

ABSTRACT

Linderniaceae Borsch, Kai Müll. & Eb.Fisch. is a family under Lamiales (APG IV), consisting more than 250 species, under 20 genera and distributed in tropical, sub-tropical and temperate regions of the world. Members of Linderniaceae are mostly herbs with quadrangular stem, opposite leaves with palmate or pinnate venation, margin entire or, serrate; pedicels in axillary, raceme, or, pseudo-umbel inflorescence; sepals connate; petals bilabiate, perfect stamens 2 or 4, staminodes 0 or 2. In India the family is represented by 56 species under 9 genera.

This PhD dissertation was carried out to find out the diversity of different Linderniaceae in the Eastern parts of Indian Himalayan region, and study the taxonomy, nomenclature, systematics, and ecology of those species. This study preliminarily sketches the overall status of Linderniaceae in the Eastern Himalayas. Half of the Indian Linderniaceae grows in the Eastern Himalayas. Total 28 species and seven genera were reported from the studied region, which constitute 50% of the total diversity of Linderniaceae in India. Among the reported species *Torenia fournieri* is the only cultivated species and used for ornamental purposes. As the elevation of the region ranges from 21 meters to 7,700 to meters, and supports six ecoregions and four biomes, it provides a suitable environment for the diversity of the Linderniaceae plants. Most of the species exhibits preference towards lowland plains, as 21 species and five genera out of the recorded 27 species and five genera occur in Terai-Duar savanna and grasslands ecoregion of the Tropical and Subtropical Grasslands, Savannas and Shrublands biome. The number of species decreases as the altitude rises, and the Eastern Himalayan broadleaf forests ecoregion, ranging from 2,000 to 3,000 meters, supports only six species and three genera. All species except *Vandellia montana* and *V. multiflora*, were recorded from multiple locations. These species are less likely to be endangered by anthropogenic or natural threats, as most of the species occur in different types of ecoregions, and are not restricted to any particular type of phytogeographic region. Though, urbanization, along with the decrease in the green spaces, and competition with the invasive alien species threaten their existence.

Within much less than five years of span many new records were reported. Among the recorded species, two were described as new species, viz., *Bonnaya gracilis* and *Torenia siliguriensis*. *B. multiflora* and *T. concolor* were recorded from India for the first time. *Lindernia hyssopioides*, *L. rotundifolia*, *L. tamilnadensis*, and *T. godefroyi* were recorded from Indian Eastern Himalaya for the first time. Unfortunately, despite the presence of herbarium specimens from the Darjeeling hills, live specimens of *Picria fel-terrae* could not be located, which might be the result of climate change and habitat destruction.

The diversity in the calyx and staminal filaments was documented from the morphological study. Three main types of calyces, viz., five-lobed, connate-tubular, and bi-lipped, were observed. Free calyx lobes were observed in *Bonnaya*, *Lindernia*, *Picria*, *Torenia anagallis*, *Vandellia*, and *Yamazakia*. Connate and tubular calyx was found in *Craterostigma* and *Torenia*. Lastly, bi-lipped calyx was exclusive to *Torenia* s.s. The anterior or the longer pair of filaments have been modified from simple to geniculate-appendaged, geniculate-swollen, or become non-functional as staminodes. Staminodes are restricted to *Bonnaya*, *Lindernia*, and *Picria*. Swollen geniculation is characterized by *Craterostigma*, *Vandellia*, and *Yamazakia*. Finally, appendaged geniculation is limited to *Torenia*. It also reported the presence of both the seed types in these species, viz., aulacospermous and bothrospermous.

Both bayesian inference and maximum likelihood phylogenetic study from the available molecular data (matK) showed congruence with results from the morphological study. This suggested rethinking the phylogenetic position of *Vandellia micrantha*, *V. montana*, and *V. multiflora*. *V. micrantha*, phylogenetically as well as morphologically, is very distinct from true *Vandellia*, i.e., *V. diffusa*. Phylogenetically it's related to *Torenia* clade and morphologically also exhibits appendaged-geniculation. *V. montana*, and *V. multiflora* on the other hand is morphologically similar to the newly established genus *Yamazakia*, and is characterized by free calyx lobes equalling ovate-lanceolate capsules. Contrary to this, true *Vandellia* exhibits partially united calyx lobes, much shorter than the capsule. The matK gene analysis also placed *V. montana* close to *Y. viscosa* and *Y. pusilla*. Therefore, all these morphological as well as molecular affinity suggest new generic treatments for the three, above mentioned species.

During nomenclature studies a few nomenclatural as well as typification issues of some Linderniaceae taxa were encountered. Evaluation of nomenclature and taxonomy of *Torenia gracilis* Benth. revealed that *T. gracilis* originally not related to *Torenia*, but to *Bonnaya*. As *T. gracilis* was not validly published and *T. gracilis* was described as a new species of *Bonnaya*, viz., *B. gracilis*.

One of the key findings was revisiting the nomenclature and taxonomy of *Mimilus violaceus* Azaola, basionym of *Torenia violacea* (Azaola) Pennell, to which *T. edentula* Benth., *T. exappendiculata* Regel and *T. peduncularis* Benth. ex Hook.f. was associated as synonyms. It was found that the name *M. violaceus* was never originally associated with any *Torenia*, rather the taxonomic identity of *M. violaceus* is unclear, as no original material except the insufficient description was traced. Besides, no suitable herbarium specimen for *T. edentula* also could not be located. Therefore, *T. edentula* was neotypified. Again, as *T. violacea* is the most used name for the taxon, to which *T. edentula* is associated, treating *T. edentula* as the accepted name for the taxon would create nomenclatural instability, so conservation of *T. violacea* was proposed against *T. edentula*. Conserved type of *M. violaceus* and lectotypes of *T. exappendiculata* and *T. peduncularis* were also designated.

The taxonomic identities of *Torenia hians* and *T. vagans* were found to be uncertain, as they have insufficient description for species level identification and the illustrations in their protologue also do not match their descriptions. The synonymy of *T. rubens* was also resolved. *T. rubens* has been treated as the synonym of *T. concolor*, since its first description as a closely related species to *T. diffusa*. *T. rubens* was found to be a synonym of *T. diffusa*. Additionally, lecto-type was designated for *T. rubens*.

Lectotypes of *Torenia concolor* and *T. rubens* var. *grandiflora* was designated, along with the second type lectotypes of *T. albomarginata*, *T. albo-violacea*, and *T. annamitica*. In total one conserved type, one neotype, five lectotype, and three second-type lectotypifications were carried out.

Palynological characters of the 16 studied species showed more or less similarities, and are considered as stenopalynous. Pollens were small (rarely medium), tricolpate in these studied species. The investigated quantitative characters of the studied taxa varied in different species and were significant regarding generic level identification.

P/E ratio was found highest in *Torenia anaglis* (1.47) and lowest in *L. tamilnadensis* (0.84). Pollen shapes also varied from prolate to suboblate. Thinnest exine found in *B. ciliata* (0.8 μm) whereas *T. violacea* (1.8 μm) shows thickest exine wall. Overall, though, palynological characters are not sufficient for species identification, but can be used for generic identification. Exine is always more than 1.3 μm in *Torenia*, and lesser in other three genera. Polar outline is circular in *Bonnaya*, whereas lobate in *Lindernia* and triangular in *Vandellia*.

Insects of primarily three orders, namely hymenoptera, lepidoptera, and thysanoptera, were recorded on flowers of three genera and six species of Linderniaceae. These insects were either smaller than the respective visiting corolla or were having very long proboscis. As Linderniaceae has small corolla with tubular opening, these insects were ideal for collecting nectar or pollen.