polygonaceae in West Bengal

SL No.	Name of the Taxa	Area of Distribution	Floristic region
1.	*Antigonon leptopus* Hooker & Arnott	Malda, Mursidabad, Bankura, Burdwan, Hoogly, Howrah (recently naturalized)	North & South Bengal plains Western undulating highland and plateau Gangetic Delta
2.	*Bistorta emodi* (Meisn.) H. Hara	Darjeeling	Darjeeling-Kalimpong Himalaya
3.	*Fagopyrum dibotrys* (D. Don) Hara	Temperate forest of Darjeeling	Darjeeling - Kalimpong Himalaya
4.	*Fagopyrum esculentum* Moench	Darjeeling, Kalimpong, Jalpaiguri	Darjeeling - Kalimpong Himalaya Terai-Duars Region
5.	*Fallopia convolvulus* (Linnaeus) A. Love	Darjeeling	Darjeeling - Kalimpong Himalaya
6.	*Homalocladium platycladum* (F. Mueller) L. H. Bailey	Darjeeling, Howrah (cultivated)	Darjeeling - Kalimpong Himalaya Gangetic Delta
7.	*Persicaria barbata* (Linnaeus) H. Hara	Moist areas	All the 5 regions

SL No.	Name of the Taxa	Area of Distribution	Floristic region
8.	*Persicaria campanulata* (Hooker *f*.) Ronse Decreane	Hilly slopes of Darjeeling (Meghma, Tumling upto Sandakphu)	Darjeeling - Kalimpong Himalaya
9.	*Persicaria capitata* (Buchanan-Hamilton *ex* D. Don) H. Gross	Darjeeling (Kurseong, Meghma), Kalimpong	Darjeeling Kalimpong Himalaya
10.	*Persicaria chinensis* (Linnaeus) H. Gross var *chinensis*	Darjeeling, Kalimpong (Mirik), Jalpaiguri, Alipurduar	Darjeeling - Kalimpong Himalaya Terai-Duars Region
11.	*Persicaria chinensis* (Linneaus) H. Gross var *hispida* Kantachot	Kalimpong (New Distributional Record)	Darjeeling - Kalimpong Himalaya
12.	*Persicaria chinensis* (Linneaus) H. Gross var *ovalifolia* (Linneaus) H. Gross	Darjeeling (Kurseong)	Darjeeling - Kalimpong Himalaya
13.	*Persicaria glabra* (Willdenow) M. Gómes	Darjeeling, Kalimpong (Mirik), Jalpaiguri, Alipurduar	Darjeeling - Kalimpong Himalaya Terai-Duars Region
14.	*Persicaria hydropiper* (Linnaeus) Spach	Throughout marshy lands	All the 5 regions
15.	*Persicaria lapathifolia* (Linnaeus) S. F. Gray var. *lapathifolia*	Throughout marshy lands	All the 5 regions
16.	*Persicaria lapathifolia* (Linnaeus) Delarbre *var. lanata* (Roxb.) H.Hara	Throughout marshy lands	All the 5 regions
17.	*Persicaria minor* (Hudson) Opiz	Marshy lands of N. Bengal	North Bengal and South Bengal plains
18.	*Persicaria nepalensis* (Meisner) H. Gross	Darjeeling (Kurseong upto Meghma), Kalimpong	Darjeeling - Kalimpong Himalaya
19.	*Persicaria orientalis* (Linnaeus) Spach	Throughout moist areas	All the 5 regions
20.	*Persicaria posumbu* (Buchanon-Hamilton *ex* D. Don) H. Gross	Marshy areas of Jalpaiguri	Terai-Duars Region
21.	*Persicaria strigosa* (R. Brown) Nakai	Darjeeling (Kurseong), Marshy areas of Jalpaiguri	Darjeeling - Kalimpong Himalaya Terai-Duars Region
22.	*Persicaria tenella* (Blume) Hara	Throughout the moist lands of N. Bengal plains	North & South Bengal plains

SL No.	Name of the Taxa	Area of Distribution	Floristic region
23.	*Polygonum microcephalum* D. Don	Temperate hilly areas of Darjeeling, Kalimpong	Darjeeling - Kalimpong Himalaya
24.	*Polygonum molle* D. Don	Throughout the temperate hilly areas of Darjeeling (Kurseong, Tumling, Meghma upto Sandakphu), Kalimpong	Darjeeling - Kalimpong Himalaya
25.	*Polygonum perfoliatum* Linnaeus	Darjeeling Himalaya, Coochbeher	Darjeeling - Kalimpong Himalaya Terai-Duars Region
26.	*Polygonum plebeium* R. Brown	Throughout the plains	All the 5 regions
27.	*Polygonum pubescens* Blume	Throughout moist areas	All the 5 regions
28.	*Polygonum runcinatum* Buchanan-Hamilton *ex* D. Don	Temperate parts of Darjeeling (Kurseong, Mirik), Kalimpong	Darjeeling - Kalimpong Himalaya
29.	*Polygonum viscosum* Buchanan-Hamilton *ex* D. Don	Moist areas of plains of Darjeeling, Jalpaiguri, Burdwan	Darjeeling - Kalimpong Himalaya Terai-Duars Region Western undulating highland and plateau
30.	*Rheum nobile* Hooker & Thomson	Darjeeling	Darjeeling - Kalimpong Himalaya
31.	*Rumex acetosella* Linnaeus	Darjeeling, Jalpaiguri, Malda	Darjeeling - Kalimpong Himalaya Terai-Duars Region North and South Bengal Plain
32.	*Rumex dentatus* Linnaeus	Darjeeling, Jalpaiguri, Malda, Burdwan, Howrah, Hoogly	Darjeeling - Kalimpong Himalaya Western undulating highland and plateau Terai-Duars Region Gangetic Delta
33.	*Rumex hastatus* D. Don	North Bengal	North and South Bengal plains
34.	*Rumex maritimus* Linnaeus	Darjeeling, Jalpaiguri, Burdwan, Howrah	Darjeeling - Kalimpong Himalaya Western undulating highland and plateau Terai-Duars Region Gangetic Delta
35.	*Rumex nepalensis* Sprengel	Darjeeling (Kurseong, Meghma, Tumling), Kalimpong	Darjeeling - Kalimpong Himalaya

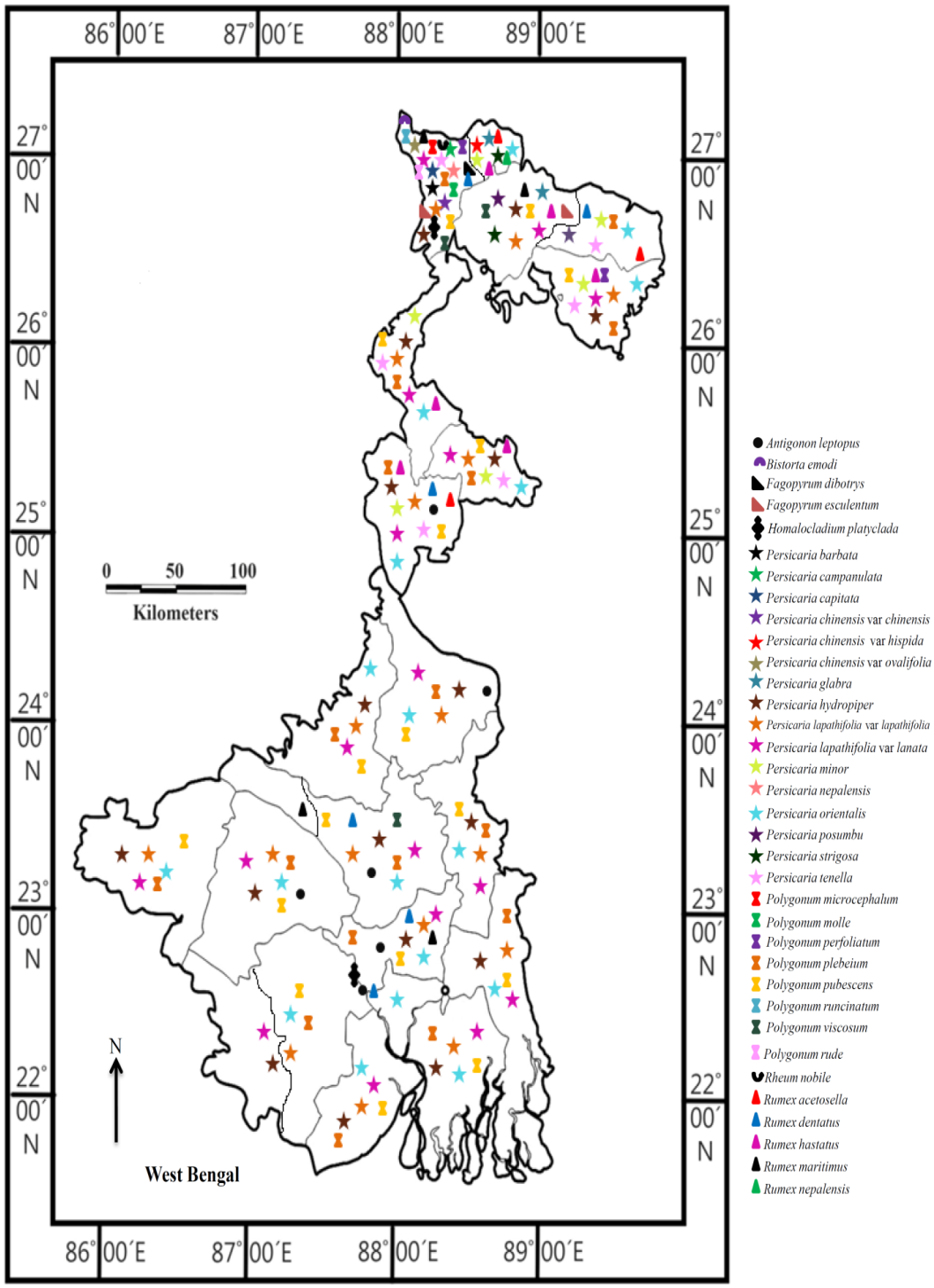

Fig. 9: District wise distribution of different taxa of Polygonaceae in West Bengal

5.1.4. Importance

Present study revealed that several economically valuable species of Polygonaceae served as resources in the vegetation of West Bengal. More than 80% of taxa recorded from this region are used for wide-ranging purposes (Fig. 10). It has been documented during survey that majority of the taxa have ethno medicinal property. Remaining taxa are used in different other purpose *viz.*, cattle feed, fire wood, bio-pesticide, cosmectics, flavouring agents; while few taxa are also used in the different parts of the state as leafy vegetables *i.e.* young leaves of *Fagopyrum esculentum* sold in the local market of Darjeeling and Kalimpong and Jalpaiguri districts, young leaves of *Rumex acetosella* (*tak palang)* sold in the local market of Central and Northern parts of west Bengal; spices and condiment i.e, roasted seeds of *Polygonum microcephalum* used as condiments in N.E. India. Dried leaves of *Rheum nobile* are used as the substitute of tobacco by some etnic community of Sandakphu, Meghma and Tumlimg regions of Darjeeling district. Details of all the ethno-botanically and economically important members of Polygonaceae are carefully accounted along with their parts used and necessary uses in table 7.

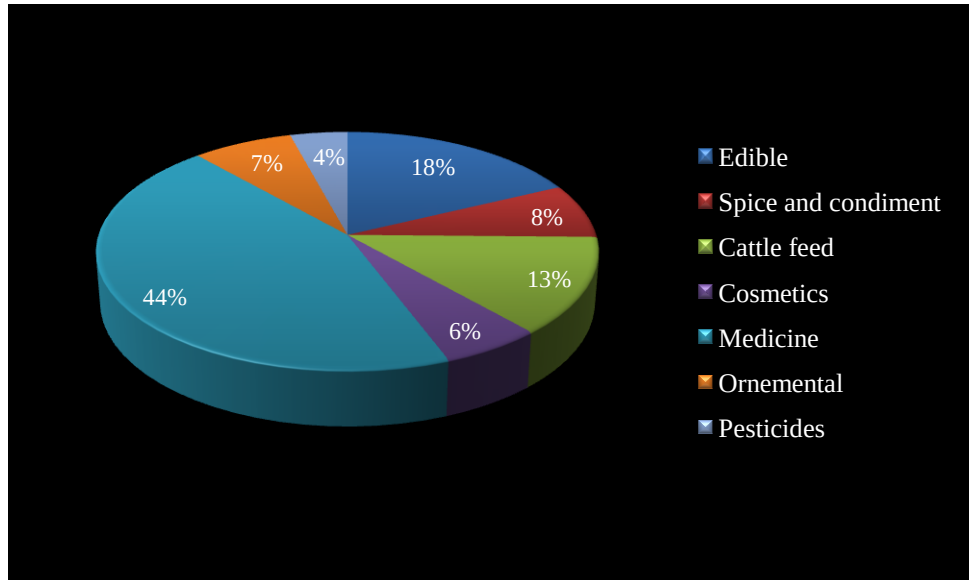

Fig. 10: Uses of Polygonaceae for different purposes

Table 7: Ethnic and commercial uses of different taxa of Polygonaceae in West Bengal

Taxa	Ethnic/ Commercial uses
Antigonon leptopus Hooker & Arnott	Ornamental
Fagopyrum dibotrys (D. Don) Hara	Seeds, leaves used for treatment of colic, choleric diarrhea and abdominal blockage troubles; young leaves used as vegetable
Fagopyrum esculentum Moench	Leaves used as vegetable
Fallopia convolvulus (Linnaeus) A. Love	Seeds are used as nutritious food
Homalocladium platycladum (F. Mueller) L. H. Bailey	Entire plants are used for the treatment of anthracia, sores, snake bite, insect bite
Persicaria barbata (Linnaeus) H. Hara	Watery sap from roots used as antiseptic
Persicaria campanulata (Hooker *f*.) Ronse Decreane	Ornamental
Persicaria capitata (Buchanan-Hamilton *ex* D. Don) H. Gross	Ornamental, whole plant extract used as antidote in snakebite and insect sting
Persicaria chinensis (Linnaeus) H. Gross var *chinensis*	Root used for fluxes, anthelminthic and neutralizes scorpion poisoning
Persicaria glabra (Willdenow) M. Gómes	Plant juice and rootstock used in pneumonia, jaundice, fevers. Leaves are antispasmodic and are used for colic
Persicaria hydropiper (Linnaeus) Spach	Seeds, leaves used for treatment of arthritis, bladder stone, cholera
Persicaria lapathifolia (Linnaeus) S. F. Gray var. *lapathifolia*	Decoctions from root used as cathartic and emetic drug
Persicaria minor (Hudson) Opiz	Young shoot and leaves are edible; Decoctions from leaves has been used in post-natal tonics and for treatment of digestion oil has been used for aromatherapy and in treatments for dandruff
Persicaria nepalensis (Meisner) H. Gross	Whole plant extract used in the treatment of swelling
Persicaria orientalis (Linnaeus) Spach	Ornamental; nuts are used in tuberculous swellings and flatulence; decoction of the ripe fruits is used in the treatment of hepatitis, sloughing ulcers, tympanites and cancer
Persicaria posumbu (Buchanon-Hamilton *ex* D. Don) H. Gross	Decoction is used in the treatment of dysentery, enteritis, boils and abscesses; aromatic leaves are added to other vegetables for flavor
Persicaria strigosa (R. Brown) Nakai	Tender roasted shoots are used for the dysentery of cattles
Polygonum microcephalum D. Don	Young shoot and seeds are used as vegetable and condiment respectively

Taxa	Ethnic/ Commercial uses
Polygonum molle D. Don	The whole plant used as astringent; young shoot, leaves and seeds are edible
Polygonum perfoliatum Linnaeus	Tender leaves, shoots and fruit are edible; whole plant is depurative, diuretic, febrifuge and also used to stimulate blood circulation; decoction is used in the treatment of dysentery, enteritis, boils and abscesses, poisonous snake bites, haematuria, cloudy urine and traumatic injuries
Polygonum plebeium R. Brown	Leaves used for the treatment of pneumonia and young leaves are used as vegetable; roots are used in treatment of baldness
Polygonum pubescens Blume	Leaves and seeds are edible; decoction of the plant, combined with onion, is used as a styptic; bruised plant is applied locally to blistered and swollen feet
Polygonum runcinatum Buchanan-Hamilton *ex* D. Don	Leaves are edible
Polygonum viscosum Buchanan-Hamilton *ex* D. Don	Aerial parts have antiHIV1, anticholinergic, analgesic and CNS depressant activities and significant cytotoxicity against the ovarian cancer cell line
Rheum nobile Hooker & Thomson	Young stems are used for salads; flowering stem used in the treatment of swellings and fullness of the abdomen; dried leaves used as a substitute for tobacco; root extract used as antiemetic, astringent, carminative, depurative, diuretic, laxative
Rumex acetosella Linnaeus	Leaves used as vegetable
Rumex dentatus Linnaeus	Root extract used as an astringent and dye
Rumex hastatus D. Don	Leaf extract applied on wounds and cuts to check bleeding and for nettle sting; root is laxative and anti rheumatic and also be used in skin disease
Rumex maritimus Linnaeus	Leaves are applied externally to burns; leaves and seed extract are also used as aphrodisiac, astringent and carminative
Rumex nepalensis Sprengel	Leaves used for treatment of colic, headache and body pain

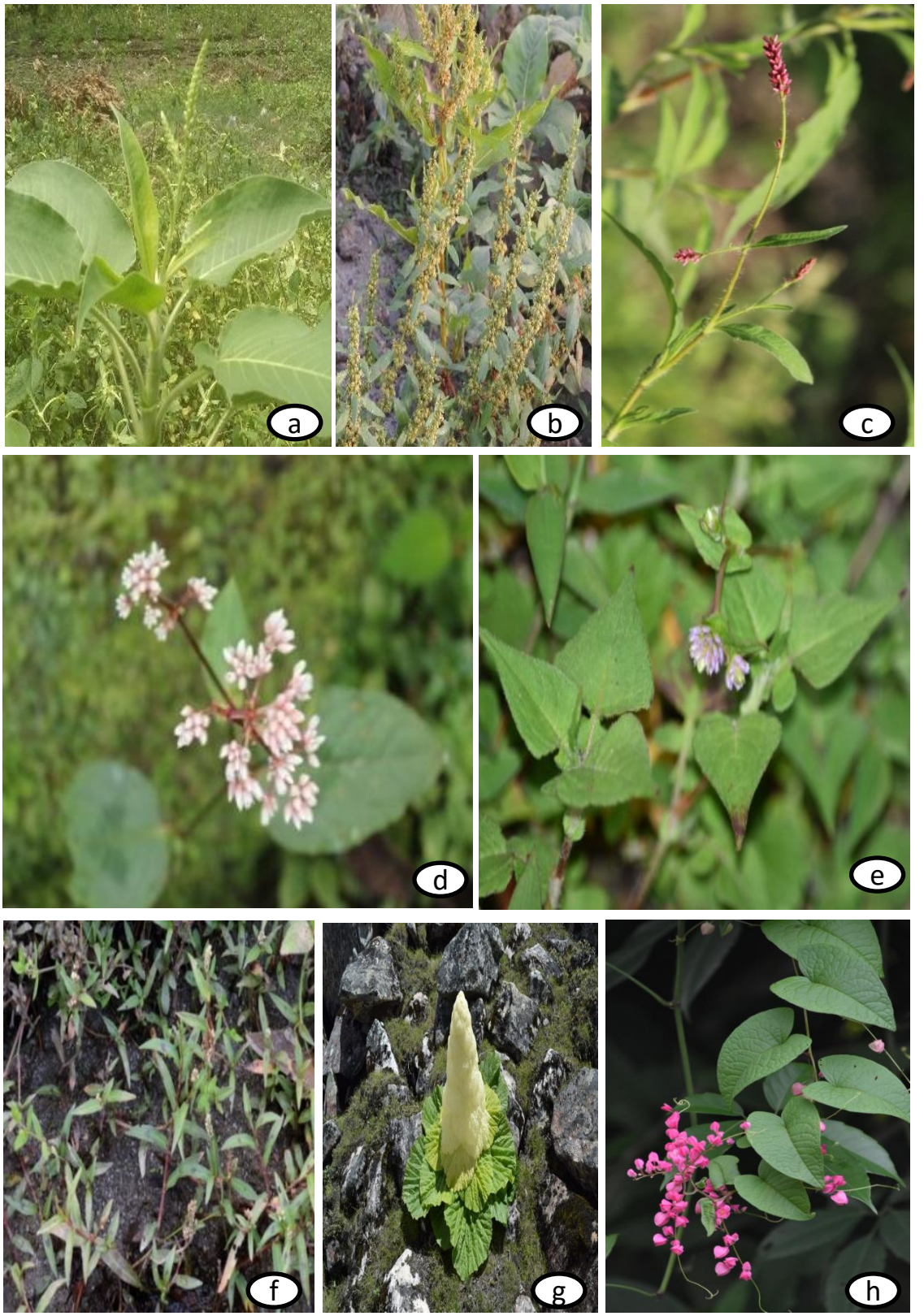

Fig. 11: Different taxa of Polygonaceae in their natural habitat **a.** *Persicaria orientalis* **b.** *Rumex dentatus* **c.** *Polygonum viscosum* **d.** *Persicaria campanulata* **e.** *Persicaria nepalensis* **f.** *Persicaria tenella* **g.** *Rheum nobile* **h.** *Antigonon leptopus*

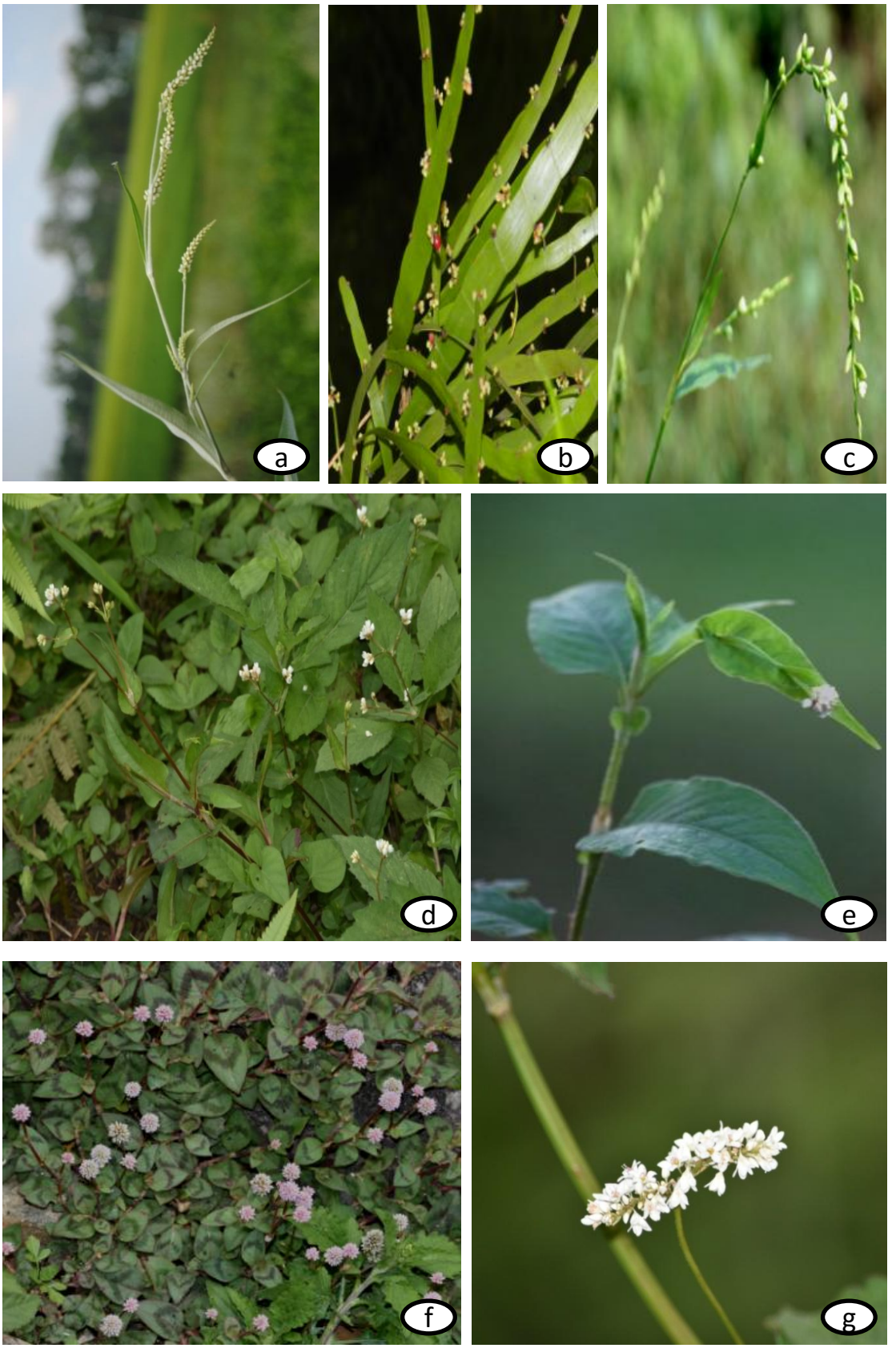

Fig. 12: Different taxa of Polygonaceae in their natural habitat **a.** *Persicaria lapathifolia* var. *lanata* **b.** *Homalocladium platyclada* **c.** *Persicaria hydropiper* **d.** *Persicaria chinensis* var. *chinensis* **e.** *Persicaria chinensis* var. *hispida* **f.** *Persicaria capitata* **g.** *Fagopyrum dibotrys*



Fig. 13: Different taxa of Polygonaceae in their natural habitat **a.** *Polygonum plebeium* **b.** *Rumex maritimus* **c.** *Rumex nepalensis* **d.** *Polygonum molle* **e.** *Persicaria runcinatum* **f.** *Persicaria glabra*

5.2. FOLIAR MACRO & MICRO MORPHOLOGY

Foliar macro and micro morphological studies were carried out for all the collecred taxa of the family Polygonaceae from West Bengal. Both qualitative and quantitative characters of lamina were examined very carefully for all the taxa to understand the peculierities and variation pattern in their shape, sizes, stomata, vein and trichomes. The accumulated macro and micro-morphological features were found quite interesting and significantly varies species to species even in varietal level. All the recorded data and their calculated results were summarized below.

5.2.1. Foliar macro morphology

Leaves are flattened lateral outgrowths of the stem and form the foliage of a plant. Leaves bear a huge number of peculiar and interesting characters that has crucial role in species level identifical especially in sterile condition. Morphological characteristic attributes of leaves are more precisely known as foliar macro morphology. Macro-morphological study for each specimen was done as per Hickey's Manual. The leaf attachment and organization, petiole feature, mean lamina length, width, area, blade class, lamina shape, symmetry, base and apex angle, shape, petiole attachment, margin type, lobation for all specimens were observed. All these parameters of the lamina vary from species to species also in varietal level and play a significant role in the identificarion of sterile specimens. Therefore, study of foliar macro morphology is quite significant for identification of the different taxa of Polygonaceae as the flowers and fruits are produced for a very brief period.

Opposite phyllotaxy was observed in *Antigonon leptopus*. Laminar shapes were assorted from ovate to lanceolate and lamina apex and base angle was more or less acute <90º (Table 8). Lamina apex shapes were varied from acute to acuminate whereas base shape was truncate (Table 8).

Alternate phyllotaxy was observed in both the recorded species of *Fagopyrum i.e.*, *F. dibotrys* and *F. esculentum* where leaves were simple. Laminar size (Table 8) varied much in these two species therefore they can be categorized under different blade class; apex and base angle was more or less same in both species *i.e.*, wide

obtuse; lamina apex shapes were varied from acute (*F. dibotrys*) to acuminate (*F. esculentum*) whereas base shape was same (Table 8).

Alternate phyllotaxy was observed in all the recorded taxa of *Persicaria*. Laminar size (Table 8) varied much in different taxa therefore they can be categorized under different blade class *viz*., nanophyll (*P. tenella*), microphyll (*Persicaria barbata, P. campanulata, P. capitata, P. glabra, P. hydropiper, P. lanigera, P. lapathifolia* var *lapathifolia, P. lapathifolia* var *lanata, P. microcephala, P. minor, P. nepalensis, P. perfoliata, P. strigosa*), notophyll (*P. chinensis* var *chinensis, P. chinensis* var *hispida, P. chinensis* var *ovalifolia, P. orientalis*) and mesophyll (*P. posumbu*); lamina apex and base angle were also varied in all taxa (Table 8) *i.e.*, acute, obtuse, wide obtuse etc.; apex shapes were varied from acute to acuminate sometimes it was appeared to be straight; whereas base shape was also diverse in different taxa (Table 8) such as lobate, rounded, cuneate, saggitate, decurrent etc.

Phyllotaxy was opposite in all five recorded species of *Polygonum* expect in *Polygonum viscosum* where it was alternate. Recorded taxa of *Polygonum* were placed under different blade class *viz*., nanophyll (*P. plebeium*), microphyll (*P. molle, P. pubescens, P. runcinatum*) and notophyll (*P. viscosum*) due to the variation of their laminar size; lamina apex and base angle were also varied in all the taxa; base shape were varied from sagittate to decurrent (Table 8) whereas apex shape was same for all the taxa *i.e.*, acuminate except for *Polygonum plebeium*, here it was straight.

Alternate phyllotaxy was observed in all the recorded four species of *Rumex* but the taxa were placed under different blade class due to variable lamina sizes (Table 8); apex and base angle were varied from acute (*R. dentatus, R. maritimus*), obtuse (*R. acetosella*) to wide obtuse (*R. nepalensis*); base shape was same i.e, decurrent except in *Rumex nepalensis* where it was lobate whereas apex shape were different in all taxa (Table 8).

Table 8: Macro morphological data of all the studied taxa of Polygonaceae from West Bengal, India

Taxa	Mean lamina length(mm)	Mean lamina width(mm)	Lamina area(mm)	Blade class	Lamina shape	Base angle	Base shape	Apex shape	Margin type	Lobation
Antigonon leptopus	78.67	29.87	2349.87	Notophyll	Ovate	Obtuse	Decurrent	Accuminate	Entire	Unlobed
Fagopyrum dibotrys	29.22	24.14	705.37	Microphyll	Ovate	Obtuse	Decurrent	Accuminate	Entire	Unlobed
Fagopyrum esculentum	82.20	28.00	2301.6	Notophyll	Oblong	Wide obtuse	Decurrent	Accuminate	Entire	Unlobed
Fallopia convolvulus	39.00	17.00	663.00	Microphyll	Ovate	Acute	Saggitate	Accuminate	Entire	Unlobed
Homalocladium platycladum	31.33	11.33	236.65	Microphyll	Ovate	Acute	Deccurent	Straight	Erose	Unlobed
Persicaria barbata	90.16	20.12	1814.01	Microphyll	Elliptic	Obtuse	Rounded	Straight	Entire	Unlobed
Persicaria campanulata	98.32	24.25	1573.25	Microphyll	Oblong	Wide obtuse	Decurrent	Accuminate	Entire	Unlobed
Persicaria capitata	25.00	18.00	450	Microphyll	Ovate	Acute	Rounded	Accuminate	Entire	Unlobed
Persicaria chinensis* var. *chinensis	95.50	30.00	2865.00	Notophyll	Oblong	Obtuse	Lobate	Accuminate	Erose	Unlobed
Persicaria chinensis* var. *hispida	97.89	32.14	3123.23	Notophyll	Oblong	Obtuse	Lobate	Convex	Erose	Unlobed
Persicaria chinensis* var. *ovalifolia	99.89	41.21	4116.47	Notophyll	Oblong	Obtuse	Rounded	Convex	Erose	Unlobed
Persicaria glabra	73.67	23.33	1096.7	Microphyll	Oblong	Wide obtuse	Sagittate	Straight	Entire	Unlobed
Persicaria hydropiper	70.00	16.00	1120	Microphyll	Elliptic	Acute	Decurrent	Accuminate	Erose	Unlobed
Persicaria lanigera	85.64	15.09	1292.30	Microphyll	Oblong	Obtuse	Decurrent	Convex	Erose	Unlobed
Persicaria lapathifolia* var. *lanata	82.32	13.56	823.76	Microphyll	Elliptic	Acute	Decurrent	Acute	Erose	Unlobed
Persicaria lapathifolia* var. *lapathifolia	76.00	10.11	768.36	Microphyll	Elliptic	Acute	Decurrent	Accuminate	Erose	Unlobed
Persicaria minor	87.3	19.11	1668.30	Microphyll	Elliptic	Acute	Cuneate	Straight	Entire	Unlobed
Persicaria nepalensis	29.00	18.00	522.00	Microphyll	Rhomboid	Obtuse	truncate	Acute	Erose	Unlobed
Persicaria orientalis	95.30	75.00	4839.9	Notophyll	Ovate	Wide obtuse	Lobate	Accuminate	Erose	Unlobed
Persicaria perfoliata	54.98	29.87	1642.25	Microphyll	Oblong	Obtuse	Decurrent	Straight	Entire	Unlobed
Persicaria posumbu	101.65	85.65	8706.32	Mesophyll	Ovate	Wide obtuse	Cuneate	Accuminate	Erose	Unlobed
Persicaria strigosa	73.67	23.33	1096.7	Microphyll	Oblong	Wide obtuse	Sagittate	Straight	Entire	Unlobed
Persicaria tenella	30.60	4.20	128.52	Nanophyll	Ovate	Acute	Decurrent	Accuminate	Entire	Unlobed
Polygonum microcephalum	73.67	22.33	1096.7	Microphyll	Oblong	Wide obtuse	Decurrent	Accuminate	Entire	Unlobed
Polygonum molle	112.20	28.60	3208.9	Notophyll	Ovate	Obtuse	Sagittate	Accuminate	Erose	Unlobed
Polygonum pubescens	95.50	23.00	2192	Notophyll	Oblong	Obtuse	Decurrent	Convex	Erose	Unlobed
Polygonum runcinatum	23.33	15.33	238.4	Microphyll	Elliptic	Wide obtuse	Sagittate	Accuminate	Entire	Lobed
Polygonum viscosum	133.00	32.00	4256	Notophyll	Elliptic	Wide obtuse	Lobate	Accuminate	Entire	Unlobed
Polygonum plebeium	15.20	8.00	121.6	Nanophyll	Elliptic	Acute	Decurrent	Straight	Entire	Unlobed
Rheum nobile	182.1	212.35	38668.94	Macrophyll	Ovate	Wide obtuse	Cordate	Rounded	Entire	Unlobed
Rumex maritimus	130.66	36.30	4742.95	Mesophyll	Ovate	Acute	Decurrent	Entire	Erose	Unlobed
Rumex nepalensis	70.00	13.33	622.1	Microphyll	Ovate	Wide obtuse	Lobate	Accuminate	Entire	Unlobed
Rumex acetosella	180.0	39.00	5420	Mesophyll	Elliptic	Obtuse	Decurrent	Accuminate	Entire	Unlobed
Rumex dentatus	130.30	36.30	4690.8	Mesophyll	Ovate	Acute	Deccurent	Straight	Erose	Unlobed

5.2.2. Morphology of Stomata

Stomata are recognized as small openings in the epidermal surface which engage with gaseous exchange among intercellular spaces of sub-epidermal cells and the atmosphere. These are enclosed by guard cells, which organize the pore size. The morphology of stomata had been regarded as a valuable taxonomic decisive factor not only morphology but also their distribution and arrangement were still taxonomically significant for the identification of different taxa. The study of stomatal complexes becomes extremely valuable to understand the evolutionary relationship of taxa.

Among the studied taxa four prominent type of stomata like anisocytic (containing single ring of 3 cells enclosing the guard cells), paracytic (2 cells completely enclosing the guard cells with their long axis parallel to long axis of guard cells), pericytic (one cell encloses both guard cells) and anomocytic (subsidiary cells same as normal epidermal cells) were observed (Fig. 14). Most of the taxa were amphistomatic *i.e.*, stomata were observed on both adaxial and abaxial surfaces of the lamina. Significant stomata variations were observed in their sizes, types, frequency and density.

Anomocytic stomata were observed in six taxa *i.e., Antigonon leptopus, Fagopyrum dibotrys, Persicaria pubescens, P. orientalis, P. strigosa* and *Polygonum viscosum* (Fig. 15). The stomata were circular to elliptical and were to be found at the same level as the epidermal cells. Guard cells were kidney shaped and the cell lumen between them is narrow at the equatorial region. Stomata were regularly distributed on both surface of the lamina.

Anisocytic stomata were observed in seven taxa *viz., Homalocladium platycladum, Persicaria chinensis* var. *chinensis, P. chinensis* var. *hispida, P. chinensis* var. *ovalifolia, P. microcephala, Polygonum runcinatum* and *P. molle* (Fig. 15, 16). In this case stomata remain surrounded by subsidiary or accessory cells and whose common wall is at right angles to the guard cells.

Paracytic stomata were observed in eight taxa *viz., Fagopyrum esculentum, Persicaria barbata, P. campanulata, P. lanigera, P. minor, P. nepalensis, P. posumbu* and *P. tenella*. In this case, the guard cell enlarges and become kidney

shaped (Fig. 15; 16; 17). Stomata remain surrounded by the two subsidiary cells that were placed parallel to the stoma. Here the stomata were present mainly on the abaxial surface of leaf.

Pericytic stomata had been shown only in five taxa *viz., Fallopia convolvulus, Persicaria lapathifolia* var. *lapathifolia*, *P. lapathifolia* var. *lanata*, *P. capitata* and *Rumex maritimus*.

More than one type of stomata were also found in some taxa of *Persicaria, Polygonum, Rheum* and *Rumex* such as in *Persicaria glabra* three different types of stomata (anisocytic, paracytic and staurocytic), in *Persicaria hydropiper* two different types of stomata (ansiocytic and paracytic), in *Persicaria perfoliata* two types of stomata (anomocytic, cyclocytic), in *Polygonum plebeium* two types of stomata (anisocytic and pericytic), in *Rheum nobile* two types of stomata (anomocytic and paracytic) and in *Rumex acetosella, R. dentatus, R. nepalensis* two different types of stomata (ansiocytic and pericytic) were observed.

Stomatal index (SI) on basal portion of lamina was ranged from 8.65 to 31.62% in *Persicaria capitata* and *Persicaria barbata* respectively, while on apex portion from 9.26 to 32.07% in *Polygonum viscosum* and *Persicaria barbata* respectively (Table 9). Significant variation in length of stomatal pore was reported from 6.06 to 32.86 µm in *Polygonum molle* and *Polygonum pubescence* respectively. Size of stomata also showed great variation within the studied taxa maximum size of stomata was observed in *Persicaria campanulata* (33.96 × 25.08 µm) and minimum size was observed in *Rumex dentatus* (18.32 × 13.20 µm).

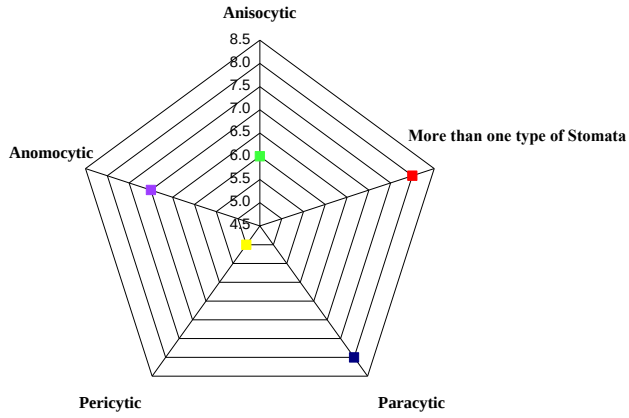

Fig. 14: Graphical representation of different type of stomata observed in Polygonaceae

Table 9: Quantitative stomatal morphology of the family Polygonaceae based on light microscopy [Abbreviation used S= Stoma; GC= Guard Cell; SC= Subsidiary Cell]

Taxa	Part of lamina	Mean length of S (µm)	Mean bradth of S(µm)	Mean length of S+GC (µm)	Mean breadth of S+GC (µm)	Mean length of GC (µm)	Mean breadth of GC (µm)	Mean length of S+SC (µm)	Mean breadth of S+SC (µm)	Mean length of SC (µm)	Mean breadth of SC (µm)	Stomatal frequency (no. of stomata /mm²)	Stomatal index(S*100/E+S)
Antigonon leptopus	Apex	11.87	9.08	21.09	15.87	9.22	6.79	25.67	19.01	4.58	3.14	98.71±4.71	11.21%
	Middle	14.31	10.71	22.34	17.65	8.03	6.94	29.81	21.17	7.47	3.52	81.60±5.11	10.69%
	Base	16.32	13.2	22.79	16.52	6.47	3.32	30.98	23.45	8.19	6.93	107.86±7.78	12.31%
Persicaria chinensis var. *chinensis*	Apex	14.89	11.46	29.82	25.22	14.93	8.02	45.54	52.74	15.72	27.52	122.70±13.17	14.39%
	Middle	21.78	8.02	28.66	26.38	6.88	11.46	47.84	55.04	19.18	28.66	181.54±3.59	16.26%
	Base	25.22	14.58	35.54	27.2	10.32	6.88	46.7	56.18	11.16	28.98	176.69±13.33	19.38%
Persicaria chinensis var. *hispida*	Apex	14.69	6.88	24.08	22.94	9.39	5.74	44.72	58.48	20.64	35.54	318.66±11.05	23.47%
	Middle	20.64	8.02	25.21	19.5	4.57	3.44	43.58	57.34	22.94	37.84	281.50±17.93	22.18%
	Base	22.94	6.88	26.38	20.64	3.44	4.58	44.72	52.74	18.34	32.1	193.11±4.38	26.45%
Persicaria chinensis var. *ovalifolia*	Apex	23.71	17.65	35.91	21.19	12.2	3.54	46.78	49.08	10.87	27.78	345.74±13.95	29.81%
	Middle	22.98	15.42	33.2	26.65	10.22	11.23	42.91	51.42	9.71	24.77	312.12±12.01	24.34%
	Base	25.29	19.01	37.87	22.9	12.58	3.89	49.08	47.98	11.21	25.08	208.88±4.24	19.76%
Persicaria minor	Apex	11.56	5.78	17.34	14.45	5.78	8.67	63.58	43.35	46.24	28.9	132.40±10.33	15.09%
	Middle	13.48	4.81	15.37	15.48	1.89	10.67	43.35	57.8	27.98	42.32	167.40±10.52	17.63%
	Base	17.34	2.89	20.45	11.63	3.11	8.72	52.25	49.13	31.8	37.5	189.01±11.59	19.42%
Persicaria posumbu	Apex	19.87	14.32	24.43	18.9	4.56	4.58	42.21	35.54	17.78	16.64	156.63±11.54	15.67%
	Middle	17.67	14.23	21.29	19.87	3.62	5.64	40.76	31.09	19.47	11.22	220.47±3.24	18.76%
	Base	15.43	12.31	22.9	17.65	7.47	5.34	43.21	29.08	20.31	11.43	182.84±9.24	16.49%
Persicaria strigosa	Apex	16.06	9.18	28.66	21.78	12.6	12.6	42.42	50.46	13.76	28.68	153.17±18.66	14.87%
	Middle	17.2	9.18	24.08	21.78	6.88	12.6	40.14	50.46	16.06	28.68	127.77±5.70	14.38%
	Base	18.34	5.74	25.22	14.89	6.88	9.15	42.23	49.29	17.01	34.4	141.42±10.46	16.24%
Persicaria orientalis	Apex	14.89	3.44	28.66	17.02	13.77	13.58	41.25	53.96	12.59	36.94	168.42±12.92	16.15%
	Middle	12.62	6.88	25.22	19.5	12.6	12.62	35.98	51.6	10.76	32.1	232.90±21.93	18.14%
	Base	6.88	9.18	26.38	14.89	19.5	5.71	37.54	52.74	11.16	37.85	216.99±15.39	19.27%
Persicaria barbata	Apex	14.89	6.88	24.08	22.94	9.19	16.06	42.42	58.48	18.34	35.54	378.07±19.33	32.07%
	Middle	20.64	8.02	25.21	19.5	4.57	11.48	44.72	57.36	19.51	37.86	374.05±10.19	31.76%
	Base	22.94	6.88	26.38	20.64	3.44	13.76	43.56	52.74	17.18	32.1	387.02±12.34	31.62%
Persicaria lanigera	Apex	11.89	7.34	19.87	15.64	7.98	8.3	27.65	29.09	7.78	13.45	92.14±6.77	10.96%
	Middle	12.31	8.76	17.67	14.43	5.36	5.67	28.43	31.1	10.76	16.67	105.11±3.67	11.17%
	Base	15.45	10.98	20.89	17.31	5.44	6.33	25.45	26.38	4.56	9.07	126.55±6.57	13.12%
Persicaria lapathifolia var. *lapathifolia*	Apex	16.06	5.74	22.94	18.33	6.88	12.59	44.72	41.28	21.78	22.95	169.17±16.83	23.28%
	Middle	19.5	8.02	26.38	22.94	6.88	14.92	75.69	43.58	49.31	20.64	227.77±5.33	25.10%

Taxa	Part of lamina	Mean length of S (µm)	Mean bradth of S(µm)	Mean length of S+GC (µm)	Mean breadth of S+GC (µm)	Mean length of GC (µm)	Mean breadth of GC (µm)	Mean length of S+SC (µm)	Mean breadth of S+SC (µm)	Mean length of SC (µm)	Mean breadth of SC (µm)	Stomatal frequency (no. of stomata /mm²)	Stomatal index(S*100/E+S)
	Base	20.64	9.18	22.35	24.08	1.71	14.9	77.98	45.86	55.63	21.78	209.27±8.42	25.22%
Persicaria lapathifolia var.	Apex	17.86	6.75	26.45	22.56	8.59	15.81	79.89	47.28	53.44	24.72	218.10±8.39	24.78%
lanata	Middle	22.33	5.65	25.67	24.67	3.34	19.02	76.45	48.97	50.78	24.3	242.89±20.12	27.67%
	Base	19.87	6.13	24.87	26.78	5.98	20.65	81.21	45.78	56.34	19	195.57±3.32	27.54%
Persicaria hydropiper	Apex	21.78	5.74	28.66	25.22	6.88	19.48	66.99	44.72	38.33	19.5	425.45±20.22	26.52%
	Middle	27.52	3.44	28.66	24.08	1.14	20.64	45.85	45.86	17.19	21.78	354.85±18.23	25.46%
	Base	14.08	4.58	24.04	26.38	9.96	21.8	50.46	55.86	26.42	29.48	397.17±22.81	25.75%
Persicaria tenella	Apex	14.89	3.44	33.36	19.5	18.47	16.06	35.54	51.6	2.18	32.1	229.27±14.17	26.37%
	Middle	13.76	6.88	29.82	14.89	16.06	8.01	37.84	52.74	8.02	37.85	181.44±13.72	24.87%
	Base	11.46	4.58	25.22	22.94	13.76	18.36	36.7	50.46	11.48	27.52	245.05±19.62	27.99%
Persicaria glabra	Apex	13.76	8.02	32.09	14.5	18.33	6.48	44.72	52.74	12.63	38.24	253.42±13.08	25.90%
	Middle	26.38	9.18	27.52	20.64	1.14	11.46	45.65	55.04	18.13	34.4	203.06±6.72	23.52%
	Base	24.08	5.74	28.66	24.08	4.58	18.34	44.72	58.48	16.06	34.4	262.94±2.50	26.05%
Persicaria campanulata	Apex	16.06	8.02	33.96	25.08	17.9	17.06	37.49	52.74	3.53	27.66	145.74±16.79	14.26%
	Middle	20.64	9.18	29.85	21.56	9.21	12.38	44.74	55.09	14.89	33.53	83.87±9.92	9.11%
	Base	21.78	5.74	24.25	24.22	2.47	18.48	36.76	58.46	12.51	34.24	114.83±19.13	12.71%
Persicaria capitata	Apex	21.78	5.36	28.36	24.08	6.58	18.72	44.72	42.61	16.36	18.53	144.96±19.90	11.25%
	Middle	22.25	7.02	28.66	25.22	6.41	18.2	43.56	43.96	14.9	18.74	286.02±10.62	21.22%
	Base	24.25	5.26	25.36	24.08	1.11	18.82	44.78	45.87	19.42	21.79	244.94±17.96	8.65%
Persicaria nepalensis	Apex	16.54	4.56	27.09	18.65	10.55	14.09	35.67	29.98	8.58	11.33	93.15±5.12	9.87%
	Middle	18.09	7.65	28.98	17.42	10.89	9.77	37.96	30.09	8.98	12.67	111.13±8.68	10.95%
	Base	14.67	6.81	26.1	13.28	11.43	6.47	39.02	29.65	12.92	16.37	155.84±2.59	13.21%
Persicaria perfoliata	Apex	17.65	7.65	22.76	11.87	5.11	4.22	31.18	35.56	8.42	23.69	188.74±8.97	25.01%
	Middle	12.98	9.8	26.57	13.2	13.59	3.4	32.97	34.53	6.4	21.33	150.15±7.86	23.31%
	Base	17.54	3.87	24.98	15.09	7.44	11.22	29.08	30.91	4.1	15.82	158.22±17.10	23.98%
Polygonum runcinatum	Apex	11.46	9.18	28.66	22.94	17.2	13.76	44.72	58.22	16.06	35.28	326.27±16.94	23.47%
	Middle	13.76	9.18	25.22	18.33	11.46	9.15	40.14	55.04	14.92	36.71	285.57±10.23	22.19%
	Base	16.06	6.88	26.38	19.5	10.32	12.62	38.98	56.18	12.6	36.68	387.00±11.76	26.45%
Polygonum plebium	Apex	16.25	3.44	28.66	18.33	12.41	14.89	37.84	58.48	9.18	40.15	58.10±8.06	20.47%
	Middle	23.84	6.88	24.08	15.26	10.24	8.38	42.25	57.25	18.17	41.99	64.11±7.49	25.21%
	Base	20.64	9.18	25.22	22.94	4.58	13.76	41.25	51.25	16.03	28.31	170.38±2.49	23.18%
Polygonum molle	Apex	6.06	3.44	33.26	22.94	27.2	19.5	40.14	54.36	6.88	31.42	242.23±23.46	24.25%
	Middle	20.64	4.58	29.82	25.22	9.18	20.64	38.98	57.34	9.16	32.12	217.23±8.82	21.25%
	Base	21.78	8.02	25.22	18.33	3.44	10.31	37.84	52.65	12.62	34.32	234.31±24.22	25.25%
Polygonum viscosum	Apex	12.63	8.02	25.52	22.94	12.89	14.92	39.85	51.67	14.33	28.73	334.62±13.18	9.36%

Taxa	Part of lamina	Mean length of S (µm)	Mean bradth of S(µm)	Mean length of S+GC (µm)	Mean breadth of S+GC (µm)	Mean length of GC (µm)	Mean breadth of GC (µm)	Mean length of S+SC (µm)	Mean breadth of S+SC (µm)	Mean length of SC (µm)	Mean breadth of SC (µm)	Stomatal frequency (no. of stomata /mm²)	Stomatal index(S*100/E+S)
	Middle	20.95	9.18	25.98	19.65	5.03	10.47	34.45	42.85	8.47	23.2	257.42±10.22	7.25%
	Base	19.06	6.88	24.08	20.42	5.02	13.54	34.95	50.37	10.87	29.95	345.07±6.55	19.25%
Polygonum pubescens	Apex	23.67	7.56	29.13	29.17	5.46	21.61	41.17	49.65	12.04	20.48	330.77±13.10	22.14%
	Middle	24.89	6.98	27.68	31.82	2.79	24.84	38.36	50.13	10.68	18.31	277.11±15.01	25.11%
	Base	29.01	8.54	32.86	19.45	3.85	10.91	43.02	49.78	10.16	30.33	396.13±4.98	29.45%
Rumex maritimus	Apex	13.76	8.02	32.09	17.2	18.33	9.18	40.14	50.45	8.05	33.25	150.50±7.12	14.26%
	Middle	11.46	9.18	26.38	21.78	14.92	12.6	38.98	49.29	12.6	27.51	77.63±8.72	9.11%
	Base	16.06	6.88	24.08	17.02	8.02	10.14	37.84	53.9	13.76	36.88	128.40±11.20	12.71%
Rumex dentatus	Apex	13.75	5.74	21.25	26.38	7.5	20.64	75.69	43.75	34.44	37.37	343.97±14.05	14.33%
	Middle	11.46	8.25	18.32	13.2	6.86	4.95	77.56	45.96	59.24	32.76	312.36±12.04	15.21%
	Base	16.06	10.25	24.08	21.78	8.02	11.53	66.89	45.73	42.81	23.95	329.77±14.93	9.36%
Rumex nepalensis	Apex	15.26	8.26	32.25	25.89	16.99	17.63	36.56	48.26	4.31	22.37	245.34±23.16	11.25%
	Middle	20.25	7.23	25.36	22.56	5.11	15.33	44.12	51.96	18.76	29.4	251.22±17.60	14.96%
	Base	21.26	8.98	24.25	23.12	2.99	14.14	36.25	54.87	12	31.75	156.21±4.74	11.89%
Rumex acetosella	Apex	14.89	5.25	21.94	17.02	7.05	11.77	44.56	50.49	22.62	33.47	237.40±25.64	21.33%
	Middle	13.76	3.44	18.56	19.5	4.8	16.06	50.25	48.31	31.69	28.81	269.43±12.08	14.78%
	Base	11.43	4.25	25.66	14.89	14.23	10.64	41.25	51.92	15.59	37.03	246.26±17.87	11.25%
Rheum nobile	Apex	18.92	9.82	26.57	17.61	7.65	7.79	42.87	54.32	16.3	36.71	74.47±6.16	8.45%
	Middle	22.98	8.09	29.54	16.54	6.56	8.45	43.87	50.87	14.33	34.33	84.55±4.02	8.89%
	Base	24.34	9.08	30.94	15.52	6.6	6.44	42.09	51.19	11.15	35.67	93.80±6.81	9.51%
Fallopia convolvulus	Apex	11.21	4.37	21.19	13.23	9.98	8.86	34.32	39.08	13.13	25.85	97.98±6.27	10.09%
	Middle	14.31	5.65	19.08	14.09	4.77	8.44	35.52	37.61	16.44	23.52	115.42±8.90	11.76%
	Base	15.09	6.05	22.39	15.42	7.3	9.37	32.98	35.54	10.59	20.12	143.32±2.34	15.45%
Fagopyrum dibotrys	Apex	16.06	9.18	28.66	21.78	12.6	12.6	42.42	50.46	13.76	28.68	219.21±3.43	26.37%
	Middle	17.2	9.18	24.08	21.78	6.88	12.6	40.14	50.46	16.06	28.68	183.33±11.96	24.87%
	Base	18.34	5.74	25.22	14.89	6.88	9.15	38.98	49.29	13.76	34.4	264.83±5.33	27.99%
Fagopyrum esculentum	Apex	14.89	3.44	28.66	17.02	13.77	13.58	37.84	53.9	9.18	36.88	182.62±12.47	21.39%
	Middle	12.62	6.88	25.22	19.5	12.6	12.62	42.42	51.6	17.2	32.1	146.27±7.48	20.36%
	Base	6.88	9.18	26.38	14.89	19.5	5.71	41.28	52.74	14.9	37.85	222.90±7.62	23.09%
Homalocladium platycladum	Apex	13.76	3.44	24.08	20.64	10.32	17.2	36.7	49.29	12.62	28.65	134.04±9.69	20.11%
	Middle	16.06	3.44	20.64	22.94	4.58	19.5	42.42	53.9	21.78	30.96	131.50±14.57	20.52%
	Base	17.2	4.58	26.38	17.2	9.18	12.62	40.14	49.29	13.76	32.09	150.12±16.35	23.03%

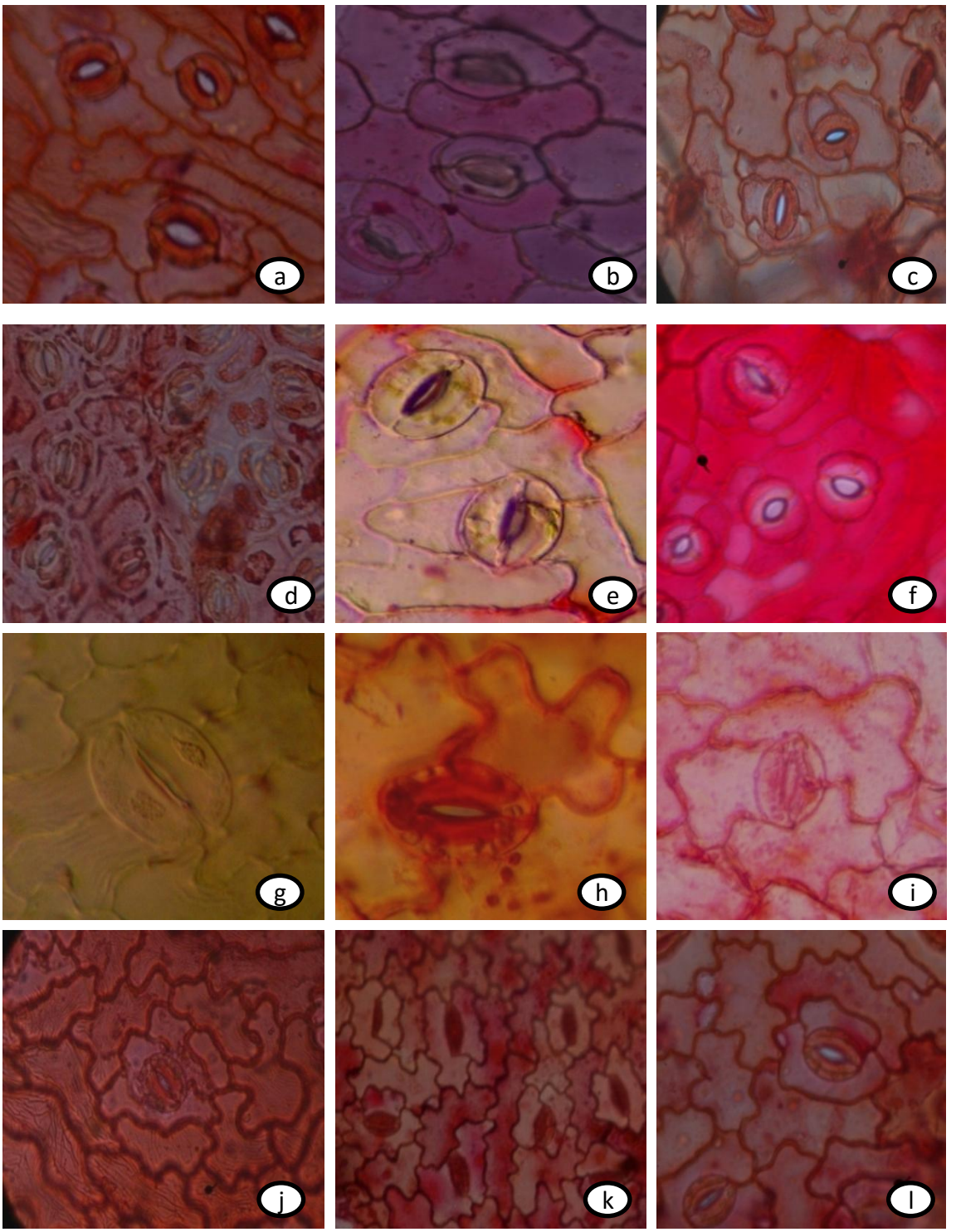

Fig. 15: Light micrographs of stomata **a.** *Persicaria chinensis* var. *chinensis* **b.** *Persicaria strigosa* **c.** *Persicaria orientalis* **d.** *Persicaria barbata* **e.** *Persicaria campanulata* **f.** *Polygonum molle* **g.** *Fagopyrum dibotrys* **h.** *Fallopia convolvulus* **i.** *Persicaria capitata* **j.** *Persicaria chinensis* var. *hispida* **k.** *Persicaria lapathifolia* var. *lapathifolia* **l.** *Persicaria lapathifolia* var. *lanata*

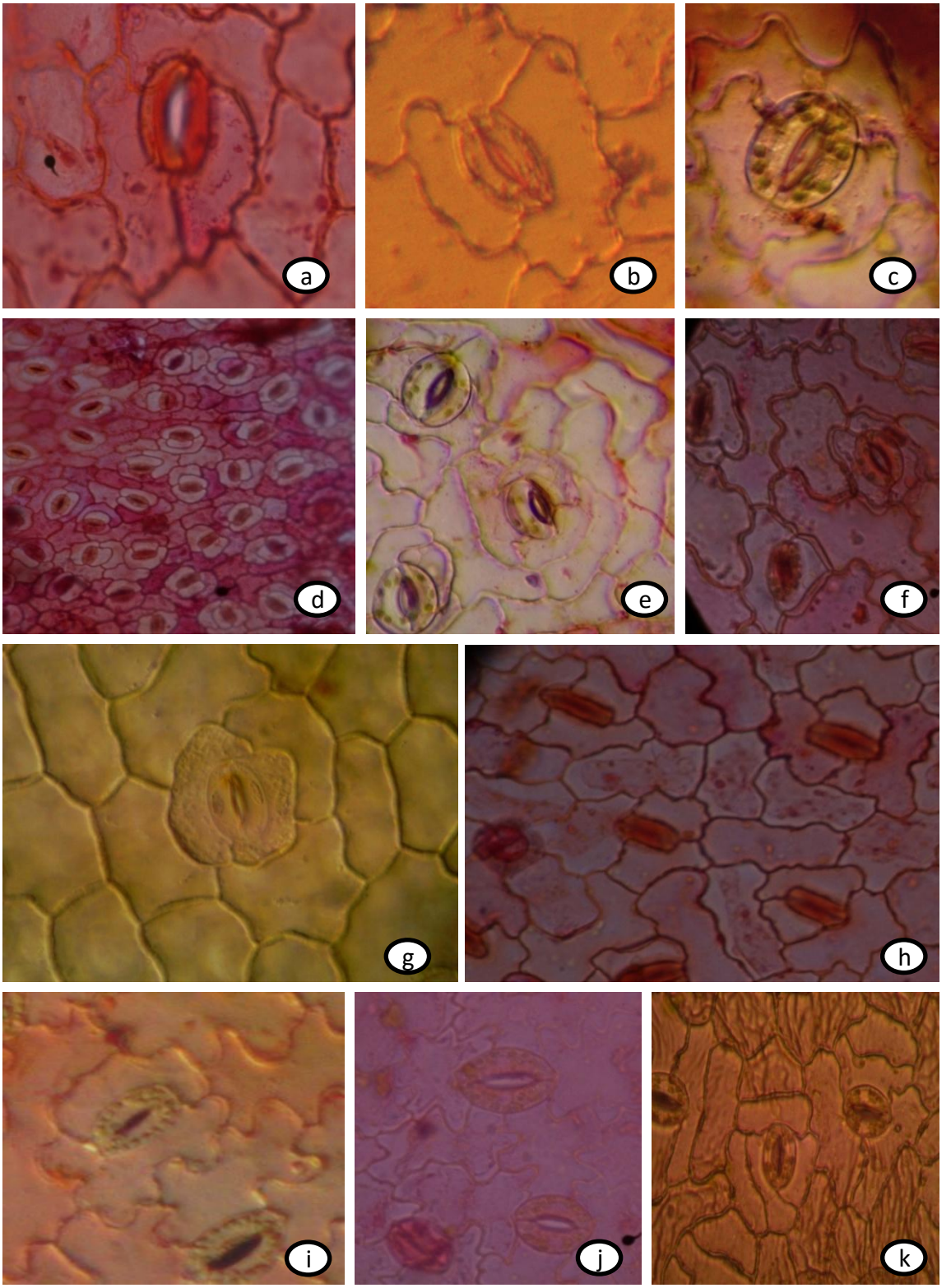

Fig. 16: Light micrographs of stomata **a.** *Rumex maritimus* **b.** *Rumex acetosella* **c.** *Persicaria chinensis* var. *ovalifolia* **d.** *Persicaria hydropiper* **e**. *Persicaria posumbu* **f.** *Persicaria tenella* **g.** *Polygonum pubescens* **h.** *Persicaria lanigera* **i.** *Persicaria minor* **j.** *Polygonum runcinatum* **k.** *Persicaria microcephala*

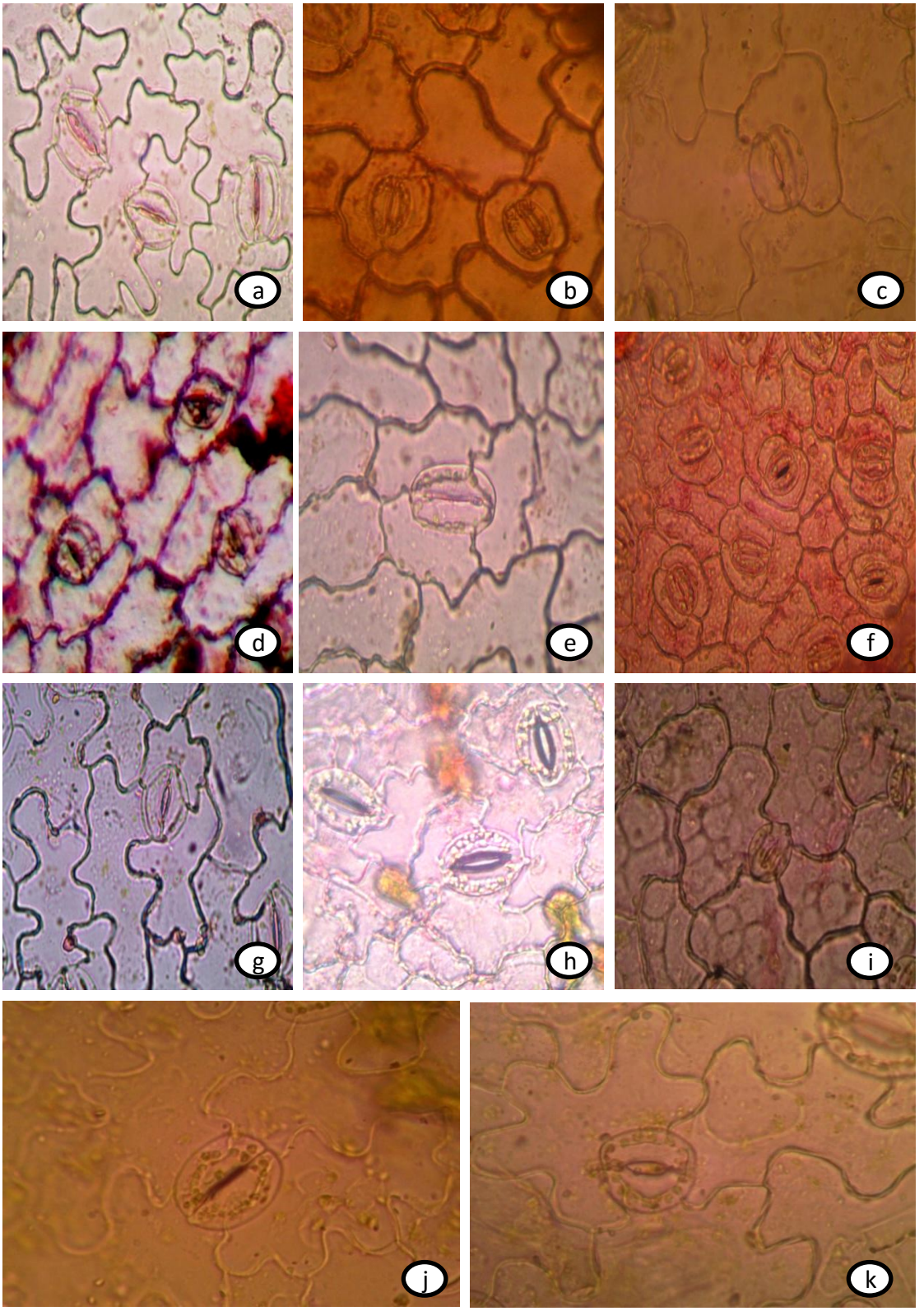

Fig. 17: Light micrographs of stomata **a.** *Homalocladium platyclada* **b.** *Rumex nepalensis* **c.** *Antigonon leptopus* **d.** *Persicaria perfoliata* **e.** *Polygonum plebeium* **f.** *Persicaria glabra* **g.** *Persicaria nepalensis* **h.** *Fagopyrum esculentum* **i.** *Rumex dentatus* **j.** *Rheum nobile* **k.** *Polygonum viscosum*

5.2.3. Venation pattern

The veins and veinlets which form the vasculature, called the ‘venation’ and the pattern of venations are of unique for various species. Venation patterns are important characteristics attributes used to determine many controversies in plant taxonomy.

5.2.3.1. Major venation pattern

The first step in describing venation is to recognize the first three orders of veins. In general the primary and secondary veins are the major structural veins of the lamina. The mid-vein or primary vein is the thickest vein of the lamina and thickness decrease gradually toward the apex. This also includes the study of inter 2º veins (veins similar to 2º and do not reach the margin), and agrophic veins (comb like complex comprising of lateral 1º or 2º veins). The primary vein or 1º vein was categorized and it was slightly different in the studied taxa where in majority of the taxa it was pinnate. In rest of the taxa, it was observed to be basal i.e., primary veins were run from the basal portion of the lamina (Table 10). The 1º vein spacing was more or less similar in all the taxa except in *Persicaria strigosa*, it was increased towards the base. In the entire taxa 2º vein category were same *i.e*., Festooned brochidodromous (one or more additional sets of loops outside of the main brochidodromous loop) (Fig. 18; 19; 20; 21; 22).

5.2.3.2. Minor venation pattern

Major differences were observed up to high order venation pattern in all the studied taxa. 3º vein category were quite variable and three major types *i.e*., alternate percurrent (tertiaries cross between adjacent secondaries with an offset), regular polygonal reticulate (tertiaries anastomose with other 3º veins to form polygons of similar size and shape) and random reticulate (rejoin with other 3º veins or 2º veins at random angles) were observed in various studied taxa (Table 10). Polygonal reticulate was most common type that found in 18 taxa (*Fagopyrum esculentum*, *Homalocladium platycladum*, *Persicaria barbata*, *Persicaria campanulata*, *Persicaria chinensis* var. *chinensis*, *Persicaria chinensis* var. *hispida*, *Persicaria chinensis* var. *ovalifolia*, *Persicaria glabra*, *Persicaria hydropiper*, *Persicaria lanigera*, *Persicaria lapathifolia* var. *lapathifolia*, *Persicaria lapathifolia* var.

lanata, *Persicaria minor*, *Persicaria tenella*, *Persicaria microcephala*, *Polygonum plebeium*, *Polygonum molle* and *Polygonum viscosum*) followed by alternate percurrent that was observed in 8 taxa (*Antigonon leptopus*, *Fagopyrum dibotrys*, *Persicaria capitata*, *Polygonum pubescens*, *Polygonum runcinatum*, *Rumex maritimus* and *Rumex dentatus*) and random reticulate type was observed in 7 taxa (*Fallopia convolvulus*, *Persicaria nepalensis*, *Persicaria perfoliata*, *Persicaria posumbu*, *Persicaria orientalis*, *Persicaria strigosa* and *Rumex nepalensis*). Highest excurrent vein was 4º vein categories except in *Rumex acetosella* where it was 2º. The 4º vein category was also diverse in all the studied taxa (Fig. 18; 19; 20; 21; 22). Four different types of vein categories (Table 10) were observed such as regular polygonal reticulate (*Fagopyrum dibotrys*, *Fallopia convolvulus*, *Homalocladium platycladum*, *Persicaria barbata*, *Persicaria chinensis* var. *chinensis*, *Persicaria chinensis* var. *hispida*, *Persicaria chinensis* var. *ovalifolia*, *Persicaria glabra*, *Persicaria lanigera*, *Persicaria minor*, *Persicaria nepalensis*, *Persicaria perfoliata*, *Persicaria strigosa*, *Persicaria tenella*, *Persicaria microcephala*, *Polygonum plebeium* and *Rumex nepalensis*), alternate percurrent (*Antigonon leptopus*, *Persicaria campanulata*, *Polygonum pubescens*, *Polygonum runcinatum*, *Rumex maritimus* and *Rumex dentatus*), dichotomizing (*Fallopia convolvulus*, *Persicaria capitata*, *Persicaria hydropiper*, *Persicaria lapathifolia* var. *lapathifolia*, *Persicaria lapathifolia* var. *lanata*, *Polygonum molle*, *Polygonum viscosum*, *Rumex acetosella* and *Rheum nobile*) and regular (*Persicaria posumbu* and *Persicaria orientalis*).

Table 10: Major and minor venation pattern in lamina of studied taxa of Polygonaceae based on light microscopy

TAXA	1° vein category	1° vein spacing	2° vein category	2° vein spacing	3° vein category	4° vein category
Antigonon leptopus	Pinnate	Irregular	Festooned brochidodromous	Irregular	Alternate percurrent	Alternate percurrent
Fagopyrum dibotrys	Pinnate	Irregular	Festooned brochidodromous	Irregular	Alternate percurrent	Regular polygonal reticulate
Fagopyrum esculentum	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Fallopia convolvulus	Supra basal	Irregular	Festooned brochidodromous	Irregular	Random reticulate	Regular polygonal reticulate
Homalocladium platycladum	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria barbata	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria campanulata	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Alternate percurrent
Persicaria capitata	Pinnate	Regular	Festooned brochidodromous	Irregular	Alternate percurrent	Dichotomizing
Persicaria chinensis* var. *chinensis	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria chinensis* var. *hispida	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria chinensis* var. *ovalifolia	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria glabra	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria hydropiper	Pinnate	Regular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Persicaria lanigera	Pinnate	Irregular	Festooned brochidodromous	Irregular	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria lapathifolia* var. *lapathifolia	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Persicaria lapathifolia* var. *lanata	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Persicaria minor	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria nepalensis	Pinnate	Regular	Festooned brochidodromous	Irregular	Random reticulate	Regular polygonal reticulate
Persicaria perfoliata	Supra basal	Irregular	Festooned brochidodromous	Irregular	Random reticulate	Regular polygonal reticulate

TAXA	1° vein category	1° vein spacing	2° vein category	2° vein spacing	3° vein category	4° vein category
Persicaria posumbu	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Random reticulate	Regular
Persicaria orientalis	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Random reticulate	Regular
Persicaria strigosa	Basal	Decrease towards base	Festooned brochidodromous	Strong intersecondaries	Random reticulate	Regular polygonal reticulate
Persicaria tenella	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Persicaria microcephala	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Regular polygonal reticulate
Polygonum plebeium	Pinnate	Irregular	Festooned brochidodromous	Irregular	Regular polygonal reticulate	Regular polygonal reticulate
Polygonum pubescens	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Alternate percurrent	Alternate percurrent
Polygonum molle	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Polygonum viscosum	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Regular polygonal reticulate	Dichotomizing
Polygonum runcinatum	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Alternate percurrent	Alternate percurrent
Rumex nepalensis	Pinnate	Irregular	Festooned brochidodromous	Strong intersecondaries	Random reticulate	Regular polygonal reticulate
Rumex maritimus	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Alternate percurrent	Alternate percurrent
Rumex dentatus	Basal	Irregular	Festooned brochidodromous	Strong intersecondaries	Alternate percurrent	Alternate percurrent
Rumex acetosella	Basal	Irregular	Festooned brochidodromous	Irregular	-	-
Rheum nobile	Supra basal	Irregular	Festooned brochidodromous	Irregular	Alternate percurrent	Dichotomizing

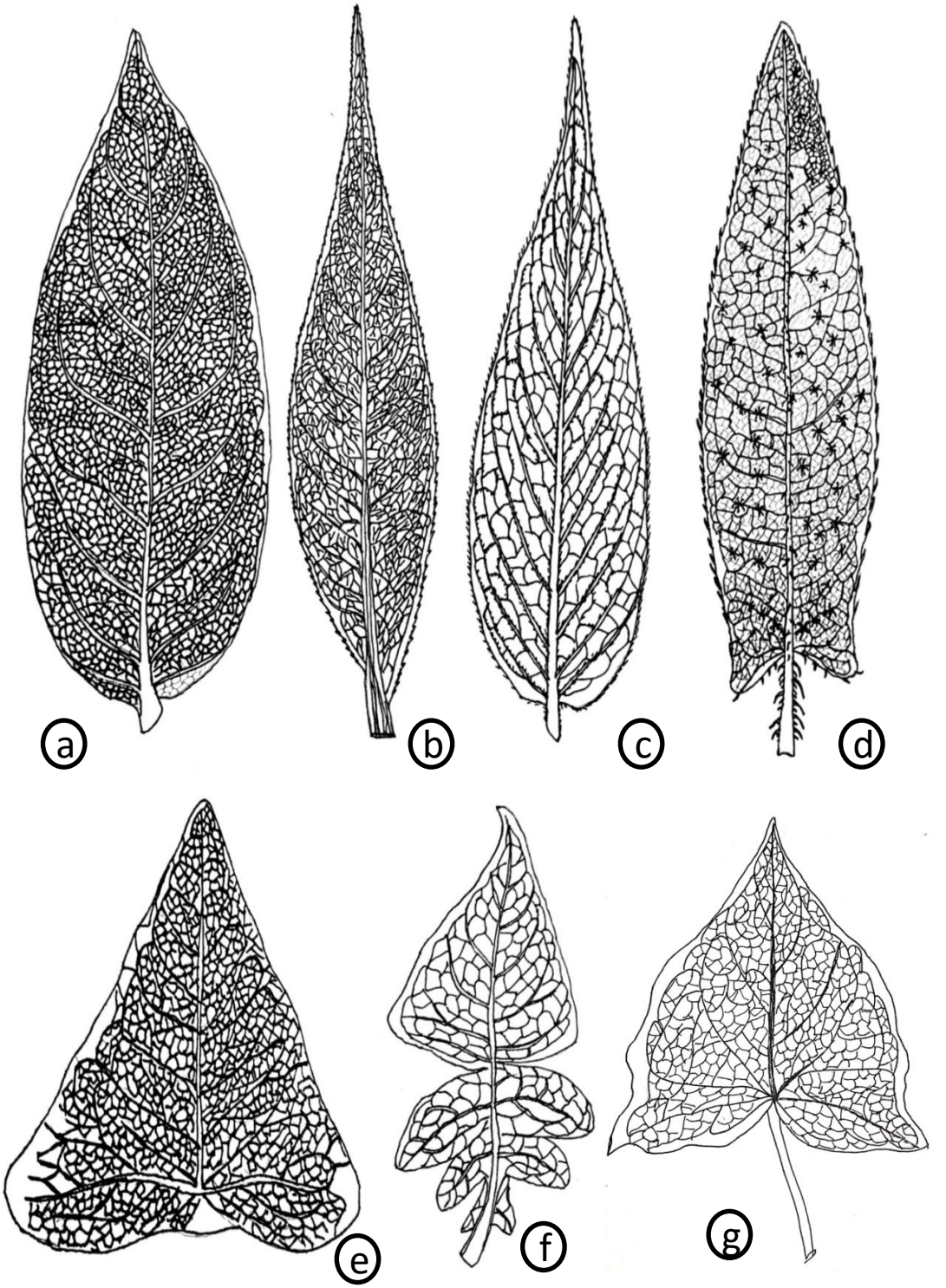

Fig. 18: Illustration of venation pattern **a.** *Persicaria chinensis* var. *chinensis* **b.** *Persicaria hydropiper* **c.** *Persicaria orientalis* **d.** *Persicaria strigosa* **e.** *Persicaria perfoliata* **f.** *Polygonum runcinatum* **g.** *Fagopyrum dibotrys*

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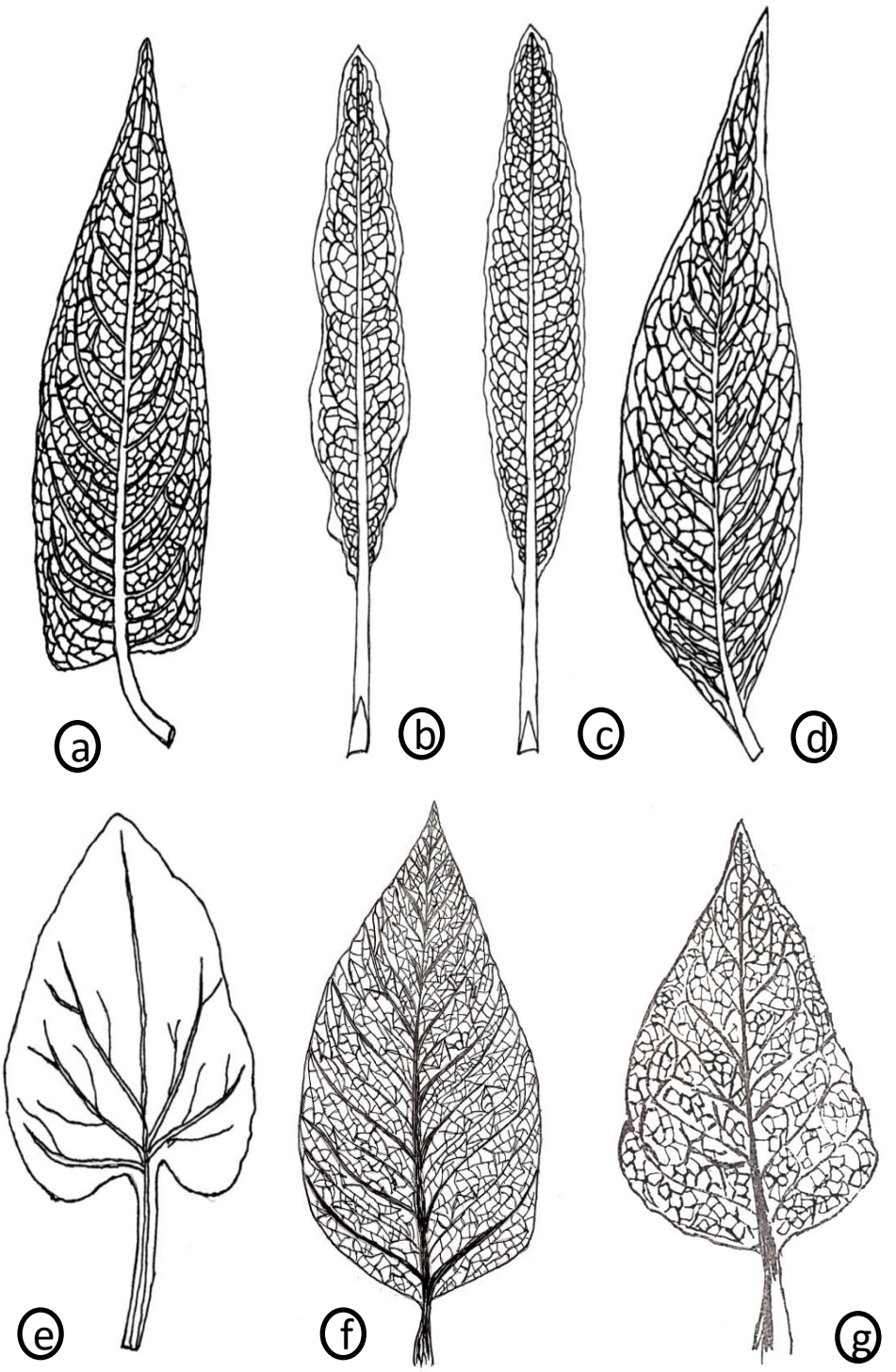

Fig. 19: Illustration of venation pattern **a.** *Rumex nepalensis* **b.** *Rumex dentatus* **c.** *Rumex maritimus* **d.** *Polygonum pubescens* **e.** *Rumex acetosella* **f.** *Persicaria campanulata* **g.** *Persicaria nepalensis*

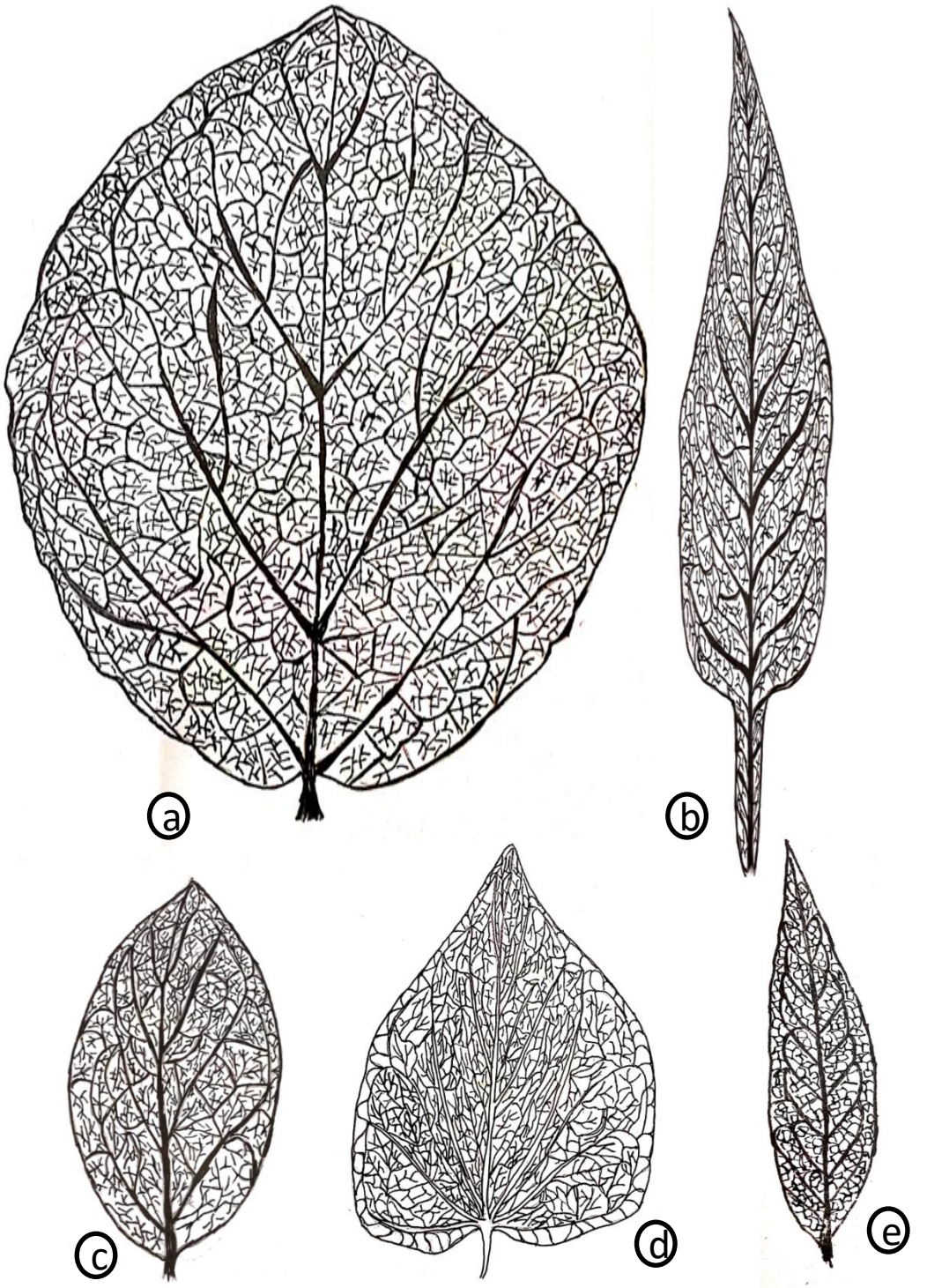

Fig. 20: Illustration of venation pattern **a.** *Rheum nobile* **b.** *Polygonum viscosum* **c.** *Perssicaria capitata* **d.** *Fagopyrum esculentum* **e.** *Persicaria minor*

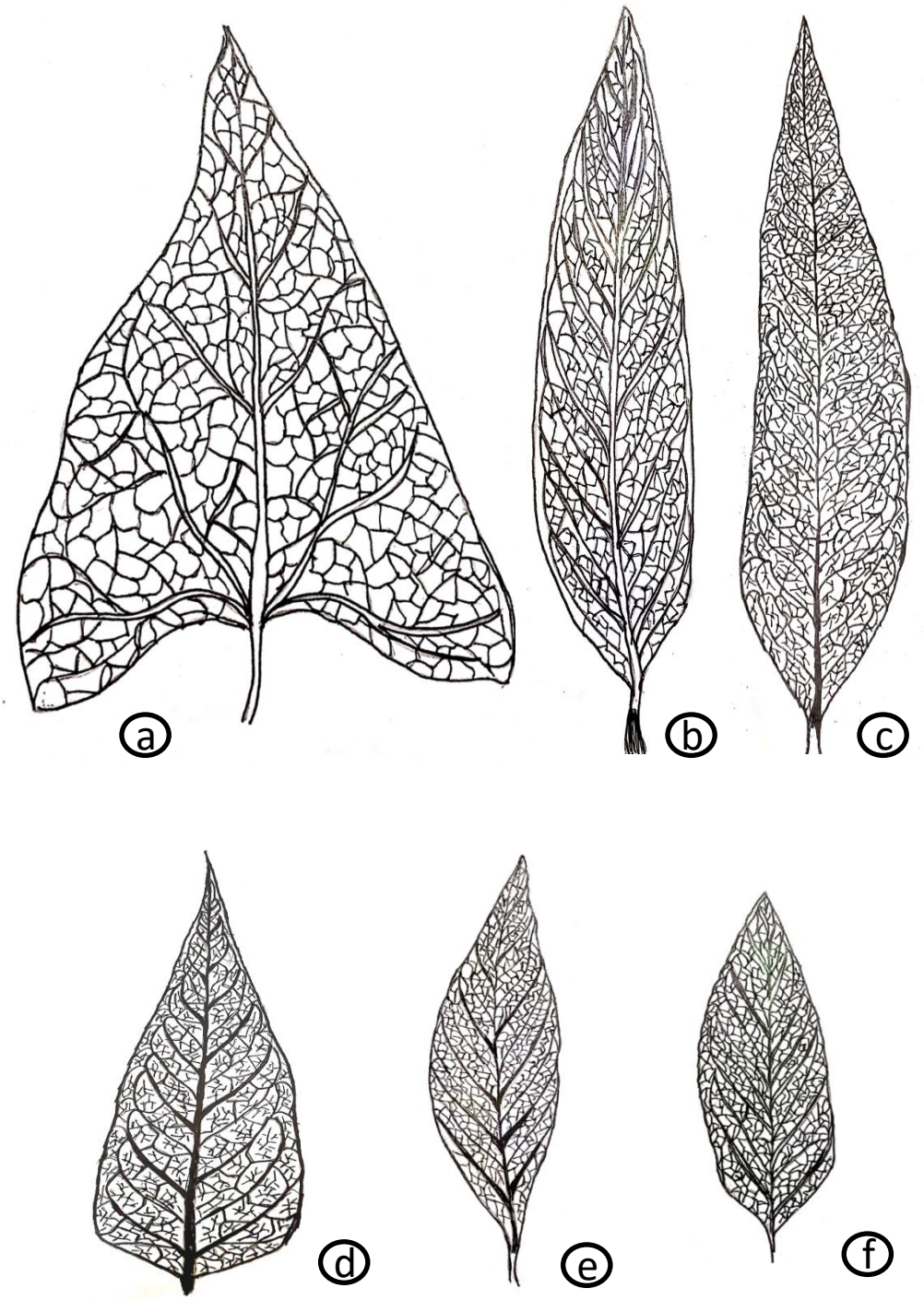

Fig. 21: Illustration of venation pattern **a.** *Fallopia convolvulus* **b.** *Persicaria barbata* **c.** *Persicaria lapathifolia* var. *lapathifolia* **d.** *Persicaria lapathifolia* var**.** *lanata* **e.** *Persicaria glabra* **f.** *Homalocladium platycladum*

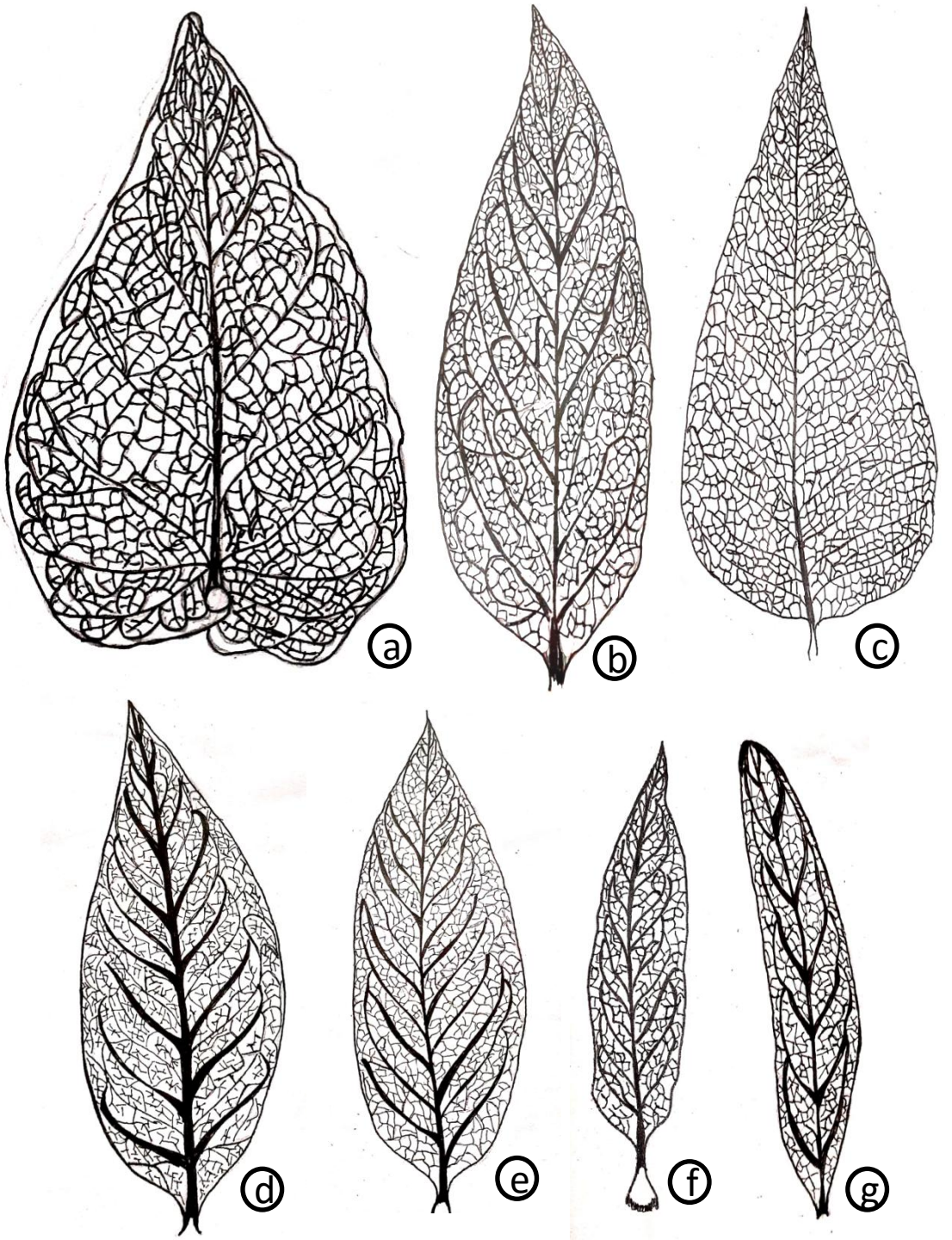

Fig. 22: Illustration of venation pattern **a.** *Antigonon leptopus* **b.** *Persicaria lanigera* **c.** *Persicaria posumbu* **d.** *Polygonum molle* **e.** *Persicaria microcephala* **f.** *Persicaria tenella* **g.** *Polygonum plebeium*

5.2.4. Morphology of Indumentums

Indumentums or trichomes are the epidermal outgrowths of various kinds. Hair is a common type of trichomes, it may be unicellular or multicellular, branched or unbranched, glandular or eglandular whereas, scale or peltate hair is a shield shaped cluster of cells attached directly to the surface or sometimes with stalk. Indumentums could be considered as valuable criteria in field of species identification as the presence and absence and location of indumentums are major diagnostic attributes in plant taxonomy. Although they are rarely found preserved in fossils but their bases are commonly found and in some cases, their cellular structure also plays important role in identification of ancient flora.

In this study, it was noticed that indumentums were entirely absent in some taxa (Table 11) but all other taxa bears two basic type of trichomes on abaxial and adaxial lamina surfaces i.e., glandular (G) and nonglandular (NG). On the basis of cell shape trichomes are further divided into two forms i.e., elongated-slender and globular (Table 11). The trichomes are distributed on both abaxial and adaxial surface of the investigated species. Trichomes are originated from some specific area and/or on entire lamina. In some taxa *i.e., Homalocladium platyclada*, *Persicaria strigosa*, *P. orientalis*, *P. perfoliata*, *P. lapathifolia* var. *lanata*, *Polygonum runcinatum*, *Rumex dentatus* trichomes were originated from the entire lamina (Fig. 22; 23) whereas in four taxa *i.e., Fagopyrum dibotrys*, *Fagopyrum esculentum*, *Polygonum plebeium* and *Rumex maritimus*, it was originated from the middle of the lamina only and in rest of the taxa it was along with the margin of lamina (Table 11; Fig. 23; 24). Longest trichomes observed in *Polygonum lanigera* (260.12µm ±8.94), whereas smallest one observed in *Rumex maritimus* (15.71µm ±0.62). The characteristic features of the trichome also showed great variation in the studied taxa (Table 11). Peltate hair was found in some taxa *i.e., Persicaria barbata*, *P. chinensis* var. *hispida*, *P. glabra*, *Polygonum plebeium* and *Fagopyrum dibotrys*. Strigose and stellate hairs were also a unique feature of this family and found in 3 taxa i.e. *Persicaria chinensis* var. *hispida*, *Persicaria strigosa* and *Rumex dentatus*.

Table 11: Qualitative and quantitative study on morphology of Indumentums of Polygonaceae based on light microscopy

Taxa	Origin	Type	Shape	Branching	Gland	Length (µm)	Features
Antigonon leptopus	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Fallopia convolvulus	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Fagopyrum dibotrys	Middle of lamina	Multicelled	Globular	Unbranched	Non glandular	37.06±1.09	Peltate hair present
Fagopyrum esculentum	Middle of lamina	Multiseriate	Slender	Unbranched	Non glandular	109.82±2.87	Long with blunt tip
Homalocladium platycladum	Entire lamina	Multiseriate	Slender, curved	Branched	Non glandular	115.6±4.98	Long, dense with blunt tip
Persicaria barbata	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	53.92±0.98	Soft, dense, slender with blunt end , peltale hair present
Persicaria campanulata	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	76.32±9.57	Long, dense
Persicaria capitata	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	62.69±5.06	Long, fine, not so dense
Persicaria chinensis* var. *chinensis	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Persicaria chinensis* var. *hispida	Entire lamina	Uniseriate	Slender, curved	Unbranched	Glandular	26.01±1.76	Strigose and stellate hairs and also peltate scale present
Persicaria chinensis* var. *ovalifolia	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Persicaria glabra	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Glandular	78.89±1.98	Long, dense, tip very sharp, peltate hair present
Persicaria hydropiper	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	101.09±5.97	Long, fine, not so dense
Persicaria lanigera	Lamina margin	Uniseriate	Elongated, slender	Unbranched	Non glandular	260.12±8.94	Long, slender, not dense.
Persicaria lapathifolia* var. *lapathifolia	Lamina margin	Multiseriate	Slender	Unbranched	Non glandular	37.01±0.87	Short , not so dense
Persicaria lapathifolia* var. *lanata	Entire lamina	Multiseriate	Slender	Unbranched	Non glandular	29.32±1.02	Short , dense
Persicaria microcephala	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Persicaria minor	Lamina margin	Multiseriate	Slender	Unbranched	Glandular	43.35±2.13	Short, not so dense.

Taxa	Origin	Type	Shape	Branching	Gland	Length (µm)	Features
Persicaria nepalensis	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Persicaria orientalis	Entire lamina	Multiseriate	Slender	Unbranched	Nonglandular	35.98±2.21	Short, soft, dense, erect
Persicaria perfoliata	Entire lamina	Uniseriate	Elongated, slender	Unbranched	Non glandular	130.05±7.34	Long, fine not so dense
Persicaria posumbu	Lamina margin	Uniseriate	Elongated, slender	Unbranched	Non glandular	98.26±3.09	Many, spiny, dense, slender
Persicaria strigosa	Entire lamina	Multiseriate	Elongated, slender	Unbranched	Nonglandular	48.44±2.94	Both strigose & stellate hairs present
Persicaria tenella	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	68.72±1.32	Short, dense, slender
Polygonum molle	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	86.32±5.57	Long, dense with sharp tip
Polygonum pubescens	Lamina margin	Multiseriate	Elongated, slender	Unbranched	Non glandular	62.02±2.09	Long, slender
Polygonum runcinatum	Entire lamina	Multiseriate	Elongated, slender	Unbranched	Non glandular	55.01±5.66	Short, dense, slender
Polygonum viscosum	Lamina Margin	Multiseriate	Elongated, slender	Unbranched	Glandular	46.76±0.76	Short, dense, slender
Polygonum plebeium	Middle of lamina	Multicelled	Globular	N.A.	N.A.	21.98±1.11	Peltate hair present
Rheum nobile	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Rumex acetosella	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Rumex dentatus	Entire lamina	Multicelled	Round	Unbranched	Non glandular	26.01±1.98	Stellate, devide into four parts
Rumex maritimus	Middle of lamina	Two celled	Elongated, slender	Unbranched	Non glandular	15.71±0.62	Short, dense, slender
Rumex nepalensis	Absent	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

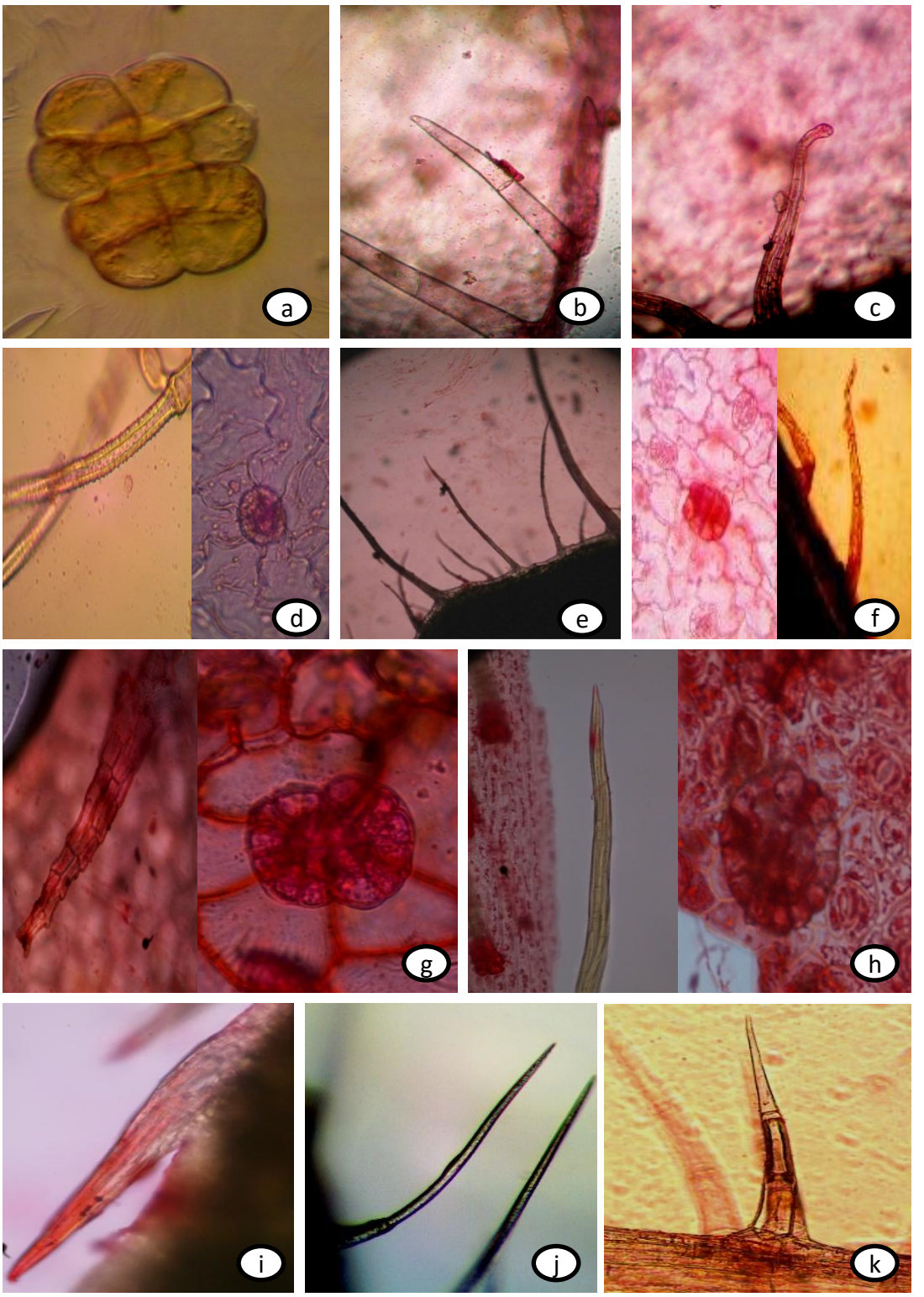

Fig. 23: Light micrographs of different types of Indumentums **a.** *Fagopyrum dibotrys* **b.** *Fagopyrum esculentum* **c.** *Homalocladium platyclada* **d.** *Persicaria barbata* **e.** *Persicaria campanulata* **f.** *Persicaria capitata* **g.** *Persicaria chinensis* var. *hispida* **h.** *Persicaria glabra* **i.** *Persicaria hydropiper* **j.** *Persicaria lanigera* **k.** *Persicaria lapathifolia* var. *lanata*

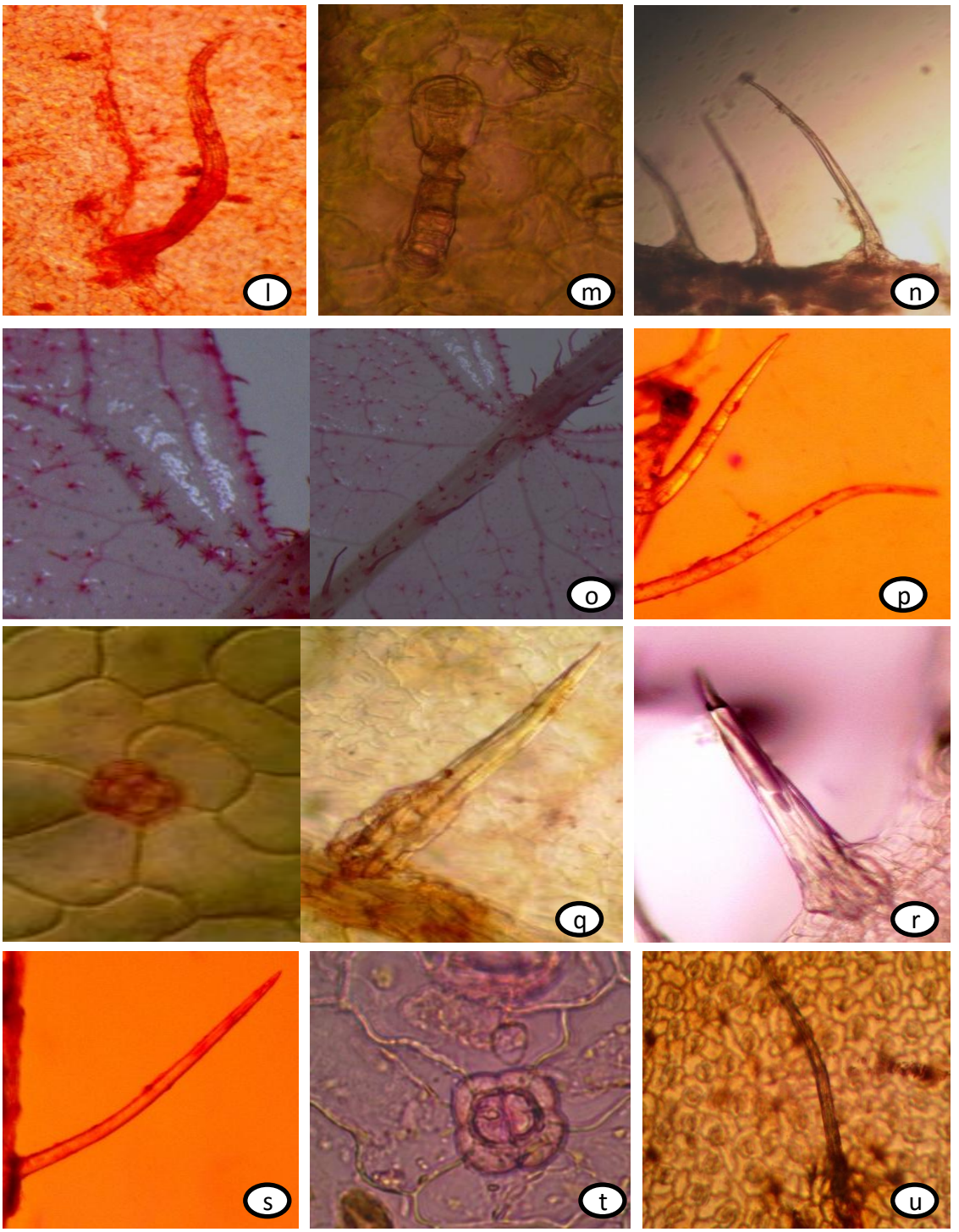

Fig. 24: Light micrographs of different types of Indumentums **l.** *Persicaria lapathifolia* var. *lapathifolia* **m.** *Persicaria minor* **n.** *Persicaria orientalis* **o.** *Persicaria strigosa* **p.** *Persicaria tenella* **q.** *Polygonum pubescens* **r.** *Polygonum runcinatum* **s.** *Polygonum viscosum* **t.** *Rumex dentatus* **u.** *Rumex maritimus*

5.2.5. Statistical analysis

Statistical analysis was conducted for collective interpretation of all the studied macro and micro morphological data. Current study was summarized under three statistical interpretations namely ANOVA, Principal component analysis (PCA) and Correlation study. Through ANOVA analysis, comparison of data sets was conducted for determining the significance level among the different attributes under study by determining variability among the samples and within the samples. PCA was conducted for reducing the complexity in the data pattern by projecting the studied parameters into different geometrical dimensions called principal components. For determining the prevalence and the relationships among the studied variables Pearson correlation study was conducted which tests the strength between two continuous variables by measuring the degree of significance among them.

5.2.5.1. ANOVA analysis

Two-way ANOVA without replicates were performed taking all the attributes under study (Table 12). From analysis it was found that the p-value for all the taxa and parameters were 0.181848 and 9.68×10^{-23} respectively.

Table 12: ANOVA analysis representing the significance level among different macro & micro morphological parameters

Source of Variation	SS	df	MS	F	P-value	F crit
Species	72948110	33	2210549	1.225131	0.181848	1.451846
Attributes	3.19E+08	23	13885747	7.695763	9.68E-23	1.543515
Error	1.37E+09	759	1804337			
Total	1.76E+09	815				

Significant at $p < 0.01$

5.2.5.2. Principal Component Analysis (PCA)

Principle Component Analysis was done to correlate different attributes under study by group clustering. PCA separates correlated attributes from uncorrelated ones. Eigen analysis results and loading scores of three principal components were showing in table 13 and 14 and score plot was shown in Fig. 25. The first principal component (PC1) was dominated by lamina length (LL), lamina breadth (LB), lamina area (LA), stomatal frequency (SF), 2º vein category (2º) and the second principal component (PC2) was dominated by blade class (BC), lamina Shape (LS),

base angle (BA), base shape (BS), apex shape (AS), margin type (MT), Lobation (LO), stomatal index (SI), 1˚ vein category (1º), 3˚ vein category (3º), 4˚ vein category (4º), origin of indumentum (OI), gland (GL), length of indumentums (LI), Cilia (CI), length of stipule (LS), breadth of stipule (BS), number of frimbrae (NF), length of frimbrae (LF). The distribution of total variation in PC1 and PC2 was 21.63% and 19.42% respectively.

Table 13: Eigen analysis of Correlation matrix

	PC1	PC2	PC3
Eigen value	5.1906	4.6604	2.2797
Variability (%)	21.6273	19.4182	9.4988
Cumulative %	21.6273	41.0456	50.5444

Table 14: The variable loading scores for each principal component (PC1 – PC3) for 34 taxa of Polygonaceae from West Bengal, India

Variables	PC1	PC2	PC3
Lamina length (LL)	0.2416	0.2311	0.0705
Lamina breadth (LB)	0.3142	0.2718	-0.0846
Lamina area (LA)	0.3350	0.2285	-0.1320
Blade Class (BS)	-0.3255	0.0145	0.0402
Lamina Shape (LS)	0.1566	0.1664	0.1936
Base Angle (BA)	-0.0207	0.2140	0.2583
Base Shape (BS)	0.0240	0.2182	0.2566
Apex Shape (AS)	0.0950	0.1871	-0.1804
Margin Type (MT)	0.0111	0.1531	0.4005
Lobation (LO)	-0.0497	-0.0881	0.1714
Stomatal Frequency (SF)	0.3352	0.2295	-0.1306
Stomatal Index (SI)	-0.2864	0.1293	-0.0123
1˚ vein category (1˚)	-0.0045	-0.1093	0.3567
2˚ vein category (2˚)	0.0251	-0.0482	0.3429
3˚ vein category (3˚)	-0.0448	0.1124	-0.3961
4˚ vein category (4˚)	-0.1345	0.2222	-0.2407
Origin of Indumentum (IO)	-0.2431	0.1343	0.0713
Gland (G)	-0.3103	0.1705	-0.0902
Length of Indumentum (IL)	-0.3047	0.1421	-0.0917
Cilia (CI)	-0.1526	0.1544	-0.1745
Length of Stipule (SL)	-0.0204	0.3702	0.1326
Breadth of Stipule (SB)	-0.0175	0.3898	0.0794
Number of Frimbrae (NF)	-0.2416	0.1982	-0.0388
Length of Frimbrae (FL)	-0.2047	0.2606	0.1489

On comparing the taxa by PCA (Fig. 26) it was observed that the first axis (PC1) was dominated by 21 taxa viz. *Fagopyrum dibotrys*, *F. esculentum*, *Persicaria barbata*, *P. campanulata*, *P. capitata*, *P. chinensis* var. *chinensis*, *P. glabra*, *P. hydropiper*, *P. lapathifolia* var. *lanata*, *P. lapathifolia* var. *lapathifolia*, *P. minor*, *P. perfoliata*, *P. strigosa*, *P. tenella*, *Polygonum pubescens*, *P. plebeium*, *Rheum nobile*, *Rumex acetosella*, *R. dentatus*, *R. maritimus* and *R. nepalensis*. The second axis (PC2) was dominated by 13 taxa viz., *Antigonon leptopus*, *Fallopia convolvulus*, *Homalocladium platycladum*, *P. chinensis* var. *hispida*, *P. chinensis* var. *ovalifolia*, *P. lanigera*, *P. microcephala*, *P. nepalensis*, *P. orientalis*, *P. posumbu*, *Polygonum molle*, *P. runcinatum*, and *P. viscosum*

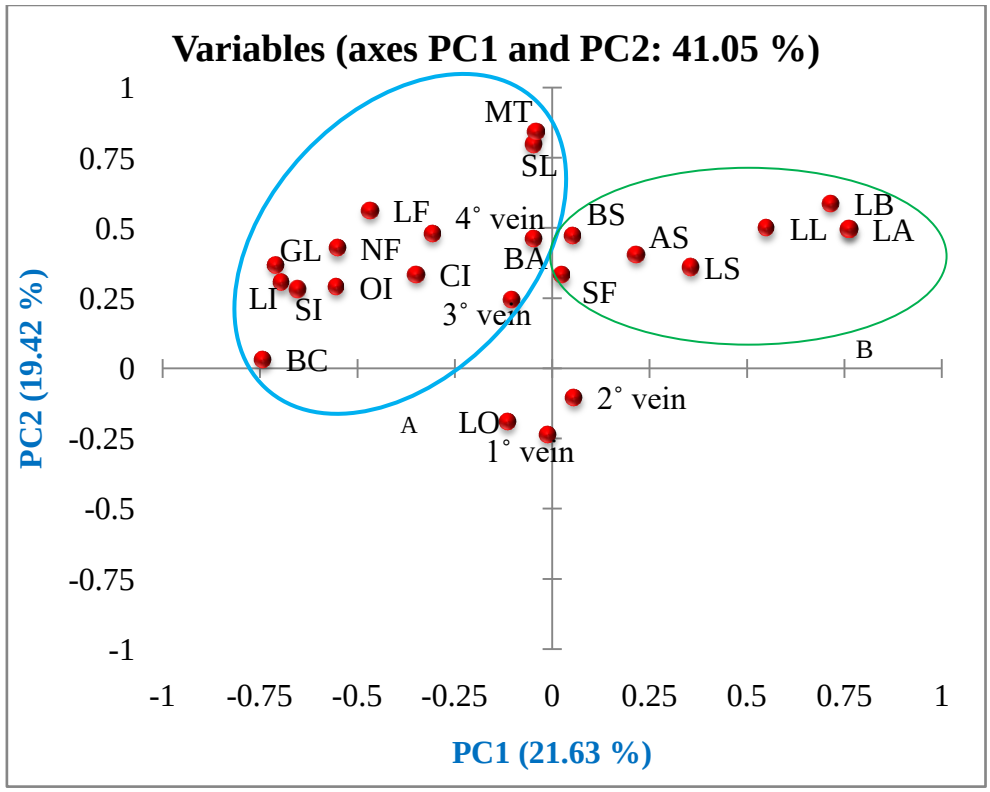

Fig. 25: Principal component analysis score plot showing the macro & micro morphological variation for studied taxa of Polygonaceae

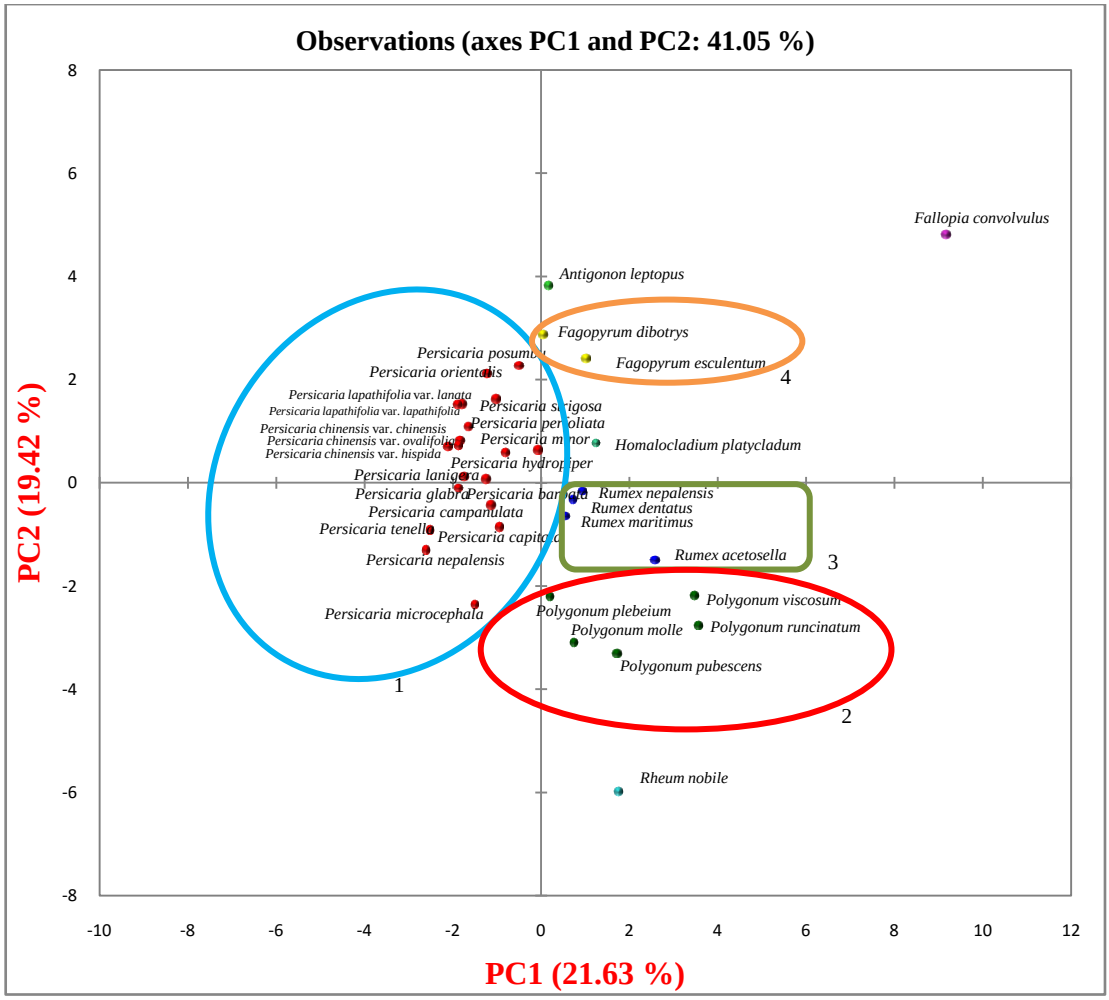

Fig. 26: Principal component analysis score plot showing the interrelationships among studied taxa

5.2.5.3. Correlation matrix analysis

Pearson correlation matrix for quantitative variables for studied taxa (Table 15) were quite distinct and stomatal frequency (SF) correlates positively with lamina length (LL) (r = 0.614), lamina width (LW) (r = 0.969) and lamina area (LA) (r = 1). Stomatal index (SI) correlates positively and significantly with blade class (r = 0.42). Indumentum length (IL) positively and significantly correlates with blade class (r = 0.48) and the origin of indementum (IO) (r = 0.63). Stipule length (SL) correlates with lamina length (r = 0.346), lamina breadth (r = 0.35) and margin type (r = 0.37). All these parameters were correlated with each other at $p < 0.01$.

Table 15: Pearson correlation matrix for quantitative macro & micro morphological variables among the studied taxa of Polygonaceae

	LL	LW	LA	Blade class	LS	BA	BS	AS	Margin type	Lobation	SF	SI	1º vein	2º vein	3º vein	4º vein	IO	Gland	IL	Cilia	SL	SB	FN
LL		***0.607**																					
LA	***0.609**	***0.968**	LA																				
Blade class	***-0.447**	***-0.521**	***-0.533**	Blade class																			
LS	.183	****0.383**	.284	-.052	LS																		
BA	.326	.163	.093	.123	****0.371**	BA																	
BS	.204	.248	.161	.089	***0.481**	.306	BS																
AS	.261	****0.39**	****0.377**	.062	.142	.092	.237	AS															
Margin type	.299	.086	.011	.064	.262	.296	.199	-.005	Margin type														
Lobation	-.229	-.075	-.078	.092	-.211	.012	.204	.114	-.123	Lobation													
SF	***0.614**	***0.969**	***1**	***-0.533**	.285	.095	.162	****0.378**	.014	-.079	SF												
SI	-.235	-.271	-.312	****0.423**	-.275	.235	.027	-.190	.108	.138	-.312	SI											
1º vein	.043	-.136	-.100	.065	-.155	.270	-.046	-.113	.191	.290	-.100	-.106	1º vein										
2º vein	.083	.048	-.028	-.120	.101	-.146	.313	-.321	.100	****0.376**	-.027	-.169	.247	2º vein									
3º vein	.051	.100	.125	.052	-.004	-.010	-.009	.180	-.178	-.211	.124	.112	-.149	-.226	3º vein								
4º vein	-.043	.060	.012	.337	.149	.156	****0.35**	.298	-.072	.036	.012	****0.411**	****-0.412**	-.215	**0.539**	4º vein							
IO	-.215	-.054	-.172	****0.356**	-.115	.189	.056	.005	.120	.277	-.172	****0.347**	.163	.160	.035	.217	IO						
Gland	-.149	-.186	-.230	***0.465**	-.310	.151	.037	.078	.021	.107	-.230	****0.39**	.115	-.009	.320	.322	***0.692**	Gland					
IL	-.270	-.153	-.210	***0.476**	-.210	.134	.084	.009	-.076	.143	-.211	**0.475**	.012	.028	.229	.237	****0.625**	***0.796**	IL				
Cilia	.165	.074	-.025	.096	-.173	.118	-.162	-.067	-.098	-.112	-.023	.338	-.241	.040	.127	.069	**0.459**	***0.519**	***0.455**	Cilia			
SL	****0.346**	****0.345**	.267	-.029	.176	.309	.335	.172	****0.368**	-.146	.269	.304	-.165	-.032	-.010	.263	.147	.231	.071	.224	SL		
SB	.275	**0.471**	****0.376**	-.019	.226	.271	.255	.236	****0.36**	-.160	****0.378**	.298	-.132	-.077	.022	.208	.307	.290	.260	.244	***0.843**	SB	
FN	-.019	-.206	-.245	****0.419**	-.052	-.015	.198	.064	.004	-.265	-.244	.314	-.246	-.048	.035	.260	.161	***0.475**	***0.488**	.295	****0.399**	***0.393**	FN
FL	.102	-.194	-.232	.319	.139	.316	.282	-.008	.299	-.272	-.229	****0.428**	-.167	-.106	.038	****0.355**	.178	.329	.278	.092	***0.62**	***0.528**	***0.668**

*, **; significant at p = 0.05, 0.01 respectively

+1 0 -1

5.2.6. Cluster analysis

All the accumulated phenetic data were futher taken in single head to analyzed numerically and finally generate the Pearson similarity co-efficient dendrogram to understand the inter-relationship among the studied taxa. The dendrogram (Fig. 27) showed two major constant clusters with closely related taxa where the first cluster was further divided into four sisters clades. The first sister clade consisted of *Homalocladium platycladum* whereas in second sister clade consist of all the taxa of *Polygonum* (*P. plebeium, P. molle, P. runcinatum, P. pubescens, P. viscosum*). The third sister clade was further subdivided into two clades where one clade consisted of *Rumex nepalensis, R. dentatus, R. maritimus, R. acetosella* and *Rheum nobile*, *Antigonon leptopus* and *Fallopia convolvulus* whereas other one composed of 19 taxa of *Persicaria* (*P. chinensis* var. *ovalifolia*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. capitata*, *P. tenella*, *P. perfoliata*, *P. minor*, *P. campanulata, P. nepalensis, P. posumbu, P. glabra, P. microcephala, P. barbata, P. hydropiper, P. orientalis, P. strigosa, P. lanigera, P. lapathifolia* var. *lapathifolia* and *P. lapathifolia* var. *lanata*) showing very close proximity among them. In second cluster, only two taxa of *Fagopyrum* (*F. esculentum* and *F. dibotrys*) were placed. Present phenogram clearly showing that the *Fagopyrum* was distantly allied with rest of the studied genera based on their phenetic characters. The entire dendrogram was found quite significant and genera wise they were forming separate cluster s and nearby cluster denotes the very close proximity among the genera.

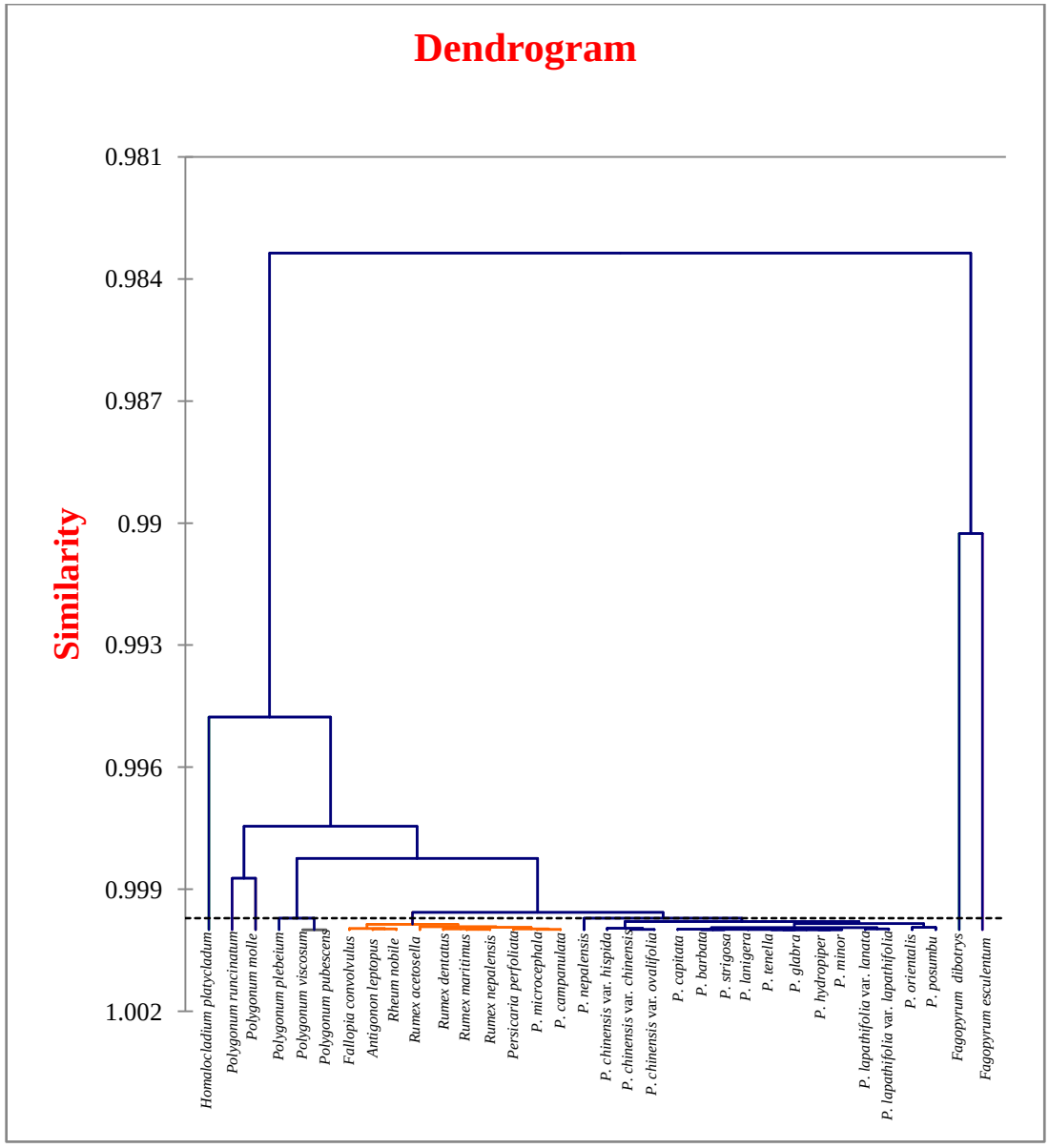

Fig. 27: Dendrogram showing inter-relationship among the taxa of Polygonaceae based on studied phenetic characters

5.2.7. Artificial identification key

Using various distinctive macro and mico morphological characters an easy identification dichotomous key was constructed for studied taxa under study from this part of the world. This key is clearly reflecting the importance of qualitative and quantitative characters that functioned as unique identification tool for taxa upto varietal level.

1a. Opposite phyllotaxy …… ……. …….. ….……..… **2**

1b. Alternate phyllotaxy …… …….. ……. ……. …… ..….. **3**

2a. Lamina unlobed …… …….. ……..…. **4**

2b. Lamina lobed ……. ……...…… ***Poygonum runcinatum***

3a. Margin entire …… …… ……. ……. …..... **5**

3b. Margin erose ……. ……. ……. ……..... **6**

4a. Base angle obtuse - wide obtuse …….. …….. ……. ..… **7**

4b. Base angle acute …….. …… …….. ……... **8**

5a. 1º vein basal or supra basal …….. ……. …….. ….. **9**

5b. 1º vein pinnate …….. ……..…… …….. . **10**

6a. 1º vein spacing irregular …….. …… ……. ……... …...……. **11**

6b. 1º vein spacing regular ……. ……..… ***Persicaria hydropiper***

7a. Apex shape accuminate …… ……... …… ….... **12**

7b. Apex shape convex …….. ……..…….. … ***Polygonum pubescens***

8a. Base shape decurrent …… …….. …….. …… ….. **13**

8b. Base shape saggitate …….. ……..…. ***Fallopia convolvulus***

9a. Blade class microphyll …… ……. ……..….. **14**

9b. Blade class mesophyll ……. …… ..…..…..... ***Rumex acetosella***

10a. 1º vein spacing irregular …… …… ……. **15**

10b. 1º vein spacing regular …… …… … ***Persicaria capitata***

11a. 2º vein spacing irregular …… ……. …… **16**

11b. 2º vein spacing strong intersecondaries …….. ……. …. **17**

12a. Anomocytic stomata ……. …….. ***Antigonon leptopus***

12b. Anisocytic stomata ……. …..…. ***Persicaria microcephala***

13a. Peltate hair present …… …..…… ***Polygonum plebeium***

13b. Peltate hair absent ……..……..… ***Homalocladium platycladum***

14a. Stellate hair present ……. .…… ***Persicaria strigosa***

14b. Stellate hair absent …… ……. ….. ***Persicaria perfoliata***

15a. Indumentums present …….…… ……. **18**

15b. Indumentums absent …….. ……..…… ***Rumex nepalensis***

16a. More than one morphotype in stomata ……...…….. ***Rheum nobile***

16b. Stomata paracytic ……. …… ……. … **19**

17a. 1º vein basal …… …….…….. ……..…. …. **20**

17b. 1º vein pinnate …… ……...… ……. **21**

18a. Indumentums glandular …… …….…….… ...…. **22**

18b. Indumentums non glandular ……... ……..……. … **23**

19a. Indumentums absent …….. …….. ***Persicaria nepalensis***

19b. Indumentums present …….. ....……. .. ***Persicaria lanigera***

20a. 4º vein alternate percurrent …….. …..…… …… **24**

20b. 4º vein regular polygonal reticulate ……. .…… ……. **25**

21a. Base angle obtuse - wide obtuse …….….. …….…….. .. **26**

21b. Base angle acute ……. ……..... ……...… …. **27**

22a. Lamina shape elliptic ……. …….……. …..….. …… **28**

22b. Lamina shape oblong …….. …..…….. ……... ***Persicaria glabra***

23a. Base shape decurrent ……..…..… …… **29**

23b. Base shape rounded …….. ……. …….…… **30**

24a. Stellate hair present …..... …….…… .. ***Rumex dentatus***

24b. Stellate hair absent ……. ……..…….. . ***Rumex maritimus***

25a. Base shape lobate ……. …….. …. ***Persicaria chinensis* var. *chinensis***

25b. Base shape rounded …..….. ……..…….. ***Persicaria chinensis* var. *ovalifolia***

26a. 3º vein random reticulate …….. ……..…….. **31**

26b. 3º vein regular polygonal reticulate……...…. ***Persicaria chinensis* var. *hispida***

27a. Apex shape acuminate ……..... ***Persicaria lapathifolia* var. *lapathifolia***

27b. Apex shape acute ……...…….…… ***Persicaria lapathifolia* var. *lanata***

28a. Base shape cuneate …… ……. …… ……. ***Persicaria minor***

28b. Base shape lobate …….. …….. .. ***Polygonum viscosum***

29a. 3º vein regular polygonal reticulate …….…… …… …. **32**

29b. 3º vein alternate percurrent ……..…….. ***Fagopyrum dibotrys***

30a. 4º vein regular polygonal reticulate ……..…….…… ***Persicaria barbata***

30b. 4º vein alternate percurrent ……....…. ***Persicaria campanulata***

31a. Stomata anomocytic ……. ……..……...…. ***Persicaria orientalis***

31b. Stomata paracytic …… ……...…..…….. ***Persicaria posumbu***

32a. Blade class nanophyll …….…….…… ***Persicaria tenella***

32b. Blade class notophyll …… ……....…. ***Fagopyrum esculentum***

5.3. POLLEN MORPHOLOGY

Pollen grains are the extremely reduced male gametophyte enclosed inside the microspore wall of seed plants or flowering plants. It is major unit of a flowering plant as through pollen grains the entire male genetic attributes are transmitted to the next generation. The term Palynology was devoted to the study of external morphological features of mature pollen grains. Pollen morphological attributes such as aperture number, type, shape, size and the exine ornamentations have played significant role in delimiting the different taxa as they are moderately conserved.

In the present study all the collected taxa were considered for the investigation of pollen morphology under LM (Light microscopy) and SEM (Scanning Electron Microscopy) to revealed different types of pollen grains. The investigation on pollen morphology gives emphasis to read data from pollen grains unit, dimensions, shape class, polarity and symmetry, apertures and exine ornamentation.

5.3.1. Pollen description

Pollen grains were monad, isopolar, radio symmetric and length of equatorial diameter (ED) size varies from 15.85 µm – 43.16 µm. Three different types of pollen grains *viz*., **pantoporate**, **tricolpate** and **tricolporate** (Table 16 and 17) and four shapes class *viz*., **prolate** (P), **sub prolate** (SP), **prolate-spheroidal** (PS) and **spheroidal** (S) were observed (Fig. 31 and 32). Exine ornamentation of all the pollen grains were not uniform but various pattern such as reticulate with pitted texture, micro reticulate, striate reticulate, micro echinate, granulate etc were observed. In case of tricolpate and tricolporate pollen grains colpi length varies from 9.17 µm to 33.84 µm. Thickness of exine varies from minimum 1.04 µm in *Persicaria capitata* to maximum 4.16 µm in *Persicaria posumbu*.

5.3.2. Pollen types

Pollen grains of all the studied taxa of Polygonaceae were broadly classified into three major types based on their apertures such as pantoporate, tricolpate and tricolporate. Species wise detailed pollen grain features were elaborated below:

5.3.2.1. Tricolpate type: Microspore or pollen grains with three colpi (Table 16)

***5.3.2.1.1. Reticulate subtype*:** Exine sculpturing as ridges arranged in network which has gaps. The taxa under reticulate subtype had been further divided into two subtypes on the basis on minute variation their network like aggangemnts of exine.

Subtype I: reticulate patterns where lumina greater than 1µm in diameter (Fig. 29 a, b, g)

Persicaria capitata (Buchanan-Hamilton *ex* D. Don) H. Gross: Pollen grains were monad, isopolar, radiosymmetric. The shape of the pollen grains was prolate spheroidal. ED: 27.44µm – 35.35µm; PA: 27.31µm – 32.73µm; colpi length varies from 21.15µm – 25.56µm, non lacunate; ora indistinct; exine reticulate - rugulate, 0.86µm – 1.15µm thick; endocolpium circular.

Persicaria tenella (Blume) Hara: Pollen grains were monad, isopolar, radiosymmetric; Grains were prolate spheroidal in equatorial view and spheroidal in polar view. ED: 22.13µm – 30.12µm; PA: 25.02µm – 31.06µm; colpi length varies from 13.78µm – 17.86µm, lacuna absent; ora indistinct; exine reticulate, 1.05µm – 1.46µm thick.

Persicaria campanulata (Hooker *f.*) Ronse Decraene: Pollen grains were monad, isopolar, radiosymmetric. The shape of the pollen grains was prolate spheroidal; ED: 25.12µm – 33.12µm; PA: 28.65µm – 34.56µm; colpi length varies from 20.76µm – 25.09µm; exine reticulate, 2.13µm – 3.04µm thick.

Subtype II: reticulate patterns where lumina less than 1µm in diameter (Fig. 27 a, 28 h)

Antigonon leptopus Hooker & Arnott: Pollen grains were monad, isopolar, radiosymmetric; shape sub prolate; ED: 21.14µm – 34.12µm; PA: 26.73µm – 33.35µm; colpi slit like, long, extending pole to pole, length varies from 17.49µm – 21.88µm; ora lolongate; exine reticulate with pitted texture, 1.58µm – 1.94µm thick.

Polygonum molle D. Don: Pollen grains were monad, isopolar, radiosymmetric; shape sub prolate; ED: 19.26µm – 34.11µm; PA: 24.23µm – 30.39µm; colpi long,

length varies from 11.09µm – 15.76µm; ora lalongate; exine micro reticulate, 1.55µm – 1.99µm thick.

***5.3.2.1.2. Granulate subtype*:** Exine sculptural element less than 1µm in diameter (Fig. 28 c)

Polygonum plebeium R. Brown: Pollen grains were monad, isopolar and radiosymmetric; grains were prolate in equatorial view; the outline of the grains were circular in polar view; ED: 13.61µm – 25.12µm; PA: 23.65µm – 29.55µm; colpi long, narrow, length varies from 15.45µm – 19.69µm; ora lalongate; exine granulates with microspinules, 2.57µm – 3.16µm thick.

5.3.2.2. Tricolporate type: Microspore or pollen grains with three colpi and a central pore in each colpi (Table 16)

***5.3.2.2.1. Micro reticulate Subtype*:** Exine sculpturing as ridges arranged in network which has gaps less than 1µm in diameter (Fig. 28 b, c, e, f)

Homalocladium platycladum (F. Muellar) L. H. Bailey: Pollen grains were monad, isopolar and radiosymmetric; grains were prolate spheroidal in equatorial view; ED: 22.33µm – 36.33µm; PA: 20.32µm – 24.12µm; colpi long, slit like, narrow, extending pole to pole, length varies from 14.52µm – 18.65µm; ora lalongate; exine microreticulate with bacula, 1.11µm – 1.65µm thick.

Fagopyrum dibotrys (D. Don) Hara: Pollen grains were monad, isopolar and radiosymmetric; grains were prolate spheroidal in equatorial view; the outline of the grains were circular in polar view; ED: 30.12µm – 47.26µm; PA: 40.32µm – 46.69µm; colpi medium, narrow, depressing at their lengths, length varies from 25.56µm – 30.26µm; ora lolongate; exine microreticulate, heterobrochate, 3.86µm – 4.27µm thick, lumina present, muri with bluntb spinules and thick.

Fagopyrum esculentum Moench: Pollen grains were monad, isopolar and radiosymmetric; grains were prolate spheroidal in equatorial view; the outline of the grains were circular in polar view; ED: 33.15µm – 47.16µm; PA: 43.21µm – 47.86µm; colpi medium to long, acute, tapering at the end, length varies from 30.25µm – 37.15µm; ora lolongate; exine microreticulate, heterobrochate, 3.10µm – 3.79µm thick, lumina present, muri with blunt spinules and thick.

Rumex maritimus Linnaeus: Pollen grains were monad, isopolar and radiosymmetric; grains were prolate in equatorial view; triangular in polar view; ED: 25.63µm – 30.01µm; PA: 25.19µm – 34.53µm; colpi medium to long, narrow, length varies from 12.12µm – 15.98µm; ora lolongate, pores oval; exine microreticulate, 1.98µm – 2.28µm thick.

Rumex acetosella Linnaeus: Pollen grains were monad, isopolar and radiosymmetric; grains were subprolate in equatorial view; ED: 13.89µm – 28.36µm; PA: 21.32µm – 29.65µm; colpi medium, narrow, length varies from 7.35µm – 11.21µm; ora lolongate, pores oval; exine striate - reticulate, 1.11µm – 1.34µm thick.

***5.3.2.2.2. Granulate Subtype*:** Exine sculptural element less than 1µm in diameter (Fig. 28 h)

Rumex dentatus Linnaeus: Pollen grains were monad, isopolar and radiosymmetric; prolate spheroidal in equatorial view; spheroidal in polar view; ED: 20.19µm – 33.26µm; PA: 25.35µm – 30.63µm; colpi narrow, length varies from 11.01µm – 13.65µm; ora lolongate; exine granulate, 1.91µm – 2.19µm thick.

***5.3.2.2.3. Microechinate - punctuate Subtype*:** Pointed sculpturing elements (echini) less than 1µm in height with small perforation (Fig. 28 d)

Fallopia convolvulus (Linnaeus) A. Love: Pollen grains were monad, isopolar and radiosymmetric; prolate spheroidal in equatorial view; triangular in polar view; ED: 14.22µm – 25.64µm; PA: 18.56µm – 23.65µm; colpi narrow with blunt end, length varies from 10.08µm – 14.29µm; ora lalongate; exine microechinate - punctate, 2.24µm – 2.98µm thick.

***5.3.2.2.4. Perforate - punctate Subtype*:** Surface having small holes or depressions less than 1µm in diameter (Fig. 28 g)

Rumex nepalensis Sprengel: Pollen grains were monad, isopolar and radiosymmetric; subprolate in equatorial view; spheroidal in polar view; ED: 24.22µm – 37.45µm; PA: 34.56µm – 37.02µm; colpi medium to long, acute, narrow, tapering at the end, length varies from 15.98µm – 20.65µm; ora lolongate; exine perforate - punctate, 1.34µm – 1.98µm thick.

***5.3.2.2.5. Striated baculate Subtype*:** Rod-shaped sculpturing elements (bacula), longer than wide and greater than 1µm high (Fig. 29 e)

Rheum nobile Hooker *f.* & Thompson: Pollen grains were monad, isopolar and radiosymmetric; prolate in equatorial view; spheroidal in polar view; ED: 25.41µm – 40.87µm; PA: 20.56µm – 36.66µm; colpi long, narrow, length varies from 13.63µm – 28.45µm; ora lalongate; exine striated baculate, 2.55µm – 3.09µm thick.

5.3.2.3. Pantoporate type: Pollen grain with pores spread over the surface. Taxa bearing pantoporate pollen grains were further subdivided into five subtypes on the basis of their lumina shape (Table 17)

5.3.2.3.1. Subtype I (Lumina pentagonal* and *hexagonal): (Fig. 29 k, f, j; 29 a, b, d, e, f, j)

Persicaria barbata (Linnaeus) H. Hara: Pollen grains were monad, isopolar, radiosymmetric spheroidal and non lacunate type; diameter of the pollen grain ranges from 38.17 µm to 43.93 µm; exine uniformly reticulate, 3.86 – 4.23 µm thick, muri simple; lumina large with pentagonal bacula.

Persicaria chinensis (Linnaeus) H. Gross var. ***chinensis***: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 31.25 µm to 36.32 µm; exine reticulate, heterobrochate, 2.13 – 2.99 µm thick, massive columellae, muri thick, curvimuate, lumina of various shapes generally pentagonal to hexagonal.

Persicaria chinensis (Linnaeus) H. Gross var. ***ovalifolia*** (Linnaeus) H. Gross: Pollen grains were monad, isopolar, radiosymmetric spheroidal and non lacunate type; diameter of the pollen grain ranges from 30.39 µm to 37.96 µm; exine reticulate, heterobrochate, 2.25 – 3.01 µm thick, muri thick with irregular folds and slit, lumina of various shape.

Table 16: Pollen morphology data of tricolpate and tricolporate grains with their Polar Axis (PA), Equatorial diameter (ED), Co-efficient variance (CV), Ratio of Polar Axis and Equatorial Diameter (ED), Size, Class, Shape, Colpi length (CL), Exine ornamentation, Exine thickness. All the measurements were taken in µm [Abbreviation used: Sub prolate =SP, Prolate spheroidal =PS, Prolate=P]

Taxa	PA (µm)	CV%	ED (µm)	CV%	P/E	Size	Class	Shape	CL (µm)	Exine type	Exine Thickness(µm)
Antigonon leptopus	30.04±1.36	4.54	26.30±3.45	13.14	1.14	Medium	Tricolpate	SP	19.43±1.20	Microreticulate	1.73±0.08
Fagopyrum dibotrys	43.49±1.84	4.24	39.44±4.83	12.24	1.10	Medium	Tricolporate	PS	28.27±1.37	Microreticulate	4.06±0.09
Fagopyrum esculentum	45.70±1.38	3.02	40.38±3.32	8.23	1.13	Medium	Tricolporate	PS	33.84±2.17	Microreticulate	3.39±0.18
Fallopia convolvulus	20.75±1.27	6.10	19.80±3.48	17.55	1.04	Small	Tricolporate	PS	12.11±1.18	Microechinate-Punctate	2.58±0.13
Persicaria capitata	30.52±1.54	5.06	31.08±2.72	8.75	0.98	Medium	Tricolpate	PS	22.63±1.40	Reticulate-rugulate	1.04±0.07
Persicaria tenella	28.12±1.70	6.04	25.50±2.54	9.97	1.11	Medium	Tricolpate	PS	15.08±1.80	Reticulate	1.25±0.11
Persicaria campanulata	32.26±1.68	5.20	29.17±2.33	7.98	1.10	Medium	Tricolpate	PS	23.37±1.52	Reticulate	2.53±0.22
Polygonum molle	28.06±1.87	6.67	24.14±3.34	13.82	1.16	Medium	Tricolpate	SP	13.08±1.17	Micro reticulate	1.78±0.11
Polygonum plebeium	27.39±1.44	5.26	19.70±3.27	16.59	1.39	Small	Tricolpate	P	17.61±1.11	Granulate with microspinules	2.90±0.15
Rumex acetosella	24.98±2.53	10.14	21.26±4.25	19.99	1.17	Small	Tricolporate	SP	9.17±0.97	Microreticulate	1.22±0.06
Rumex dentatus	28.12±1.62	5.76	27.46±3.28	11.93	1.02	Medium	Tricolporate	PS	12.60±0.76	Granulate	2.02±0.07
Rumex maritimus	29.83±1.93	6.46	23.15±4.05	17.49	1.28	Small	Tricolporate	P	13.80±0.98	Microreticulate	2.11±0.07
Rumex nepalensis	36.12±0.67	1.86	29.83±4.34	14.56	1.21	Medium	Tricolporate	SP	17.73±1.57	Perforate-punctate	1.63±0.18
Rheum nobile	29.18±3.81	13.05	34.04±3.97	11.67	0.85	Medium	Tricolporate	P	19.93±3.89	Striated baculate	2.88±0.14
Homalocladium platycladum	22.09±0.99	4.49	27.45±3.64	13.25	0.80	Medium	Tricolporate	PS	16.64±1.17	Microreticulate	1.47±0.13

Persicaria glabra (Willdenow) M. Gómez: Pollen grains were monad, isopolar, radiosymmetric spheroidal and non lacunate type; diameter of the pollen grain ranges from 40.98 µm to 44.23 µm; exine reticulate, 1.11 – 1.98 µm thick, muri thick, curvimurate, lumina of various shapes (generally pentagonal to hexagonal) and size, sporadically with few baculae.

Persicaria hydropiper (Linnaeus) Delarbre: Pollen grains were monad, isopolar, radiosymmetric and non lacunate type; pollen grains were spheroidal in equatorial view; the outline of the grains were circular in polar view; diameter of the pollen grain ranges from 38.56 µm to 47.12 µm; exine reticulate, 3.87 – 4.65 µm thick, muri irregularly shaped, curvimurate, lumina of various shapes.

Persicaria lapathifolia (Linnaeus) Delarbre var. ***lapathifolia***: Pollen grains were monad, isopolar, radiosymmetric and non lacunate type; pollen grains were spheroidal in equatorial view; the outline of the grains were circular in polar view; diameter of the pollen grain ranges from 26.89 µm to 31.49 µm; exine reticulate, 1.85 – 2.56 µm thick, muri with longitudinal folds and slits, lumina with irregular pentagonal shape.

Persicaria lapathifolia (Linnaeus) Delarbre var. ***lanata*** (Roxburgh) H. Hara: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 23.45 µm to 30.56 µm; exine reticulate, 2.01 – 2.97 µm thick, muri thick, lumina with irregular pentagonal shape.

Persicaria microcephala **(**D. Don) H. Gross: Pollen grains were monad, isopolar, radiosymmetric and non lacunate type; pollen grains were spheroidal in equatorial view; pores ellipsoidal; diameter of the pollen grain ranges from 32.89 µm to 37.65 µm; exine reticulate, 2.76 – 3.96 µm thick, muri with longitudinal folds and heavy slits, lumina with irregular shape.

Persicaria nepalensis (Meissner) Miyabe: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 30.45 µm to 33.06 µm; exine reticulate, 2.03 – 2.88 µm thick, muri thick, lumina with hexagonal shape.

Persicaria posumbu (Buchanon-Hamilton *ex* D. Don) H. Gross: Pollen grains were monad, isopolar, radiosymmetric and non lacunate type; pollen grains were spheroidal in equatorial view; pores spheroidal; diameter of the pollen grain ranges from 34.12 µm to 35.98 µm; exine reticulate, 4.05 – 4.29 µm thick, lumina with hexagonal shape.

Polygonum pubescens Blume: Pollen grains were monad, isopolar, radiosymmetric and non lacunate type; pollen grains were spheroidal in equatorial view; pores spheroidal; diameter of the pollen grain ranges from 13.73 µm to 17.95 µm; exine reticulate, 0.84 – 1.36 µm thick, lumina with pentagonal and hexagonal shape.

5.3.2.3.2. Subtype II (Lumina with longitudinal folds)*:* (Fig. 29 i, d)

Persicaria chinensis (Linnaeus) H. Gross var. ***hispida*** Kantachot : Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 29.69 µm to 34.56 µm; exine reticulate, 2.99 – 3.75 µm thick, muri thick, lumina broad having longitudinal folds.

Persicaria minor (Hudson) Opiz: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 28.12 µm to 30.98 µm; pores ellipsoidal; exine reticulate, 2.45 – 2.98 µm thick, muri thick, lumina broad having longitudinal folds.

5.3.2.3.3. Subtype III (Lumina broad)*:* (Fig. 30 c)

Persicaria lanigera (R. Brown) Sojak: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 30.65 µm to 32.78 µm; exine reticulate, 3.01 – 3.21 µm thick, muri thin, lumina broad.

5.3.2.3.4. Subtype IV (Lumina with baculae)*:* (Fig. 30 g, k)

Persicaria orientalis (Linnaeus) Spach: Pollen grains were monad, isopolar, radiosymmetric, spheroidal and non lacunate type; diameter of the pollen grain ranges from 37.12 µm to 41.26 µm; pores oval to ellipsoidal; exine reticulate, 3.26 – 4.36 µm thick; lumina granulose; muri thick, regularly shaped

Polygonum viscosum Buchanon-Hamilton *ex* D. Don: Pollen grains were monad, isopolar, radiosymmetric, non lacunate, spheroidal in shape; diameter of the pollen grain ranges from 21.15 µm to 27.89 µm; exine 3.06 – 3.65 µm thick, muri regularly shaped, lumina with baculae having slit and longitudinal fold.

5.3.2.3.5. Subtype V (Lumina with baculoid rod)*:* (Fig. 30 h, i)

Polygonum runcinatum Buchanon-Hamilton *ex* D. Don: Pollen grains were monad, isopolar, radiosymmetric, non lacunate, spheroidal in shape; diameter of the pollen grain ranges from 22.56 µm to 29.03 µm; exine reticulate, 2.03 – 2.80 µm thick, lumina with baculoid rods.

Persicaria strigosa (R. Brown) Nakai: Pollen grains were monad, isopolar, radiosymmetric, non lacunate, spheroidal in shape; diameter of the pollen grain ranges from 17.63 µm to 21.95 µm; exine uniformly reticulate, 1.54 – 1.99 µm thick, muri studded with loose bacula, lumina large.

5.3.3. Statistical analysis

Statistical analysis was conducted for all the studied pollen morphological data to determine the significance and inter-relationship among them. In the present study three statistical analyses namely ANOVA, Principal component analysis (PCA) and Correlation study was taken into consideration. Through ANOVA analysis, comparision of data sets was performed for determining the significance level (P-value) among the different attributes as well as among the different taxa under study by determining inconsistency between the samples and within the samples. PCA was conducted for reducing the intricacy in the data pattern by projecting the studied parameters as well as taxa into different geometrical dimensions which were konown as principal components. For determining the pervasiveness and the relationships among the studied variables Pearson correlation study was conducted which examined the strength between two continuous variables by measuring the degree of significance among them.

Table 17: Pollen morphology data of pantoporate grains pollen diameter (PD), co-efficient variance (CV), size, shape, exine ornamentation, exine thickness. All the measurements were taken in µm

Taxa	PD (µm)	CV%	Size	Shape	Exine type	Exine Thickness (µm)
Persicaria chinensis* var *chinensis	33.50±1.07	3.21	Medium	Spheroidal	Reticulate	2.66± 0.18
Persicaria chinensis* var *hispida	31.99±1.28	3.99	Medium	Spheroidal	Coarsely reticulate	3.37± 0.16
Persicaria chinensis* var *ovalifolia	34.67±2.04	5.87	Medium	Spheroidal	Reticulate	2.77± 0.19
Persicaria barbata	41.06±1.74	4.25	Medium	Spheroidal	Reticulate	4.05± 0.10
Persicaria glabra	42.97±1.04	2.42	Medium	Prolate spheroidal	Reticulate	1.45± 0.23
Persicaria hydropiper	43.16±2.57	5.95	Medium	Spheroidal	Reticulate	3.37± 0.13
Persicaria lanigera	31.84±0.06	2.13	Medium	Spheroidal	Reticulate	3.12± 0.06
Persicaria lapathifolia* var *lapathifolia	29.31±1.41	4.80	Medium	Spheroidal	Reticulate	2.18± 0.16
Persicaria lapathifolia* var *lanata	27.16±2.08	7.66	Medium	Spheroidal	Reticulate	2.50± 0.27
Persicaria nepalensis	26.25±1.60	6.09	Medium	Spheroidal	Reticulate	2.34± 0.21
Persicaria orientalis	39.30±1.10	2.81	Medium	Spheroidal	Reticulation murate	3.87± 0.29
Persicaria strigosa	19.63±1.43	7.26	Small	Prolate spheroidal	Uniformly reticulate	1.74± 0.13
Persicaria microcephala	35.46± 2.35	6.62	Medium	Spheroidal	Reticulate	3.45± 0.23
Persicaria minor	29.33±0.74	2.52	Medium	Spheroidal	Reticulate	2.65±0.13
Persicaria posumbu	35.62±0.76	2.13	Medium	Spheroidal	Reticulate	4.16±0.06
Polygonum pubescence	15.85±1.07	6.75	Small	Spheroidal	Reticulate	1.11± 0.14
Polygonum runcinatum	25.83±1.72	6.64	Medium	Prolate spheroidal	Uniformly reticulate	2.32± 0.34
Polygonum viscosum	25.57±1.58	6.20	Medium	Prolate spheroidal	Reticulation murate	3.27± 0.11

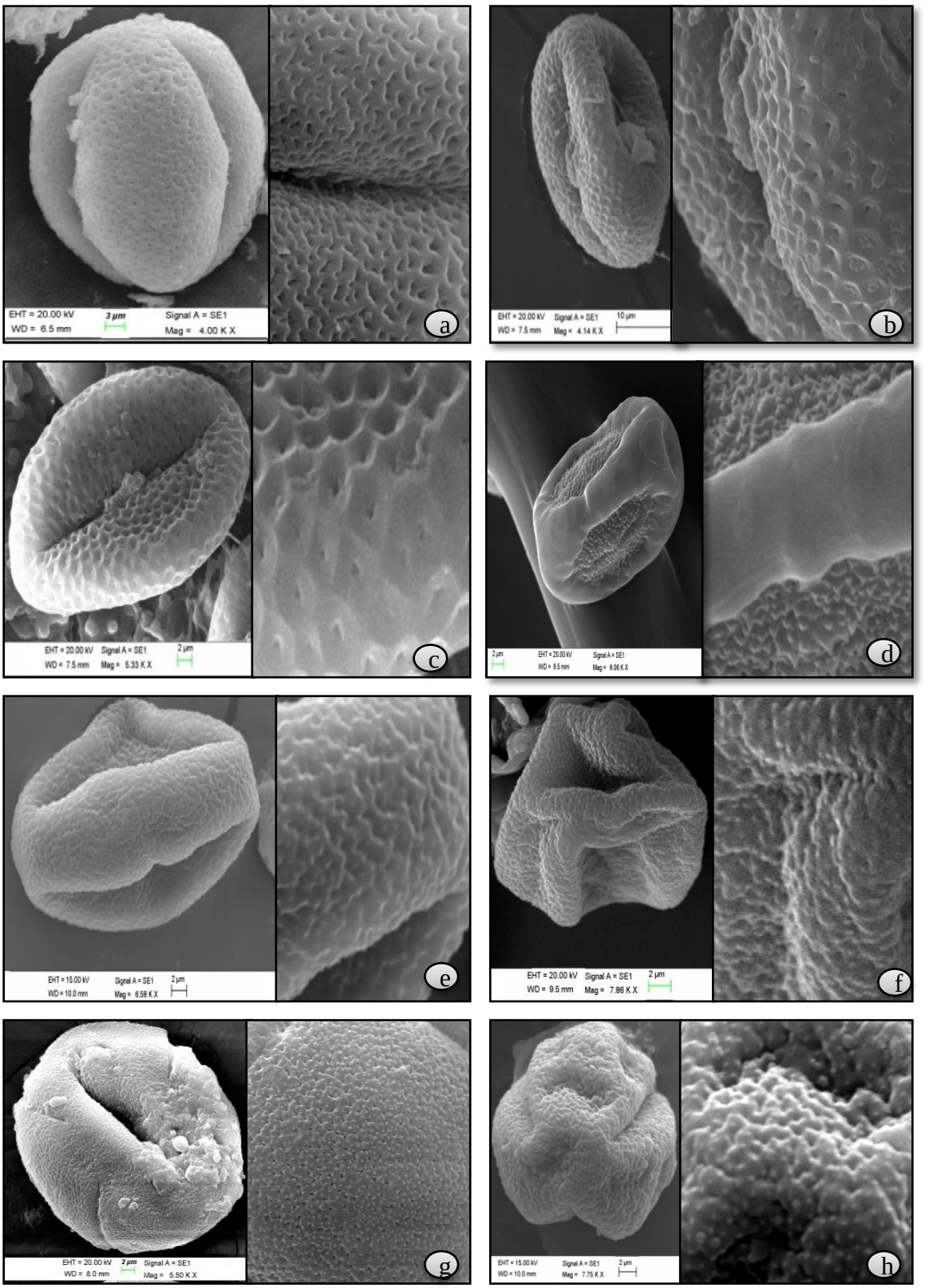

Fig 28: SEM micrographs of pollen grains a. *Antigonon leptopus* b. *Fagopyrum dibotrys* c. *Fagopyrum esculentum* d. *Fallopia convolvulus* e. *Rumex acetosella* f. *Rumex maritimus* g. *Rumex nepalensis* h. *Rumex dentatus*

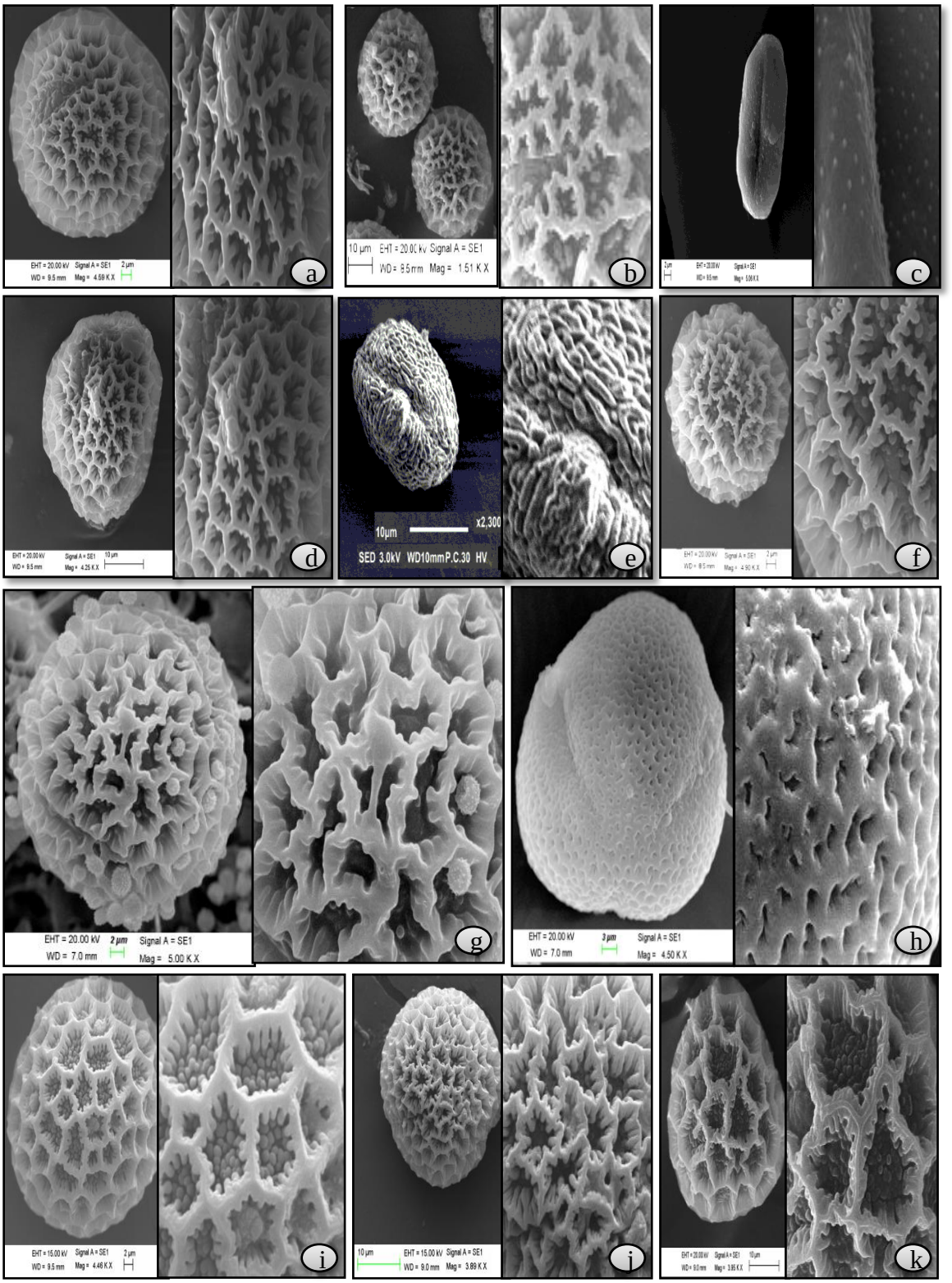

Fig. 29: SEM micrographs of pollen grains **a.** *Persicaria capitata* **b.** *Persicaria tenella* **c.** *Polygonum plebeium* **d.** *Persicaria minor* **e.** *Rheum nobile* **f.** *Persicaria chinensis* var. *chinensis* **g.** *Persicaria campanulata* **h.** *Polygonum molle* **i.** *Persicaria chinensis* var. *hispida* **j.** *Persicaria chinensis* var. *ovalifolia* **k.** *Persicaria barbata*

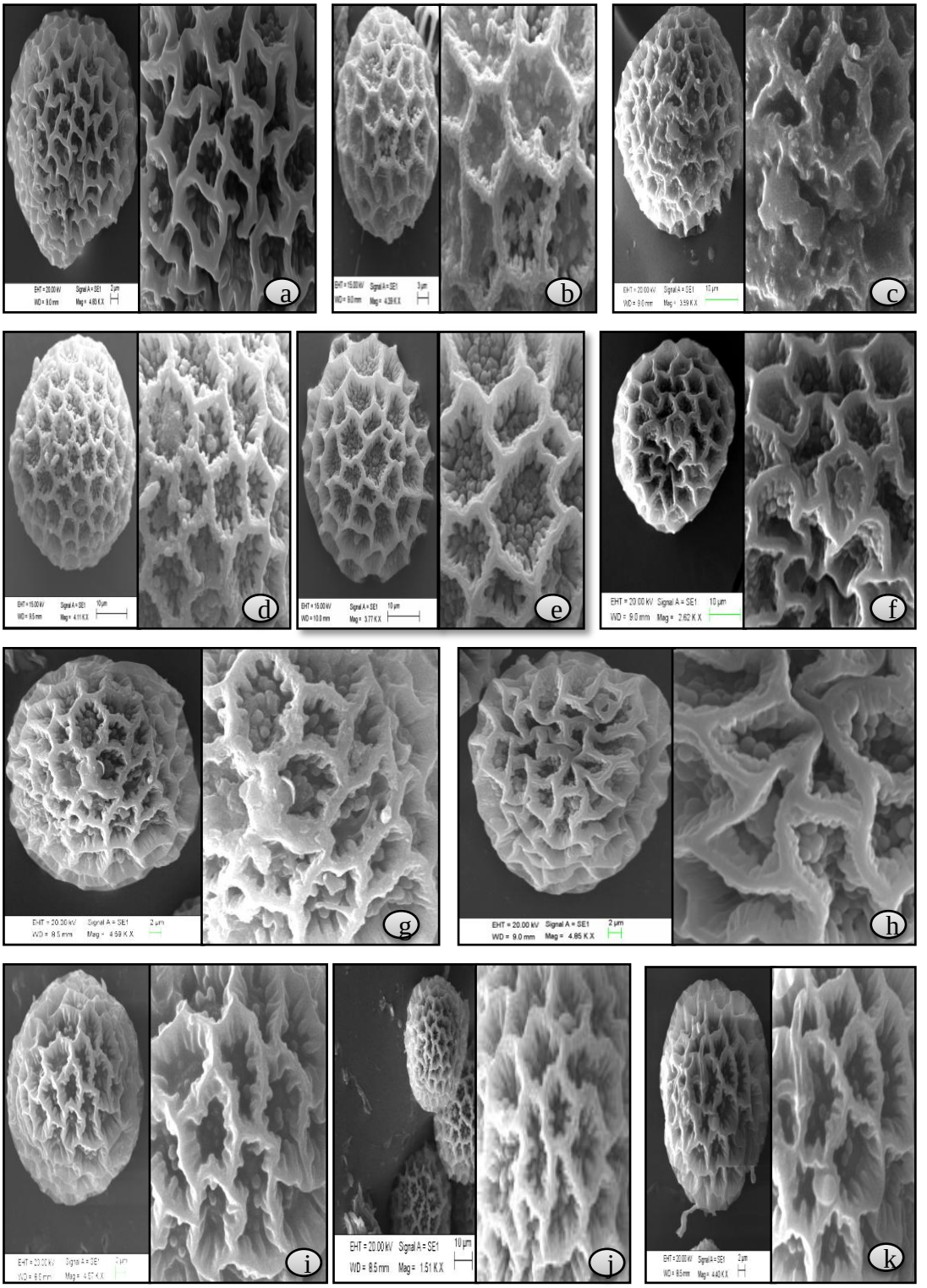

Fig. 30: SEM micrographs of pollen grains **a.** *Persicaria glabra* **b.** *Persicaria hydropiper* **c.** *Persicaria lanigera* **d.** *Persicaria lapathifolia* var. *lapathifolia* **e.** *Persicaria lapathifolia* var. *lanata* **f.** *Persicaria nepalensis* **g.** *Persicaria orientalis* **h.** *Polygonum runcinatum* **i.** *Persicaria strigosa* **j.** *Persicaria microcephala* **k.** *Polygonum viscosum*

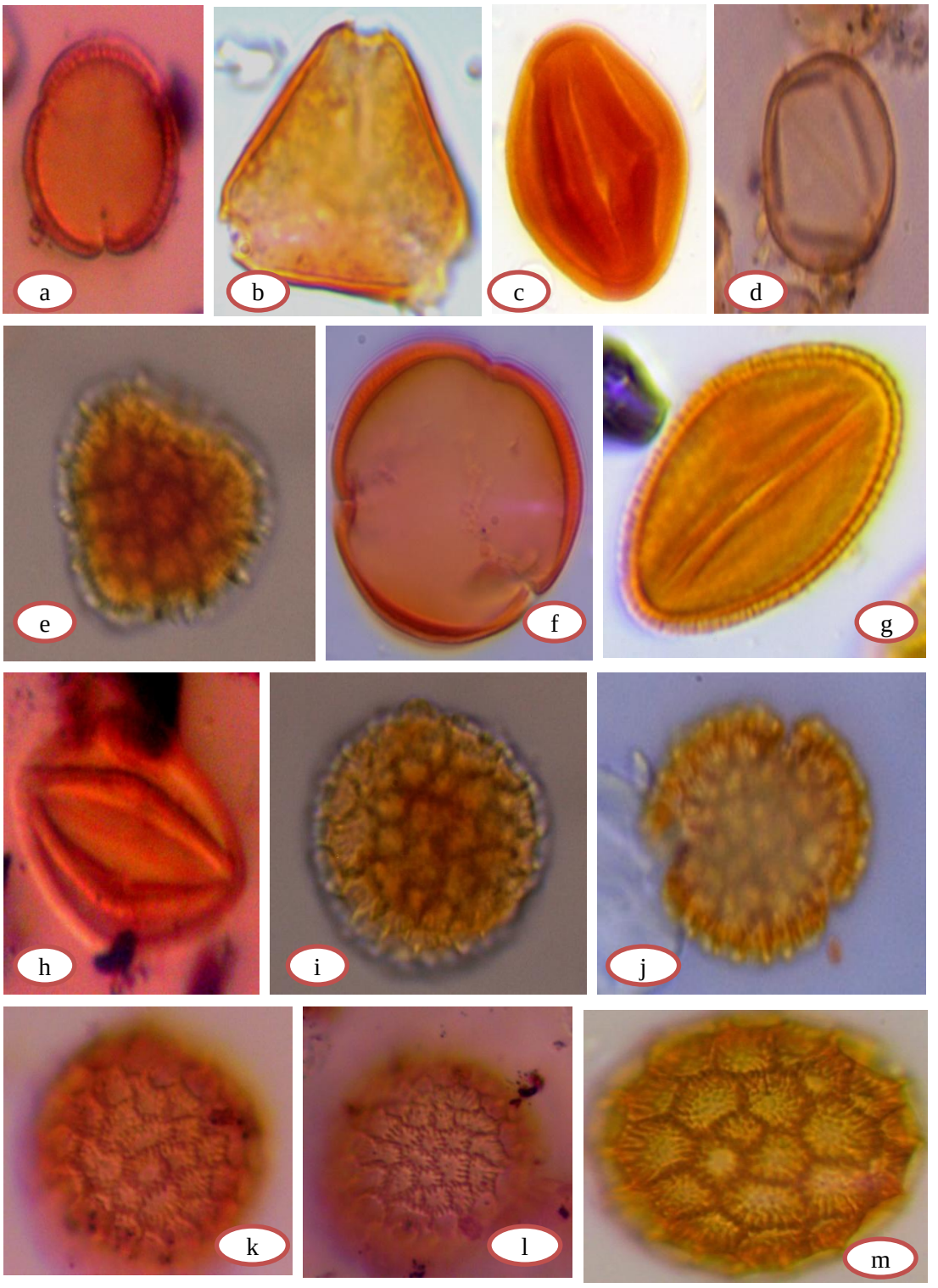

Fig. 31: Light micrographs of pollen grains **a**. PV of *Polygonum molle* **b**. PV of *Rumex maritimus* **c**. EV of *Rumex dentatus* **d**. EV of *Rumex nepalensis* **e**. *Persicaria barbata* **f**. PV of *Rumex acetosella* **g**. EV of *Fagopyrum dibotrys* **h**. EV of *Polygonum plebeium* **i**. *Polygonum runcinatam* **j**. *Persicaria capitata* **k**. *Persicaria campanulata* **l**. *Persicaria lapathifolia* var *lapathifolia* **m**. *Polygonum viscosum*

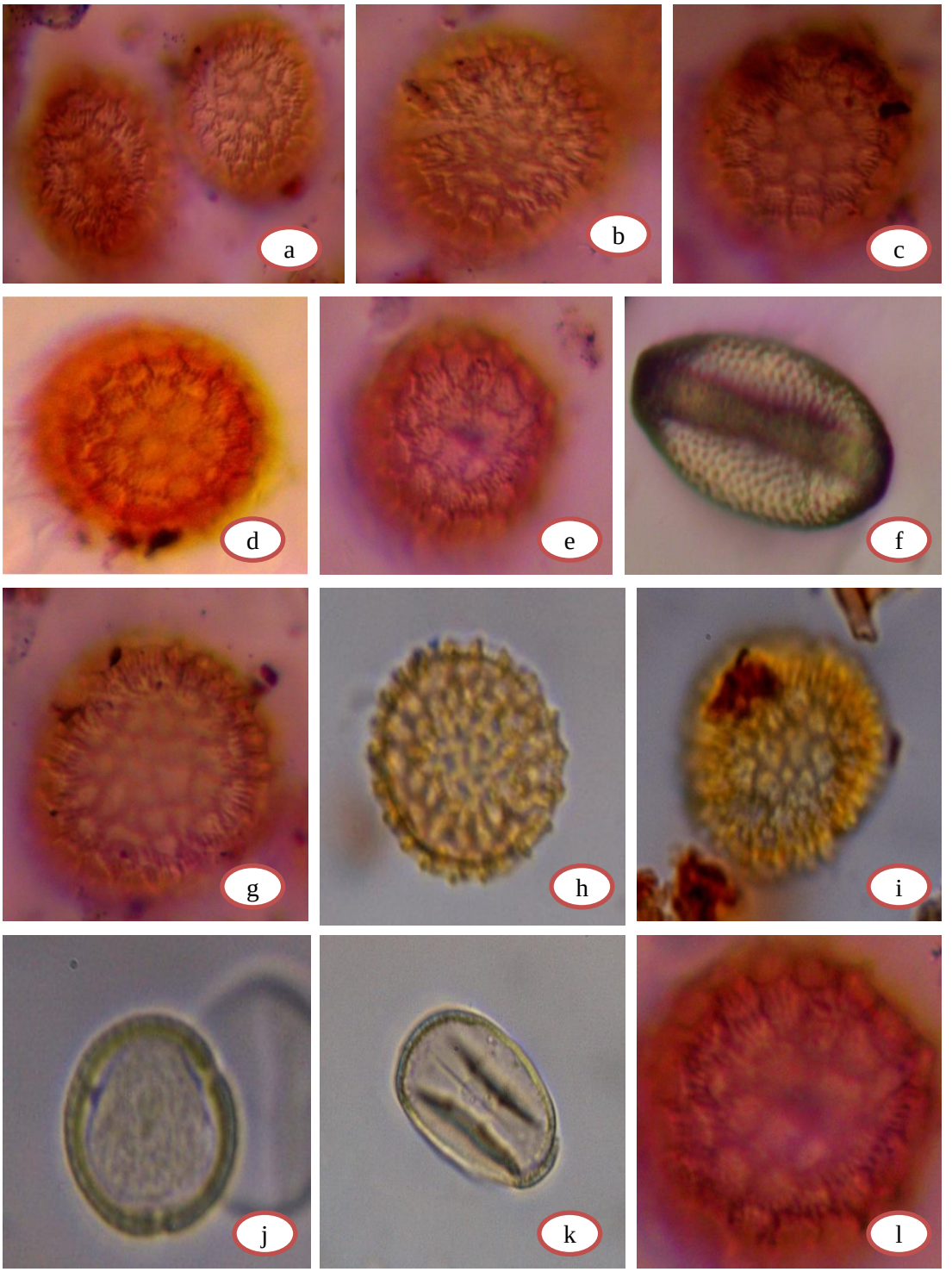

Fig. 32: Light micrographs of pollen grains **a**. *Persicaria lanigera* **b**. *Persicaria tenella* **c**. *Persicaria chinensis* var *chinensis* **d**. *Persicaria strigosa* **e**. *Persicaria chinensis* var *hispida* **f**. EV of *Fallopia convolvulus* **g**. *Persicaria hydropiper* **h**. *Persicaria minor* **i**. *Persicaria microcephala* **j**. PV of *Rheum nobile* **k**. EV of *Fagopyrum esculentum* **l**. *Persicaria posumbu*

5.3.3.1. ANOVA analysis

Two-way ANOVA without replicates were performed taking all the attributes under study (Table 18). From analysis it was found that the p-value of taxa and parameters under study were 1.16×10^{-5} and 1.5×10^{-133} respectively.

Table 18: ANOVA analysis representing the significance level among different Pollen morphological parameters under study

Source of Variation	SS	df	MS	F	P-value	F crit
Species	5225.947	32	163.3108	2.740155	1.16E-05	1.504061
Parameters	290591.7	6	48431.96	812.6287	1.5E-133	2.14605
Error	11443.03	192	59.59913			
Total	307260.1	230				

Significant at $p < 0.01$

5.3.3.2. Principal component analysis (PCA)

Principle Component Analysis was done to correlate different attributes under study by group clustering. PCA separates correlated attributes from uncorrelated ones. Eigen analysis results and loading scores of three principal components were showing in table 19 and 20 and score plot was shown in Fig. 33. The first principal component (PC1) was dominated by colpi length, shape, polar axis, polar axis/ equatorial axis ratio (P/E) and the second principal component (PC2) was dominated by aperture type, equatorial diameter and exine thickness. The distribution of total variation in PC1 and PC2 was 44.96% and 21.67% respectively.

On comparing the taxa under study by PCA (Fig. 34) it was observed that the first axis (PC1) was dominated by 25 taxa viz., *Antigonon leptopus, Fallopia convolvulus, Homalocladium platycladum, Persicaria barbata, P. campanulata, P. capitata, P. chinensis* var. *chinensis, P. chinensis* var. *hispida, P. chinensis* var. *ovalifolia, P. glabra, P. lanigera, P. lapathifolia* var. *lanata, P. lapathifolia* var. *lapathifolia, P. microcephala, P. minor, P. nepalensis, P. orientalis, P. posumbu, Polygonum molle, P. plebeium, P. viscosum, Rheum nobile, Rumex acetosella R. maritimus* and *R. nepalensis*. The second axis (PC2) was dominated by 8 taxa viz., *Fagopyrum dibotrys, F. esculentum, Persicaria hydropiper, P. strigosa, P. tenella, Polygonum pubescens, P. runcinatum,* and *Rumex dentatus*.

Table 19: Eigen analysis of Correlation matrix

	PC1	PC2	PC3
Eigenvalue	3.1469	1.5172	1.0174
Variability (%)	44.9554	21.6743	14.5349
Cumulative %	44.9554	66.6297	81.1646

Table 20: The variable loading scores for each principal component (PC1 – PC3) for studied taxa of Polygonaceae from West Bengal, India

Variable	PC1	PC2	PC3
ED	-0.2119	0.5964	-0.3049
PA	0.5150	0.2558	0.0249
Shape	0.4980	0.0123	-0.0111
Exine thickness	-0.2270	0.4888	-0.4461
Colpi length	0.4815	0.3109	-0.0308
Aperture	0.0313	0.4653	0.7070
P/E	0.3969	-0.1633	-0.4545

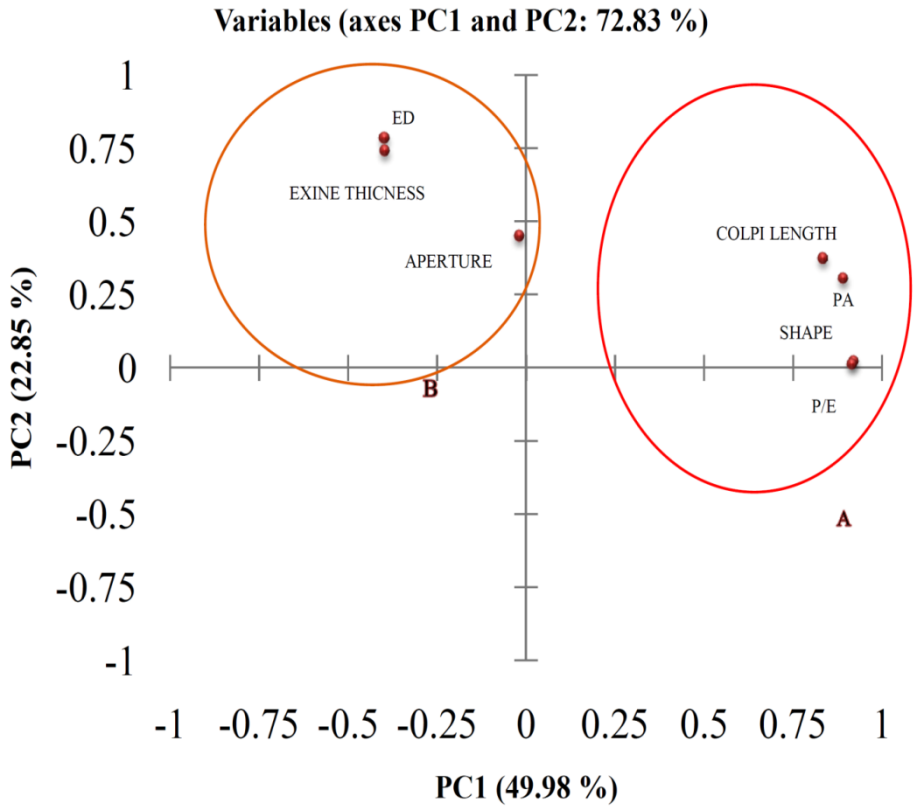

Fig. 33: Principal component analysis score plot showing the pollen morphological variation among the studied taxa of Polygonaceae

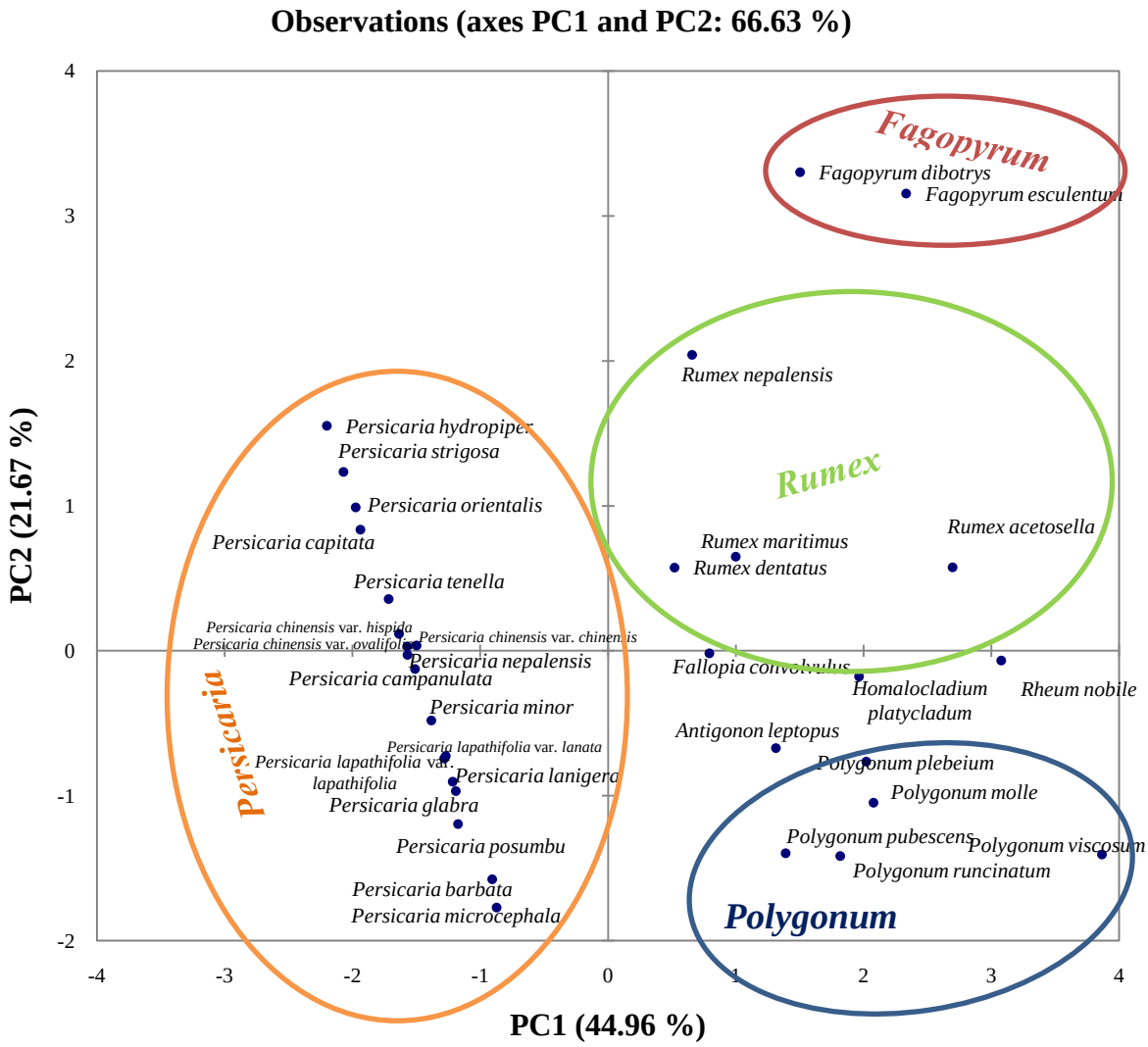

Fig. 34: Principal component analysis score plot showing the interrelationships among the taxa based on pollen morphological characters

5.3.3.3. Correlation matrix analysis

Pearson correlation matrix for quantitative variables for studied taxa (Table 21) were quite distinct and equatorial diameter (ED) correlates positively with exine thickness (r = 0.4952). Polar axis (PA) correlates positively and significantly with pollen grains shape (r = 0.7170), colpi length (r = 0.9697). Shape correlates with colpi length (r = 0.6623), P/E (r = 0.6253). All these parameters were correlated with each other at $p < 0.001$.

Table 21: Pearson correlation matrix for quantitative variables among the studied taxa of Polygonaceae

	ED	PA	Shape	Exine thickness	Colpi length	Aperture
PA	-0.0996					
Shape	-0.3353	***0.7170				
Exine thickness	***0.4952	-0.2454	-0.2584			
Colpi length	-0.0085	***0.9697	***0.6623	-0.1689		
Aperture	0.1031	0.1790	-0.0976	0.1192	0.1252	
P/E	-0.3106	**0.5020	***0.6253	-0.1253	*0.4042	-0.2144

+1 0 -1

*, **, *** are significant at p = 0.05, 0.01 and 0.001 respectively

5.3.4. Cluster analysis

Accumulated data were analyzed numerically to generate the Pearson similarity co-efficient dendrogram for studied taxa of Polygonaceae to understand their interrelationship. The dendrogram (Fig. 35) showed two major constant clades with closely related taxa where the first clade was further divided into three sisters clades. The first sister clade consisted of *Rumex nepalensis*, *R. dentatus*, *R. maritimus*, *R. acetosella*, *Rheum nobile*, *Fagopyrum esculentum* and *F. dibotrys*. In second sister clade, all the taxa of *Polygonum* (*P. plebeium*, *P. molle*, *P. runcinatum*, *P. pubescens*, *P. viscosum*) and *Homalocladium platycladum* were placed. The third sister clade was further subdivided into two clades where one clade consisted of *Antigonon leptopus* and *Fallopia convolvulus* and the second clade composed of 18 taxa of *Persicaria* (*P. chinensis* var. *ovalifolia*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. capitata*, *P. tenella*, *P. minor*, *P. campanulata*, *P. nepalensis*, *P. posumbu*, *P. glabra*, *P. microcephala*, *P. barbata*, *P. hydropiper*, *P. orientalis*, *P. strigosa*, *P. lanigera*, *P. lapathifolia* var. *lapathifolia* and *P. lapathifolia* var. *lanata*) showing very close proximity. The entire dendrogram was quite significant and all taxa of same genera forming separate cluster and nearby cluster denotes the close proximity among genera.

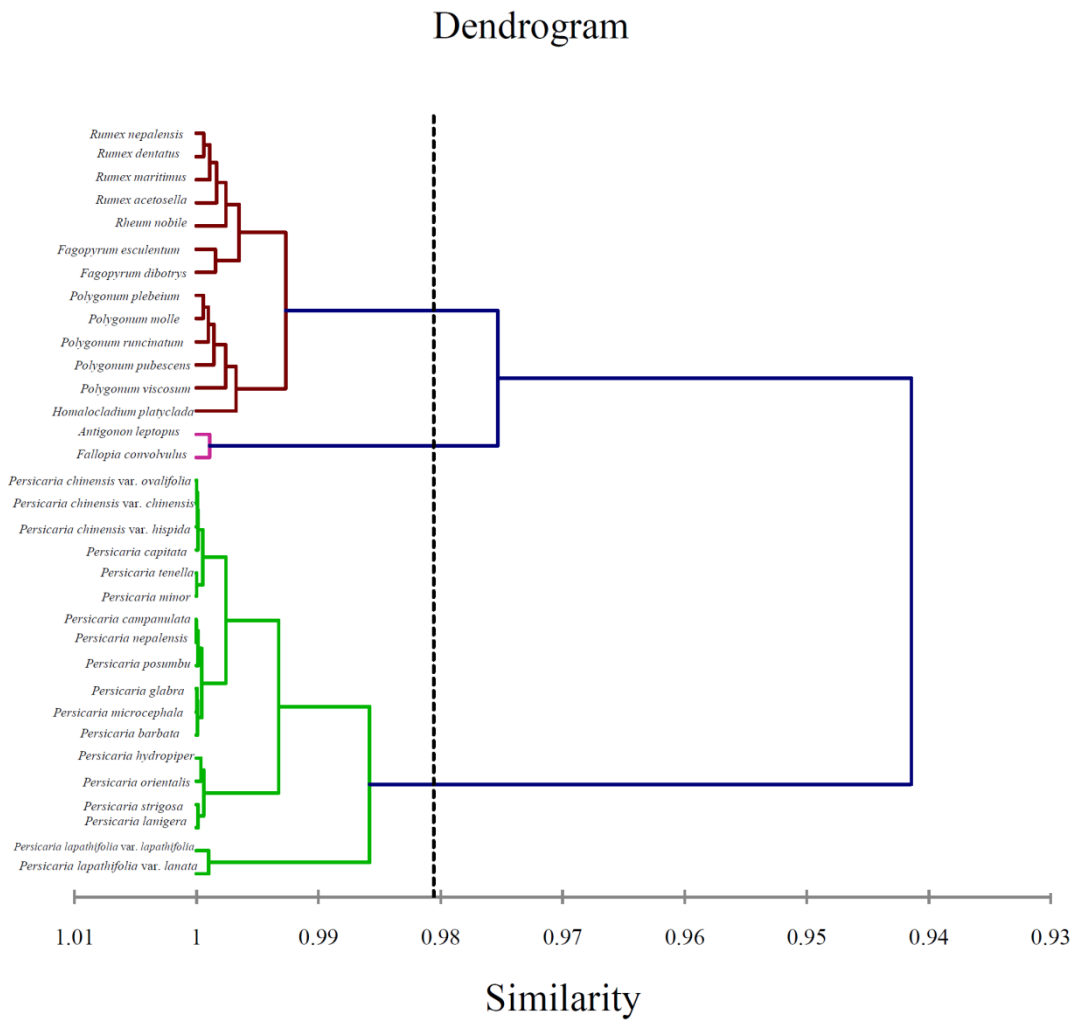

Fig. 35: Dendrogram showing inter-relationship among taxa based on pollen morphological characters

5.3.5. Artificial identification key

Using various distinctive pollen grain characters an easy identification dichotomous key was constructed for studied taxa under study from this part of the world. This key is clearly reflecting the importance of qualitative and quantitative characters that functioned as unique identification tool for taxa upto varietal level.

1 + Pollen grains with colpi **2**

- Pollen grains without colpi **3**

2 + Colpi with pore **4**

- Colpi without pore **5**

3 + Pollen grains small in size (15.85µm – 19.63 µm) **6**

- Pollen grains medium in size (33.24µm – 42.16 µm) **7**

4 + Ora lalongate .... ……..…… **8**

- Ora lolongate **9**

5 + Pollen grains small .... ***Polygonum plebeium***

- Pollen grains medium **10**

6 + Pollen grains prolate sphroidal in shape ....…..... ***Persicaria strigosa***

- Pollen grains spheroidal in shape ..... ***Polygonum pubescens***

7 + Lumina with baculae **11**

- Lumina granulose .... …..... . ***Persicaria orientalis***

8 + Pollen grains prolate spheroidal in shape …….. ……..... …….. .. **12**

- Pollen grains prolate in shape…… ……. ***Rheum nobile***

9 + Colpi long narrow **13**

- Colpi with tapering end ..... ***Rumex nepalensis***

10 + Pollen grains subprolate in equatorial view **14**

- Pollen grains prolate spheroidal in equatorial view **15**

11 + Exine thicknesss 1.45 µm .... ***Persicaria glabra***

- Exine thickness more than 1.45 µm **16**

12 + Exine micro echinate – punctuate …… .. ***Fallopia convolvulus***

- Exine micro reticulate ……. ……..…… ***Homalocladium platycladum***

13+ Exine reticulate **17**

- Exine granulate .... ***Rumex dentatus***

14 + Exine micro reticulate .... ***Polygonum molle***

- Exine reticulate with pitted texture .... ***Antigonon leptopus***

15 + P/E ratio 1.10 .... ***Persicaria campanulata***

- P/E ratio less than 1.10 .... **18**

16 + Exine granulate to reticulate ..... ***Persicaria chinensis* var. *chinensis***

- Exine reticulate **19**

17 + Pollen grains small in size (24.95 µm – 28.96 µm) **20**

- Pollen grains medium in size (43.38 µm – 45.74 µm) **21**

18 + Exine reticulate – regulate .... ***Persicaria capitata***

- Exine reticulate .... ***Persicaria tenella***

19 + Muri thin, regularly shaped **22**

- Muri thick irregularly shaped .... ……..……..... . **23**

20 + Shape subprolate in equatorial view ..... ***Rumex acetosella***

- Shape prolate in equatorial view .... ***Rumex maritimus***

21+ Colpi length 33.84 µm .... ***Fagopyrum esculentum***

- Colpi length 28.27 µm .... ***Fagopyrum dibotrys***

22 + Pollen grains diameter 25.57 µm .... ***Polygonum viscosum***

- Pollen grains diameter more than 25.57 µm **24**

23 + Lumina broad having longitudinal folds .... ……..……..... **25**

- Lumina mostly hexagonal, pentagonal **26**

24 + Exine not uniformly reticulate …… …… ***Persicaria lanigera***

- Exine uniformly reticulate …….. ……..... . .. ***Polygonum runcinatum***

25 + Pollengrains diameter 29.33µm .. ….. ……..…… ***Persicaria minor***

- Pollen grains diameter 31.99µm ……...… ***Persicaria chinensis* var. *hispida***

26 + Exine 4.16 µm thick .... ***Persicaria posumbu***

- Exine less than 4.16 µm **27**

27 + Pollen grains average diameter 43.16µm ..... ***Persicaria hydropiper***

- Pollen grains diameter less than 43.16µm **28**

28 + % of Co-efficient variance (CV) >5 .... **29**

- % of Co-efficient variance (CV) <5 .... **30**

29 + Intine indistinct ..... ***Persicaria chinensis* var. *ovalifolia***

- Intine distinct **31**

30 + Exine 2.18 µm thick .... ***Persicaria lapathifolia* var. *lapathifolia***

- Exine 4.05 µm thick .... ***Persicaria barbata***

31 + Muri curvimurate ……..... . ……..……. **32**

- Muri with longitudinal folds .... ***Persicaria microcephala***

32 + Pollen grains diameter 26.25µm ……..... . ***Persicaria nepalensis***

- Pollen grains diameter 27.16 µm .... ***Persicaria lapathifolia* var. *lanata***

5.4. MORPHOLOGICAL PHENOGRAM

All the accumulated macro, micro morphology and pollen morphological data were analyzed numerically to generate the Pearson similarity co-efficient dendrogram for studied taxa of Polygonaceae to understand their interrelationship. The dendrogram (Fig. 36) showed that all the studied genera forming separate cluster. *Homalocladium platycladum* was forming separate clade from the other taxa. All the taxa of *Polygonum* (*P. plebeium*, *P. molle*, *P. runcinatum*, *P. pubescens*, *P. viscosum*) were clustered together and showed close proximity with *Fallopia convolvulus*. The third sister clade was further subdivided into two cluster where all 18 taxa of *Persicaria* (*P. chinensis* var. *ovalifolia*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. capitata*, *P. tenella*, *P. minor*, *P. campanulata*, *P.*

nepalensis, *P. posumbu*, *P. glabra*, *P. microcephala*, *P. barbata*, *P. hydropiper*, *P. orientalis*, *P. strigosa*, *P. lanigera*, *P. lapathifolia* var. *lapathifolia* and *P. lapathifolia* var. *lanata*) and all the four taxa of *Rumex* (*R. nepalensis*, *R. dentatus*, *R. maritimus*, *R. acetosella*) were showing sister relationships. *Rheum nobile*, *Fagopyrum esculentum* and *F. dibotrys* forming separate cluster and was showing very close proximity. The entire dendrogram was quite significant and all taxa of same genera forming separate cluster and nearby cluster denotes the close proximity among genera.

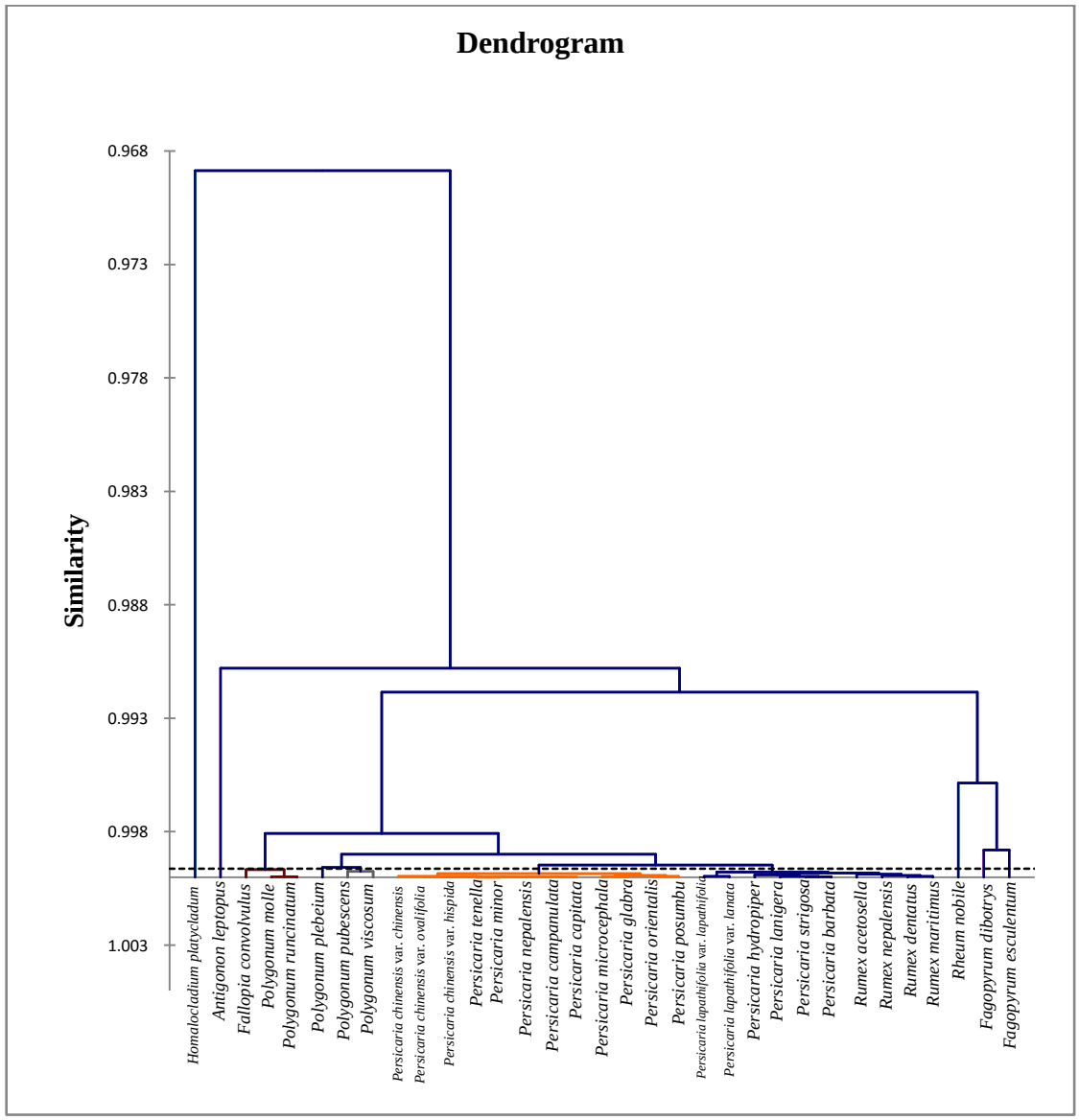

Fig. 36: Dendrogram showing inter-relationship among taxa based on macro, micro and pollen morphological characters

5.5. MOLECULAR DOCUMENTATION

Fresh leaf sample for all the collected taxa of Polygonaceae were collected from their natural habitats of different parts of West Bengal. The present study extended the knowledge of some previous researchers by sequencing conserved chloroplast region of several members of Indian Polygonaceae (*viz*., 6 sequence of *rbcL*, 17 sequences of *trnL-F* and 10 sequences of *matK* from 19 species of Polygonaceae) that were not sequenced earlier. Based on these sequences of three chloroplast DNA region, phylogeny of the eight genera of Himalayan *Polygonum* sensu lato were re-evaluated.

5.5.1. Sequence analysis

The *rbcL, matK* and *trnL-F* gene sequences of different taxa of eight genera *viz*., *Persicaria, Rheum, Rumex, Antigonon, Fagopyrum, Fallopia, Muehlenbeckia* and *Polygonum* were compared with other sequences available and submitted to GenBank (Appendix 1). Altogether 33 sequences were submitted to GenBank including 6 sequences of *rbcL* genes, 10 sequences of *matK* genes and 17 sequences of *trnL-F* genes following BLASTn analysis. Sequencing of the five *Persicaria-rbcL* genes showed 99% nt identity with other *Persicaria* species available in the GenBank whereas, the *Rumex-rbcL* gene showed 98% nt identity with *R. flexuous*. The *matK* sequences of the nine *Persicaria* species showed 97-99% nt identity with other *Persicaria-matK* sequences found in the GenBank and the *Rumex-matK* gene showed 99% nt identity with *R. patientia* sequence. The *trnL-F* sequences of the *Prisecaria* species also showed 97-99% nt identity with other *Persicaria-trnL-F* sequences. The *Antigonon, Fagopyrum, Muehlenbeckia, Rumex* and *Polygonum trnL-F* sequences showed 93%, 98%, 98%, 98-99% and 99% nt identity respectively with the other *trnL-F* sequences available in the GenBank (Table 22).

Table 22: List of sequences submitted to GenBank from 19 taxa of Polygonaceae, their accession number and nt identity with other related taxa.

Isolate	Place of collection	GenBank Accession No.	BLAST similarity	Most similar isolate
a. *rbcL*				
1. *Persicaria lapathifolia var. lanata*	Kathambari beel, Jalpaiguri	MH757120	99%	*Persicaria hydropiperoides* (HM850244)
2. *Persicaria lanigera*	Gabgachi-chatral beel, Malda	MK015865	99%	*Persicaria capitata* (FM883623)
3. *Persicaria glabra*	Domohani beel, Jalpaiguri	MH824149	99%	*Persicaria longiseta* (FM883631)
4. *Persicaria strigosa*	Kathambari beel, Jalpaiguri	MG808037	99%	*Persicaria meisneriana* (EF653772)
5. *Persicaria tenella*	Lochka River Bed, Darjeeling	MF447884	99%	*Persicaria tinctoria* (EU554023)
6. *Rumex dentatus*	Burdwan, West Burdwan	MG766137	98%	*Rumex flexuosus* (KT626844)
b. *matK*				
1. *Persicaria microcephala*	Singamari, Darjeeling	MH757121	99%	*Persicaria sieboldii* (AB038185)
2. *Persicaria strigosa*	Kathambari beel, Jalpaiguri	MG808036	99%	*Persicaria perfoliata* (HM357916)
3. *Persicaria tenella*	Lochka River Bed, Darjeeling	MF371114	99%	*Persicaria posumbu* (KF224975)
4. *Persicaria lapathifolia var. lanata*	Kathambari beel, Jalpaiguri	MH757119	99%	*Persicaria tinctoria* (KJ939220)
5. *Persicaria lanigera*	Gabgachi-chatral beel, Malda	MK044697	97%	Persicaria capitata (HM851074)
6. *Persicaria glabra*	Domohani beel, Jalpaiguri	MH834391	98%	*Persicaria posumbu* (KF224975)
7. *Persicaria nepalensis*	Pankhabari road, Kurseong	MH324414	97%	*Persicaria sieboldii* (AB038185)
8. *Persicaria campanulata*	Tiger Hill, Darjeeling	MH324415	99%	*Polygonum chinense* (GQ434134)
9. *Persicaria barbata*	Lochka River Bed, Darjeeling	MK015867	99%	Persicaria pensylvanica (KY978033)
10. *Rumex nepalensis*	Lebong Road, Darjeeling	MH898986	99%	*Rumex patientia* (KY377980)

c. *trnL–F*				
1. *Antigonon leptopus*	Malda Station Road, Malda	MG913344	93%	*Triplaris americana* (AJ312251)
2. *Fagopyrum dibotrys*	Sukhiapokhri Road, Darjeeling	MH854502	98%	*Fagopyrum tataricum* (HQ843172)
3. *Muehlenbeckia platyclada*	NBU campus, Darjeeling	MH674191	98%	*Muehlenbeckia australis* (JF831303)
4. *Persicaria barbata*	Lochka River Bed, Darjeeling	MH824148	99%	*Persicaria kawagoeana* (EU197025)
5. *Persicaria hydropiper*	Domohani beel, Jalpaiguri	MH854504	99%	*Persicaria hydropiper* (HQ843164)
6. *Persicaria microcephala*	Singamari, Darjeeling	MH824147	99%	*Persicaria nepalensis* (JN235056)
7. *Persicaria glabra*	Domohani beel, Jalpaiguri	MH834392	98%	*Persicaria japonica* (HQ843162)
8. *Persicaria lanigera*	Gabgachi-chatral beel, Malda	MK015866	99%	*Persicaria sphaerocephala* (HQ843171)
9. *Persicaria lapathifolia var. lanata*	Kathambari beel, Jalpaiguri	MH674192	99%	*Persicaria maculosa* (EU024781)
10. *Persicaria tenella*	Lochka River Bed, Darjeeling	MG575521	99%	*Persicaria minor* (EU197033)
11. *Persicaria strigosa*	Kathambari beel, Jalpaiguri	MG821320	99%	*Persicaria meisneriana* (EF653798)
12. *Persicaria runcinata*	Darjeeling Govt. College	MH854501	97%	*Persicaria sphaerocephala* (HQ843171)
13. *Persicaria orientalis*	Nayagram beel, Malda	MH854503	99%	*Polygonum orientale* (HQ843155)
14. *Polygonum molle*	Tonglu, Darjeeling	MH674190	99%	*Aconogonon molle* (EF653790)
15. *Rumex nepalensis*	Lebong Road, Darjeeling	MK034859	98%	*Rumex crispus* (KR537741)
16. *Rumex maritimus*	Lochka River Bed, Darjeeling	MG780830	99%	*Rumex patientia* (AF303432)
17. *Rumex dentatus*	Burdwan, West Burdwan	MG780829	99%	*Rumex crispus* (KR537741)

5.5.2. Phylogenetic analysis

Results for separate analyses of the chloroplast data (*rbcL, matK* and *trnL-F*) showed well-supported differences in relationships. Both Bayesian (BI) and maximum likelihood (ML) analyses produced trees with similar topologies.

5.5.2.1. *rbcL* Analysis

In the ML tree of the *rbcL* gene of the eight genera of the Polygonaceae (Fig. 37) *Persicaria, Rumex, Rheum, Fagopyrum* and *Antigonon* formed separate clusters, whereas, *Polygonum, Muehlenbeckia* and *Fallopia* clustered together. *Oxygonum sinuatum* was taken as outgroup. *Rheum* was closely related to *Fagopyrum* whereas *Rumex* was closely related to *Persicaria*. Although some of taxa of *Polygonum* were clustered with *Perasicaria.* From the ML tree it was clearly observed that *Persicaria* was monophyletic in origin while *Polygonum* was paraphyletic in origin. The phylogenetic tree reconstructed with BI analysis (Fig. 38) showed that all the eight genera *i.e., Persicaria, Rumex, Rheum, Fagopyrum, Antigonon, Polygonum, Muehlenbeckia* and *Fallopia* formed separate clusters. Here also *Rheum* shows sister relationship with *Fagopyrum*. *Antigonon* were closely related with *Fagopyrum*. It was clearly observed also from BI analysis that *Persicaria* was monophyletic in origin while *Polygonum* was paraphyletic in origin. The results of BI analysis were similar to the results of ML analysis. The pairwise similarities of these sequences have been presented in the colour-coded matrix (Fig. 39).

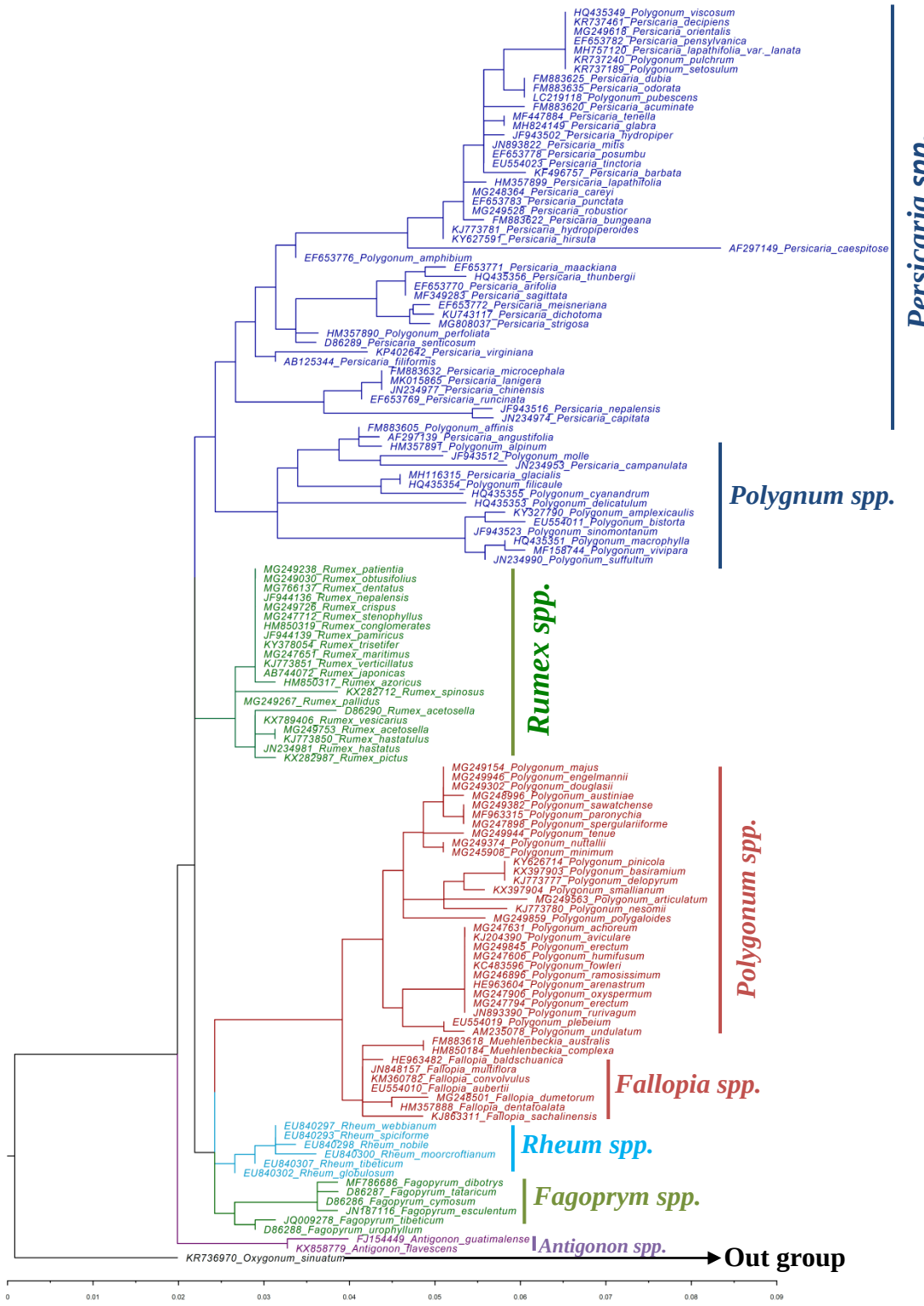

Fig. 37: Phylogenetic tree generated by Maximum Likelihood (ML) method consisting of *rbcL* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicated

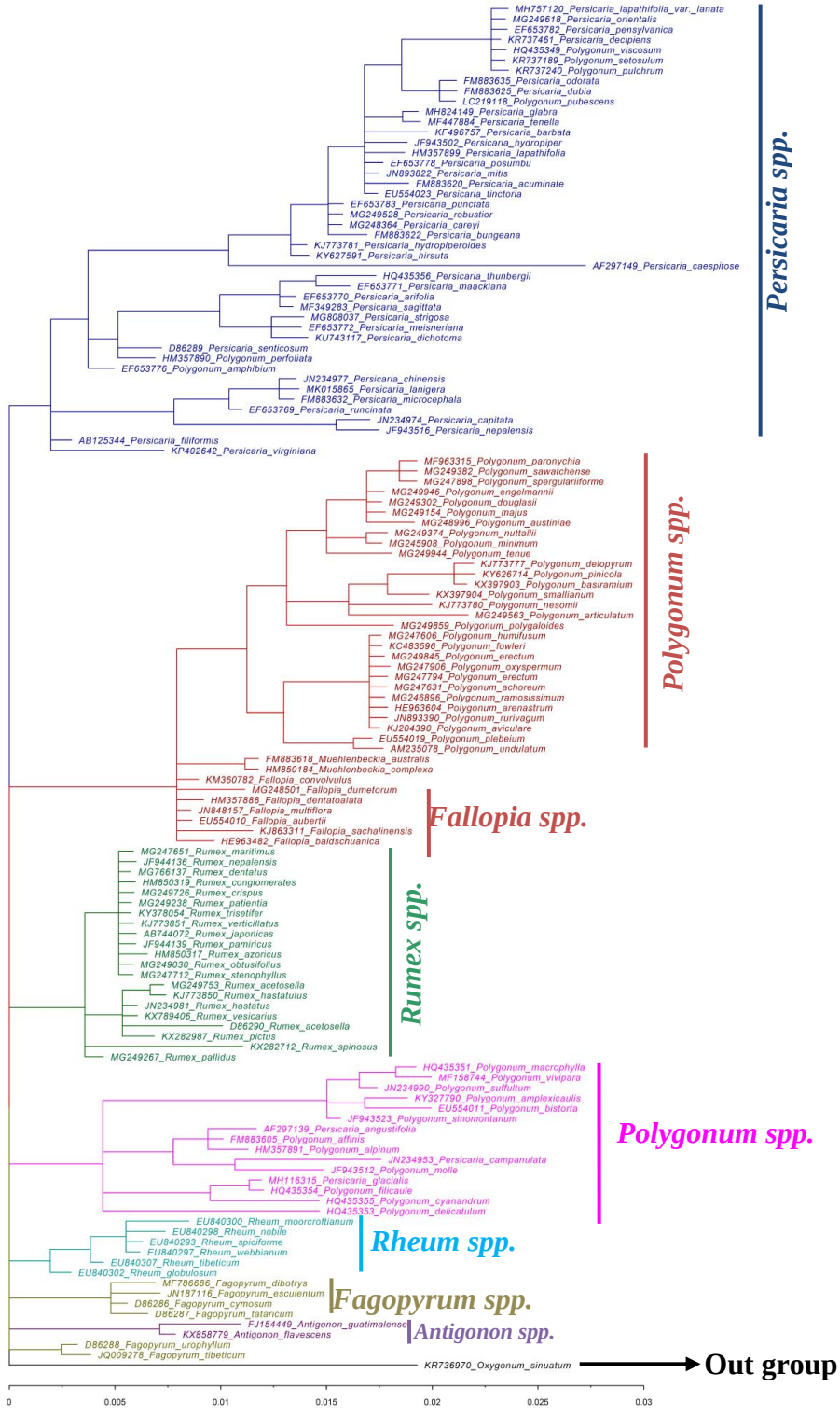

Fig. 38: Phylogenetic tree generated by Bayesian phylogenetic inference (BI) method consisting of *rbcL* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicated

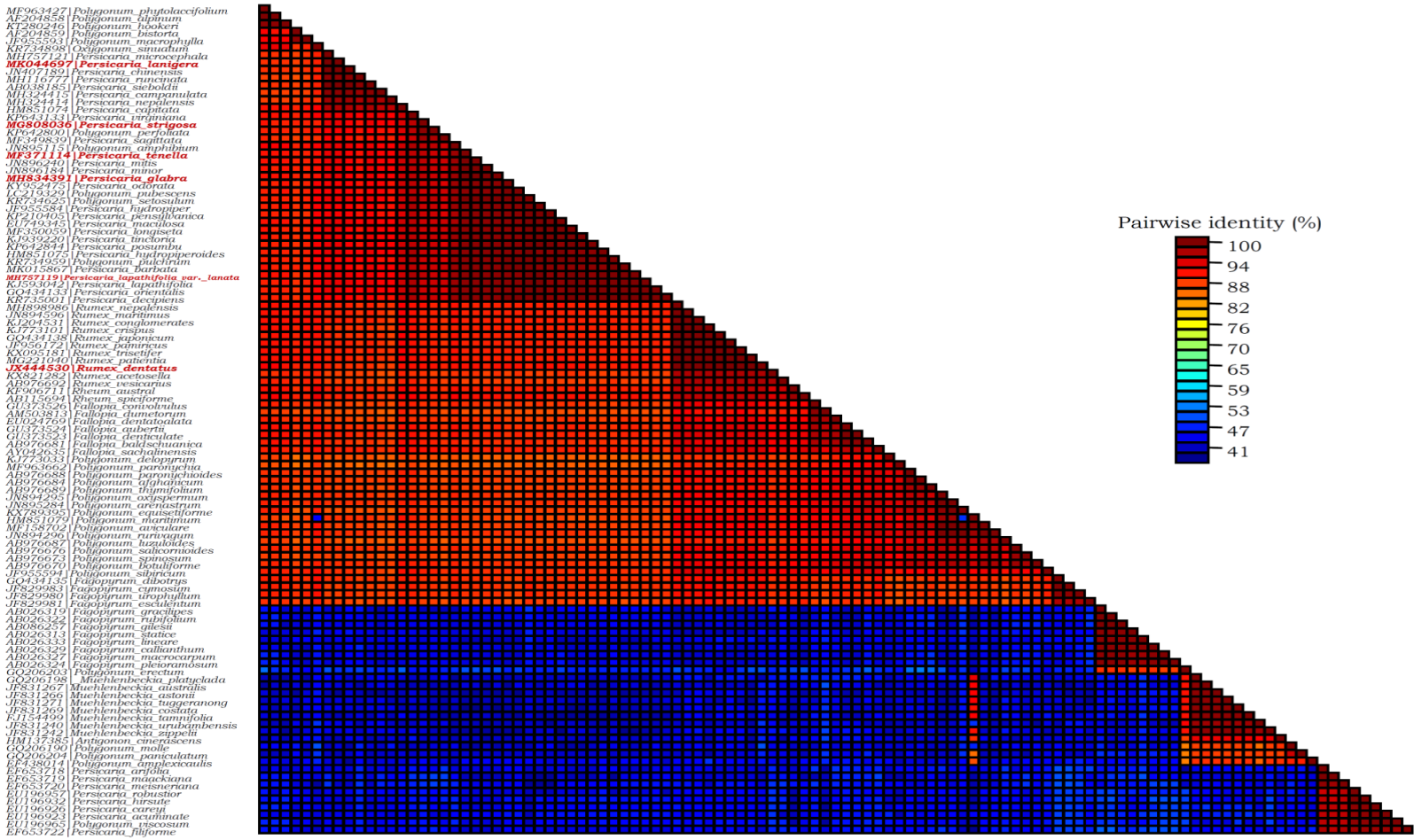

Fig. 39: Nucleotide sequence identity matrix of *rbcL* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. Identity percentages are indicated on the right side corner of the matrix

5.5.2.2. *matK Analysis*

Another ML tree was generated using the *matK* gene of the eight genera of the Polygonaceae (Fig. 40), where all the eight genera formed separate clusters, although *Polygonum*, *Persicaria* and *Fagopyrum* formed more than one clusters. However, *Muehlenbeckia* was closely related to *Polygonum*. *Fallopia* was also found to be closely related to *Polygonum* but distantly related to *Fagopyrum*. *Rumex* and *Rheum* showed close relationship with *Fagopyrum* just like *rbcL* analysis. The phylogenetic tree reconstructed with BI analysis (Fig. 41) showed similar clustering pattern supporting the ML trees such as *Muehlenbeckia* was closely related to *Polygonum*; *Fallopia* was also found to be closely related to *Polygonum.* But *Rumex* and *Rheum* were showimg different clustering pattern *i.e.*, in ML analysis they were closely related to *Fagopyrum* whereas in BI analysis they were distantly related to *Fagopyrum*. *Polygonum*, *Persicaria* and *Fagopyrum* formed more than one clusters also in this analysis. The pairwise similarities of these sequences have been presented in the colour-coded matrix (Fig. 42).

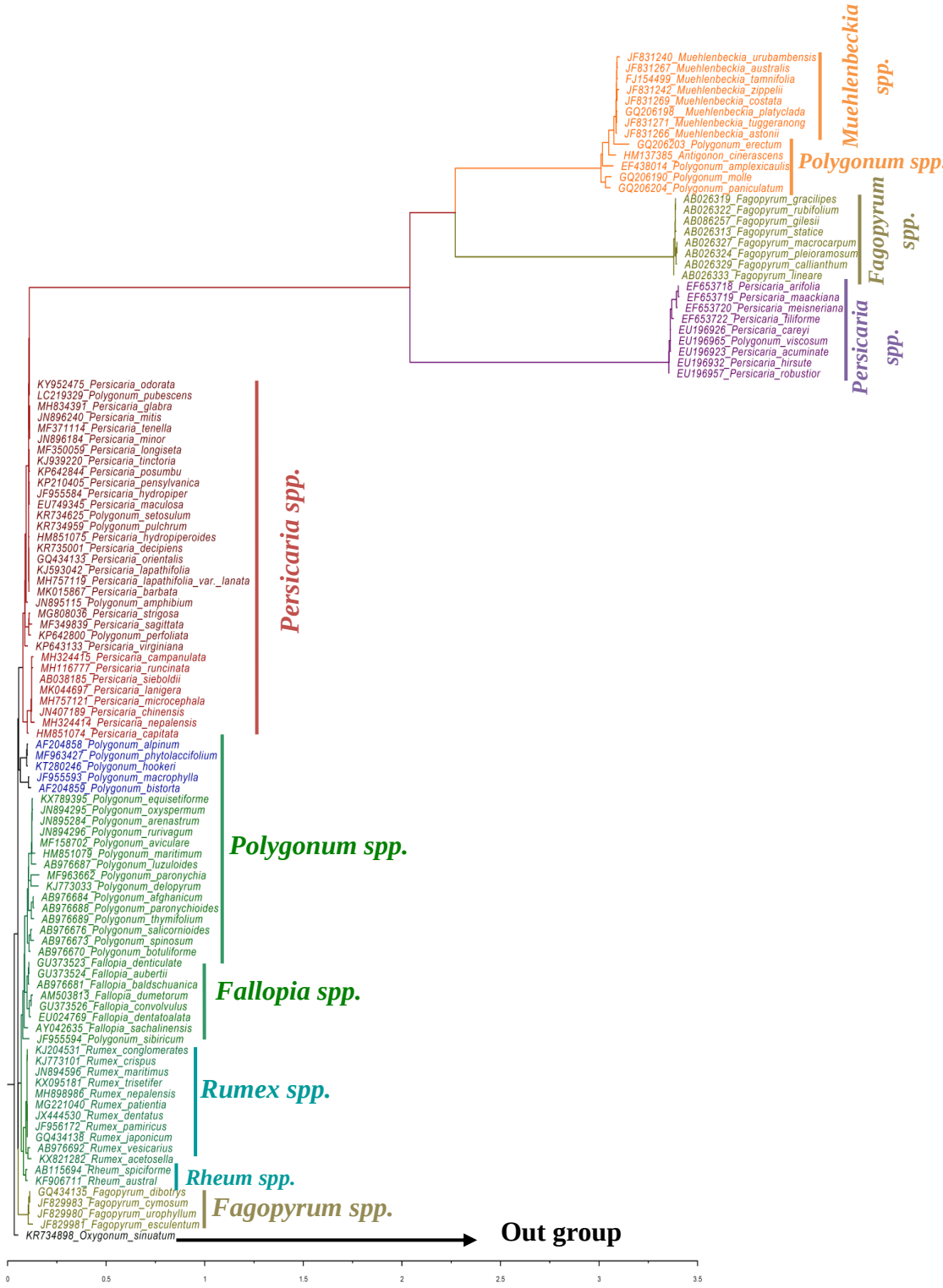

Fig. 40: Phylogenetic tree generated by Maximum likelihood (ML) method consisting of *matK* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicated

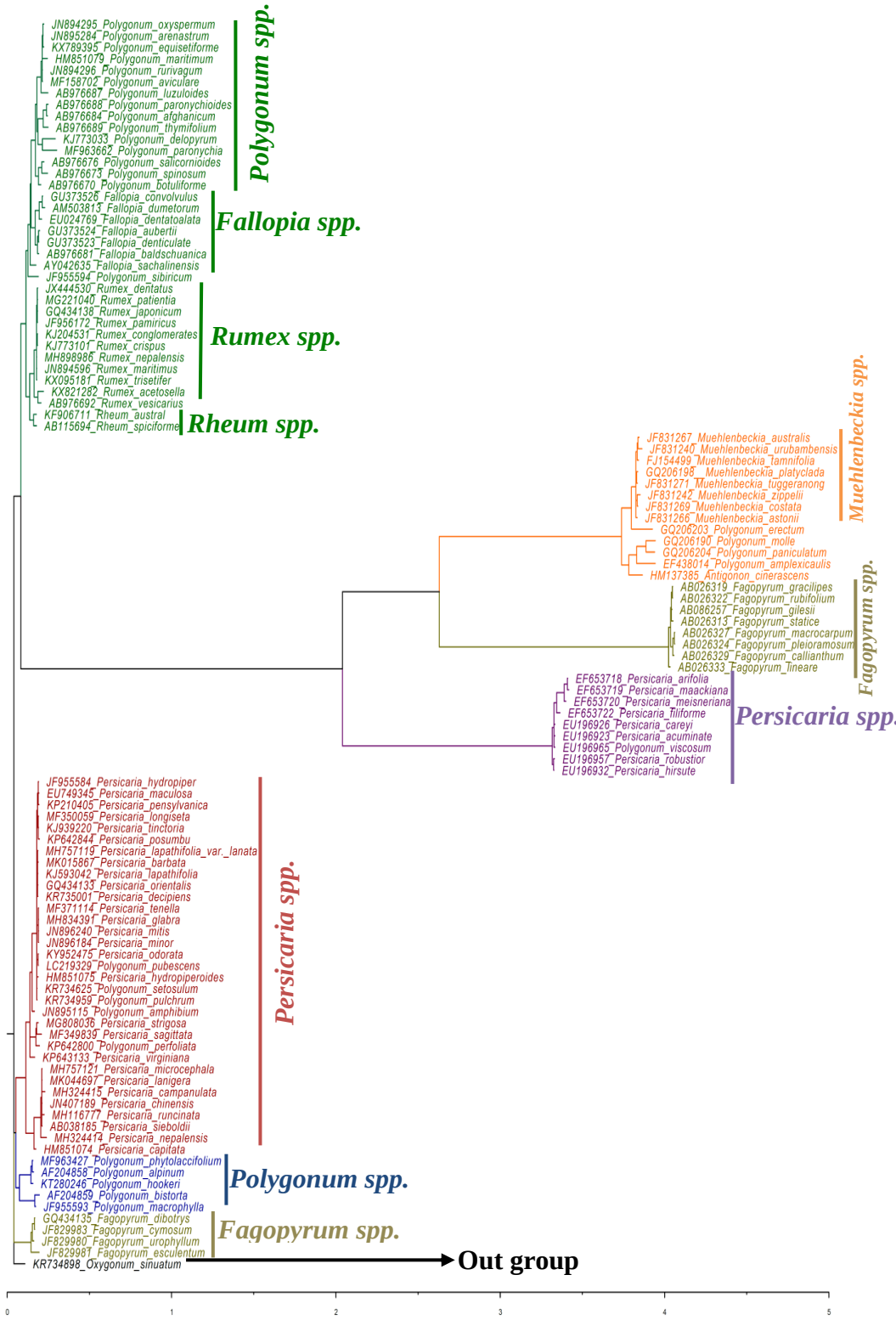

Fig. 41: Phylogenetic tree generated by Bayesian phylogenetic inference (BI) method consisting of *matK* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicated

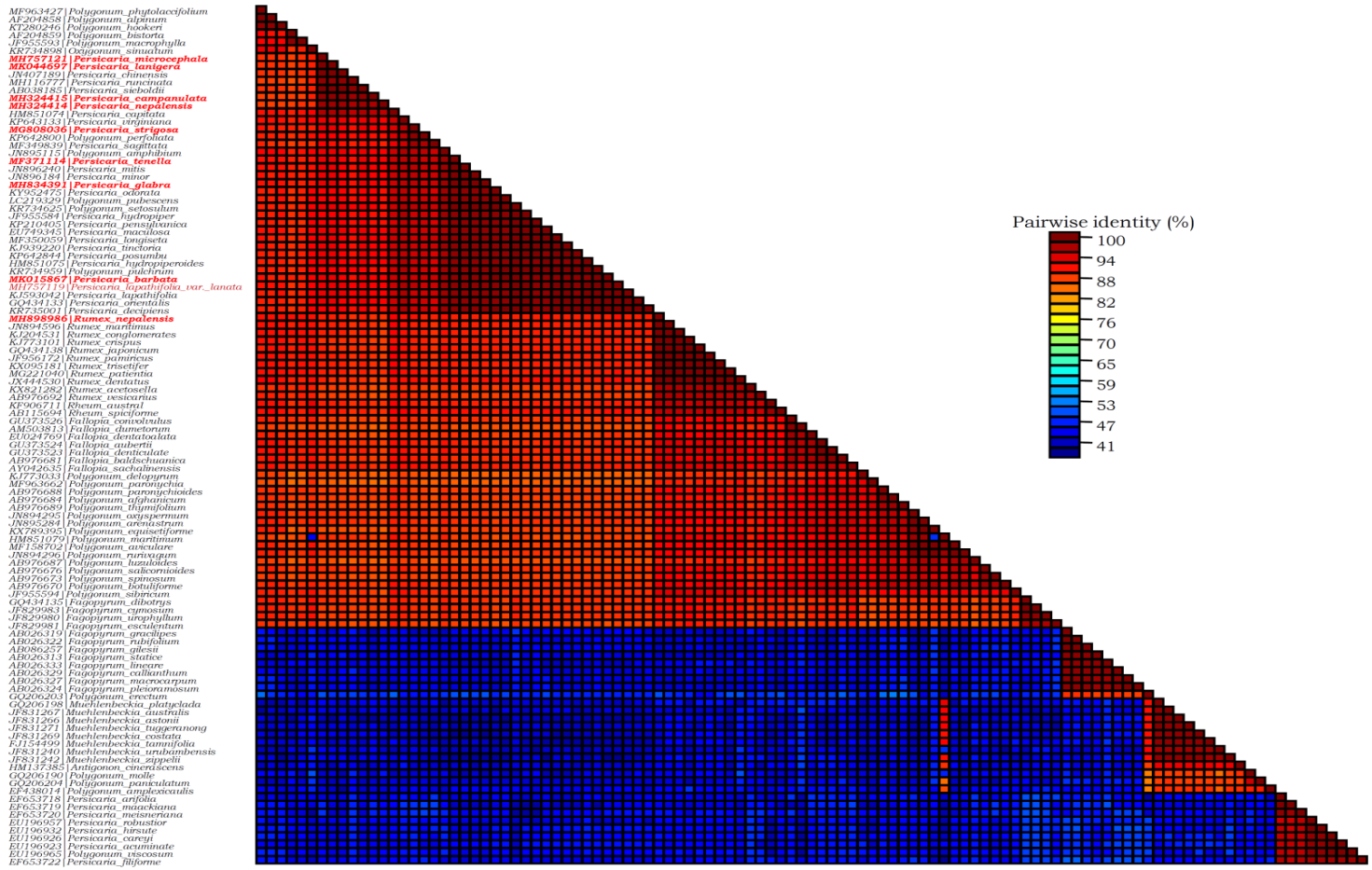

Fig. 42: Nucleotide sequence identity matrix of *matK* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. Identity percentages are indicated on the right side corner of the matrix

5.5.2.3. *trnL-F Analysis*

The phylogenetic ML tree based on *trnL-F* genes of Polygonaceae (Fig. 43) revealed more or less similar results with *rbcL* and *matK* data analysis. Here also *Fallopia*, *Muehlenbeckia* and *Polygonum* clusters form a single group outgrouped with *Antigonon*. Other four genera *Persicaria*, *Rumex*, *Rheum* and *Fagopyrum* formed separate clusters where *Rumex* and *Rheum* closely related to *Fagopyrum. Polygonum* also formed one separate cluster which strongly supports its polyphyletic origin. The phylogenetic trees reconstructed with BI analysis (Fig. 44) showed more or less similar clustering pattern supporting the ML tree analysis. In this analysis all the taxa of *Fallopia* were nested within the cluster of *Muehlenbeckia*. In BI analysis, *Rumex* and *Rheum* were also showing close relationship to *Fagopyrum*. *Fallopia*, *Muehlenbeckia* and *Polygonum* clusters also form a single group outgrouped with *Antigonon* in BI analysis. From these analyses it was clearly observed that *Polygonum* was polyphyletic in origin whereas all the other taxa were monophyletic in origin. The pairwise similarities of these sequences have been presented in the colour-coded matrix (Fig. 45).

In the entire phylogenetic analysis the *Persicaria* cluster was comprised of several *Polygonum* species. However, in all the cases (*rbcL*, *matK* and *trnL-F*) most of the genera were found to be polyphyletic in origin.

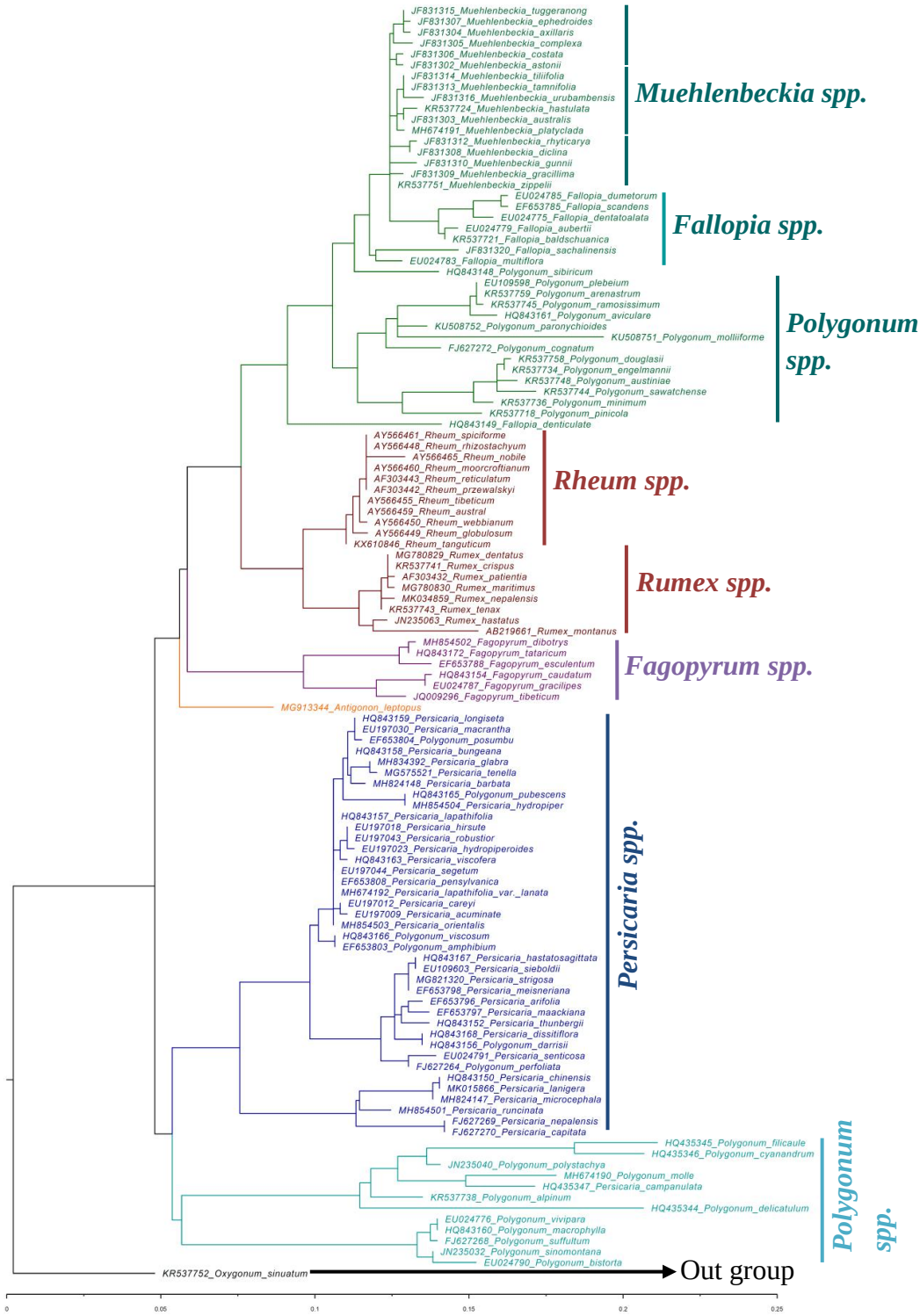

Fig. 43: Phylogenetic tree generated by Maximum likelihood method consisting of *trnL-F* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicate

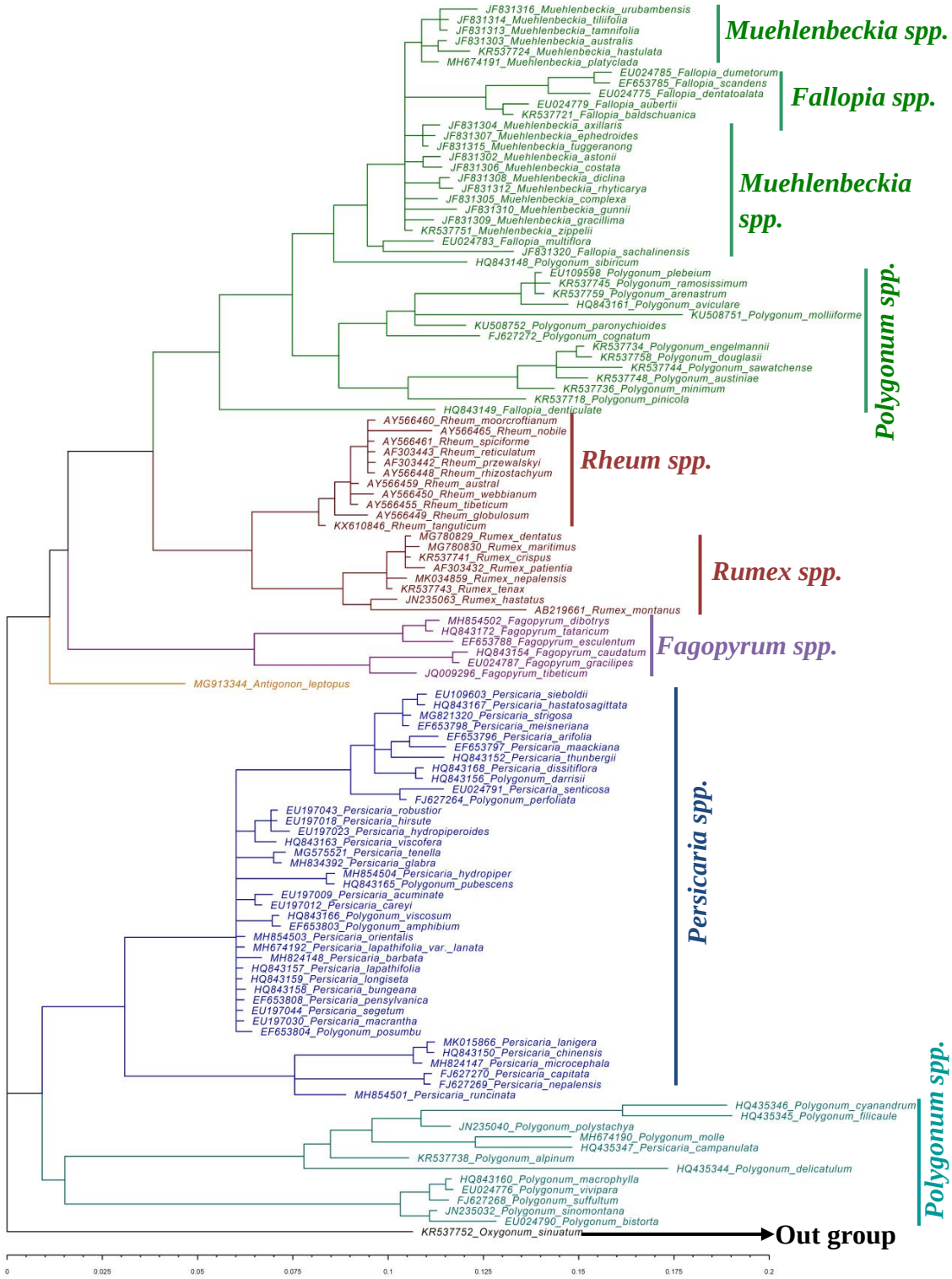

Fig. 44: Phylogenetic tree generated by Bayesian phylogenetic inference method consisting of *trnL-F* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. GenBank accession numbers along with the species have been indicated

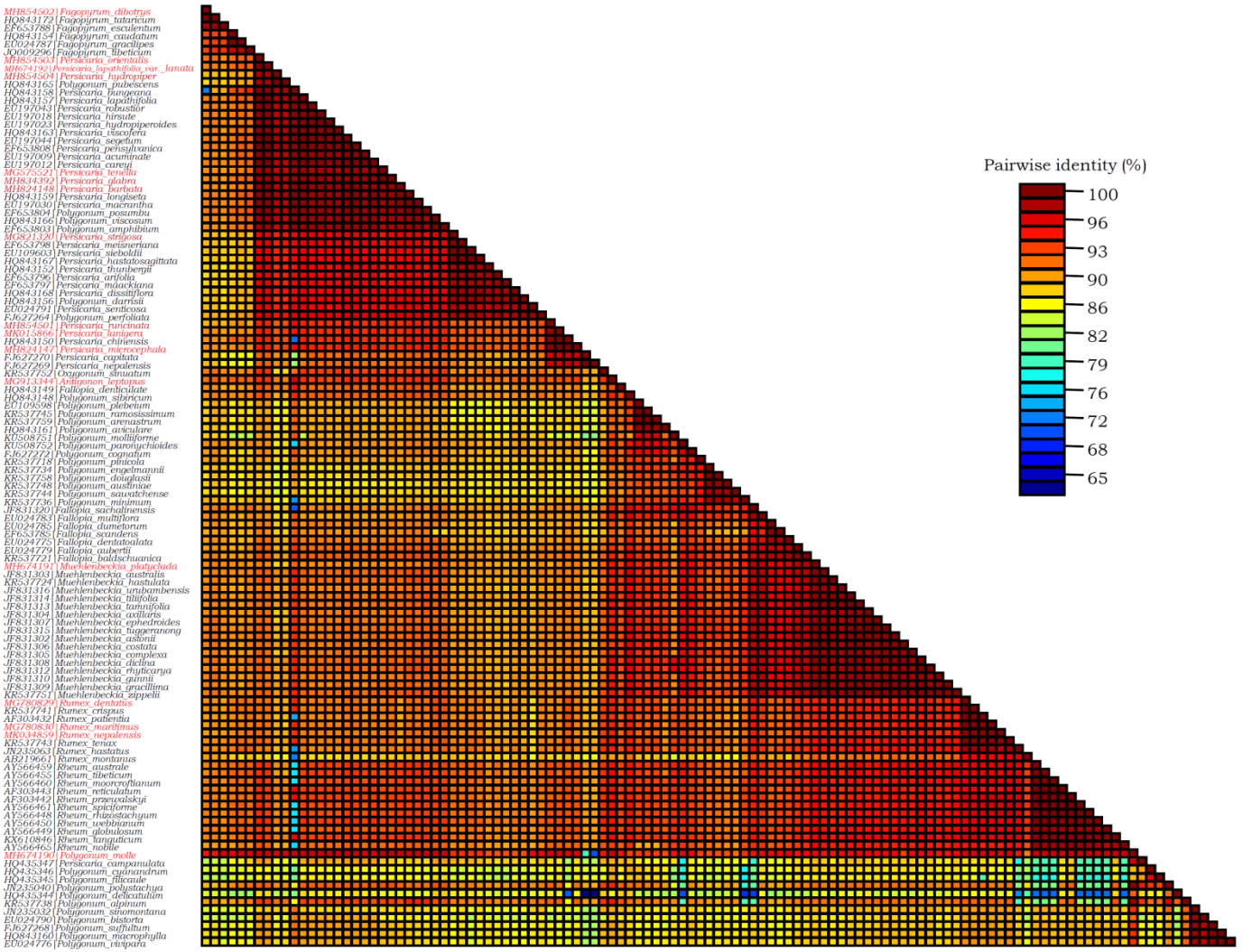

Fig. 45: Nucleotide sequence identity matrix of *trnL-F* gene of the members of Polygonaceae of the present study and that of other members of Polygonaceae reported worldwide. Identity percentages are indicated on the right side corner of the matrix

6. DISCUSSION

Darjeeling-Kalimpong Himalaya including Sikkim and terai-Duars of sub-Himalayan topography forms a fundamental part of the Eastern Himalayan region that are the storehouse of rich and diversified biological resources, representing of a huge number of endemic, rare, endangered and economically important plants (Bhujel and Das 2002; Chowdhury 2009). Till now, a large number of botanists, naturalists and tourists from different parts of the world are paying attention to this region. Due to apposite environmental set-up, the region becomes one of the richest floral diversity in India. This region uniformly represents plant groups of various habits such as herbs, shrubs, small to large climbers and trees. Many wild species having therapeutic, religious and socio-cultural values are found to be of immense economic significance for the local ethnic people including food and ornamental potentiality (Sarkar 2011). On the other hand, a large number of trees belonging to the diverse families are known for their high quality timber, which are quite costly, durable and are much demanding in global market. However, many plant species of this region were found to be threatened and endangered (Das *et al.* 2010). North and South Bengal plain starts from the south of Terai region and continues up to the left bank of the Ganges. The region is about 50 to 100m above the sea level. The Western undulating highlands and plateau forms the eastern periphery of the Chota Nagpur and is made up of igneous rocks of the Archaean era as well as coal-bearing mudstone and quartzite rocks of Carboniferous period. Members of Polygonaceae are common both in the plains as well as in the mountainous ranges. Maximum members of this family are found in wild habitat throughout the state but few taxa are cultivated in gardens, sanctuaries and parks etc.

The members of the Polygonaceae are highly valued for their medicinal properties. The Genus *Polygonum* is growing as weed in different habitats and it has several economical and ecological importances. Some species of Polygonaceae were extensively used in traditional medicine system among the various ethnic groups in West Bengal as well as in India. Seeds and young leaves of *Fagopyrum dibotrys* (D. Don) Hara was used for treatment of colic, choleric diarrhea and abdominal blockage troubles in different parts of West Bengal. Various communities are used watery sap from roots of *Persicaria barbata* (Linnaeus) H. Hara as antiseptic. Local

people of Bengal plains are used Tender leaves, shoots and fruit of *Polygonum perfoliatum* Linnaeus as vegetable; whole plant are also used as depurative, diuretic, febrifuge and to stimulate blood circulation; leaves decoction is used in the treatment of dysentery, enteritis, boils and abscesses, poisonous snake bites, haematuria, cloudy urine and traumatic injuries. There are large numbers of ornamental plants in Polygonaceae. However, from West Bengal only four species are used as ornamentals namely *Antigonon leptopus*, *Coccoloba uvifera*, *Persicaria capitata*, *Persicaria orientalis*. Young leaves of *Fagopyrum dibotrys*, *Fagopyrum esculentum*, *Fagopyrum tartaricum*, *Rumex acetosella*, young shoot of *Rumex hastatus* and rhizome of *Bistorta amplexicaulis* have extensive local market value for their medicinal and commercial properties. Further study focused on cultural, medicinal and commercial aspects of Polygonaceae are required to unveil valuable bio resource.

Polygonaceae had been studied worldwide by various taxonomists in different laboratories to understand their evolution and phylogeny. As the members of this family are confined to Himalayan regions, so the West Bengal occupies the prominent position regarding their diversity. But, very little works was documented on the Polygonaceae from this region. Controversies about the phylogeny and affinity of some species of this region and their uncertain positioning of the genera and their relationship are still remains uncertain. Literature study revealed that no such detailed information were available on qualitative and quantitative morphology and anatomy on epidermal cells outline, stomata, trichomes, glands and palynology of the members of Polygonaceae used for understanding of their phylogeny from this region. So, the present study was focused on foliar macro-micromorphology (stipule, leaf architectures, trichomes, stomata, venations etc) in combination with other evidences such as pollen morphology and molecular data analysis of the available members of Polygonaceae from West Bengal in order to establish the authentic species level identification and more importantly to resolve the controversy of the systematic position of *Polygonum* and *Persicaria*.

The present work evidently exhibited that Polygonaceae is one of the well known families throughout West Bengal, represented by the recorded 9 genera and 35 species. According to earlier available literature (Maiti 1985; Prain 1906; Srivastava 2014) it was revealed that among the recorded 35 taxa, only 28 taxa of

Polygonaceae were reported earlier from the study area (Maiti and Sikdar 1985; Srivastava 2014). Among the recorded taxa, *Persicaria* Mill. was the largest genus with 13 species, followed by *Polygonum* L. with 8 species, *Rumex* L. with 5 species, *Fagopyrum* Mill. with 2 species, *Antigonon* Endl., *Bistorta* Adans., *Fallopia* Adans., *Homalocladium* (F. Muell.) L. H. Bailey and *Rheum* Hook. and Thompson with 1 species.

Different qualitative attributes such as habit, presence or absence of petiole, Ochreae, tepal number, shape, ovary and fruit shape could be used for the delimitation of different studied genus. Moreover, few significant quantitative characters *i.e.*, plant height, length/width of lamina and characteristic features of ochreae, tepal, filament and style also proved to be taxonomically important characters for the identification of different taxa below the rank of genus.

Among the recorded taxa *Antigonon leptopus* is the only climber member of the family. Another identifying feature of the species is the absence of ochreate stipule. *Homalocladium platycladum* segregated from the other recorded genera due to the presence of phylloclade.

Fagopyrum is an economically important genus of Polygonaceae (Campbell 1995) and known as the good source of Polyphenols (Holasova *et al.* 2002). The most distinguishable feature of this genus is the long sized nut and disc shaped glands alternating with stamens. The reported two species segregated from each other by their habitat like annual (*F. dibotrys*) and perennial (*F. esculentum*), anthers position basifixed (*F. dibotrys*) and dorsifixed (*F. esculentum*).

Fallopia is a prostrate or twining herb having 9 species worldwide, mostly found in northern temperate regions of Asia and Europe and among them only 1 species are reported from West Bengal. Plant habit, stem and pubescence leaf, tepal and nut shape are the characteristic features of the genus. Angular stem, articulated pedicel above the middle (Stewart 1972), narrowly keeled pubescent tepals and granular nut (Ronse Decraene and Akeroyd 1988) are key characteristic features of *F. convolvulus*.

The most important and controversial genus *Persicaria* shows the wide range of variation in morphological attributes and it also differ from other genera on the basis

of inflorescence type and stamens number. The systematic position of *Persicaria* and *Polygonum* are still very confusing (Steward 1930; Wilson 1990; Heywood *et al.* 2007). Hooker (1886) described 24 species under section *Persicaria* from undivided British India while Maiti and Sikdar (1985) listed 14 species from West Bengal based on the available herbarium specimens at CNH. Present study recorded a total of 13 species of *Persicaria* from the various altitudinal and topographical habitats of West Bengal.

In the present study three varieties of *P. chinensis* have been reported from the study area *i.e., P. chinensis* var. *chinensis*, *P. chinensis* var. *ovalifolia* and *P. chinensis* var. *hispida*. Among the three varieties *Persicaria chinensis* var chinensis is quite common in wild in between 120m to 2800m of Himalaya whereas rest two varieties are quire uncommon in nature. The distribution of *Persicaria chinensis* var *hispida* was earlier known only from Myanmar, Thailand, China and North east India and is endemic to South-east Asia, present work first time recorded from the boundary of West Bengal at Durpin (Kalimpong) of Darjeeling Himalaya. The varieties are distinguished from each other by their base shape, length, width, surface of lamina and orchreae and presence and absence of gland in penduncle.

P. hydropiper is a very common and frequently occurring species and phyto-geographically distributed throughout the state near the water bodies. Its important morphological features are brown stem with reddish streaks, scabrous ochreae and 5 glandular tepals (Ronse Decraene and Akeryod 1988). Less common species of *P. posumbu* seems to be similar with more common *P. orientalis* but can be separated by presence of acuminate - caudate leaf apex and 7 stamens in *P. posumbu* while acute - acuminate leaf apex and 5 stamens in *P. orientalis*. Based on some quantitative characters such as leaf and ochreae length and tepal size, both species are also distinguished from each other.

P. nepalensis is another most frequently observed species of *Persicaria*, characterized by winged petiole, 4 tepals, 5 stamens, 2 styles and dark brown nut. Instead of a separate species, Hooker (1886) proposed it as the variety of *P. alata* Buchanon-Hamilton *ex* Spreng due to the presence of winged petiole in both.

Genus *Polygonum* is mainly distributed throughout the world such as NE India, Pakistan, Nepal, China, Japan, Bangladesh, Myanmar, Malaysia and Europe. Present

study reported 7 species of *Polygonum* from West Bengal. The habit range, stem type and color, lamina shape, apex, margin, inflorescence type, ochreae and tepal shape are the identifying character of the genus.

P. plebeium is an annual herb with prostrate, angular stem. Hooker (1886) proposed 9 varieties for *P. plebeium* based on the characters of stem, length of internodes and leaf shape. *P. plebeium* characterized by 3 – 4 flowers in a cluster, short pedicel and unequal tepals. *P. molle* is an annual shrub with retrorsely hirsute stem, dark brown, tubular, membranous ochreae. Among them, *P. perfoliatum* having unique characteristic feature *i.e.*, green herbaceous tubular ochreae with orbicular wing at apex and lamina are triangular-peltate, abaxially usually sparsely retrorsely prickly along veins.

Rumex is a perennial or annual herb, extremely variable genus having 200 species in the temperate regions of the world, of these 22 species are present in India (Srivastava 2014). In the present study, 5 species of *Rumex* L. were taxonomically studied from West Bengal. The major characteristic attribute of the genus is the presence of 6 tepals arranged in two whorls (outer three small and inner three enlarged forming valves). *R. dentatus* and R. *maritimus* are pretty similar each other, however quantitative characters such as leaf, ochreae and tepal length of these two species are the key points to differentiate them from each other. Economically important species of *R. acetosella* are quite available throughout the state. The species easily segregated from the other species of *Rumex* having unisexual flower.

Although morphological features are undeniably significant and simply studied attributes but in this case on the basis of morphological evidence species identification merely is not possible because the morphological variations are inadequate to be taxonomically informative with any degree of certainty in Polygonaceae. For that reason in the present study other parameters are also taken in consideration to resolve the confusion about the systematic position of different taxa of Polygonaceae.

Foliar macro and micro morphology more precisely leaf-architecture was frequently used as important parameter for solving numerous taxonomic disputes (Moore 2008). Hickey initially used this parameter *i.e.*, leaf shape, gland position, venation pattern and marginal configuration to represent the placement of plant species

(Hickey 1973). After that many authors categorize the plant groups and subgroups by using the leaf-architecture data. Beside these, morphology of stomata also provide taxonomically significant diagnostic characters, like stomatal index, stomata type and the occurrence of stomata on the leaf surface (Tripathi and Mondal 2012). Therefore, the leaf architecture study was undertaken in the present work to produce a comprehensive account of 34 taxa of Polygonaceae from West Bengal, India. The current study provides valuable information concerning micro-morphological features under light microscopy, which play significant role in the identification of Polygonaceae at genus and species levels. The study mainly paying attention to epidermal cells, stomatal complex, types of stomata, subsidiary cells and trichomes.

The foliar morphological exploration of *Fagopyrum* species from India was performed for the first time in this manuscript. It discovered numerous significant micro-morphological attributers which exhibited interesting inter-specific significance for identification. The shape of epidermal cells ranges from thick walled hexagonal, pentagonal and polygonal to irregular cells with undulating walls. *F. dibotrys* and *F. esculentum* was showing mesomorphic nature of plants. The stomata were distributed on both adaxial and abaxial lamina surfaces. Paracytic type of stomata was recorded in *F. esculentum* while in *F. dibotrys* it was anomocytic. Inamdar (1971) reported anomocytic, anisocytic and paracytic stomata in *F. dibotrys*. Quantitatively, stomatal length, breadth, stomatal frequency and stomal index were also showing variation in both species. Indumentums also bear significant importance for resolving the delimitation of angiosperms (Werker 2000). Metcalfe and Chalk (1950) provided modest information about indumentums in Polygonaceae. Non glandular, multiseriate unbranched trichomes were found in both the taxa of *Fagopyrum*. Venation pattern of the two species of *Fagopyrum* were more or less similar but variation was found in case of 3º and 4º vein categories which plays significant role in the identification for both the taxa.

The shape of the epidermal cells was irregular with smooth and undulate walls in both the surfaces of lamina *Fallopia convolvulus.* Here pericytic type of stomata was found on both leaf surfaces but more on abaxial surface. The presence of non glandular unicellular trichomes was reported by Lersten and Curtis (1992) but in the present study no such trichomes were recorded in *F. convolvulus.*

Enormous range of variation was observed in the shape of epidermal cells of the studied taxa of *Persicaria* and found to be supportive as an additional taxonomic tool. The cells were smooth and thick walled, tubular or elongated, pentagonal, hexagonal, heptagonal, octahedral, polygonal or irregular and occasionally not arranged in definite pattern. The plants growing in humid conditions were characterized by undulating cell walls. Kapoor *et al.* (1971) recorded irregular epidermal cells only on abaxial surface of some taxa of *Persicaria* viz., *P. lapathifolia*, *P. glabra* and *P. nepalensis*. Ayodele and Olwokudejo (2006) investigated irregular cells on abaxial surface of *P. nepalensis*. In *P. orientalis* and *P. posumbu* irregular cells with undulating walls were recorded on adaxial surface. In *P. minor*, epidermal cells were pentagonal, hexagonal and octahedral on both surfaces while cells were pentagonal in *P. chinensis*. Typical benzene ring like cells was found in *P. barbata*. All taxa of the genus were visibly amphistomatic (Inamdar 1971) except *P. chinensis* which was hypostomatic (Kapoor *et al.* 1971). Diversity in stomatal morphology was recorded in the studied taxa. Most frequent type of stomata was paracytic. More than one type of stomata were also found in some taxa of *Persicaria* such as in *Persicaria glabra* three different types of stomata (anisocytic, paracytic and staurocytic), in *Persicaria hydropiper* two different types of stomata (ansiocytic and paracytic), in *Persicaria perfoliata* two types of stomata (anomocytic, cyclocytic) were observed. The results were in accordance with previous worker such as Inamdar (1969, 1971) reported anomocytic, anisocytic and paracytic stomata in *P. glabra*. Trichomes are absent in four taxa such as *P. chinensis* var. *chinensis*, *P. chinensis* var. *ovalifolia*, *P. microcephala* and *P. nepalensis*. Majority of the taxa bears non glandular trichomes expect *P. minor*, *P. glabra* and *P. chinensis* var. *hispida* which served as their distinctive characteristic features. Elongated, slender and uniseriate trichomes were found in *P. chinensis* var. *hispida*, *P. lanigera*, *P. perfoliata* and *P. posumbu*. In the present study elongated, slender and multiseriate trichome with blunt end found in *P. barbata* whereas Inamdar (1971) used the terminology small shaggy trichomes for *P. barbata* but Payne (1978) did not provide any report for such structure of trichomes in his vocabulary of plant hair terminology. Lersten and Curtis (1992) observed long, multicellular, eglandular trichomes in *P. capitata*, during the present investigation the recorded result was similar. Haraldson (1978) assumed that *Persicaria* was an exceptionally developed genus on the basis of their trichome structure. Moreover,

the diversity was recorded in trichomes of the genus *viz*, one-celled, two-celled and four-celled peltate trichomes, stillate trichomes and spheroidal trichomes. The most common type is four-celled peltate trichome. Glandular trichomes were the typical capitate trichomes with short stalk were found only in *P. glabra* along with two-celled peltate trichomes. Capitate trichomes were common in Polygonaceae (Soleredor 1908; Kapoor *et al.* 1971; Haraldson 1978) but presently recorded only in *P. glabra*. Lersten and Curtis (1992) found spheroidal glands in 21 *Persicaria* species along with capitate trichomes. The investigation of detailed venation pattern of *Persicaria* species from India was performed for the first time in the present work. The 1º and 2 º venation patterns of all the taxa were more or less similar but they showed great variations in their higher degree venation pattern such as 3º and 4º vein category which plays important taxonomic tool for the identification of the studied taxa.

Shape of the leaf epidermal cells of *Polygonum* species varied from tetrahedral, pentagonal, hexagonal, heptagonal and polygonal benzene ring like structure to irregular with thick and undulating walls. In *P. molle*, epidermal cells were polygonal to irregularly shaped cells. Irregular cells with thick and undulating walls were found in *P. pubescens*, *P. plebeium* and *P. runcinatum*. Ayodele and Olwokudeji (2006) reported striated polygonal cells in *P. plebeium*. The variation in epidermal cell shape was helpful to some extent for the distinction of taxa. Leaves were primarily amphistomatic with different stomatal frequency and also more than one type of stomata was observed in single taxa. Stomatal distribution on adaxial and abaxial surface of lamina is not a reliable feature (Lersten and Curtis 1992). During the present study three stomatal types were recorded in this genus (Anisocytic, anomocytic and pericytic). Pericytic stomata along with anisocytic type were found in *P. plebeium*. Kapoor *et al.* (1971) also recognized three different types of stomata in *P. plebeium* viz., anomocytic, anisocytic and paracytic type whereas, Ayodele and Olwokudejo (2006) recorded only one type of stomata (anisocytic) while recently Ahmed *et al.* (2009) reported two different types *i.e.*, diacytic and amphianisocytic stomata for the same species. In the studied taxa of *Polygonum* two different types of 1º vein were found *viz*., pinnate (*P. plebeium, P. molle* and *P. viscosum*) and basal (*P. pubescens* and *P. runcinatum*). Variation also found in minor venation pattern *i.e.*, 3º and 4º vein category. In 4º vein three

different pattern were found viz., regular polygonal reticulate (*P. plebeium*), alternate percurrent (*P. pubescens* and *P. runcinatum*) and dichotomizing (*P. molle* and *P. viscosum*), regular (*P. posumbu* and *P. orientalis*). Indumentums are reliable attributes for species distinction of *Polygonum* (Schotsman 1950). In the genus *Polygonum*, non glandular trichomes were the most common type except in *P. plebeium* where glandular trichomes were present. The results were in accordance with the previous worker Ayodele and Olwokudejo (2006). The size of the trichome significantly showed variation in studied taxa of *Polygonum*.

Previously very little or no detailed foliar morphological description of the available taxa of *Rumex* from West Bengal was done. Therefore, current investigation can be considered as the first detailed qualitative and quantitative study of leaf epidermis of *Rumex* species. Shape of the epidermal cell ranges from pentagonal, hexagonal and polygonal to irregular cells. Irregular cells with undulating walls were confined to adaxial surfaces of *R. acetosella, R. dentatus* and *R. nepalensis* whereas polygonal cells were found on both lamina surfaces of *R. maritimus*. The characteristic feature of the genus *Polygonum i.e.*, thick and pitted walls were observed only in *R. nepalensis*. Amphistomatic leaves and more than one type of stomata were characteristic features of the genus *Rumex*. Pericytic and anisocytic type of stomata were observed together in *R. acetosella, R. dentatus* and *R. nepalensis* but in case of *R. maritimus* only pericytic stomata was found. Inamdar (1971) also found paracytic stomata in *R. dentatus* and *R. hastatus* which do not correspond to the present findings of pericytic stomata for the same taxa. Trichomes were absent in *R. nepalensis* and *R. acetosella*. Trichomes were only of non glandular type in the other two taxa of *Rumex*. Stellate hair which is divided into four parts was distinguishing feature of *R. dentatus*. Major venation pattern *i.e.*, 1º and 2º vein category were more or less similar in all the taxa of *Rumex*. In all the taxa the 1º vein was basal except in *R. nepalensis* where it was pinnate. Variation was found in minor venation pattern. Highest excurrent vein was 4º except in *Rumex acetosella* where it was 2º.

Though the detailed investigation of leaf architecture showed their importance as taxonomic tool but was not so much obliging in the delimitation of different taxa. Various quantitative features such as length and width of stomata and trichomes on adaxial and abaxial surface, stomatal frequency and stomatal index could be employed for the species delimitation. The characters have great taxonomic

significance when used in combination with other characters but delimitation of different taxa based on only leaf architecture especially in case of Polygonaceae is much difficult (Lersten and Curtis 1992).

Degree of significance among the various micro and macro morphological attributes were determined through ANOVA analysis and result showing highly significance among the attributes at $p<0.01$ level.

PCA has been used by various authors to evaluate the systematic importance of various quantitative attributes. In PCA all the studied macro and micro morphological attributes were distributed into two major group *viz*., A and B and the studied species were distributed in four groups. Group 1 represents all the taxa of *Persicaria*, group 2 represents species of *Polygonum*, species of *Rumex* were in group 3 while group 4 represents species of *Fagopyrum*. In group A, margin type, length of stipule, number of fimbriae, length of fimbriae, base angle, blade class, stomatal index, origin of indumentums, 3º and 4º vein category were grouped together which revealed that these attributes were positively correlated with each other. In group B, stomatal frequency, lamina length, lamina width, lamina area, base shape, apex shape, lamina shape were placed which reveal increased the value of one attributes increases the other while group A and B were inversely related with each other. Taxa of *Fagopyrum*, *Antigonon leptopus*, *Homalocladium platycladum* and *Fallopia convolvulus* were grouped on the positive side of PC1 based on their macro and micro morphological attributes. Twelve taxa of *Persicaria* (*Persicaria capitata*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. chinensis* var. *ovalifolia*, *P. hydropiper*, *P. lanigera*, *P. minor*, *P. orientalis*, *P. perfoliata*, *P. posumbu*, *P. strigosa*) with similar type of margin, blade class, stomatal index, 3º and 4º venation pattern were grouped on the positive side of PC2. Rest of the taxa of *Persicaria* bearing contrasting attributes than the above mentioned twelve taxa were distributed on the negative side of PC2. All the five species of *Polygonum*, *Rheum nobile*, all the four species of *Rumex* having contrasting character with *Fagopyrum*, *Homalocladium platycladum*, *Fallopia convolvulus* and *Antigonon leptopus* and were grouped on the negative side of PC1. Calculated differences among all taxa were significant. Thus these characteristics should be useful for the identification of the studied taxa.

Correlation plays an imperative role in understanding the relationships between the differences and the similarities among different studied macro and micro-morphological attributes of all taxa. The present study revealed that, apex shape was positively and significantly correlated to the length and area of the lamina. Stomatal frequency was showing positive correlation with the length, width and area of the lamina which was quite obvious. Origin of indumentums and length of the indumentums were positively correlated with blade class. Stipule length and breadth were also showing positive correlation with lamina length and width. Significant negative correlation was found between number of fimbriae with lamina length and width. Stomatal frequency was also negatively correlated to the blade class.

Pearson similarity co-efficient dendrogram were established through numerical analysis of all the accumulated data from all the foliar macro and micro morphological attributes under study for all the studied taxa of Polygonaceae to understand the inter-relationship among them. The dendrogram showed that all the taxa of *Persicaria* forming four clusters. In one cluster all the varieties of *Persicaria chinensis* were grouped together as the morphological characteristic attributes among them were more or less similar. Another cluster consist of morphologically much similar taxa of *Persicaria i.e. P. posumbu* and *P. orientalis* as they both had ovate lamina with wide obtuse base angle, acuminate apex, erose margin, venation pattern were also similar in these two taxa. All the taxa of *Polygonum* also forming two clusters, one consists of *P. molle* and *P. runcinatum* indicating similarity in some morphological attribute among them *i.e.*, both the taxa bears lamina with saggitate base and acuminate apex, anisocytic stomata. Such promiximity may be due to their similar geographical distribution in high altitude of west Bengal. In other cluster remaining taxa of *Polygonum* (*P. pubescence*, *P.* viscosum and *P. plebeium*) were grouped together, this was probably due to their similar distributional pattern. *Homalocladium platyclada* separated from the other studied taxa due to the presence of phylloclade and it makes the separate cluster. *Antigonon leptopus* and *Fallopia convolvulus* shows very close proximity as both the taxa shared some common characters *viz*., both the taxa lack ochreate stipule. The entire dendrogram was quite significant and all taxa of same genera forming separate cluster and nearby cluster denotes the close proximity among taxa

Another important parameter which used in this study was palynology. The morphology of pollen grains could be acknowledged as a conserved character for systematic study and to establish the evolutionary lineage among the plants as it preserved in soil for a long period of time. Generally, the shape, size of pollen grains is quite specific to the family, genus as well as in species level. Therefore, palynology was frequently used as an important feature in resolving problems of systematic and inferring the phylogenetic relationships (Erdtman 1943; Walker and Doyle 1975; Punsalpaamuu 1999). The study had revolutionized with the discovery of electron microscope by which the surface structures of exine and intine can be studied which was never possible with light microscope (Cole and Behnke 1975).

It had been found that Polygonaceae is an example of one of the diverse eurypalynous family and its wide-ranging variations have enormous systematic potential at all levels, especially for generic delimitation (Nowicke and Skvarla 1977). Exine and its sculpturing also have great systematic significance in Polygonaceae (Hong and Hedgeberg 1990).

Detail study on pollen grains of all the collected taxa of Polygonaceae revealed interesting features on various attributes *viz*., unit, polarity, outline, shape, size, colpi number and length, exine sculpturing and thickness that were quite significantly supportive to reduce the taxonomic errors in species level identification.

Pollen grains of all examined species had monad, isopolar and radiosymmetric grains with variable shapes ranges from spheroidal to prolate spheroidal and prolate to sub prolate type. The most dominant type was spheroidal grains found in 14 taxa followed by prolate spheroidal in 12 taxa, while sub prolate in 4 taxa and prolate in 3 taxa were least common type and the result are quite similar with some past reports (Wang and Feng 1994; Zhang and Zhou 1998; Hong *et al.* 2005; Yasmin *et al.* 2010).

Wodehouse (1931) observed the size of *Persicaria* pollen grains varied from 51µm to 70µm. Wang and Feng (1994) noted great variations in the pollen grains size of some Chinese species of *Persicaria* such as *P. lapathifolia* (35.8 µm), *P. longiseta* (38.4 µm), *P. hydropiper* (43.5 µm). Zhang and Zhou (1998) comprehensively studied the pollen grains morphology of *P. amphibia, P. barbata, P. glabra*, *P. hydropiper*, *P. lapathifolia, P. longiseta*, *P. orientalis* and *P. maculosa* from China

and reported average pollen grains diameter varied from 42.1 µm to 64.5 µm. In the present study medium sized pollen grains (24.14µm – 43.16µm) were dominant and observed in 27 taxa while in 6 taxa the pollen grains were small (15.85µm – 23.15µm). Largest pollen grains observed in *Fagopyrum esculentum* (45.70 x 40.38µm) and *Polygonum pubescens* (15.85µm) with smallest pollen grains.

All the taxa of *Persicaria* bears pantoporate pollen grain but *Persicaria tenella*, *P. capitata* and *P. campanulata* had tricolpate pollen grain and the results matched with various previous works (Wang and Feng 1994; Zhang and Zhou 1998). Both pantoporate and tricolopate types of pollen grain were observed among the taxa of *Persicaria* and *Polygonum* but distinct variation lies among their exine ornamention, exine thickness and in the arrangement of lumina and muri. Pollen grains of *Polygonum* are of smaller in dimension than that of *Persicaria* and lumina of *Polygonum* mostly bear baculae having slit and longitudinal fold, muri regularly shaped where as in *Persicaria* lumina are large and granulose. All these distinct pollen grain features strongly support *Persicaria* and *Polygonum* as an individual or as separate genera. In four species of *Rumex*, two species of *Fagopyrum* and *Fallopia convolvulus* the pollen grains were of tricolporate type (Den Nijs *et al.* 1980; Van Leeuwen *et al.* 1988; Nokwicke and Skvarla 1979; Wang and Feng 1994; Zhang and Zhou 1998; Zhou *et al.* 2002). In studied *Polygonum* species both pantoporate (*Polygonum pubescens*, *Polygonum runcinatum* and *Polygonum viscosum*) and tricolpate (*Polygonum molle* and *Polygonum plebeium*) pollen grains were observed. Length of the colpi among the studied species ranges from 9.17 – 33.84µm.

Exine ornamentation was a very important characteristic features of pollen grain and was quite species specific (Moore and Webb 1978). Based on exine thickness the pollen grains were grouped into 4 class starting from 1.04 –1.80µm for 10 taxa, 2.04 – 2.93µm for 13 taxa, 3.30 – 3.99µm for 7 taxa and more than 4µm for 3 taxa. The results of the present studies are in accordance with earlier authors (Zang and Zhou 1998; Yasmin *et al.* 2010). The gathered morphological data were quite close for similar species growing in various ranges of Himalayas in China, Pakistan and India except minute differences in their sizes, colpi length and exine thickness.

Degree of significance among the various pollen attributes were determined through ANOVA analysis and result showing highly significance at $p<0.01$ level.

To draw the significant relationship among the various attributes of pollen grains and also within the studied taxa, entire accumulated data were further analyzed through PCA and Correlation matrix analysis. PCA has been used by various authors to evaluate the systematic importance of pollen grains data (de Abreu *et al.* 2015; Mezzonato-Pires *et al.* 2015). Based on PC analysis *Rumex* and *Fagopyrum* were grouped on the positive side of PC1 with tricolporate aperture, long colpi and relatively large polar axis. Eight taxa of *Persicaria* (*P. capitata*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. chinensis* var. *ovalifolia*, *P. hydropiper*, *P. orientalis*, *P. strigosa* and *P. tenella*) with spheroidal shape, thick exine and large equatorial diameter were grouped on the positive side of PC2. Rest of the taxa of *Persicaria* having thin exine, relatively small equatorial diameter than the above mentioned eigth taxa were distributed on the negative side of PC2. *Antigonon leptopus*, *Fallopia convolvulus*, *Homalocladium platycladum*, *Polygonum molle*, *P. plebeium*, *P. pubescens*, *P. runcinatum*, *P. viscosum* and *Rheum nobile* with contrasting attributes of *Rumex* and *Fagopyrum* were grouped on the negative side of PC1. The calculated differences among all taxa were significant and these characteristic features might be useful for the identification of the studied taxa.

Correlations play an important role in understanding the relationships between the differences and the similarities among different studied attributes of pollen grains of all taxa. The present study revealed that, polar axis of the pollen grains were positively and significantly correlated to the shape, colpi length, aperture, ratio of polar axis and equatorial diameter (P/E). Equatorial diameters of the pollen grains were positively correlated to the exine thickness and aperture of the pollen grains. Shape of the pollen grain was showing positive correlation to the colpi length and P/E ratio. Positive correlations were also found between the exine thickness and the aperture type of pollen grains. Colpi length of the grain was also positively correlated with aperture and P/E ratio. Significant negative correlation was found between aperture and P/E ratio of the pollen grains, polar axis and thickness of exine. Exine thickness of the pollen grain was also negatively correlated to the colpi length and P/E ratio.

Accumulated data from all the morphological characteristics of the pollen grains under study were analyzed numerically to establish the Pearson similarity co-efficient dendrogram for all the studied taxa of Polygonaceae to understand the interrelationship among them. The dendrogram showed that the *Rumex nepalensis*, *R. dentatus*, *R. maritimus*, *R. acetosella*, *Rheum nobile*, *Fagopyrum esculentum* and *F. dibotrys* were clustered together as they all bears tricolporate type of pollen grains. All the taxa of *Polygonum* (*P. plebeium*, *P. molle*, *P. runcinatum*, *P. pubescens*, *P. viscosum*) were forming one cluster. In this cluster P. plebeium and P. molle shows close proximity than the others as they both bears tricolpate grains while the other bears pantoporate type of grains but all of them have other similar pollen morphological attributes therefore they were clustered together. The third sister cluster was further subdivided into two clades where one clade consisted of *Antigonon leptopus* and *Fallopia convolvulus* and the second clade composed of 18 taxa of *Persicaria* (*P. chinensis* var. *ovalifolia*, *P. chinensis* var. *chinensis*, *P. chinensis* var. *hispida*, *P. capitata*, *P. tenella*, *P. minor*, *P. campanulata*, *P. nepalensis*, *P. posumbu*, *P. glabra*, *P. microcephala*, *P. barbata*, *P. hydropiper*, *P. orientalis*, *P. strigosa*, *P. lanigera*, *P. lapathifolia* var. *lapathifolia* and *P. lapathifolia* var. *lanata*) showing very close proximity. In this big cluster, three varieties of *P. chinensis* shows very close proximity as they bears similar pollen grains morphology with minute differences in their size and lumina shapes. *Persicaria capitata*, *P. tenella* and *P. campanulata* showed close proximity as they bears tricolpate type of pollen grains. Two variety of *Persicaria lapathifolia* were cluster together as they shared similar pollen morphotype with mute differences in the size of the pollen grains. The entire dendrogram was quite significant and all taxa of same genera forming separate cluster and nearby cluster denotes the close proximity among genera.

For obtaining more consistent results all the macro, micro and pollen morphological data were taken into consideration and were analyzed numerically to establish the Pearson similarity co-efficient dendrogram to understand the inter-relationship among all the studied taxa of Polygonaceae. From the dendrogram it was easily observed that *Homalocladium*, *Antigonon* and *Polygonum* were exhibit sister relationship among them while *Persicaria*, *Rumex*, *Rheum* and *Fagopyrum* showed very close proximity. More or less similar type of clustering was found when the

macro and micro morphological data and pollen morphological data were analyzed separately.

For further confirmation about the systematic position of Polygonaceae, molecular documentation was also taken in consideration for the present study. The debate regarding the distinctness of *Persicaria* and *Polygonum* was a century - old one and had also affected recent phylogenetic studies of the group. In this communication, high resolution phylogeny of Polygonaceae based on three chloroplast DNA region *viz*., *rbcL, matK* and *trnL-F* were made and moreover, phylogenetic analysis of many less known members of Himalayan Polygonaceae, including *Persicaria strigosa*, *P. glabra, P. tenella, P. lanigera* and *P. lapathifolia* var *lanata* had been first ever attempted here. The present study focused on new findings based on extended taxon sampling and Maximum Likelihood (ML) and Bayesian phylogenetic inference (BI) analyses of three chloroplast markers, which can be useful for the systematic positioning of different genera of Polygonaceae. Maximum likelihood was considered to evaluate alternative trees. Conversely it considers the likelihood of each tree elucidating the given data based on a model of evolution. In this method, it compares how different trees predict the observed data (Swofford *et al.* 1993). ML analyses had an advantage over maximum parsimony (MP) as the probability of nucleotide substitutions and rates of these substitutions were taken into consideration, explaining the phylogenetic relationships of taxa in a more practical way. Another important deliberation of this method is the branch length, which parsimony ignores, with changes being more expected to happen along long branches than short ones. ML is computationally intensive and it is the best approach to inferring phylogenies from a theoretical point of view as it is impossible to explore all trees as there are too many. Metropolis (1953) revolutionized Bayesian Inference and it became a widely used method amongst phylogeneticists. Some advantages of BI over maximum parsimony (MP) and maximum likelihood (ML) methods are the likelihood of account for the phylogenetic ambiguity, use of prior information and amalgamation of complex models of evolution that inadequate computational analyses for traditional methods. Although overcoming complex analytical operations the posterior probability still involves a summation over all trees and, for each tree, integration over all possible combinations of substitution model parameter values and branch lengths. Molecular differences were detected

among the species although these were not differentiated at the morphological level. The current study shows that uniting *Persicaria* with *Polygonum sensu stricto* is unnatural and indeed, cuts across the unique affinities of both the taxa. Their apparent resemblance can only be linked by their more distant affinities within the subfamily Polygonoideae. From the phylogenetic study it was also observed that most of the members of the family are monophyletic in origin.

During the present study on phylogeny of Polygonaceae based on *rbcL* gene the eight genera were subdivided into two groups where five genera (*Persicaria, Rumex, Fagopyrum, Rheum* and *Antigonon*) represented one group and *Polygonum*, *Fallopia* and *Muehlenbeckia* formed another group. The phylogenetic study based on *matK* and *trnL-F* genes of these eight genera also showed that *Fallopia* and *Muehlenbeckia* were closely associated with *Polygonum*. Nevertheless, during the present phylogenetic study the two genera *Polygonum* and *Persicaria* were found to be distantly related forming different clusters. However in the present study first tribal division proposed by Haraldson (1978) proved to be nearly in line with the present data based on their molecular data, but a new delimitation of genera is proposed. Present study denotes a division of *Polygonurn* L. *sensu lalo* and its related taxa into two tribes: Polygoneae (containing *Polygonum* L. *sensu stricto, Fallopia* Adans. and *Muehlenbeckia* Mesin.) and *Persicarieae* (containing *Persicaria* Mill., *Fagopyrurn* Mill., *Antigonon* Endl., *Rheum* L and *Rumex* L). Similar division was also supported by morphological study to a certain extent. Decraene and Akeroyd (1988) and Decraene *et al.* (2000) also reported similar tribes for the family Polygonaceae, placing *Persicaria, Fagopyrum, Aconogonon, Bistorta, Koenigia* under the tribe Persicarieae and *Polygonum, Muehlenbeckia, Fallopia, Rheum, Rumex* under the tribe Polygoneae. The stated tribe division by the above workers matches with the current study, while the genera placed under the tribes did not completely matched.

Sanchez and Kron (2008) also showed similar type of grouping through phylogenetic analysis, where they made comprehensive studies on phylogenetics of Polygonaceae with particular interest on Eriogonoideae. Three choloroplast region (*rbcL, matK* and *ndhF*) analyses by Sanchez and Kron (2008) showed that subfamily Polygonoideae is polyphyletic. They grouped the subfamily Polygonoideae in 3 tribes (Persicarieae, Polygoneae and Rumiceae) consisting of 11 genera (*Polygonum*

L, *Atraphaxis* L., *Emex* Campd., *Fagopyrum* Mill., *Fallopia* Adans., *Koenigia* L., *Muehlenbeckia* Meisn., *Oxyria* Hill., *Persicaria* (L.) Mill., *Rheum* L. and *Rumex* L.). However, during the present phylogenetic analysis based on these three chloroplast DNA region *viz.*, *rbcL*, *matK* and *trnL-F*, it was also observed that these eight genera can be subdivided into two tribes- Persicarieae and Polygoneae as proposed by Haraldson (1978); Decraene and Akeroyd (1988) and Decraene *et al.* (2000).

Persicarieae: The taxonomic delimitation of *Persicaria*, *Fagopyrurn*, *Antigonon*, *Rheum* and *Rumex* were remarkably convoluted even by Polygonaceae standards. The position of *Rumex* in Persicarieae group and as sister to Polygoneae having weak support in molecular studies (Sanchez *et al.* 2009, 2011; Schuster *et al.* 2011) and the branching order of genera were also hardly ever resolved. Present findings give good support for the sister relationship of Polygoneae and Rumiceae. In case of *Rumex*, results are similar to the findings by Navajas-Pérez *et al.* (2005) showing that the genus is monophyletic in origin. Present study was showing that *Fagopyrum* exhibit the sister relationship with *Persicaria*. This placement was in accordance with the finding by Kim and Donoghue 2008.

Polygoneae: The current analyses do not deviate from the well-established relationships of Polygoneae being composed of the three genera (*Polygonum*, *Muehlenbeckia* and *Fallopia*). The analyses clearly showing that *Polygonum* is polyphyletic in origin and the sister relationship among these three genera were supported by both ML and BI analysis of three chloroplast marker (*rbcL*, *matK* and *trnL*-F).

The segregation of these two tribe also supported by the other evidences such as anatomy (Perdrigeat 1900; Laubengayer 1937; Vautier 1949; Haraldson 1978), pollen morphology (Gross 1913; Wodehouse 1931; Hedgeberg 1946; Nowicke and Skvarla 1977), chromosome numbers (Jaretzky 1928; Love and Love 1956) and chemical substances (Jaretzky 1925) which has provided a considerable data to split the tribe. The treatment of the Polygonaceae by Haraldson (1978) and Decraene and Akeroyd (1988) have suggested that the taxa, in the broad sense, segregated into two separate tribes: Polygoneae and Persicarieae. The Persicarieae have prominent nectar-secreting emergences, which may be free or fused, while in Polygoneae nectarial zones are not well developed externally (Ronse Decraene and Smets 1991).

Tribe Polygoneae emend. Haraldson (1978) are shrubs with outer tepals often winged, smaller or larger than inner, while tribe Persicarieae Dumortier (1827) are generally herbs with outer tepals not winged, keeled or angular, often smaller than inner or absent. In Polygoneae the stamens are dilated at the base, outer stamens are reduced in size, whereas in Persicareae the stamens are not dilated at the base, inner stamens are reduced in size. Taxa with a trifid venation pattern of tepals are placed in Persicareae this probably represents the primitive type, while taxa with a dendricular venation pattern found in Polygoneae. The tepal epidermis is strongly papillose, never smooth and has irregular to elongated cells in case of Polygoneae, while in case of Persicareae, the tepal epidermis consists of rectangular to elongated cells with a smooth or usually longitudinally striate cuticle.

Decraene and Akeroyd 1988 also maintained *Persicaria* as a distinct genus and they separated it from *Polygonum s.s*. on the basis of the floral characters *i.e.,* the outer tepals were never keeled or angular in *Persicaria* and differ from the inner tepals only in size (Graham and Wood 1965) whereas in *Polygonum*, outer tepals were often differentiated from the inner by smaller and pointed or slightly angular around the single main vein; trifid venation was observed on tepal which was different from the dendricular venation of *Polygonum*; the species of *Persicaria* have inter-staminal, free or fused nectarines while in *Polygonum*, filaments are never flattened and strongly subulate, but are often cylindrical and filiform (Trail 1896) and no nectaries are visible. Though *Polygonum* can be separated from *Persicaria* by comparison with their morphological character states but their boundaries are not clear due to the high level of variability within the genus (Decraene and Akeroyd 1988).

During the entire phylogenetic study it was also observed that within the cluster of *Persicaria* species, several *Polygonum* species were amalgamated, indicating a need of taxonomical repositioning of some of the studied taxa. Based on the study of *rbcL*, *matK* and *trnL-F* gene sequences of Polygonaceae some name changes had also been proposed, *i.e., Polygonum viscosum* Buch.-Ham. *ex* D. Don, Prodr., Fl. Nepal. 71. 1825 ≡ *Persicaria viscosa* (Buch.-Ham. *ex* D. Don) H. Gross *ex* Nakai, Rep. Veg. Quelp. 42. 1914; *Polygonum amphibium* L., Sp. Pl. 1: 361. 1753 ≡ *Persicaria amphibia* (L.) Delarbre, Fl. Auvergne ed. 2: 519. 1800; *Polygonum filicaule* Wall. *ex* Meisn, Pl. Asiat. Rar. 3: 59. 1832 ≡ *Persicaria minuta* (Hayata)

Nakai, Fl. Jap. Suppl. 173. 1936; *Polygonum pulchrum* Blume, Bijdr. Fl. Ned. Ind. 11: 530. 1826 ≡ *Persicaria pulchra* (Blume) Soják, Preslia 46: 154. 1974; *Polygonum pubescens* Blume, Bijdr. Fl. Ned. Ind. 2: 532. 1825 ≡ *Persicaria pubescens* (Blume) H. Hara , J. Jap. Bot. 17(6): 335. 1941; *Polygonum setosulum* A. Rich., Tent. Fl. Abyss. 2: 227. 1850 ≡ *Persicaria setosula* (A. Rich.) K. L. Wilson, Kew Bull. 45: 632. 1990; *Polygonum posumbu* Buch.-Ham. *ex* D. Don, Prodr. Fl. Nepal. 71. 1825 ≡ *Persicaria posumbu* (Buch.-Ham. *ex* D. Don) H. Gross, Bot. Jahrb. Syst. 49(2): 313. 1913; *Persicaria angustifolia* (Pall.) Ronse Decr., Bot. J. Linn. Soc. 98: 367. 1988 ≡ *Polygonum angustifolium* Pall. Reise Russ. Reich. 3: 230. 1776; *Persicaria campanulata* (Hook. *f*.) Ronse Decr., Bot. J. Linn. Soc. 98: 367. 1988 ≡ *Polygonum campanulatum* Hook. *f.* Fl. Brit. Ind. 5: 51. 1886; *Persicaria maculosa* Gray, Nat. Arr. Brit. Pl. 2: 269. 1821 ≡ *Polygonum fusiforme* Greene, Erythea 1(12): 259–260 1893; *Polygonum viscosum* Buch.-Ham. *ex* D. Don, Prodr., Fl. Nepal. 71 1825 ≡ *Persicaria viscosa* (Buch.-Ham. *ex* D. Don) H. Gross *ex* Nakai, Rep. Veg. Quelp. 42. 1914. The other taxonomical evidences viz. gross morphology, foliar macro and micro morphology and palynology did not support all the name changes. But, combining all the studied parameter it was observed that taxonomical repositioning of two of the studied taxa was needed. Thus amalgamated study of all taxonomic marker *viz*., foliar macro and micro morphology, palynology and phylogenetic study through *rbcL*, *matK* and *trnL-F* genes of Polygonaceae, it can be said that the taxa *Polygonum microcephalum* and *Polygonum perfoliatum* were probably misplaced under the genus *Polygonum*, their actual taxonomic position appears to be within the genus *Persicaria* as the studied attributes of these two taxa were more analogous with *Persicaria* than *Polygonum*.

7. CONCLUSION

Polygonaceae has the status of being one of the trickiest families of angiosperms to identify due to its ambiguity in morphological attributes. Any taxa are difficult to identify on the basis of morphological character like Polygonaceae where floral parts are seasonal, they can be easily identify and classify using different taxonomical parameter. As in the present study, taxa can be recognized from any parts of the plant therefore these methods appear much easier than morphology especially when flowers and fruits are not properly available. This is one of the most extensive studies of the family Polygonaceae from West Bengal that includes thirty six taxa belonging to nine genera. Some taxa of this family were widely used in traditional medicine system among the various ethnic groups in West Bengal. From the field survey it was observed that the members of the family were widely distributed throughout the state mostly confined to marshy places and the hilly slopes of Darjeeling - Kalimpong Himalaya. It was observed that members of Polygonaceae (wild and cultivated) are the important component of floral diversity and ecosystem of various water bodies, marshy lands and wet habitat in different altitudinal ranges and climates of West Bengal. The work is evocative in nature that highlights the utility of different taxonomic parameters *viz*., morphological, palynological and molecular markers.

Both qualitative and quantitative morphological attributes related to plant habit, stem, leaves, ochreae, tepals, stamen, style, ovary and nut have been used for the delimitation of the taxa. As this study was based on extensive survey during different season from all over the West Bengal for four consecutive years, therefore the geographic range of the taxa were very large and great covenant of morphological variations were discovered. Even though morphological markers have taxonomic importance but in case of the family Polygonaceae these characters are not enough to distinguish different taxa. However, it is important to emphasize that the revision of neglected morphological characters and combined them with modern imminent and newest techniques will be very useful in further authentication, identification and classification of taxa of Polygonaceae.

Leaf architecture of thirty five taxa were critically examined with the use of light microscopy to evaluate both adaxial and abaxial leaf surface features such as shape of epidermal cells, stomata and trichome types and their distribution frequency. Such a comprehensive micro-morphological studies of some taxa of Polygonaceae has been conducted first time in this work. Epidermal cell shapes are variable but generally polygonal. Six different stomatal patterns have been reported for seven genera i-e, anomocytic, anisocytic, paracytic, pericytic, staurocytic and cyclocytic type, infrequently two or three stomata types on the same leaf surface. Glandular trichomes included peltate trichomes, capitate trichomes and stellate trichomes. It has been proved during this study that most of characters are tremendously unique and stable. These characters could not be solely used as the base for the taxonomic classification of the family Polygonaceae. There are some differences at specific level that permit the delimitation of the taxa and can serve as good taxonomic tools and on this basis identification keys have been provided.

Based on comprehensive studies on pollen morphology, significant diversity in the pollen characters including shape and size of pollen grains, colpi length, exine intine thickness and sculpturing of exine is noted in the family and found to be taxonomically useful. Maximum variation related to aperture number is examined in *Persicaria* species where pollen are tricolpate and pantoporate while related to sculpturing two main pollen types, each divided into several subtypes have been observed in the genus. Present pollen study proved that the family Polygonaceae is eurypalynous family. Also, pollen morphological characters are generally distinct at generic level and in most cases pollen types varied from one species to another.

In order to investigate inter and intra specific relationships more precisely the phylogeny and variability polygonaceous species, phylogenetic analysis based on three chroloplast genome (*rbcL, matK* and *trnL-F*) were made. These results have been compared with previous morphological and molecular investigations so that to evaluate the worth of this technique. From the entire study few interference could be drawn that *Persicaria chinensis* can be segregated into three varieties viz., *P. chinensis* var. *chinenis*, *P. chinensis* var. *ovalifolia* and *P. chinensis* var. *hispida*; uniting *Persicaria* with *Polygonum* sensu stricto is unnatural and indeed, cuts across the unique affinities of both the taxa; most of the members of the family are

monophyletic in origin except *Polygonum*; sister relationship was observed in between Polygoneae and Rumiceae; studied genera can be subdivided into two tribes- Persicarieae and Polygoneae.

All these studies help to make corrections in the previous published work and also strengthen the treatment of complex family Polygonaceae. Morphological markers are still the most significant and relatively easily studied features of great importance to the taxonomist but pollen morphological characters are taxonomically potential traits and play significant role in generic identification and classification in the family Polygonaceae.

All the accumulated data from different studied parameters (macro and micro morphology, pollen morphology and molecular phylogeny) of 35 selected Indian taxa may definitely be serving as important and useful tools in comparative studies as well as understanding or reconsidering the systematics and evolutionary phylogeny of the family Polygonaceae. Pollen morphology is important for delimiting the taxa but it will gives more better result if it should be used in combination with other taxonomic evidences viz., morphology, anatomy, cytology and ecology. The examined remarkable pollen features (with three major pollen types and twelve subtypes examined from only nine genera of the family) were found quite significant and recommend that there is much scope for further research on pollen morphology of the family Polygonaceae from different part of India in order to establish phylogenetic lines. If molecular phylogeny analysis is extended to other members of the Polygonaceae from different parts of World, there would be probability of getting a comprehensive account of their genetic relationship in future and so the studies should be continued for more reliable data and to establish the authentic species level identification and more importantly understanding the genuine phylogenetic lineage to understand the evolution of Polygonaceae.

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9. A. Appendix I

Sequences submitted in the GenBank

rbcL

>MH757120|*Persicaria lapathifolia* var. *lanata*
ATTCAAAGCTGGTGTTAAAGAGTATAAATTGAATTATTATACTCCTGACTATGAAC
CCCACGCACATGATATCTTGGCAGCATTTCGAGTAACTCCTCAACCTGGAGTTCCA
CCAGAAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAAC
TGTGTGGACCGATGGACTTACCAGCCTTGATCGTTACAAAGGACGATGCTACGGCA
TCGAGCCTGTTGCTGGAGAAGAAAATCAATATATTGCTTATGTAGCTTACCCATTA
GACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCATTGTAGGTAATGT
ATTTGGGTTCAAAGCCCTGCGTGCTCTACGTTTGGAGGATTTGCGAATCCCTCCTG
CTTATACGAAAACTTTCCAAGGCCCACCTCACGGTATCCAAGTTGAGAGAGACAAA
TTAAACAAATACGGACGTCCCCTATTGGGATGTACTATTAAACCTAAATTGGGATT
GTCCGCTAAGAACTACGGTCGAGCAGTTTATGAATGTCTTCGTGGTGGGCTTGATT
TTACCAAAGATGATGAAAACGTGAACTCCCAACCATTTATGCGTTGGAGAGACCGT
TTCTTATTCTGTGCCGAAGCTATTTTCAAATCACAGTCTGAAACAGGTGAAATCAA
AGGACATTACTTGAATGCTACTGCAG

>MK015865|*Persicaria lanigera*

AAGTGTTGGATTCAAAGCTGGTGTTAAAGAATATAAATTGACTTATTATACTCCTG
ACTATGAACCTCATGACCATGATATCTTGGCAGCATTTCGAGTAACTCCTCAACCT
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GCTACAACATCGAGCCTGTTCCTGGAGAAGAAAGTCAATTTATTGCTTATGTAGCT
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GGGTAATGTATTTGGGTTCAAAGCCCTGCGTGCTCTACGTTTGGAGGATTTGCGAA
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AGAGATAAATTGAACAAATACGGACGTCCCCTATTGGGATGTACTATTAAACCTAA
ATTGGGGTTGTCCGCTAAGAACTACGGTCGAGCAGTTTATGAGTGTCTTCGCGGCG
GGCTTGATTTTACCAAAGATGATGAAAACGTGAACTCCCAACCATTTATGCGTTGG
AGAGACCGTTTCTTATTCTGTGCCGAATCTATTTTTAAATCACAGTGTGAAACAGG
TGAAATGAAAGGACA

>MH824149|*Persicaria glabra*

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>MG808037|*Persicaria strigosa*
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>MF447884|*Persicaria tenella*
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>MG766137|*Rumex dentatus*
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matK

>MH898986|*Rumex nepalensis*

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>MH757121|*Persicaria microcephala*

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>MG808036|*Persicaria strigosa*

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>MF371114|*Persicaria tenella*

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>MH757119|*Persicaria lapathifolia* var. *lanata*

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>MK044697|*Persicaria lanigera*

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>MH834391|*Persicaria glabra*

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>MH324414|*Persicaria nepalensis*

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>MH324415|*Persicaria campanulata*

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>MK015867|*Persicaria barbata*

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trnL-F

>MG780829|*Rumex dentatus*

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>MG780830|*Rumex maritimus*

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>MK034859|*Rumex nepalensis*

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>MH674190|*Polygonum molle*

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>MH854503|*Persicaria orientalis*

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>MH854501|*Persicaria runcinata*

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>MG821320|Persicaria strigosa

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>MG575521|*Persicaria tenella*

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>MH674192|*Persicaria lapathifolia* var. *lanata*

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>MH834392|*Persicaria glabra*

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>MH824147|*Persicaria microcephala*

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>MH854504|*Persicaria hydropiper*

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>MH824148|*Persicaria barbata*

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>MH674191|*Muehlenbeckia platyclada*

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>MG913344|*Antigonon leptopus*

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>MH854502|*Fagopyrum dibotrys*

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9. B. Appendix 2

List of publications

1. Paul. P. and M. Chowdhury. 2019. Diversity of members of Polygonaceae from West Bengal, India. *Plant Archives* 19(S2): 157 – 164.

2. Paul. P. and M. Chowdhury. 2016. *Persicaria chinensis* (Linnaeus) var. *hispida* (Hooker *f*.) Kantachot (Polygonaceae): a new distributional record for West Bengal, India. *Asian Journal of Biological and Life Science* 5(3): 260 – 262.

3. Paul. P., Mridushree Basak, Dibakar Chowdhury, M. Chowdhury and A. P. Das. 2016. Study of foliar micro- morphology of eight species of *Persicaria* P. Miller (Polygonaceae) from India. *Pleione* 10(1): 14 – 22.

9. C. Appendix-3

Reprints

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DIVERSITY OF MEMBERS OF POLYGONACEAE FROM WEST BENGAL, INDIA

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Abstract

Polygonaceae is an economically important angiospermic plant family and mostly distributed in moist areas of plains and hilly areas. Present study recorded the occurrence of 36 taxa representing 9 genera of Polygonaceae growing in wild, home gardens, roadsides and cultivated areas from different parts of West Bengal. Among the recorded taxa, 22 species have medicinal values, 10 species are edible, and 4 ornamental.

Key Words: Polygonaceae; diversity; distribution; uses; West Bengal; India.

Introduction

Polygonaceae are known informally as the knotweed family or smartweed-buckwheat family and the type genus is *Polygonum*, first coined by Antoine Laurent de Jussieu in 1789 in his book, *Genera Plantarum.* Due to presence of many swollen nodes on stem, the family name has derived as Greek words *poly* means many and *goni* means knee or joint. The family comprises about 1200 species of 56 genera distributed globally and in India, a good number species are distributed mainly in the Ganga-Brahmaputra Plains, Himalayas and sub-Himalayan moist areas. Polygonaceae is a very complex family with exceptionally diverse morphological variation and habit ranges (annual or perennial herbs, shrubs to lianas and trees) species level identification is quite perplexing. The most idiosyncratic and highly variable attribute of the family is presence of swollen nodes on stems, presence of membranous or hyaline sheath uniting the stipules forming ochrea. Polygonaceae is characterized by its alternate simple leaves mostly with ochreate stipules, flowers with free tepals and stamens, trigonus ovary with sub terminal styles, nuts trigonus and shiny etc which have been found to be widely debated. Ultimately, the two subfamilies Polygonoideae and Eriogonoideae have been universally accepted based on existence of ochrea (Choudhury *et al*., 2012). From time to time different workers have shown their curiosity in Polygonaceae in terms of diversity, ethnic uses, taxonomy, floral morphology, nutrition, pharmacology, medicine, pollen morphology, foliar trichomes and stomata, stipule character, genetics, cytology, molecular systematic and phylogeny of different members of the family (Ayodele and Olowokudejo 2006; Yasmin *et al.,* 2010; Sanchez *et al.,* 2009). The members of the family were highly valued for their curative uses for treatment of various ailments as folk medicine in different part of India by various racial communities.

Materials and Methods

Study area:

The State of West Bengal lies between 21°45' – 27° 16' N latitude and 85° 55' – 89° 56' E longitude, covering the total geographical area of about 88,752 sq km. It is bounded on the North by Sikkim and Bhutan, on the East by Assam and Bangladesh, on the South by Bay of Bengal on the West by Bihar, Jharkhand and Orissa and on the North West by Nepal. The land of West Bengal is consists of various types of topography including high altitude Himalayan ranges from North, sub -Himalayan Terai, Duars, Central Bengal is part of great Gangetic plains and Southern and Western plateau, and salt water great Gangetic estuarine and coastal areas of Southern Bengal. The area is basically located in sub-tropical region and facing the heavier rainfall during summer and monsoon seasons and three pre-dominant seasons namely pre-monsoon, monsoon and post-monsoon are quite prominently recognizable. The pre-monsoon starts from the 1st week of February and extended up to the middle of May whereas, monsoon starts from the last week of May and extended up to end of September. The post-monsoon season begins from the 3rd week of November and extended up to last week of January. November to February is recorded as the driest months of the year. The temperature of this region fluctuates from 48° C during summer to about 1°C in winter.

Methodology

During 2015 – 2018 extensive field exploration were undertaken for the documentation of various species of Polygonaceae available in different habitats of West Bengal (Fig 1). Plant specimens were collected at their vegetative, flowering and fruiting stages and were processed and mounted on standard herbarium sheets following conventional herbarium techniques (Jain & Rao 1977; Chowdhury, 2009). The processed plant specimens were identified using the relevant taxonomic literatures (Hooker 1886; Prain 1908; Grierson & Long 1983) and by matching with the reliable specimens housed in various herbaria (CAL, NBU, ASSAM). Identified specimens were deposited into NBU Herbarium with accession number. Vernacular names and status of different species were documented during field work from the local people and some of the information was noted down from available literature (Watt and Breyer-Brandwijk 1962; Szczawinski and Hardy 1972; Liu *et al*., 1981; Agarwal 1997; Qaiser 2001; Ghosh *et al*., 2003; Khatun *et al.*, 2015; Keya *et al.,* 2017).

Result

A Total of thirty six taxa of Polygonaceae (Fig. 2) were collected from different moist q and temperate habitats of West Bengal. All the recoded species were tabulated (Table 1) alphabetically accompanied by habit, life span, flowering and fruiting time, availability status, bio-geography and ethnic uses.

Table 1 : Species diversity of Polygonaceae in West Bengal [Abbreviation used C= Climber; H= Herb; S= Shrub; P= Perennial; A= Annual; Co=Common; Ab= Abundant; VF= Very Few; F=Few]

Taxa	Habit	Life Span	Fl. & Fr. period	Status	Distribution	Ethnic uses
Antigonon leptopus Hooker & Arnott [NBU – 9861]	C	P	July – Nov.	Co	Malda, Mursidabad, Bankura, Burdwan, Hoogly, Howrah (recently naturalized); India, West Indies, Africa, N, C & S America, Native to Mexico, Australia	Ornamental
Bistorta emodi (Meisn.) H. Hara [NBU – 7635]	H	P	July – Sept.	F	Darjeeling; India (Sikkim, Kashmir, Himachal Pradesh, Uttarakhand), Bhutan, W China	-
Fagopyrum dibotrys (D. Don) Hara [NBU – 9858]	H	P	June – Sept.	Ab	Temperate forest of Darjeeling; India, Nepal, Bhutan, China, Tibet, Vietnam, Myanmar	Seeds, leaves used for treatment of colic, choleric diarrhea and abdominal blockage troubles; young leaves used as vegetable
Fagopyrum esculentum Moench [NBU – 5657]	H	A	May – Oct.	Co	Darjeeling, Kalimpong, Jalpaiguri; India (Sikkim, Himachal Pradesh, Jammu & Kashmir), Pakistan, Iran, China, Tibet, S Europe, N America	Leaves used as vegetable
Fallopia convolvulus (Linnaeus) A. Love [NBU – 7825]	H	A	May –Sept.	VF	Darjeeling; India, Nepal, Bhutan, Pakistan, Afghanistan, Kazakhstan, Mongolia, Korea, Japan, Russia, Europe, introduced in N America	Seeds are used as nutritious food
Homalocladium platycladum (F. Mueller) L. H. Bailey	S	P	Feb. – May	F	Darjeeling, Howrah (cultivated); India, Australia, Pacific Islands (New Zealand), America	Entire plants are used for the treatment of anthracia, sores, snake bite, insect bite
Persicaria barbata (Linnaeus) H. Hara [NBU – 10314]	H	P	Aug. – Oct.	Co	Moist areas of W. Bengal; India, Nepal, Bhutan, Pakistan, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, New Guinea, Philippines, China,	Watery sap from roots used as antiseptic
Persicaria campanulata (Hooker *f.*) Ronse Decreane [NBU – 10312]	H	P	July – Aug.	F	Hilly slopes of Darjeeling (Meghma, Tumling upto Sandakphu); India (Sikkim), Nepal, Bhutan, Myanmar	Ornamental
Persicaria capitata (Buchanan-Hamilton *ex* D. Don) H. Gross [NBU – 7829]	H	P	July – Sept.	Co	Darjeeling (Kurseong, Meghma), Kalimpong; India (Arunachal Pradesh, Meghalaya, Sikkim), Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia	Ornamental, whole plant extract used as antidote in snakebite and insect sting
Persicaria chinensis (Linnaeus) H. Gross var *chinensis* [NBU – 10162]	S	P	Mar. – Sept.	Ab	Darjeeling, Kalimpong (Mirik), Jalpaiguri, Alipurduar; India, Nepal, Bhutan, introduced in Pakistan, Sri Lanka, China, Japan, Myanmar, Philippines, Vietnam	Root used for fluxes, anthelminthic and neutralizes scorpion poisoning
Persicaria chinensis (Linneaus) H. Gross var *hispida* Kantachot [NBU – 10317]	H	P	Aug. – Nov.	VF	Kalimpong (New Distributional Record); India (Khasi Hills of Meghalaya, Kohima of Nagaland) Myanmar, Thailand, China	-

Persicaria chinensis (Linneaus) H. Gross var *ovalifolia* (Linneaus) H. Gross [NBU – 10313]	H	P	July – Nov.	VF	Darjeeling (Kurseong); India, S Japan, Malaysia, Myanmar, Nepal, Thailand	-
Persicaria glabra (Willdenow) M. Gómes [NBU – 10334]	H	P	Mar. – Sept.	Co	Darjeeling, Kalimpong (Mirik), Jalpaiguri, Alipurduar; India, Bhutan, Bangladesh, Sri Lanka, Myanmar, Philippines, Thailand, Vietnam; Africa, Australia, N & S America, Pacific Islands	Plant juice and rootstock used in pneumonia, jaundice, fevers. Leaves are antispasmodic and are used for colic
Persicaria hydropiper (Linnaeus) Spach [NBU – 10332]	H	A	April – Oct.	Ab	Throughout marshy lands of W. Bengal; India, Pakistan, Japan, Temperate Asia, N & W Africa, N America, Europe.	Seeds, leavesused for treatment of arthritis, bladder stone, cholera
Persicaria lapathifolia (Linnaeus) S. F. Gray var. *lapathifolia* [NBU – 10331]	H	A	Mar – Sept.	Ab	Throughout marshy lands of W. Bengal; India, Pakistan, Temperate Asia, Japan, N & W Africa, N America, Europe.	Decoctions from root used as cathartic and emetic drug
Persicaria lapathifolia (Linnaeus) Delarbre *var. lanata* (Roxb.) H.Hara [NBU – 10324]	H	A	Mar. – Nov.	Co	Throughout marshy lands of W. Bengal; India, Pakistan, China, Temperate Asia, Japan, N America, Europe	–
Persicaria minor (Hudson) Opiz [NBU – 10190]	H	A	April – Aug.	Co	Throughout marshy lands of North Bengal; India (Kerala), Malaysia, Thailand, Vietnam, Indonesia Australia	Young shoot and leaves are edible; Decoctions from leaveshas been used in post-natal tonics and for treatment of digestion oil has been used for aromatherapy and in treatments for dandruff
Persicaria nepalensis (Meissner) H. Gross [NBU – 10311]	H	A	June – Sept.	Co	Darjeeling (Kurseong upto Meghma), Kalimpong; India (Arunachal Pradesh, Meghalaya, Kashmir to Sikkim,), Pakistan, Afghanistan, Nepal, Bhutan, China, Japan, Malaysia, Thailand, Indonesia, Philippines, Korea, Russia, New Guinea, Tropical Africa,	Whole plant extract used in the treatment of swelling
Persicaria orientalis (Linnaeus) Spach [NBU – 7824]	H	A	May – Sept.	Ab	Throughout moist areas of West Bengal; India, China, Japan, Korea Malaysia, Thailand, Indonesia, Philippines	Ornamental; nuts are used in tuberculous swellings and flatulence; decoction of the ripe fruits is used in the treatment of hepatitis, sloughing ulcers, tympanites and cancer
Persicaria posumbu (Buchanon-Hamilton *ex* D. Don) H. Gross [NBU – 10187]	H	P	May – Oct.	Co	Marshy areas of Jalpaiguri; India (Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Sikkim), Nepal, Bhutan, China, Bangladesh, Malaysia	Decoction is used in the treatment of dysentery, enteritis, boils and abscesses; aromatic leaves are added to other vegetables for flavor
Persicaria strigosa (R. Brown) Nakai [NBU – 9870]	H	A	May – Oct.	Co	Darjeeling (Kurseong), Marshy areas of Jalpaiguri; India, Nepal, Bhutan, Bangladesh, Myanmar, Malaysia, Thailand, Indonesia, Vietnam, Australia, New Guinea	Tender roasted shoots are used for the dysentery of cattles

Persicaria tenella (Blume) Hara [NBU – 5816]	H	A	Mar. – Sept.	Ab	Throughout the moist lands of North Bengal plains; India (Himachal Pradesh, Jammu & Kashmir, NE India specially Assam, Manipur, Meghalaya, Sikkim, Uttarakhand, Tamilnadu) Pakistan, Nepal, China, Japan, Bangladesh, Myanmar, Malaysia, Europe	-
Polygonum microcephalum D. Don [NBU – 10320]	H	P	April – Oct.	VF	Temperate hilly areas of Darjeeling, Kalimpong; India (Assam, Meghalaya, Nagaland, Sikkim), Nepal, Bhutan, China, Bangladesh	Young shoot and seeds are used as vegetable and condiment respectively
Polygonum molle D. Don [NBU – 10329]	S	A	Aug. – Nov.	Ab	Throughout the temperate hilly areas of Darjeeling (Kurseong, Tumling, Meghma upto Sandakphu), Kalimpong; India (Arunachal Pradesh, Sikkim), Nepal, Bhutan, N Myanmar, Thailand, Indonesia	The whole plant used as astringent; young shoot, leaves and seeds are edible
Polygonum perfoliatum Linnaeus [NBU – 10359]	H	A	June – Oct.	VF	Darjeeling Himalaya, Coochbeher; Nepal, Bhutan, India (Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Sikkim, Uttarakhand), China, Japan, Korea, Bangladesh, Vietnam, Malaysia, Thailand, Indonesia, Philippines, New Guinea, Russia, N. America	Tender leaves, shoots and fruit are edible; whole plant is depurative, diuretic, febrifuge and also used to stimulate blood circulation; decoction is used in the treatment of dysentery, enteritis, boils and abscesses, poisonous snake bites, haematuria, cloudy urine and traumatic injuries
Polygonum plebeium R. Brown [NBU – 5615]	H	A	May – Aug.	Co	Throughout the plains of West Bengal; India, Kazakhstan, Nepal, Myanmar, Philippines, Indonesia, Thailand, Russia, Japan, N Africa, Australia, Europe (introduced)	Leaves used for the treatment of pneumonia and young leaves are used as vegetable; roots are used in treatment of baldness
Polygonum pubescens Blume [NBU – 10330]	H	A	Aug. – Nov.	F	Throughout moist areas of West Bengal; India, Bhutan, Indonesia, Japan, Korea	Leaves and seeds are edible; decoction of the plant, combined with onion, is used as a styptic; bruised plant is applied locally to blistered and swollen feet
Polygonum rude Meissner [NBU – 10582]	S	P	Aug. – Nov.	VF	Darjeeling (Sandakphu); India, Nepal, Bhutan. N. Myanmar, Thailand	-
Polygonum runcinatum Buchanan-Hamilton *ex* D. Don [NBU – 10326]	H	P	July – Sept.	Co	Temperate parts of Darjeeling (Kurseong, Mirik), Kalimpong; India (Assam, Jammu & Kashmir, Nagaland, Sikkim, Tamilnadu), Nepal, Myanmar, Malaysia, Philippines, Thailand, Indonesia (Sumatra)	Leaves are edible
Polygonum viscosum Buchanan-Hamilton *ex* D. Don [NBU – 10319]	H	A	July – Oct.	Co	Moist areas of plains of Darjeeling, Jalpaiguri, Burdwan, India, Nepal, Japan, Korea, Russia	aerial parts have antiHIV1, anticholinergic, analgesic and CNS depressant activities and significant cytotoxicity against the ovarian cancer cell line

Rheum nobile Hooker & Thomson [NBU – 10347]	H	P	June – Sept.	VF	Darjeeling; India (Sikkim), Afghanistan, Bhutan, China, Myanmar, Nepal, Pakistan	Young stems are used for salads; flowering stem used in the treatment of swellings and fullness of the abdomen; dried leaves used as a substitute for tobacco; root extract used as antiemetic, astringent, carminative, depurative, diuretic, laxative
Rumex acetosella Linnaeus [NBU – 10161]	H	P	Jan. – April	Co	Darjeeling, Jalpaiguri, Malda; India, Kazakhstan, China, Japan, Korea, Mongolia, Russia, Europe, North America.	Leaves used as vegetable
Rumex dentatus Linnaeus [NBU – 7018]	H	A	May – Aug.	VF	Darjeeling, Jalpaiguri, Malda, Burdwan, Howrah, Hoogly; India (Jammu & Kashmir to Sikkim), Afghanistan, Kazakhstan, Nepal, Russia, N Africa, S.E. Europe	Root extract used as an astringent and dye
Rumex hastatus D. Don [NBU – 7021]	S	P	June – Oct.	F	North Bengal; India(Kashmir, Uttarakhand, Chandigarh, Himachal Pradesh), Kazakhstan, Kyrgyzstan, Mongolia, Russia, Tajikistan, Europe	leaf extract applied on wounds and cuts to check bleeding and for nettle sting; root is laxative and anti rheumatic and also be used in skin disease
Rumex maritimus Linnaeus [NBU – 7020]	H	A	May – July	Co	Darjeeling, Jalpaiguri, Burdwan, Howrah; India, Kazakhstan, Myanmar, Mongolia, Russia, Europe, N America	Leaves are applied externally to burns; leaves and seed extract are also used as aphrodisiac, astringent and carminative
Rumex nepalensis Sprengel [NBU – 10165]	H	P	Sept.– Mar.	Co	Darjeeling (Kurseong, Meghma, Tumling), Kalimpong; India, SW Asia, Pakistan, Afghanistan, Tajikistan, Nepal, Bhutan, Myanmar, Indonesia, Japan (introduced), Vietnam.	Leaves used for treatment of colic, headache and body pain

Discussion

According to earlier available literature (Maiti, 1985; Prain 1903; Srivastava 2014) it was revealed that among the recorded 36 taxa, only 28 species of Polygonaceae were reported earlier from the study area (Table 2). The distribution of *Persicaria chinensis* var *hispida* was earlier known only from Myanmar, Thailand, China and North east India and is endemic to South-east Asia, present work recorded from Durpin (Kalimpong) of Darjeeling Himalaya (Paul & Chowdhury, 2016). The members of the Polygonaceae are highly valued for their medicinal properties. The Genus *Polygonum* is growing as weed in various habitats and it has several economical and ecological importances. Some species of Polygonaceae were extensively used in traditional medicine system among the various ethnic groups in India. *Polygonum aviculare* Linneaus is an accepted plant in international pharmaceutical market, sold in German drug stores as Homeriana Tea; it contains 2 – 2.5% sugar, traces of essential oil, tannin, resin and wax (Bamber, 1916). In China, *Fagopyrum dibotrys* (D. Don) Hara was used for the treatment of lung diseases, including lung tumor (Liu *et al.,* 1981). There are large numbers of ornamental plants in Polygonaceae. However, from West Bengal only four species are used as ornamentals namely *Antigonon leptopus, Coccoloba uvifera*, *Persicaria capitata, Persicaria orientalis*. Young leaves of *Fagopyrum dibotrys*, *Fagopyrum esculentum*, *Fagopyrum tartaricum*, *Rumex acetosella*, young shoot of *Rumex hastatus,* and rhizome of *Bistorta amplexicaulis* have extensive local market value. Further study focused on cultural, medicinal and commercial aspects of Polygonaceae are required to unveil valuable bio resource.

Table 2: Number of taxa of Polygonaceae reported by different workers

Taxa	Prain, 1903	Maiti, 1985	Srivastava, 2014	Present work, 2019
Genus	3	8	4	9
Species	25	28	25	36
Sub-Species	4	5	2	5

Conclusion

Present study concludes that Polygonaceae is the most diversified family. Most of the members of this family are confined to Himalayan regions, so the study area occupies the prominent position regarding their diversity. But rapid urbanization, over population and drastic climate change alter the natural habitats of many important species such as *Rheum nobile, Bistorta emodi, Persicaria campanulata* etc. Extensive collection of useful roots, fruits, seeds etc. from plants effects the natural regeneration of population of the species. On the other hand the indigenous knowledge especially the uses of the herbal drugs are in threat due to modernization of the society and loss of interest among the young generation of ethnic and rural peoples about the traditional healing methods. It is, therefore, an urgent need to protect the plants to save the diversity of Polygonaceae as well as the ethnic culture of the district.

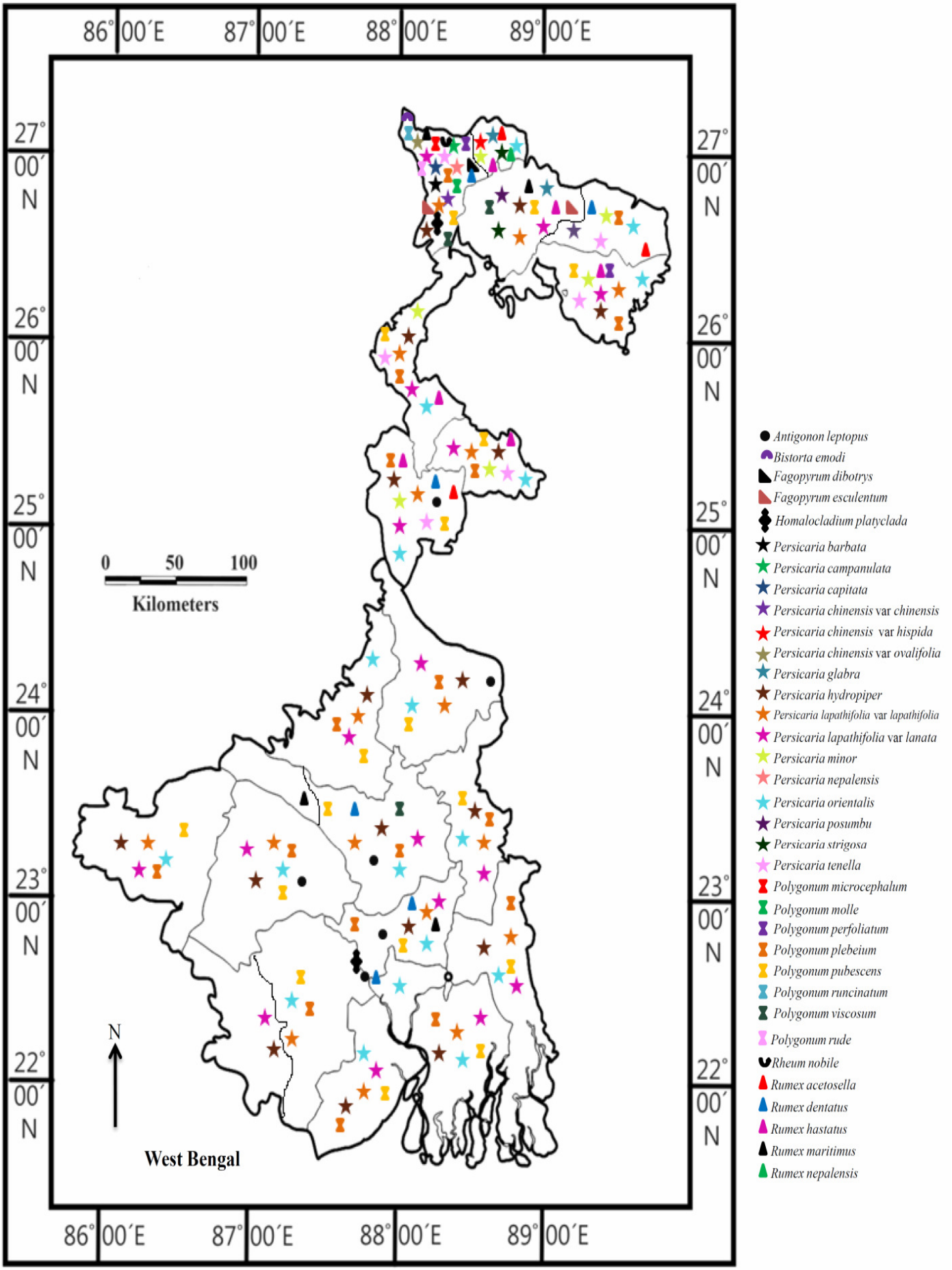

Fig. 1 : Distribution of different taxa of Polygonaceae in the different parts of West Bengal



Fig 2. : Different taxa of Polygonaceae in their natural habitat 1. *Persicaria orientalis* 2. *Rumex dentatus* 3. *Polygonum plebeium* 4. *Rumex maritimus* 5. *Persicaria tenella* 6. *Persicaria campanulata* 7. *Polygonum molle* 8. *Fagopyrum debotrys* 9. *Persicaria runcinatum* 10. *Polygonum viscosum Persicaria barbata* 11. *Persicaria glabra* 12. *Persicaria chinensis* var *chinensis* 13. *Rumex nepalensis* 14. *Persicaria capitata* 15. *Persicaria nepalensis* 16. *Fallopia convolvulus* 17. *Persicaria chinensis* var *hispida* 18. *Persicaria lapathifolia* var *lanata* 19. *Persicaria hydropiper* 20. *Homalocladium platyclada*

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Persicaria chinensis (Linnaeus) H. Gross var. *hispida* (Hooker *f.*) Kantachot (Polygonaceae): a new distributional record for West Bengal, India

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Abstract

Present work spotted a small bushy habitat of, *Persicaria chinensis* (Linnaeus) H. Gross var. *hispida* (Hooker *f.*) Kantachot, a less known member of family Polygonaceae A. Jussieu on the hilly slops at Kalimpong of Darjeeling Himalaya of West Bengal. This weak annual herb is quite rare and recorded from its extended geographical area outside the Meghalaya and Nagaland of India and first time enlisted for the flora of West Bengal. The taxonomic features, ecological notes and photographs of the species are provided.

Key words : *Persicaria chinensis* (Linnaeus) H. Gross var. *hispida* (Hooker f.) Kantachot, distribution, new record, West Bengal

INTRODUCTION

Family Polygonaceae A. Jussieu (Buckwheat or Knotweed family) comprises 59 genera and about 1384 species (www.plantlist.org) distributed from the tropics to arctic, although most species are concentrated in the northern temperate region [1],[2],[3]. Many members of this family are confined to Himalayan regions of which West Bengal and Sikkim occupies the prominent position. In India around 121 species and 29 varieties belonging to 12 genera of this family are growing in various habitats [4]. *Persicaria chinensis* (Linnaeus) H. Gross is a large herb with climbing tendency and is growing in various climatic conditions starting from the sub-himalayan plains ascending to the altitude of 1800 m of Himalayas. *Persicaria chinensis* (Linnaeus) H. Gross is showing various morphotypes and some of them are already established as varieties by various authors. Sir J. D. Hooker described 6 varieties of *Persicaria chinensis* (Linnaeus) H. Gross including *Polygonum chinense* var. *chinense*, *Polygonum chinense* var. *ovalifolium* Meissner, *Polygonum chinense* var. *paradoxum* (Hector Léveillé) A. J. Li, *Polygonum chinense* var. *hispidum* Hooker *f. Polygonum chinense* var *corymbosum* Meissner, *Polygonum chinense* var. *parvifolia* Hooker *f.* from the undivided India.

J. D. Hooker (1886) [5] established the variety *P. chinense* var. *hispidum* Hooker *f.* based on the deposited herbarium specimen (Collection No. *175*; CAL accession no. *374594*) that was collected by Gallatly from the hills of Tenasserim, a Tenasserim Hills or Tenasserim Range is the geographical name of a roughly 1,700 km long mountain chain of Myanmar, which is not now a part of India. This species was recorded from the Mountain slopes of Himalayan between the ranges of 600-2800 m in China [6]. In India, this species was recorded only from Khasi hills of Meghalaya and Kohima of Nagaland [4] few years back. Now, beyond these two locations it is first time recorded from the West Bengal and as 3rd distributional record from India (Fig. 1).

Prain (1903) [7] has first time accounted the species strength of this family from the undivided Bengal. 48 species of Polygonaceae, among them three varieties of *Polygonum chinense* (*Polygonum chinense* var. *ovalifolium* Meissner, *Polygonum chinense* Linnaeus var. *chinense* and *Polygonum chinense* var. *brachiata* (Linnaeus) H. Gross were reported from this state [8]. Paul *et al* (2016) [9] recently studied the detailed foliar micro-morphology of eight species of *Persicaria* from this region.

OBSERVATION & DISCUSSION

During the survey of various members of Polygonaceae in West Bengal (since 2015) in different geographical areas specially from Northern part of West Bengal, few interesting specimens of *Persicaria chinensis* (Linnaeus) H. Gross were collected from the hilly slopes of Kalimpong of Darjeeling district of West Bengal. The specimen was critically investigated using various literatures [5], [6] and matching with the specimens of CAL and finally identified the specimens as *Persicaria chinensis* (Linnaeus) H. Gross var. *hispida* (Hooker *f.*) Kantachot. The voucher specimens pertaining to this species will be deposited in the CNH, Sibpur, Howrah and NBU herbaria. Detailed morphological description, photographs and ecological annotations for the plant are provided in the article.

Persicaria chinensis (Linnaeus) H.Gross var. *hispida* (Hooker *f.*) Kantachot, Thai Forest Bull. Bot. 38: 135. 2010. *Polygonum chinense* Linneaus Sp. Pl. 1: 363. 1753; *Polygonum chinense* var. *hispidum* Hooker *f.,* Fl. Brit. Ind. 5(13): 45. 1886; *Polygonum chinense* var *scabra* Gage, Rec. Bot. Surv. India 2: 408.1903 Li *et al*., Fl. China 5. 301. 2003. (Fig 2)

Perennial herbs. Stems erect, 84 cm tall, ligneous at base, much branched, striate, retrorsely hispid. Petiole 2 cm, auriculate at base; lamina ovate-elliptic, 4 16 x 1.5 8 cm in diameter, both surface hispid, base broadly cordate, margin entire, apex shortly acuminate; ocrea tubular, 1.2 cm long, membranous, hairy, much veined. Inflorescence terminal, capitates, 4 mm long, aggregated, hispidly hairy; bract broadly ovate, each 3 flowered. Perianth white, 5-parted; tepals ovate, acrescent in fruit; stamens 8, included; style 3, connate. Achenes included in persistant perianth, black, opaque, broadly ovoid, trigonous, 3 mm long.

Flowers & Fruits: August - November.

Distribution: Myanmar, Thailand, China and India (Khasi

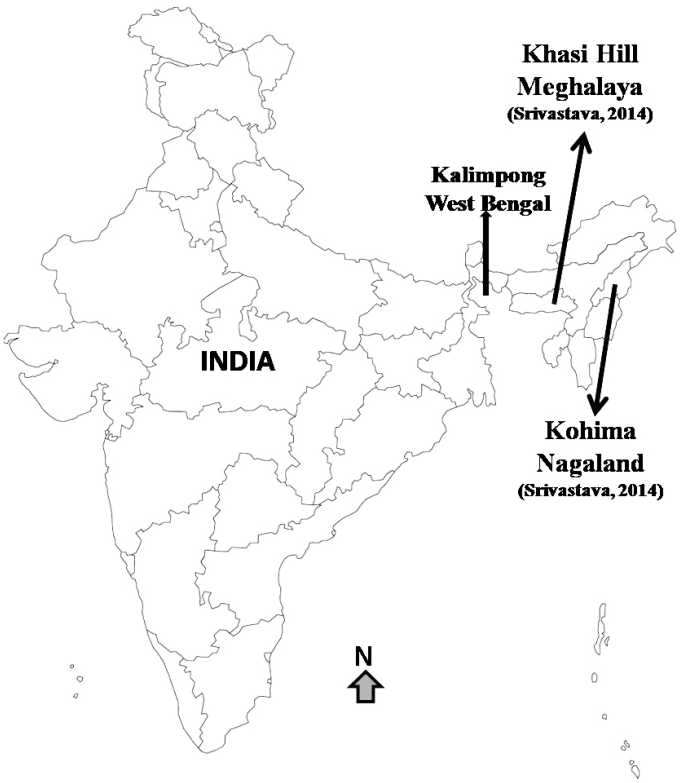

Fig. 1: Indian geographical distribution of *Persicaria chinensis* (Linnaeus) H. Gross var. *hispida* (Hooker f.) Kantachot

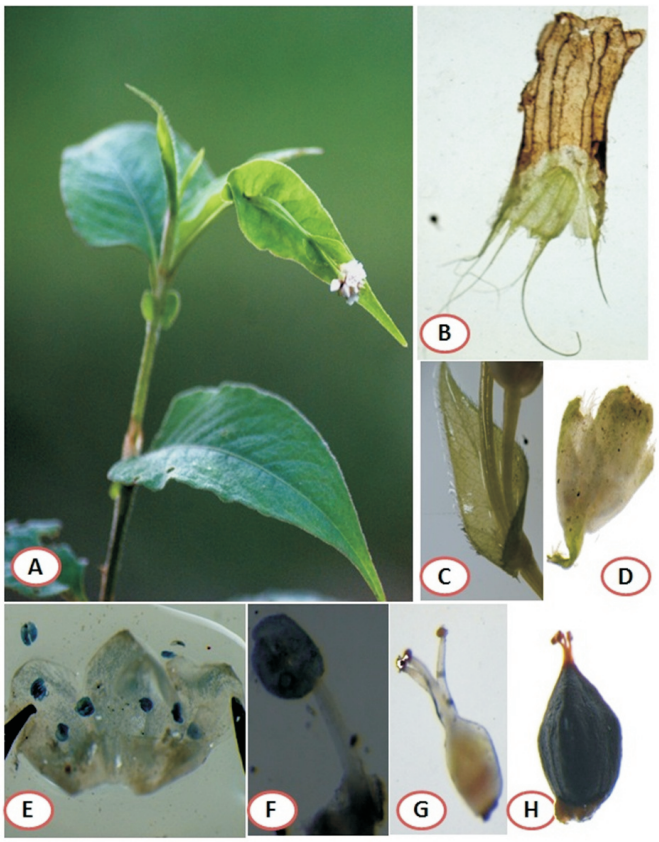

Fig 2. . *Persicaria chinensis* (Linneaus) H. Gross *var hispida* (Hooker *f.*) Kannachot A. Plant in habit B. Ocrea C. Hispid Bract D. Single flower E. Split open perianth F. Androecium G. Gynoecium H. Achene

hills of Meghalaya, Kohima of Nagaland and now from hilly slopes (Durpin) of Kalimpong, Darjeeling, West Bengal); rare occurrence.

Ecological Notes: The species is growing on moist bushy hilly slopes in association with *Persicaria runcinatum* Buchanon-Hamilton *ex* D. Don, *Persicaria chinense* (Linneaus) H. Gross, *Oplismenus burmannii* (Retzius) P. Beauvois, *Commelina diffusa* Burman *f.*, *Pauzolzia hirta* Blume *ex* Hasskarl, *Sida cordifolia* Linneaus etc.

Specimen examined: Durpin (27°02'14.79" N latitude & 88°27'36.98" E longitude), Kalimpong, West Bengal, Payel Paul & M. Chowdhury, *0038, 0040, 0042 dated* 04th October, 2015.

CONCLUSION

Persicaria chinensis (Linnaeus) H. Gross var. *hispida* (Hooker *f.*) Kantachot is one of the important variety that is reported from Myanmar, Thailand, China and North east India and is endemic to South-east Asia. This species is first time recorded outside the North-east India (Meghalaya and Nagaland). The Species is quite rare in distribution and it is gradually spread over extended ranges of Himalaya. Presently only one considerably large population of this variety is traced at Durpin (Kalimpong) of Darjeeling Himalaya.

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Study of foliar micro-morphology of eight species of *Persicaria* P. Miller (Polygonaceae) from India

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Abstract

Eight species of *Persicaria* Miller [*P. chinensis* (Linnaeus) H. Gross, *P. strigosa* (R. Brown) Nakai, *P. orientalis* (Linnaeus) Spach, *P. barbata* (Linnaeus) H. Hara, *P. lapathifolia* (Linnaeus) Delarbre, *P. hydropiper* (Linnaeus) Delarbre, *P. tenella* (Blume) H. Hara, and *P. glabra* (Willdenow) M. Gómez] were investigated with respect to leaf architecture and epidermal characters under light microscope. While the venation pattern of studied species was more or less uniform, the shape and size varied much. All the species found distinct with their description based on leaf architectural characters. A phenogram of eight species of *Persicaria* was constructed based on studied characters. Cluster analyses using leaf architectural characters depicted the relationship among these taxa.

***Key words*:** *Persicaria*, Polygonaceae, Leaf architecture, Indumentum, Stomata, Phenogram

INTRODUCTION

Polygonaceae A. Jussieu, commonly known as the Buckwheat, Smartweed or Knotweed family is one of the complex groups among the dicots regarding the identification of its members. The family name is derived from Greek word "*Polygonon*" (Komarov 1970), [*Polys* = many; *gonon* = Knee, referring to the prominent nodes of many species]. A family of around 1,200 species, representing 48 genera are geographically distributed from the tropics to the arctic, although most species are concentrated in the northern temperate region (Heywood 1978; Freeman & Reveal 2005; Sanchez & Kron 2008). Polygonaceae is a very complex family and due to its extremely diverse morphology and habit ranges (annual or perennial herbs, shrubs to lianas and trees), the species level recognition become difficult and confusing. The most distinctive and highly variable feature of the family is the presence of membranous or hyaline sheath uniting the stipules forming ochrea and it become reduced or rudimentary or absent in the subfamily Eriogonoideae (Srivastava 2014).

Classification of the Polygonaceae was mainly based on morphological characters such as the presence or absence of ochrea as nodal sheath, woodiness, tepal arrangements, etc., which have been found to be widely debated (Yasmin *et al*. 2010). *Persicaria* Miller is one of the larger genera of Polygonaceae containing approximately 150 species (Wilson 1990; Kantachot 2010) and easily recognized by the presence of thin filament of stamens and the rectangular cells of tepal epidermis (Ronse Decraene & Akeroyd 1988).

Comprehensive foliar anatomy and its variability in this family was examined by many previous workers including Metcalfe and Chalk (1950), Inamdar (1971), Kapoor *et al.* (1971), Mitchell (1971), Lersten and Curtis (1992), Ayodele and Olwokudejo (2006) and Yasmin *et al.* (2010). In the present study, 8 species of the genus *Persicaria* P. Miller was studied with aim to procure micro-morphological characters of leaf and establishing possibilities to distinguish different species of the genus based on epidermal cells, indumentum, stipule structure and stomatal types, both qualitatively and quantitatively.

MATERIALS AND METHODS

The present work has been carried out with freshly collected specimens from the Darjeeling district [26°31' N and 27° 13' N Latitudes and 87° 59' E to 88° 53' E Longitudes] of West Bengal where Polygonaceae is one well represented family in its flora (Das & Chanda 1987). The eight species under study were: *Persicaria chinensis* (Linnaeus) H. Gross, *P. strigosa* (R. Brown) Nakai, *P. orientalis* (Linnaeus) Spach, *P. barbata* (Linnaeus) H. Hara, *P. lapathifolia* (Linnaeus) Delarbre, *P. hydropiper* (Linnaeus) Delarbre, *P. tenella* (Blume) H. Hara and *P. glabra* (Willdenow) M. Gómez. The plants were collected from different parts of Darjeeling district covering an wide altitudinal range, from 130 – 2500 m. The specimens were identified using various floras (Prain 1903; Grierson & Long 1983; Zhengyi *et al.* 2003) and matched at NBU and CAL. The present status of their nomenclature was determined through the consultation of www.theplantlist.org. Voucher specimens were deposited at the NBU Herbarium.

The freshly collected leaves were processed according to the modified method of Mishra *et. al.* (2011). Specimens were immersed in 2.5 % solution of NaOH until complete clearing. But, most of the specimens are very delicate thus clearing of vein was very tough and were cleared within 15 – 20 days. After taking out from the solution, the leaves were washed with water to remove the sodium hydroxide and cleared with soft brush. Indumentum study was also conducted using these cleared leaves. In case the leaves remained opaque after clearing it was boiled in lactic acid to achieve the desired level of clearing (Lama 2004). For the stomatal study peeling of leaf lamina mainly from dorsal surface were taken with conventional techniques and were mounted in glycerin for observation.

As the leaves are very delicate, carefully epidermal layer were removed through conventional techniques. The leaf skeleton of each species were mounted and stained with safranin for better examination.

Both, qualitative and quantitative micro-morphological foliar characters were observed under a light microscope (Magnus trinocular research microscope). Dendrogram based on similarity co-efficient was generated with help of XLSTAT 2009 software (Levei *et al.* 2013).

RESULT AND DISCUSSION

The leaves of all the eight species of *Persicaria* are simple and petiolate. Basic morphological differences were investigated first and presented in Table 1A&B. And, details of indumentum structure has been presented in Table 2. The details of venation type, vein terminal, degree of venations were critically observed (Table 3). All those venation characters were specific for each species and these micro-morphological characters are quite useful regarding the species level identification. To understand the importance of these char-

Table 1A. Macro-morphological parameters of different species of *Persicaria*, part I

Species	Leaf attachment [phyllotaxy]	Leaf organis-ation	Petiole feature	Mean Lamina length (mm)	Mean lamina width (mm)	Lamina area (mm^2)	Blade class
Persicaria chinensis	Alternate	Simple	Base swollen	96.67	34.00	2191.2	Notophyll
Persicaria strigosa	Alternate	Simple	Base swollen	73.67	22.33	1096.7	Microphyll
Persicaria orientalis	Alternate	Simple	Base swollen	97.33	75.67	4909.9	Notophyll
Persicaria barbata	Alternate	Simple	Base swollen	98.33	24.00	1573.3	Microphyll
Persicaria lapathifolia	Alternate	Simple	Base swollen	70.00	13.33	622.1	Microphyll
Persicaria hydropiper	Alternate	Simple	Base swollen	77.00	19.00	975.3	Microphyll
Persicaria tenella	Alternate	Simple	Base swollen	36.00	6.67	160.1	Nanophyll
Persicaria glabra	Alternate	Simple	Base swollen	33.00	5.67	124.7	Nanophyll

Table 1B. Macro-morphological parameters of different species of *Persicaria*, part I

Species	Lamina shape	Laminar symme-try	Lamina L:W ratio	Base angle	Apex angle	Base shape	Petiole attachment	Apex shape	Margi n type	Lobation
Persicaria chinensis	Oblong	Symmet-rical	2.84:1	Obtuse	Acute	Lobate	Marginal	Acuminate	Erose	Unlobed
Persicaria strigosa	Oblong	Symmet-rical	3.29:1	Wide obtuse	Acute	Sagitt-ate	Marginal	Straight	Entire	Unlobed
Persicaria orientalis	Ovate	Symmet-rical	1.29:1	Wide obtuse	Acute	Lobate	Marginal	Acuminate	Erose	Unlobed
Persicaria barbata	Elliptic	Symmet-rical	4.09:1	Acute	Acute	Decurr-ent	Marginal	Acuminate	Erose	Unlobed
Persicaria lapathifolia	Elliptic	Symmet-rical	5.25:1	Acute	Acute	Decurr-ent	Marginal	Acuminate	Entire	Unlobed
Persicaria hydropiper	Elliptic	Symmet-rical	4.05:1	Acute	Acute	Decurr-ent	Marginal	Acuminate	Entire	Unlobed
Persicaria tenella	Ovate	Symmet-rical	5.39:1	Obtuse	Acute	Round-ed	Marginal	Straight	Entire	Unlobed
Persicaria glabra	Ovate	Symmet-rical	5.82:1	Acute	Acute	Round-ed	Marginal	Straight	Erose	Unlobed

Table 2. Indumentum structure in eight species of *Persicaria* under study[*Abbreviation used*: M = Multiseriate; A = Absent; NG = Non-glandular; U = Unbranched; ES = Elongated & Slender]

Specimen	Origin	Type	Shape	Branching	Gland	Length (O.D.)	Features
Persicaria chinensis	A	A	A	A	A	A	A
Persicaria strigosa	Almost entire abaxial surface of leaf	M	ES	U	NG	56-89	Both strigose & stellate hairs present
Persicaria orientalis	Entire leaf	M	ES	U	NG	40-61	Long, Soft, Dense, Erect
Persicaria barbata	Margin of lamina	M	ES	U	NG	76-97	Soft, Dense, Slender
Persicaria lapathifolia	Margin of lamina	M	ES	U	NG	28-37	Short, not so dense
Persicaria hydropiper	Margin of lamina	M	ES	U	NG	77-89	Long, fine, not so dense
Persicaria tenella	Margin of lamina	M	ES	U	NG	64-88	Short, dense, slender
Persicaria glabra	Margin of lamina	M	ES	U	NG	79-95	Long, dense, tip very sharp

Table 3. Pattern of venation, 1° – 5° categories in eight species of *Persicaria* P. Miller

Species	1° vein category	2° vein category	2° Vein spacing	Inter 2° veins	3° vein category	4° vein category	5° vein category	Agrophic veins
Persicaria chinensis	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Regular polygonal reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic
Persicaria strigosa	Basal	Festooned brochido-dromous	Decrease towards base	Strong intersecon-daries	Random reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic
Persicaria orientalis	Pinnate	Festooned brochido-dromous	Decrease towards base	Strong intersecon-daries	Random reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic
Persicaria barbata	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Regular polygonal reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic
Persicaria lapathifolia	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Regular polygonal reticulate	Dichoto-mizing	Dichoto-mizing	Simple agrophic
Persicaria hydropiper	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Alternate per-current	Alternate per-current	Dichoto-mizing	Simple agrophic
Persicaria tenella	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Regular polygonal reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic
Persicaria glabra	Pinnate	Festooned brochido-dromous	Irregular	Strong intersecon-daries	Regular polygonal reticulate	Regular polygonal reticulate	Dichoto-mizing	Simple agrophic

Table 4. Determined Stomatal Frequency and Stomatal Index for the eight species of *Persicaria* under

Species	Portion of leaf	Mean number of stomata (S)	Mean number of epidermal cell (E)	Area of microscopic field (mm^2)	Stomatal Frequency (no. of stomata/ mm^2)	Stomatal index (S*100/E+S)
Persicaria chinensis	Apex	29.00	152.33	0.18	161.11	15.99%
	Middle	34.33	153.67	0.18	190.72	18.26%
	Base	35.67	148.33	0.18	198.16	19.38%
Persicaria strigosa	Apex	25.67	147.00	0.18	142.61	14.87%
	Middle	23.00	137.00	0.18	127.77	14.38%
	Base	27.33	141.00	0.18	151.83	16.24%
Persicaria orientalis	Apex	31.33	162.67	0.18	174.05	16.15%
	Middle	39.67	179.00	0.18	220.38	18.14%
	Base	45.67	191.33	0.18	253.72	19.27%
Persicaria barbata	Apex	70.67	149.67	0.18	392.61	32.07%
	Middle	67.33	144.67	0.18	374.05	31.76%
	Base	74.00	160.00	0.18	411.11	31.62%
Persicaria lapathifolia	Apex	32.67	107.67	0.18	181.50	23.28%
	Middle	41.00	122.33	0.18	227.77	25.10%
	Base	37.67	111.67	0.18	209.27	25.22%
Persicaria hydropiper	Apex	75.67	209.67	0.18	420.38	26.52%
	Middle	65.00	190.33	0.18	361.11	25.46%
	Base	74.33	214.33	0.18	412.94	25.75%

Species	Portion of leaf	Mean number of stomata (S)	Mean number of epidermal cell (E)	Area of microscopic field (mm^2)	Stomatal Frequency (no. of stomata/ mm^2)	Stomatal index (S*100/E+S)
Persicaria tenella	Apex	38.33	107.00	0.18	212.94	26.37%
	Middle	33.00	99.67	0.18	183.33	24.87%
	Base	47.67	122.67	0.18	264.83	27.99%
Persicaria glabra	Apex	31.67	116.33	0.18	175.94	21.39%
	Middle	26.33	103.00	0.18	146.27	20.36%
	Base	40.33	134.33	0.18	224.05	23.09%

Table 5. Measurement of different parameters of stomata and guard cells

Species	Portion of leaf	Mean length of stomata (µm)	Mean breadth of stomata (µm)	Mean length of stomata+guard cell (µm)	Mean breadth of stomata+guard cell (µm)	Mean length of guard cell (µm)	Mean breadth of guard cell (µm)
Persicaria chinensis	Apex	14.89	11.46	29.82	25.22	29.82	8.02
	Middle	21.78	8.02	28.66	26.38	28.66	11.46
	Base	25.22	4.58	35.54	17.20	35.54	6.88
Persicaria strigosa	Apex	16.06	9.18	28.66	21.78	28.66	8.02
	Middle	17.20	9.18	24.08	21.78	24.08	8.02
	Base	18.34	5.74	25.22	14.89	25.22	9.18
Persicaria orientalis	Apex	14.89	3.44	28.66	17.02	28.66	5.74
	Middle	12.62	6.88	25.22	19.50	25.22	8.02
	Base	6.88	9.18	26.38	14.89	26.38	9.18
Persicaria barbata	Apex	14.89	6.88	24.08	22.94	24.08	5.74
	Middle	25.21	8.02	20.64	19.50	20.64	3.44
	Base	22.94	6.88	26.38	20.64	26.38	4.58
Persicaria lapathifolia	Apex	16.06	5.74	22.94	18.33	22.94	8.02
	Middle	26.38	8.02	19.50	18.33	19.50	9.18
	Base	20.64	9.18	20.64	22.94	20.64	5.74
Persicaria hydropiper	Apex	21.78	5.74	28.66	24.08	28.66	3.44
	Middle	28.66	3.44	27.52	25.22	27.52	6.88
	Base	24.08	4.58	24.08	24.08	24.08	9.18

Species	Portion of leaf	Mean length of stomata (µm)	Mean breadth of stomata (µm)	Mean length of stomata+guard cell (µm)	Mean breadth of stomata+guard cell (µm)	Mean length of guard cell (µm)	Mean breadth of guard cell (µm)
Persicaria tenella	Apex	14.89	3.44	33.26	17.02	33.26	3.44
	Middle	13.76	6.88	29.82	19.50	29.82	4.58
	Base	11.46	4.58	25.22	14.89	25.22	8.02
Persicaria glabra	Apex	13.76	8.02	32.09	22.94	32.09	9.18
	Middle	26.38	9.18	27.52	19.50	27.52	5.74
	Base	28.66	5.74	24.08	20.64	24.08	3.44

Table 6. Details of the measurements of stomata with subsidiary cells

Species	Portion of leaf	Mean length of stomata+subsidiary cell (µm)	Mean breadth of stomata+subsidiary cell (µm)	Mean length of subsidiary cell (µm)	Mean breadth of subsidiary cell (µm)
Persicaria chinensis	Apex	35.54	52.74	26.38	21.78
	Middle	37.84	55.04	27.52	25.22
	Base	36.70	56.18	27.52	16.06
Persicaria strigosa	Apex	42.42	50.46	25.22	17.20
	Middle	40.14	50.46	28.66	18.34
	Base	38.98	49.29	30.96	14.89
Persicaria orientalis	Apex	37.84	53.90	41.28	12.62
	Middle	42.42	51.60	42.42	6.88
	Base	41.28	52.74	50.46	14.89
Persicaria barbata	Apex	44.72	58.48	44.72	11.46
	Middle	43.58	57.34	66.49	13.76
	Base	44.72	52.74	60.78	16.06
Persicaria lapathifolia	Apex	75.68	41.28	44.72	13.76
	Middle	77.98	43.58	56.18	16.06
	Base	66.49	45.86	47.02	17.20
Persicaria hydropiper	Apex	45.86	44.72	50.46	11.46
	Middle	50.46	45.86	63.06	16.06
	Base	40.14	45.86	61.92	14.89
Persicaria tenella	Apex	35.54	51.60	61.92	12.62
	Middle	37.84	52.74	66.49	6.88
	Base	36.70	50.46	63.06	14.89
Persicaria glabra	Apex	44.72	52.74	42.42	11.46
	Middle	45.86	55.04	50.46	13.76
	Base	44.72	58.48	44.72	16.06

acters similarity co-efficient among the collected species of the genus, some more micro-morphological and anatomical characters (Plate I) like stomatal type, size, index and indumentums were also studied (Table 4). Details of measurements stomata, guard cells, stomatal aperture and with subsidiary cells have been presented in Tables 5 & 6. Accumulated all the characters were then numbered and analyzed to establish the similarity co-efficient dendrogram for the eight species under study.

The dendrogram (Fig. 1) showed that there are three constant clustered groups in studied *Persicaria* spp. based on similarity in leaf architectural characters. In the first clade

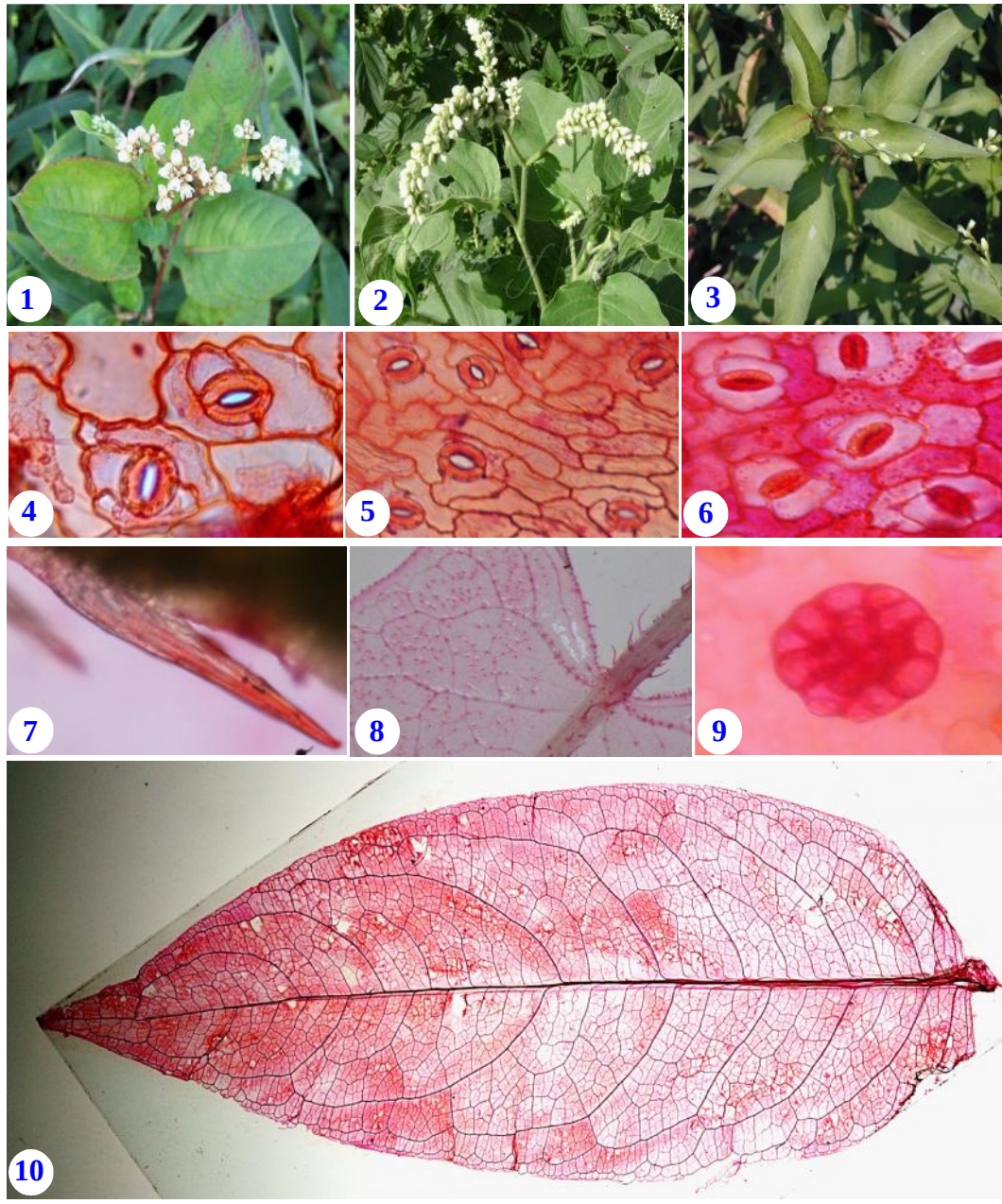

PLATE – I. Habit of **1.** *Persicaria chinensis*; **2.** *Persicaria orientalis*; **3.** *Persicaria hydropiper*. Stoma in **4.** Anisocytic in *Persicaria orientalis*; **5.** Anisocytic in *Persicaria chinensis*; **6.** Paracytic in *Persicaria hydropiper*. Indumentum in **7.** Multiseriate hair of *Persicaria hydropiper*; **8.** Stellate hair of *Persicaria strigosa*; **9.** Peltate scale of *Persicaria chinensis*. **10.** Venation of *Persicaria chinensis*

there are two species, *P. tenella* and *P. glabra*. Next, *P. chinensis, P. orientalis* and *P. strigosa* are branched from same clade where, *P. chinensis* and *P. orientalis* appeared to be more related than *P. strigosa.* Finally, the other branch split into three lines where the *P. hydropiper* and *P. lapathifolia* exhibited more proximity than *P. barbata*. The results of

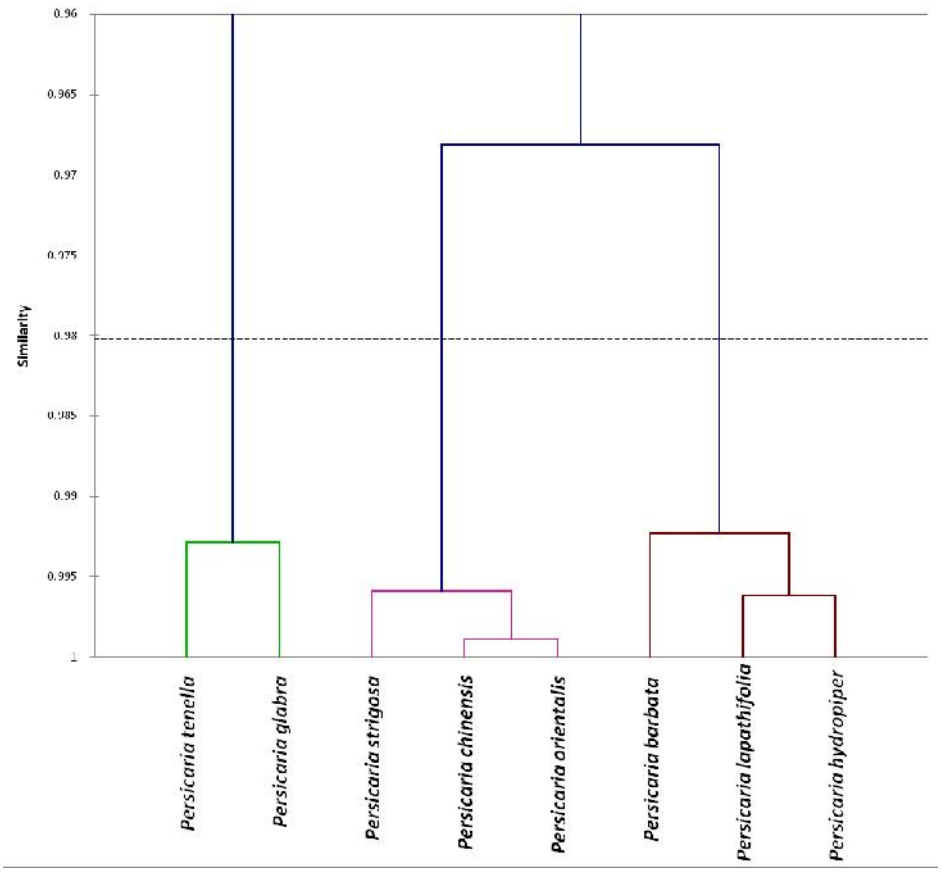

Figure 1. Phenogram showing the inter-relationship among the eight species of *Persicaria* Miller

this study indicated that leaf architectural characters are essential and must be combined with floral characters of those species to support and to make their current status stronger as eight distinct and separate species.

CONCLUSION

The leaf architecture, indumentums and stomata types among the members of Polygonaceae has similarities to some extent, at the same time; there are recognizable variations at genus and species levels. This genus specific or species specific variations might be exploited for their taxonomic delimitation and understanding intergeneric and interspecific phylogeny. Sterile specimens could also be easily identified upto the species or varietal level using such differential characters. The distinct clusters were clearly showing the inter relationship among the species.

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