SYSTEMATICS STUDIES ON SECTION EPIPHYTICAE OF FAMILY BALSAMINACEAE

Thesis Submitted to the University of Calicut
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DOCTOR OF PHILOSOPHY

in

BOTANY

Under the faculty of Science

by

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CERTIFICATE

This is to certify that the thesis entitled **"SYSTEMATICS STUDIES ON SECTION EPIPHYTICAE OF FAMILY BALSAMINACEAE"** is an authentic record of research work carried out by **Ms. Reshma Ashok** under my supervision in fulfilment of the requirement for the degree of Doctor of Philosophy, in Botany of university of Calicut. The result embodied in this thesis have not been included in any other thesis submitted previously for the award of any degree or diploma of any other university or institution. Also certified that the content of the thesis has been checked using anti-plagiarism data base and no unacceptable similarity was found through the software check.

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I **Reshma Ashok**, hereby declare that the thesis entitled **"SYSTEMATICS STUDIES ON SECTION EPIPHYTICAE OF FAMILY BALSAMINACEAE"** submitted to the university of Calicut, for the award of the degree of Doctor of Philosophy in Botany, is a bona fide record of the original research work carried out by me under the supervision and guidance of Dr. Ignatius Antony and co-guidance of Dr. Anto P. V., Department of Botany, St. Thomas College, Thrissur and it has not been submitted earlier either in part or full for the award of any degree or diploma to any candidate of any university.

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Dedication

To my Amma and Achan
For raising me to believe that anything is possible
To my Husband
For unconditional love and support
To my Child
For always being the loving and understanding son

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

ABBREVIATIONS

° C	Degree Celsius
cm	Centimetre
nm	Nanometre
µm	Micro meter
mm	Milli meter
m	Meter
ft	Feet
alt	Altitude
DTM	Digital Terrain Model
SRTM	Shuttle Radar Topographic Mission
AUC	Area Under the Receiving Operator Curve
r	Pearson's correlation
min	Minute
sec	Second
h	Hour
%	Percentage
pH	Potential of Hydrogen
MaxEnt	Maximum entropy
Bio	Bioclimatic variable
TRI	Terrain Ruggedness Index
ROC	Receiver operating characteristic curve
Cu	Copper
***Impatiens* sp. 1**	*Impatiens* species 1

Systematics studies on section *Epiphyticae* of family Balsaminaceae

The genus *Impatiens* belongs to the family Balsaminaceae, is a species rich genus distributed in five major hot spots around the world. This genus is notorious among the botanists due to delicate nature of the flowers, variations in morphological characters, rapid hybridization, and high degree of endemism. Due to these intricacies, the classification of genus *Impatiens* is still incomplete. The intergeneric classification proposed by Hooker divides this genus into 7 sections and one among them is section *Epiphyticae*. This section is a narrow endemic, distributed only in Southern Western Ghats. The section includes 7 species located at various locations of Southern Western Ghats. The present study deals with the taxonomy, anatomy, palynology, seed morphology and potential distribution of *Impatiens* belongs to the section *Epiphyticae*. All the species belongs to section *Epiphyticae* are epiphytes on trees and do not show any preference to the host tree. Due to the unique nature of the spur they are also known as, Parrot billed *Impatiens*.

Critical examination of a specimen collected from Wagamon was identified to be noval and was confirmed as a novelty hence recognized as a new species. This species is closely allied with *I. parasitica* and known only from the type locality. The variation in morphology of *I. parasitica* collected from different localities confirmed the rapid evolution-taking place in this genus. During the study 8 different morpho types of *I. parasitica* was collected. They show variations in floral characters but the seed and fruit are similar. In the future, these morphotypes may develop to new species. On critical examination of the type specimen of *I. kulamavuensis* concluded that it is a synonym of *I. parasitica*.

The ambiguity remained in the structure of floral parts especially lateral united petal of *Epiphyticae Impatiens* was resolved in this study. This is the first attempt to elucidate the anatomical features of *Epiphyticae Impatiens*. This attempt resulted in significant data on the anatomy of leaf and stem. The pollen grains of all the species under study have a medium size and shape is oblate spheroidal in *I. auriculata* and prolate spheroidal in all other 6 species under consideration. The surface of the pollen grains consists of reticulate ornamentation. All the pollen grain under study is tetrazonocolpate. The MaxEnt algorithm helps to predict the potential distribution of species under study. Only four species out of the seven species reported a good result hence the final model is accepted. According to the model all the studied species show distribution in Idukki district as well as Agasthyamalai regions.

ബാൽസാമിനേസി കുടുംബത്തിലെ *എപ്പിഫൈറ്റിക്കേ* വിഭാഗത്തെക്കുറിച്ചുള്ള സിസ്റ്റമാറ്റിക്സ് പഠനം

ലോകമെമ്പാടുമുള്ള അഞ്ച് പ്രധാന ഹോട്ട്സ്പോട്ടുകളിലായ് വ്യാപിച്ചുകിടക്കുന്ന ജനുസ്സിൽ ഒന്നാണ് *ഇംപേഷ്യൻസ്* ജനുസ്സ്. ഈ ജനുസ് ബാൽസാമിനേസി കുടുംബത്തിൽ പെടുന്നു. പൂക്കളുടെ അതിലോലമായ സ്വഭാവം, രൂപഘടനയിലെ വ്യതിയാനങ്ങൾ, ദ്രുത സങ്കരീകരണം, ഉയർന്ന തോതിലുള്ള എൻഡമിസം എന്നിവ കാരണം ഈ ജനുസ്സ് സസ്യശാസ്ത്രജ്ഞർക്കിടയിൽ കുപ്രസിദ്ധമാണ്. ഈ സങ്കീർണതകൾ കാരണം, *ഇംപേഷ്യൻസ്* ജനുസ്സിന്റെ വർഗ്ഗീകരണം ഇപ്പോഴും അപൂർണ്ണമാണ്. ഹുക്കർ നിർദ്ദേശിച്ച ഇന്റർജെനറിക് വർഗ്ഗീകരണം ഈ ജനുസ്സിനെ 7 വിഭാഗങ്ങളായി വിഭജിക്കുന്നു, അവയിലൊരു വിഭാഗമാണ് *എപ്പിഫൈറ്റിക്കേ*. ഈ വിഭാഗം, തെക്കൻ പശ്ചിമഘട്ടത്തിൽ മാത്രം വ്യാപിച്ചുകിടക്കുന്നു. തെക്കൻ പശ്ചിമഘട്ടത്തിലെ വിവിധ സ്ഥലങ്ങളിൽ സ്ഥിതി ചെയ്യുന്ന 7 സ്പീഷീസുകൾ ഈ വിഭാഗത്തിൽ ഉൾപ്പെടുന്നു. വർഗ്ഗീകരണം, ആന്തരീക ഘടന, പാലിനോളജി, വിത്ത് രൂപഘടന, *ഇംപേഷ്യൻസിന്റെ* ഭൂമിശാസ്ത്രപരമായ വിതരണസാധ്യത കണ്ടെത്തൽ എന്നിവയുമായി ബന്ധപ്പെട്ടതാണ് ഇപ്പോഴത്തെ പഠനം. *എപ്പിഫൈറ്റിക്കേ* വിഭാഗത്തിൽ പെടുന്ന എല്ലാ സസ്യങ്ങളും മരങ്ങളിലെ എപ്പിഫൈറ്റുകളാണ്, അവ ആതിഥേയ വൃക്ഷത്തോട് യാതൊരു മുൻഗണനയും കാണിക്കുന്നില്ല. സ്പർസിന്റെ തനതായ സ്വഭാവം കാരണം, "തത്ത ഇംപേഷ്യൻസ്" എന്നും ഇവ അറിയപ്പെടുന്നു.

വാഗമണ്ണിൽ നിന്ന് ശേഖരിച്ച ഒരു സസ്യത്തിന്റെ പരിശോധനയിൽ പുതുമയുള്ളതായി സ്ഥിരീകരിക്കുകയും പുതിയ ഇനമായി അംഗീകരിക്കുകയും ചെയ്തു. ഈ ഇനം *ഇ. പാരാസിറ്റിക്ക* അടുത്ത് വിന്യസിച്ചിരിക്കുന്ന, പഠനത്തിനിടെ 8 വ്യത്യസ്ത മോർഫോ തരം *ഇ. പാരാസിറ്റിക്ക* ശേഖരിച്ചു. *ഇ. കുളമാവ്എൻസിസ്*ന്റെ തരം മാതൃകയുടെ നിർണായക പരിശോധനയിൽ, *ഇ. പാരാസിറ്റിക്ക*യുടെ പര്യായപദമാണ് *ഇ. കുളമാവ്എൻസിസ്*, അതിനാൽ *ഇ. പാരാസിറ്റിക്ക*യുടെ കീഴിൽ ലയിപ്പിച്ചു. *എപ്പിഫൈറ്റിക്കേ ഇംപേഷ്യൻസിന്റെ* ലാറ്ററൽ യുണൈറ്റഡ് ദളങ്ങളുടെ കാര്യത്തിൽ, നിലനിന്നിരുന്ന അവ്യക്തത പഠനത്തിലൂടെ പരിഹരിച്ചു.

എപ്പിഫൈറ്റിക്കേ ഇംപേഷ്യൻസിന്റെ അനാട്ടമി സവിശേഷതകൾ വ്യക്തമാക്കുന്നതിനുള്ള ആദ്യ ശ്രമമാണിത്. ഈ ശ്രമം ഇലയുടെയും തണ്ടിന്റെയും അനാട്ടമിയെക്കുറിച്ചുള്ള സുപ്രധാന ഡാറ്റയിൽ കലാശിച്ചു. അബാക്സിയൽ, അഡാക്സിയൽ പ്രതലങ്ങളിലെ ഇലയുടെ എപ്പിഡെർമൽ സെല്ലുകളുടെ ആകൃതി സമാനമാണ്, സ്റ്റോമാറ്റ അനാമോസൈറ്റിക് ആണ്.

പഠനത്തിലുള്ള എല്ലാ സ്പീഷിസുകളുടെയും പൂമ്പൊടിക്ക് ഇടത്തരം വലിപ്പവും ആകൃതി ഓബ്ലേറ്റ് സ്ഫെറോയിഡലും ആണ്. *ഇ. ഓറിക്കുലേറ്റയിൽ* പ്രോലേറ്റ്

സ്ഫെറോയിഡൽ ആണ് ആകൃതി. *എപ്പിഫൈറ്റിക്കേ ഇന്വേഷ്യൻസിന്*റെ വിത്തുകൾ അവയുടെ എപ്പിഫൈറ്റിക് ജീവിതരീതിയുമായി പൊരുത്തപ്പെടുന്നു. വിത്തുകളുടെ ഉപരിതലം ചുരുണ്ട മുടി കൊണ്ട് സജ്ജീകരിച്ചിരിക്കുന്നു. MaxEnt അൽഗോരിതം പഠനത്തിൻകീഴിലുള്ള സ്പീഷിസുകളുടെ സാധ്യതയുള്ള വിതരണത്തെ പ്രവചിക്കാൻ സഹായിക്കുന്നു. ഏഴ് സ്പീഷീസുകളിൽ നാല് സ്പീഷീസുകൾ മാത്രമേ നല്ല ഫലം റിപ്പോർട്ട് ചെയ്തിട്ടുള്ളൂ അതിനാൽ അന്തിമ മാതൃക അംഗീകരിക്കപ്പെട്ടു. മാതൃകയനുസരിച്ച്, പഠിച്ച എല്ലാ ഇനങ്ങളും ഇടുക്കി ജില്ലയിലും അഗസ്ത്യമല പ്രദേശങ്ങളിലും വിതരണം കാണിക്കുന്നു.

The Western Ghats, commonly called "Sahyadri mountain range" is a continues stretch of mountain ranges running parallel to the western cost of Indian peninsula. It is located between 10.1667° N, 77.0667° E, and cover around 1600 km. The weather pattern of entire Indian peninsula is fascinatingly influenced by these mountain ranges. It acts as a barrier intercepting the moisture laden south western monsoon winds, which results in the condensation of the moisture and precipitation. The tropical evergreen forests and montane forest ecosystem is responsible for the warm tropical climate of Indian peninsula. Western Ghats is famous for its exceptionally high degree of biodiversity and endemic plants. It is one of the eighth 'Hottest hot spot' of biodiversity along with Sri Lanka. Western Ghats is home for more than 5000 species of flowering plants; among them 2100 species belongs to 56 genera are strictly endemic to this region.

The family Balsaminaceae is famous for its majestically beautiful blooms and high degree of endemism. This family comprises of two genera: *Hydrocera* Blume ex Wight and Arnott (1834) and *Impatiens* Linn. (1753). *Hydrocera* is a monotypic genus, which includes semi aquatic plant *Hydrocera triflora* (Linnaeus, 1753) commonly found in Indo Malayan region. Flowers are zygomorphic with free petals and fruits are indehiscent pseudo berry.

The name *Impatiens* derived from the weird seed dispersal mechanism of these plants. The ripe pods explode even with a light touch stimulus and the seeds are dispersed to far distances, seeming as if these where impatient to open. The name derived from Latin word "Impatiens" which means impatient. This unique seed dispersal mechanism is very helpful for the plant to regenerate.

The genus *Impatiens* is commonly called "Jewel weeds", one of the species rich genus distributed in five major hot spots around the world: Southeast Asia and south-western China, Eastern to central Himalayas, Southern India, tropical Africa, and Madagascar (Grey Wilson, 1980). Several new species are added to the world flora from these regions each year (e.g., Saravanan and Kaliamoorthy, 2022; Richard *et al*., 2021; Hu *et al*., 2020). More than 1000 accepted species of *Impatiens* are there around the world (Mabberley, 2008; Bhaskar., 2012; Yu, 2012). Southwest China accounts for more than 270 species of *Impatiens* so far (Yu, 2012; Chen, 2001; Chen *et al*., 2007). Tropical Africa contributes around 130 species of *Impatiens* to the world flora (Abrahamczyk *et al*., 2016; Rahelivololona *et al*., 2018). A few species of *Impatiens* are reported from the temperate regions of Europe and North America.

Phylogenetic studies by Janssen *et al*., (2006) shows that centre of origin of *Impatiens* was South China. According to Bhaskar (2012) the centre of origin of *Impatiens* was Western

Ghats. The most primitive species of the genus *Impatiens* is *I. latifolia* L. and *I. leschenaultii* (DC.) Wall. ex Wight and Arnot (N=3), which are reported from Western Ghats. The rich diversity and abundance of endemic *Impatiens* found in Western Ghats suggest that, it is one of the centres of evolution and diversification of this genus (Arigela *et al*., 2019).

***Impatiens* in India**

In India two major biodiversity hot spots of *Impatiens* are present, that are Eastern Himalaya and Western Ghats (Bhaskar, 2012). So far 320 species of *Impatiens* are reported from India. Among them around 148 species are strictly endemic to India. North Eastern states of India also harbour a large number of *Impatiens* with high degree of endemism. About 14 species of *Impatiens* are reported from Assam (Vivekananthan *et al*., 1997; Barooah & Ahmed, 2014), 17 species from Nagaland (Hooker, 1905; Vivekananthan *et al*., 1997). In the recent years several new species are identified from these regions. More than 110 species of *Impatiens* are strictly endemic to Western Ghats. Luxuriant rain obtained during the South-West and North-East monsoon season, and various edaphic factors in this region are responsible for huge diversity and well flourished growth of *Impatiens* in this region.

Except a few species, *Impatiens* prefers a higher altitude (>1500 meter). Annual rain falls around 2000 mm per annum and an average temperature of 20 degree Celsius is suitable for the growth of *Impatiens*. This genus always prefers wet and humid conditions for their growth. The shola forests and grass lands are home for many *Impatiens* species. The banks of perennial streams and waterfalls are also ideal for this genus, since enough humidity is available. A few species are lithophytic and few grow as epiphytes on moss covered tree trunks and on thick canopy.

According Hooker (1874) *Impatiens* found in South Indian can be classified into seven sections, *Scapigerae, Epiphyticae, Annuae, Microsepalae, Tomentosae, Sub Umbellatae* and *Racemosae*. Of this section *scapigerae* and *Epiphyticae* show endemism to Southern Western Ghats. According to Hooker (1910) Palghat gap is the major factor which determines the dispersion of genus *Impatiens* in Western Ghats. Scapigerous species originate from northern side of Palghat gap and caulescent pedunculate forms in the southern parts of Western Ghats.

Impatiens balsminae and *I. chinensis* are the two species distributed throughout India. The species of *Impatiens* found in north India and South India is strikingly different and show many morphological peculiarities. The species found in South Indian have a pair of lateral sepals, short swollen ellipsoid pod, whereas the North Indian species have two pairs of lateral

sepals and elongated narrow pods. These two groups may separate from each other in the past and started developing in parallel lines. During this development each group acquired many unique characters and their own endemic species are evolved. Various environmental factors and phytogeographical changes may result in the extinction of their common ancestor or it may change to a new one.

Impatiens is a non-endemic genus with enormous endemic species. Most of this endemic *Impatiens* are confined to Western Ghats, hence this region is considered as the phylogenetically most significant region of India. Within Western Ghats Pandurangan and Nair (1995) identified three major endemic areas, Anamalai (Anaimudi), Coorg and Nilgiris. Endemic species are very prone to extinction as they are very rare in occurrence. Any activities, both anthropogenic and natural that disturb the population of an endemic species may leads to their extinction. Frequent landslides, floods and forest fire taking place in these regions considerably reduce the population of many endemic *Impatiens*. The studies of Nai r (1991) on the endemism in Western Ghats with special references to *Impatiens* suggest that, six well defined regions of distribution are there.

Economic importance of *Impatiens*

Impatiens is considered as the 'Dicot counterpart of orchids' (Yuan *et al*., 2004) due to its zygomorphic flowers and floral parts similar to orchids. The flowers showing resupination through the twisting of pedicel. The charming diversity in the shape, size and colour of *Impatiens* flowers create them a suitable subject to adorn home garden. These plants are often regarded as 'Poor man's orchid'. Some of the common garden plants are *I. auricoma* Baill. (African queen), *I. balsamina* L. (Balsams) and *I. walleriana* Hook. F. (Busy lizzie). Most of the wild *Impatiens* has horticultural value, and in Western countries many hybridization efforts are taken to make new combinations suitable for the garden.

I. glandulifera commonly known as "Himalayan balsam" is an invasive species that invaded Europe, North America and New Zealand. Many species are facing the threat of being eliminated from their native habitat, because of the rapid growth and multiplication of this species. *I. capensis* is another invasive species found in Europe, including Poland. Both these Systematics studies on section *Epiphyticae* of family Balsaminaceae 6 species are introduced for ornamental purpose, later they spread and out compete the native species and established rapidly.

Many species of *Impatiens* have potential medicinal properties and being used from the ancient times onwards. The seeds of *I. balsaminae* L. is used to treat difficult labour and used as an antidote for fish poisoning in some countries (Ching S, 1977). *I. textori* Miq. and *I. siculifer* Hook f. are used for the ailment of various disease in traditional Chinese medicine. Antianaphylatic, antibacterial, antifungal activity, antiallergic, antidermatic and antitumor activity is reported in different species of *Impatiens*.

Epiphyticae Impatiens

The classification of genus *Impatiens* of India proposed by Hooker (1874), enumerated the existence of section called "*Epiphyticae*" which is found in Southern Western Ghats only. Seven species are included in this section; these are distributed in various locations of Southern Western Ghats. The first reported species of *Epiphyticae* section is *I. viridiflora* Wight. This species was reported by Robert Wight (1837) from Shevagiri hills. Plants belong to this section bear elongated, thick and brightly coloured spur. Owing to the peculiar nature of this spur these plants are informally described as "Parrot billed *Impatiens*". All of the species are located in the regions having thick canopy and branches of trees that are covered with mosses.

Like majority of the species of the *Impatiens*, *Epiphyticae* species are also annual plants with herbaceous habit. The stem is monoliform in some plants, thick and fleshy. All other floral parts also exhibit the thick and fleshy nature. Lateral petals are narrow and elongated; they may remain close to the spur or spreading outward. Dorsal petal is orbicular and keeled at the abaxial side. Lateral united petals are lobed, wing shaped and inserted in the spurred lower sepal. Anthers are five and syngenecious, ovary is pentacarpellary, syncarpous and unilocular. Seeds are hairy, hairs are spirally coiled. These hairs help to remain attached to the mosses, covering the tree trunks and germinate later. No specificity is shown for the host plants by these epiphytic species.

Research Problem

Most of the regions of Western Ghats are subjected to environmental degradation due to various anthropogenic activities. A documentation of flora and fauna of Western Ghats is highly required. Western Ghats is rich in terms of abundance of endemism. There was no previous attempt to understand the importance and characteristics of this endemic *Impatiens*. The frequent changes in environment of Western Ghats clearly effect the distribution of highly endemic species like *Impatiens*. In this scenario the need of detailed study on this species based

on fresh specimens and reinterpret their taxonomy, threat status and distribution is highly required.

Impatiens flowers are notorious among botanists for their changeable characters and the fragile nature of flowers. The flowers lost many of its characters as soon as it is collected from the field. The intensity of variation found in this actively evolving group, make the studies more and more difficult. It is not easy to derive phylogenetic relation among the species using morphological characters.

Objectives

1. To study the taxonomy and morphology of *Epiphyticae Impatiens.*

2. To analyse the anatomy of vegetative parts such as leaf and stem of *Epiphyticae Impatiens.*

3. To study the pollen and seed morphology of *Epiphyticae Impatiens.*

4. To predict the potential geographical distribution of *Epiphyticae Impatiens.*

2.1 Taxonomy of *Impatiens* from Western Ghat

The insight about genus *Impatiens* was first brought to the world by Hendrick Van Rheed. He incorporated six plates of *Impatiens* along with their Latin description in his epic treatise Hortus Malabaricus (1678). His book deals with the medicinal uses of these plants, used by the local health practitioners of south India. Later these six species are recognized as four different species. First systematic study of the genus *Impatiens* was done by Carl Linneaus (1753). He described seven species of *Impatiens* in his monumental work "Species Plantarum". One of the species proposed by him under the name *I. triflora* was later segregated into a new genus and named as *Hydrocera triflora*. Among the six species of *Impatiens* four species occur in India which includes *I. balsaminae*, *I. chinensis*, *I. latifolia* and *I. oppositifolia*.

Lamarck (1785) mentioned eight species of *Impatiens* in his work Encyclopaedia methodique: botanique. He identified a new species, *I. fasciculata* from Malabar. Along with this new species he enumerated all the seven species identified by Linneaus. Roth (1821) identified a new taxon from Mysore and named after the type locality, *I. mysoorensis*. This species was described using the collections of Heyne. Along with this species, he described the species *I. triflora* now known as *H. triflora*.

In the beginning the genus *Impatiens* was treated under family Gentianaceae, later in 1822, A. Richard proposed the Balsaminaceae family having 4 genera viz *Hydrocera* Blume ex Wight and Arnot, *Impatiens* Riv. ex L., *Impatientella* Perrier and *Semiocardium* Zoll. Later genus *Impatientella* and *Semiocardium* treated as synonym to *Impatiens* (Mabberley, 2008). The contribution of Roxburg to the annals of *Impatiens* was remarkable. He enlisted 16 taxa of *Impatiens* in his book Flora Indica (1824), including the new species *I. tripetala*. The other species reported are based on collections of Wallich and Heyen. The perspective of De condolle (1824) on Balsaminaceae was different from that of contemporary botanist. He classified the family into two genera *Balsamina* and *Impatiens*. The genus *Balsamina* is characterized by 5 bilocular anthers, 5 distinct stigma, single flowered pedicel, solitary or aggregated and puberulous capsule. This genus is classified into two groups. The characters of genus *Impatiens* includes, 5 anthers, 3 bilocular and the rest single locular, 5 united stigma, many flowered, branched pedicel and glabrous capsule. De condolle enumerated 31 species in the family Balsaminaceae from India, Sri Lanka and Nepal out of which 24 found in India.

Wight and Arnot (1834) reported 21 species of *Impatiens* from India. They discarded the classification introduced by De Condolle as it was not completely based on permanent

characters. Wight and Arnot proposed a new classification, which divides the genus into 3 distinct groups. The group one consists of alternate leaves, axillary, single or several flowered inflorescences and 6 species are included in this group. The group two is characterized by alternate leaves, peduncled inflorescence with several flowers and 4 species are included in this group. The group three consists of opposite leaves, axillary inflorescence, single flowered or many flowered and 11 species are included in this group. They identified 3 new taxa and which are *I. rheedei, I. kleinii*, and *I. filiformis*. The existence of genus *Hydrocera* also mentioned in this book. Arnot (1835) enumerated 20 new species proposed by various authors from India and Sri Lanka. Arnot identified 14 new species and reported in his paper, of these 4 species are common to India and Sri Lanka. Jhon Lindely (1836) enumerated the characters of family Balsimnaceae. He stated that Balsaminaceae show affinities to Geraneaceae.

Epiphyticae species was first reported by Robert Wight (1837) in Madras Journal of Literature and Science. In his paper, he reported 17 species of *Impatiens* including two *Epiphyticae* species, *I. auriculata* and *I. viridiflora*. The first species is collected from hill tops of Courtellum and the flowering time is August to September. They form large tufts on the branch of trees, which are exposed to rain and mist. The wing petals are elongated and hanging down like dog's ear hence the name *I. auriculata*. The second species was collected from Shevagiri hills at an elevation of 1500 m high. The sepals of these plants are all green and lateral sepal is smaller than *I. auriculata*. Illustrations of both the plants are also given.

Royle (1839) reported the presence of 29 species from Himalayan Mountain regions. Description of *I. bicolour* and *I. glandulifera* are also provided. In the second volume illustrations of these 2 species are included. In the later years Wight (1844, 1845, 1846 and 1850) published a series book named "Icones plantarum Indiaeorientalis or figures of Indian plants". Description and illustration of 22 species of *Impatiens* are provided in different volumes. Wight (1850) reported another new *Epiphyticae* species, *I. jerdoniae* in volume 4 of this series. This species was reported from Sisparaha ranges of Nilgiris. Illustrations are done by Mr. Jerdon based on the plants collected from Ootucamund. The spur is saccate and bright red coloured. Hooker W. J. (1850) reported *I. pulcherrima* from Andaman Nicobar Islands. Beddome (1858) described 13 new species from Anamallay hills including one *Epiphyticae* species, *I. parasitica*. This plant was collected from trees at an elevation of 5000–6000 feet. A detailed key to the so far known species of *Impatiens* are also provided. Beddome (1874) provides the illustration and brief description of 14 species of *Impatiens*, including 2 species

belongs to section *Epiphyticae*. He considers epiphytic *Impatiens* as parasitic plants, hence the name *I. parasitica*.

Hooker made a breakthrough in the history of Indian *Impatiens*. Hooker and Thomson (1859) studied *Impatiens* in India. They divide the genus into two groups, Scapigerae and Caulescentes and seven sections on the basis of their habitat. Phyllotaxy is used as the major key character, along with type of inflorescence and seed characters. They identified 111 species, which includes 15 new species from this region. They provide a detailed enumeration of morphological variation and floral morphology of *Impatiens*. Dalzell and Gibson (1861) reported 14 taxa from Bombay, no *Epiphyticae* species was reported. Drury (1864) reported more than 50 species of *Impatiens* from India including 4 *Epiphyticae* species.

Hooker (1874) revised the classification proposed by Hooker and Thomson in the previous year. The new system was more elaborate, comprehensible and made identification of *Impatiens* easy. On the basis of capsule morphology and seed surface the entire genus is divided into two series. Series A comprises of peninsular species with short, ellipsoid capsule which is swollen at middle. Series B comprises of species found in Himalayas with elongate, linear capsule. Sections proposed in the earlier work were retained as such. Hooker reported 123 species from India. The section *Epiphyticae* includes 3 species which are, *I. parasitica*, *I. jerdoniae* and *I. viridiflora*. Their description and location also provided. A global level attempt to classify *Impatiens* was by Warburg and Reiche (1895). They proposed a new system of classification wherein the genus is divided into two groups Caulimpatiens and Acaulimpatiens, based on the position of leaves. Grey Willson (1980a) stated that, the classification provided by them was artificial.

Cooke (1901) reported 16 species of *Impatiens* and 6 varieties of *I. balsaminae*, including one new variety from presidency of Bombay. Hooker (1904, 1905, 1906) in his article "Epitome of the British Indian species of *Impatiens*" described 60 species of *Impatiens*. The section *Epiphyticae* includes 4 species. Hooker (1910a) described 12 new species from Western Peninsular India based on Meebolds' collection. In the same year he proposed many new species including, 6 new from Western Himalaya, one from Nepal (*I. coriosepala*), one from lower Burma (*I. lacei*), and 3 from Nilgiris and China. M.S Ramaswami (1912) reported 3 species from Tirunelveli district, based on the collections of D. Hooper.

Gamble (1915) reported 70 species of *Impatiens* from Madras presidency, including 4 *Epiphyticae* species. He considered *I. jerdoniae* as a variety of *I. parasitica*. Fyson (1915)

described 28 species from Nilgiris and Pulney hill tops, illustrations are also provided. Sedgwick (1919) reported a new species (*I. kleiniformis*) from Castle rock, Karnataka, which is closely allied to *I. kleinii*. Blatter (1933) published "Revision of the flora of the Bombay presidency- Balsaminaceae". According to him, Balsams are the most perplexing groups of the Indian flora. He reported 20 species from the region. Santhapu (1953) in his book "The flora of Khandala on the Western Ghats of India" observed that *I. kleinii* is most conspicuous soon after the beginning of monsoon season and *I. balsaminae* was common throughout the monsoon. He included five species of *Impatiens* in this book. Chandhrabose (1978) described a new species from Akamalai, Anamalai Coimbatore district, Tamilnadu. The species is named as *I. chandhrasekharanii* in honour of Dr. N. Chandhrasekharan Nair, Deputy Director, Botanical survey of India, Coimbatore.

Bhaskar and Razi (1978) presented a brief account on the *Impatiens* of peninsular India. They identified two new species and four new varieties. They collected *I. dendricola* from the type locality after 40 years. They also provide details about the pollen morphology, chromosome number, seed characters and anatomy. Bhaskar (1981) provides a description about the endemism of the genus *Impatiens* in South India. In this article the origin of *Impatiens* in South India, distribution of various species and reasons for endemism are discussed. The affinities of the South Indian *Impatiens* with Ceylon and North India is also discussed here. Bhaskar and Razi (1982) reported two new taxa of *Impatiens* from South India. *I. agumbeana* belongs to section *Scapigerae* and *I. raziana* belongs to section *Annuae*. Manilal and Sivarajan (1982) observed three species of *Impatiens*; *I. lucida*, *I. flaccid* and *I. balsaminae* from Kozhikode district.

Chandrabose *et al*., (1984) described a new species *I. konalarensis* from South India. The species was collected from Konalar, Anamalai hills, Coimbatore. The species was similar to *I. elegans*, still having marked differences. Manilal (1988) reported *I. jerdoniae* from Silent Valley National Park. This species was common in the tree trunks and moist rocks. Mohanan and Henry (1994) reported 14 species of *Impatiens* from different regions of Thiruvanthapuram. Pandurangan and Nair (1995) identified a new *Epiphyticae* species from Kulamavu, Idukki district. The species (*I. kulamvuensis*) was named after the type locality, Kulamvu.

Kumar and Sequiera (1996) described a new species *I. sivarajinii* from Silent valley national park, Palakkad, Kerala. Sasidharan and Sivarajan (1996) reported 8 species of

Impatiens from Thrissur district. They reported the presence *I. auriculata* from Thrissur district, but other literatures indicate that this species is strictly endemic to Agasthyamalai. Vivekandthan *et al*., (1997) described 53 species of *Impatiens* from India, in flora of India, including five *Epiphyticae* species of from Western Ghats.

Sasidharan (1999) reported the presence of 9 species of *Impatiens* from Chinnar Wildlife Sanctuary. They could observe *I. parasitica* from this location. This species was collected from Pothumala. Ravikumar *et al*., (2000) collected two, rare and endemic *Impatiens*, *I. dendricola* and *I. stocksii* from Talacauvery MPCA, Coorg District, Karnataka. Distribution status and detailed taxonomic account of the species based on fresh specimens are also provided.

Kumar and Sequiera (2002) reported 2 new *Epiphyticae Impatiens* from Southern Western Ghats, *I. violaceae* from Idamalakudi and *I. sholayarensis* from Sholayar forest ranges of Thrissur district. Mohanan and Sivadasan (2002) reported 13 species including one *Epiphyticae* species *I. auriculata*, from Agasthyamalai, Thriuvanathapuram. *I. auriculata* was collected from two locations, Athirumalai and Agasthyamalai peak. Sasidharan (2004) observed 120 species of *Impatiens* from various locations of Kerala. They could collect all the seven *Epiphyticae* species of *Impatiens* reported so far. Detailed enumerations of all these species are also included. Threat status and distribution records of these species are also available. Kumar *et al*., (2005) collected 11 species of *Impatiens* from Pathanmthitta district, Kerala.

Daniel *et al*., (2005) identified many species of *Impatiens* from Kerala. They could collect 6 *Epiphyticae* species of *Impatiens* from different localities. Colour images of these species are also available. Bhaskar (2006) reported a new epiphytic scapigerous species *I. clavata* from Bisle Ghat, Karnataka. Dessai, J. R. N. and Janarthanam, M. K. (2008) provide a brief account on taxonomy and distribution of *I. talbotii* Hook. F. distributed in Goa and Karnataka of the Western Ghats. An elaborative historical account, a detailed description, distribution and illustrations are also provided.

Raju (2009) studied about the reproductive biology of three endangered species *I. coelotropis* Fischer, *I. phoenicea* Bedd. and *I. platyadena* Fischer. All of these species are endemic to Western Ghats. It is the first comprehensive study which deals with phenology, floral biology, pollination biology, pollen-pistil interaction, breeding systems, seed germination, and seedling establishment of *Impatiens* species. The candidate species for this

study show limited distribution in the wild, according to the author this is because of habitat loss, narrow environmental niche, fragmentation of populations, poor fruit set, incompatibility, low percentage of seed germination, disease and pest infestation.

Dessai and Janarthanam (2011) studied the taxonomy of *Impatiens* distributed in the Northern and Central Western Ghats. They collected 28 species of *Impatiens* from the study area; they elevated *I. balsamina* L. var. *rosea* Hook. F. to species level and five different taxa have been synonymised. Based on the phytogeographic studies most of the studied species are found to be narrow endemics. The phylogenetic tree prepared supports the infrageneric classification proposed by Hooker and Thomson (1859) and Warburg and Reiche (1895). This study was a comprehensive account of the genus *Impatiens* found in Northern and Central Western Ghats.

Kallappa (2015) studied the reproductive dynamics of *I. gardneriana*, *I. grandis* and *I. verticillata*, three endemic species found in Western Ghats. Insight about the distribution, phenology, floral biology, pollination biology, pollen-pistil interaction, breeding systems, seed germination, seedling establishment etc. is available from this study. Raju *et al*., (2015) newly described a species from Tamil Nadu, *I. courtallensis*. This species is characterized by typical opposite deccusate leaves, minute flower (≤4mm across), milky white, boat shaped lower sepal with outwardly curved tip, minute spur, seeds with prominent caruncle and typical squarish pollen grains. Raju and Pandurangan (2015) rediscovered *I. munnarensis* Barnes which is endemic to Idukki district of Kerala. It was rediscovered from a new locality Megamalai hills, Tamil Nadu, India after 78 years.

Raju *et al*., (2015) described a new species *I. matthewiana*, from Western Ghats. This species belongs to section *Scapigera* and allied to *I. scapiflora* and *I. pseudo-acualis*. Tarun *et al*., (2016) identified 3 new species of *Impatiens* from Mukuruthi National Park, Tamil Nadu. These species are inhibiting at an altitude higher than 2000m. *I. taihmushkulini* is classified as endangered species. Prabukumar *et al*., (2016) reported another new species from Muthikulam forest region of Palakkad district and is named as *I. glaberata*, due to its glabrous nature.

Bhaskar and Sreerangeswara (2017) reported two new species *I. kotebettii* and *I. madapurae* from Kotebetta, Bramhagiri Mountains in the Western Ghats. Both the species belongs to section *Annuae* and are named after its type locality. Joe *et al*., (2017) rediscovered *I. rufescens* var. *agastyamalayensis* was described based on herbarium specimen of C. A. Barber collected in 1901 from Agastyamala. After conducting a close examination of fresh

specimens collected from the type locality, they elevate the status of this variety into species. Mani and Thomas (2017) reported a new species *I. brittoi* from Adimali, Idukki district. This species is morphologically allied to *I. herbicola*. Based on the IUCN threat criteria, it is an endangered species.

Manudev *et al*., (2017) described a new taxa *I. stolonifera*, from southern part of Western Ghats, which belongs to section *Scapigera*. Prabhukumar *et al*., (2017) reported two new species from Idukki district. *I. mankulamensis* was obtained from Mankulam forest and is named after the type locality. *I. panduranganii* was collected from Pettymudi and is named in honour of Dr. A. G. Pandurangan, Scientist F and former Head PS and ES Division, JNTBGRI, Thiruvananthapuram.

Mani *et al*., (2018) identified two new species of *Impatiens* from Western Ghats. *I. saulieria* is collected from Kakkyam and *I. josephia* is collected from Idukki. Chinnaiyan *et al*., (2018) reported *I. pendula* from Tamil Nadu, which was earlier known from the Western Ghats of Karnataka and Kerala. Bhaskar and Sreerangeswara (2018) reported a new species *I. bhimgadensis* from Karnataka. This species belongs to section *Annuae* and is morphologically similar to *I. rupicola* Hook. F. and *I. ramosissima* Dalzell.

Salish *et al*., (2019) reported a new species, *I. eravikulamensis* from Eravikulam National Park and named after the type locality Eravikulam. This species was collected from Meghamalai hills and is closely allied to *I. inconspicua* and *I. meghamalayana*. Arigela *et al*., (2019) identified a new species *I. tanyae*, from Kodaikanal Wildlife Sanctuary in Western Ghats area of Tamil Nadu.

Mani *et al*., (2020) identified a new species, *I. periyarensis* from Western Ghats. The habitat of this species is dripping rocks in semi evergreen forests of Idukki districts. Along with this new species they rediscovered *I. aliciae* after its type collection by Barnes in 1933. Raju *et al*., (2020a) reported a new species *I. dindigulensis* from Kodaikanal Wildlife Sanctuary. Raju *et al*., (2020b) reported two new species from Western Ghats region of Tamil Nadu. *I. palniensis* collected from Palani hills (Kodaikkanal Wildlife Sanctuary) and *I. tamilnadense* from Meghamalai Wildlife Sanctuary. Raju and Kamalabhai (2020c) reinstated the species status of *I. hookeriana*. In the past literature this species was treated as heterotypic synonym of *I. grandis*. A detailed comparison chart to distinguish both the species in the field is also provided. Mohan *et al*., (2020) identified two new scapigerous *Impatiens* from Idukki district. *I. nidholapathra* is allied to *I. tirunelvelica* from which it differs by its membranous and silky

lanuginose leaves and *I. grandispora* is allied to *I. stolonifera* from which it differs by its purplish white flowers with red patches of papillae near the centre and considerably larger pollen grains. Arya *et al*., (2021) identified three new species *I. achudanandanii*, *I. danii*, and *I. shailajae* from Southern Western Ghats, Kerala. Richard *et al*., (2021) reported a new species from Southern Western Ghats, eastern slopes of Agasthyamalai Biosphere Reserve. Karuppusamy *et al*., (2021) rediscovered *I. viridiflora*, one of the epiphytic species from Meghamalai wild life sanctuary 185 years after the type collection. They could locate the plant populations in two different locations other than the type locality.

Tharani *et al*., (2021) rediscovered *I. laticornis* from Mukuruthi National Park 92 years after the type collection. Mohan *et al*., (2021) reported a new species *I. raktakesara* from Western Ghat regions oh Idukki district. This species is characterized by the presence of uniseriate monoliform trichomes on the upper surface of the leaf and red coloured anthers. This species is assessed as endangered one according to the criterions of IUCN red list. Jeevith *et al*., (2022) prepared a checklist of *Impatiens* found in Nilgiris and Palani Hills of southern Western Ghats. 36 species are identified from the study area including 6 species endemic to Western Ghats and 26 species endemic to southern Western Ghats. Saravanan and Kaliamoorthy (2022) described two new epiphytic species *I. keralensis* and *I. kurichiarmalayana* from Wayanad district, Kerala, India. Biju *et al*., (2022) described a new species *I. thulunadensis* from Kasargod district. This species found in wetlands and allied to *I. kodachadriensis*. Arigela and Ahamed Kabeer (2022) synonymized *I. dindigulensis* Ramasubu and Anjana Chandran, *I. eravikulamensis* Hareesh and Salish, *I. ramasubbuana* Kottaim and P. Murugan and *I. thulunadensis* Sindhu Arya, P. Biju and V.S.A. Kumar with *I. tomentosa* B. Heyne ex Wight and Arnot. They also provide amended descriptions for *I. tomentosa*, *I. pallidiflora* and *I. tanyae*.

2.2 Anatomy of *Impatiens*

Anatomical characters of vegetative organs can be considered as a supportive data in taxonomic research. It can be used for preliminary identification of taxa from herbarium materials. Distinct difference in anatomical characters can be observed in different species of the same family. In the case of family Balsaminaceae little attention was given to the anatomy of vegetative parts so far. McClatchie (1917) studied the anatomy of root system of *I. royalei*, a species which have Indian origin. The appearances of adventitious roots are observed in the early stages itself. Secondary roots are also formed from the thick lateral branches. Bexon and Wood (1930) examined the anatomy of polycotylous seedlings of *I. royalei*. The seedlings

examined show hemitricotyls, tricotyls and amphitrisyncotyls condition. Some of the seedlings with hemitricotyls show tetrarch symmetry just like normal seedlings, whereas some of the seedlings show pentarch condition. Meyer and Walker (1931) observed the vegetative anatomy of *I. pallida*. Anatomy of seedlings, mature root, stem and leaf is provided along with photographs. The nodes are eight ranked and arranged in three spirals. Paranchymatous cells consist of calcium oxalate crystals.

Narayanan (1974) examined the floral morphology of *H. triflora*, *I. leschenaultia*, *I. arguita* and *I. levingei*. The genus *Impatiens* consists of basic pentamerous plan but due to the adnation of floral parts it become tetramerous. The haplostemonous condition of anthers is due to the suppression of the antipetalous staminal whorl. Elias and Gelbandn (1977) studied the anatomy and morphology of extrafloral nectaries and hydathodes, of two Himalayan species of *Impatiens*; *I. scabrida* and *I. balfourii*. In both the species nectaries are found in the stipular position and large raphide bearing idioblast are present at the centre of each nectaries. Hydathodes occur on all leaf teeth distal to those bearing nectaries, they are vascularized with xylem element. Structures intermediate between nectaries and hydathodes are present in *I. balfourii* but not in *I. scabrida*.

Grey Wilson (1980b) made some observations on the floral vascular anatomy of *Impatiens*. According to him, the *Impatiens* flower is a structure based on 5 sepals, 5 petals, 5 stamens and a 5-locular ovary. In most species one lateral sepal is absent and is represented by a rudimentary trace. Lateral petals are not free but united to form lateral united petals. The vascular strands of lateral united petals show the independent origin of two petals. Rama Devi (1991) examined the six species of *Impatiens* vis *I. balsamina* L., *I. bicolor* Hook. F., *I. fimbriata* Hook., *I. holstii* Engler et Warb. Ex Engler, *I. radicans* Benth. and *I. ureceolata* Basker. This study suggests that anterior perianth is formed by the adnation between anterolateral sepals and anterior petal. They strongly support the placement of Balsaminaceae in the order Geraniales.

Lens *et al*., (2005) investigated the wood anatomy 31 species of plants belonging to different families (Balsaminaceae, Marcgraviaceae, Pellicieraceae, and Tetrameristaceae) of Balsaminoidericales clade. The members of Balsaminaceae family differ from other members of Balsaminoidericales clade because of secondary wood. Due to this peculiar character, it is difficult to compare the systematic position of Balsaminaceae family with other families of this clade. Caris *et al*., (2006) studied the floral development of three commonly cultivated species

of *Impatiens*; *I. columbaria*, *I. hawkeri*, and *I. niamniamensis*. The position and developmental patterns of different floral whorls are studied using scanning electron microscope. According to them in majority of the species the anteriolateral sepals become reduced and a morphocline is observed in species with five sepals over species with rudimentary sepals that fuse postgenitally with the anterior petal, to species where congenital fusion between these sepals and the anterior petal has taken place.

Kilmko *et al.*, (2009) evaluated how habitat conditions influence the anatomical structures of *I. parviflora*. Light is the major factor that is responsible for anatomical variations. Plants collected from the anthropogenic locality, shows the typical characteristics of heliophilous plants. These plants have thick layer of sclerenchymatous cells. Plants growing in shaded regions have lesser strengthening tissues. Markov and Yusufova (2013) studied the initial stages of root system development in three species of *Impatiens*, *I. nolitangere*, *I. parviflora* and *I. glandulifera*. Rahman *et al*., (2016) examined the variation in foliar epidermis, stomata and trichomes of 10 species and 2 sub species of *Impatiens* from Pakistan. They also constructed a taxonomic key using this observation. Stomata are exclusively anomocytic in all Pakistani species.

2.3 Morphology of seed and palynology

Gavit (1990) provided a brief description on the seed morphology of two species of *Impatiens*, *I. balsamina* and *I. kleinii* from Gujarat. Song *et al*., (2005) studied the seed coat morphology 38 species of *Impatiens* from China. Based on the images obtained after SEM, the studied species can be classified into four morphological types, laevigate, granulate, reticulate and protrusive. These morphological types are further divided into several sub types. Laveigate type of seed can be seen only in *I. chinensis* and granulate type in *I. balsamina*. Reticulate seed coat was the most common and is found in 18 species out of the 38. All of these 18 species are found the basal position on the molecular phylogenetic tree. So, this character can be considered as an ancestral character.

Utami and Shimizu (2005) studied the seed coat morphology of 65 species of *Impatiens* around the world. The seed coat morphology is an important character; still this cannot be used as universal key character. The seeds are exarillate, exalbuminous and exotesta may contain papilla or hair. Wei *et al*., (2007) examined the seed coat morphology of 14 species of *Impatiens* using Scanning Electron Microscopy. They also observed the seed types reported by Song *et*

al., In their opinion seed morphology is a character that can be used for species level identification.

Abid *et al*., (2011) provided a detailed description on seed morphology of *Impatiens* found in Pakistan. According to them seed characters co related with other morphological characters can be used for identification at species level. Seeds of Pakistani species are either elliptic or ovate, and the surface is granulated except *I. glandulifera*. The colour of the seed is brown or variant of brown. Janssens *et al*., (2012) carried out a detailed study to infer the evolutionary history of Asian *Impatiens* using palynological evidences. The pollen grains of 115 species were studied using SEM and light microscopy. Pollen grains having triangular shape, three aperture and reticulate ornamentation is considered as the ancestral type and rectangular pollen having four apertures with reticulate ornamentation evolved later as the main type. Generally, pollen grains of Asian *Impatiens* are medium sized. Maciejewska and Janczak (2016) investigated the range of morphological variability of seeds of *I. glandulifera* collected from different locations of Poland. The seed coat is rugosely ruminate type and there is a co relation between morphological variability of seeds and type of vegetation from which they originated.

The study of Rewicz (2020) provided authentic data on the seed coat micromorphology of nine species of *Impatiens* from North East India. They could distinguish three morphological groups based on the epidermal cells of the seed, reticulate, protrusive, and granulate (represented by one taxon). In reticulate type the epidermal cells comprise of reticulations of varied shape and size, in protrusive type protrusions of various size and shape are present, and in granulate type evenly covered granulate protrusions are present. The seed shape and ornamentation of *I. sulcata* and *I. drepanophora* were different from the previous records, this suggests the high degree of phenotypic plasticity exhibited by these plants. Pechimuthu *et al*., (2020) examined the pollen grains of 18 species of *Impatiens* collected from Nilgiris, Tamil Nadu. All the species under study have monad type pollen grain. The following species viz *I. fruticosa, I. clavicornu, I. levingei, I. latifolia* and *I. rufescens* have heteropolar pollen grains and others have isopolar pollen grains. All the species studied possess reticulate exine ornamentation except *I. fruticosa*.

Pavlova and Glogov (2021) studied the pollen morphology of invasive and native species of *Impatiens* viz, *I. glandulifera*, *I. balfourii* and *I. noli-tangere* from Bulgeria. The pollen grains of *I. balfourii* are 5-zonocolpate, *I. glandulifera* and *I. noli-tangere* are 4 zonocolpate with similar pollen morphology. In order to favour the invasive capacity of *I. glandulifera*, pollen heteromorphism is visible. Song *et al*., (2022) examined 117 species of

Impatiens around the world. The seed coat morphology can be considered as a taxonomically important character. These characters are useful for evolutionary and ecological studies. Seed coat ornamentations are possible adaptation of the plant to the environment.

2.4 Ecological niche modelling of *Impatiens*

Mandle *et al*., (2010) studied the difference in climatic niches of native and introduced populations of *I. walleriana*. This species is native to tropical east Africa and introduced in North and South America, the Pacific Islands, Australia, and New Zealand due to its horticultural value. The study revealed that *I. walleriana* showed a broader climatic range, being found in areas far wetter than the native range. Models are developed for both native and introduced ranges. When models of each range area were used to predict the other range, predicted patterns of potential occurrence were similar. Yao *et al*., (2018) developed a model to study the distribution of potential suitable habitat of *I. hainanensis*. This attempt provides information useful for the in-situ conservation and reintroduction of this endemic *Impatiens*. The environmental factors that influence the distribution of *I. hainanensis* are Slope, precipitation of the driest quarter and coefficients of precipitation variation. Prasad G. (2019) studied the population of three endemic species of *Impatiens* (*I. johnii, I. platydena* and *I. coelotropis*) in Idukki district. The population assessment, spatial distribution mapping was done using GPS and GIS. Their model predicted that, Doddabetta, Ooty, Naduvettam, Walakkad peaks in Silent valley, Chembra, Banasuramala, Palani hills, Peaks of Agasthyamala and Shendurunii WLS and Periyar are the suitable areas for conservation activities of these species.

Rewicz *et al*., (2022) carried out the first attempt to study the present and future distribution of *I. capensis* (orange balsam) under various climate change scenarios. The model created by them for the present time, showed slightly broader potential geographical ranges of both native and invasive populations. The species is found settled far outside the modelled climate niche, in some areas. This indicates the greater potential adaptation of *I. capensis*. The model developed for future climate scenarios shows that the suitable niche in America will extend due to climate change and in Europe a habitat loss of 31–95% will also occur.

Efforts to study the ecological niche of *Impatiens* in Western Ghats were not carried out yet. So ecological niche modelling done for some other endemic species in Western Ghats are mentioned here Pownitha *et al*., (2022) investigated the distribution of two medicinally important liana species, *Coscinium fenestratum* and *Embelica ribes*. Both this species are

endemic to Western Ghats and their distribution is highly affected by climate change. Suitable areas for the cultivation of these species are predicted using maximum entropy model for both current and future scenarios. Palkar *et al*., (2020) predicted the potential distribution areas of the endemic species *Garcinia indica*. The major climatic factor influencing the distribution of this species is temperature and precipitation. Most suitable habitat for is Konkan regions of Maharashtra, Goa and Karnataka.

Jalal and Singh (2017) predicted the areas suitable for the in-situ conservation of the endemic species *Habenaria suaveolens* using maximum entropy approach. Sumangala *et al*., (2017) investigated the distribution of *Saraca asoca* in the present and future climate scenarios. Maximum entropy model was used for the model building. The variables that contribute maximum to the model building were annual precipitation (Bioclim 12) and precipitation in the driest quarter (Bioclim 17). Sen *et al*., (2016) predicted potential distribution of *Piper nigrum* in the present and two future climate change scenarios viz (A1B) and (A2A) for the year 2080. The niche model was developed using three topographic and nine uncorrelated bioclim variables. A reduction in the suitable habitat of *P. nigrum* was predicted by the mode

3.1 Systematic treatment

3.1.1 Literature Survey

Information related to the present study and all the relevant literature were collected from different sources like articles and papers published in various scientific correspondences and books available in libraries and information retrieval system. Different electronic reference systems including database of Indian dissertations and Ph.D. Thesis repository Elsevier, JSTOR, Science Direct, Shodhganga, Springer link, UGC-JCC-infonet database, Wiley etc. are also used. The literature retrieval system such as Biodiversity heritage library of New York Botanic Garden (https://www.biodiversitylibrary.org), online Periodicals repository of NISCAIR (http://nopr.niscair.res.in), Botanical literature from the Missouri Botanical Garden Library (http://botanicus.org), International Plant Name Index (www.ipni.org), Plants of the world (http://www.plantsoftheworldonline.org), and World Checklist of Selected Plant Families (http://wcsp.science.kew.org), were also utilized.

Various herbaria consulted to examine the available specimens. Following are the list of herbaria and their details (Table 1). The acronyms of herbaria are in accordance to Index Herbariorum (Thiers, 2016).

Table 1: List of herbaria consulted

E	Herbarium, Royal Botanic Garden, Edinburgh
CMPR	Herbarium, Center for Medicinal Plant Research, Kerala, India
K	Herbarium, Royal Botanic Gardens, Kew, England, UK
KFRI	Herbarium, Division of Botany, Kerala Forest Research Institute, Peechi, India
MH	The Madras Herbarium, Botanical Survey of India, Southern Regional Centre
BM	National History Museum, London, England
STC	Herbarium, St. Thomas college (Autonomous), Thrissur

3.1.2 Collection of specimens

Extensive and intensive field trips were conducted for collecting fresh specimens of Impatiens during period 2018–2021. Various forest ranges of Southern Western Ghats throughout Kerala and Tamil Nadu were visited during monsoon and post monsoon season.

The photographs of plant including habit, habitat and morphology were taken using canon digital camera from the field itself. Field data such as habit, habitat, height of the plant, color of various parts was noted in the field notebook. All other relevant information like host tree, other association etc. are also noted. The whole plants were preserved in Formalin-Acetic Acid-Alcohol (FAA) for the preparation of herbarium. For anatomical studies, stem and leaves are wet preserved in FAA and pollen grains are wet preserved in 100% alcohol for palynological studies. Mature seeds are stored in labelled vessels for morphological studies.

3.1.3 Herbarium Preparation

The collected specimens where examined and entire plant having all the vegetative and reproductive parts were treated with formaldehyde and sealed in polythene covers. Herbaria were prepared as per the standard herbarium techniques (Fosberg and Sachet, 1965 and Jain and Rao, 1977). The specimens where dried in oven and were mounted on standard handmade sheets (28 × 42 cm). The sheets were labelled with standard labels (14.5 × 11 cm) and are deposited in CMPR and STC.

3.1.4 Morphological studies

Five specimens were selected from the collected plants and were examined critically for morphological studies. Detailed examinations of floral parts are done using Leica S8APO stereo microscope. Dried specimens are soaked in water for 1–2 hours and boiled before examination. Photographs are taken using Leica S8APO stereo microscope and measurements of floral parts are also taken. The flowers of *Impatiens* consist of a pair of lateral sepals, lower sepal modified into a spur, a hooded dorsal petal and a pair of lateral united petals. Androecium is sygenecious and gynoecium pentacarplary, syncarpous,

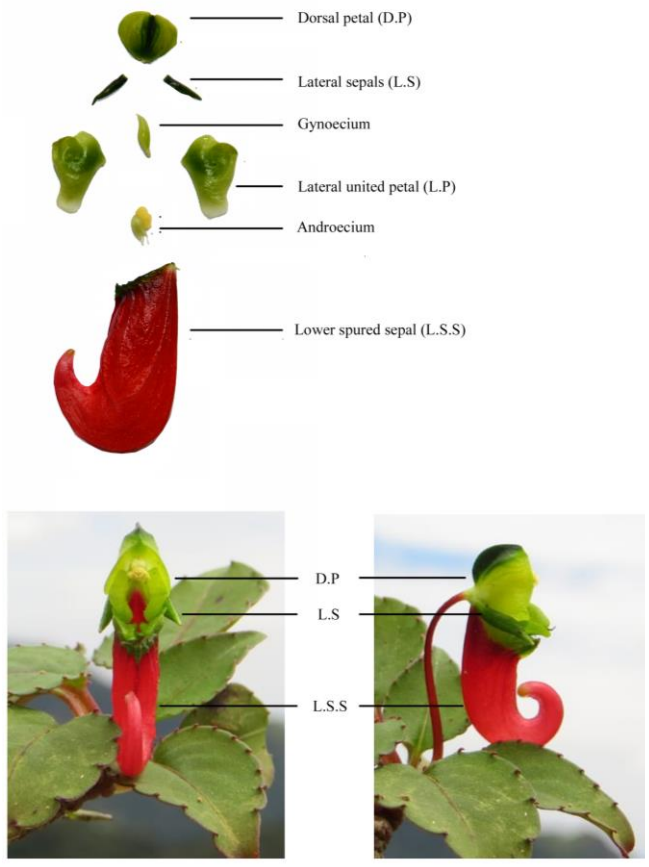

Figure 1: Different floral parts of *Epiphyticae Impatiens*

unilocular and superior (Figure 1). The examined specimens were identified using articles, Floras, Monographs, Revisions, publications, etc. In addition, the identified specimens were confirmed by comparing with protologue.

3.2 Anatomy of stem and leaf

Freshly collected specimens and preserved specimens were used for anatomical studies. Matured leaf just below the inflorescence was taken for the study. Epidermal peels were taken using scalpel. Matured stem was chosen to study the stem anatomy. Free hand sections are taken using double sided razor and the sections are stained with safranin. Stained sections where mounted on glass slide using glycerine and viewed under Labomed compound microscope. Photographs of the sections are taken using Micaps digital camera with 5x to 100x magnification. Measurements of different parts were taken using Image J software. Stomatal index was calculated using the average value taken from 10 readings from the surface of lamina. Salisbury's (1927) formula was used to calculate the stomatal index.

$$\text{Stomatal index} = \frac{\text{Number of stomata}}{\text{Number of stomata} + \text{Number of epidermal cells}} \text{X } 100$$

3.3 Palynology and seed morphology

The pollen grains preserved in 100% alcohol was used for palynological studies. Preserved pollen grains were washed with 70% alcohol and centrifuged at 5000 RPM for 15 minutes. The sediments were collected after removing the supernatant and it is treated with hexane for 10–15 minutes to remove the chemical coating. SEM images were taken after chemical treatment.

Seeds were collected from matured pods of fresh specimens, which are kept in labelled bottles. The sizes of the seeds are measured using Leica S8APO stereo microscope. A total of 10–15 seeds from single plant where measured and the average was taken. SEM images of the seed were taken to study seed coat morphology in detail.

For SEM analysis both seeds and pollens were placed on aluminium stubs using double sided adhesive tape. Then the specimens are sputter coated with gold particle using a Hummer VII gold coating apparatus. They were observed and photographed under JEOL Model JSM-6390LV SEM and Gemini SEM 300 with different magnifications.

3.4 Prediction of Potential geographical distribution

3.4.1 Species occurrence data and Environmental Variables

Distribution data of species under was obtained from both primary and secondary sources. Non-overlapping occurrence points were collected from the field during 2018–2021.Some of the occurrence points were obtained by retrieving data and information from the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org).

Environmental variables used for the study were obtained from the WorldClim dataset (www.worldclim.org). Nineteen bioclimatic variables (Hijmans *et al*., 2005) with a spatial resolution of 30 seconds where downloaded. Topographic variables such as slope, elevation, aspect, and terrain ruggedness index (TRI) where generated using the Digital Terrain Model (DTM) of Shuttle Radar Topographic Mission (SRTM) with 90 m resolution. These were computed with the help of the QGIS algorithm and DTM images were downloaded from the www.srtm.usgs.gov website. A total of 23 predictor variables were used for the model building (Table 2). Multi co-linearity among the variables was checked by calculating Pearson's correlation (r) and the variables having a coefficient value of >±0.7 were highly correlated and hence excluded.

Table 2: Predictor variables used in model building

Code	Environmental variable
Bio 1	Annual mean temperature
Bio 2	Mean diurnal range (mean of monthly max. and min. temp.)
Bio 3	Isothermality ((Bio2/Bio7) × 100)
Bio 4	Temperature seasonality (standard deviation × 100)
Bio 5	Maximum temperature of warmest month
Bio 6	Minimum temperature of coldest month
Bio 7	Temperature annual range (Bio5-Bio6)
Bio 8	Mean temperature of wettest quarter
Bio 9	Mean temperature of driest quarter
Bio 10	Mean temperature of warmest quarter
Bio 11	Mean temperature of coldest quarter
Bio 12	Annual precipitation
Bio 13	Precipitation of wettest period

Bio 14	Precipitation of driest period
Bio 15	Precipitation seasonality (CV)
Bio 16	Precipitation of wettest quarter
Bio 17	Precipitation of driest quarter
Bio 18	Precipitation of warmest quarter
Bio 19	Precipitation of coldest quarter
TRI	Terrain ruggedness
Aspect	Aspect
Slope	Slope
Elevation	Elevation

3.4.2 Prediction of potential geographical distribution

Maximum Entropy Modelling implemented in the software MaxEnt was used to predict the potential distribution. It predicts the environmental niche of a species by finding a probability distribution of a species occurrence that is based on a distribution of maximum entropy (regarding a set of environmental variables) (Philips *et al*., 2006). This model works well, even with a small number of occurrence points. The number of iterations used is 500 with a convergence threshold of 0.00001 and a maximum of 10,000 background points, algorithm parameters were set to auto features (Phillips and Dudik, 2008) and all other parameters were set at default settings. To evaluate the model's goodness-of-fit, Area Under the receiver operating characteristic curve (AUC) was used. The value of AUC ranges from 0 to 1 and based on this value models are classified into 5 groups: Excellent (0.9), Good (0.8≤0.9), Bad (0.6≤0.7), Invalid (0.5≤0.6) (Haffman *et al*., 2008). To compute the percentage of variable importance, Jackknife procedure was used.

4.1 Systematic treatment

Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliopsida
Order	Ericales
Family	Balsaminaceae
Genus	*Impatiens*

***Impatiens* L.**

Sp. Pl., 2: 937. 1753; DC. Prodr., 1: 687. 1824; Roxb., Fl. Indica, 2: 452. 1824; Wight and Arnot, Prodr. Fl. Ind. Orient., 135. 1834; Hooker and Thomson in J. Proc. Linn. Soc. Bot., 4: 118. 1859; Dalzell and Gibson, Bombay Fl., 42. 1861; Hooker, Fl. Brit. India, 1: 440. 1874; Cooke, Fl. Bombay, 1: 168. 1901; Gamble, Fl. Madras, 1: 134. 1915; Manilal and Sivarajan, Fl. Calicut, 56. 1982; Manilal, Fl. Silent valley, 39. 1980; Vajaravelu, Fl. Palaghat, 99. 1990; Mohanan and Henry, Fl. Thiruvanthapuram, 97. 1994; Subramanian, Fl. Thenmala, 50. 1995; Sasidharan and Sivarajan Flo. Pla. Thrissur Dis., 77. 1996; Vivekananthan *et al*., in Hajra *et al*., Fl. India, 4: 99. 1997; Sasidharan, Study. Fl. Chinnar wil. San., 51. 1999; Sivarajan and Mathew, Fl of Nilambur, 116. 1999; Yoganarasimhan, Med. Pla. India, 284. 2000; Mohanan and Sivadasan, Fl. Agasthyamalai, 128. 2002; Anil Kumar *et al*., Fl. Pathanmthitta, 95. 2005; Daniel Fl. Kerala, 1(2). 532. 2005; Sunil and Sivadasan, Fl. Alappuzha, 78. 2009

Annual or perennial caulescent or acaulescent herbs, sub shrubs, terrestrial or epiphytic. Rarely tubers or rootstock present. Stem branched or unbranched, translucent, flaccid, succulent, rarely monoliform, woody at base, persistent leaf scares in some case, quadrangular to terete, glabrous to tomentose. Leaves simple, alternate, opposite, whorled, or radical; palmately lobed in *I. chandrashekharani*. Exstipulate, petiolate to sessile, petiole terete to channelled, glabrous to hairy, with glands at base. Lamina ovate to linear; cuneate to cordate at base; crenate to serrate along the margin, with bristles in some cases; acute to obtuse at tip; pinnately veined, glabrous to hairy on both surface; light green to yellowish green. Inflorescence solitary, racemes, umbel or fascicle; bracteates; pedicel long to short; hairy to glabrous. Flowers complete bisexual, zygomorphic, resupinate through 1800, attractive. Sepals 3; 5 in rare cases; lateral sepals small linear to oblanceolate, large and attractive in rare cases; glabrous to tomentose, green to purple; lower sepal small to large, funnel shaped or saccate;

spurred in most cases, spur elongated, narrow, straight or curved, coiled, clavate, hooked, thick, cylindrical; brightly coloured, glabrous. Petals 3 to 5; dorsal petal, small to large, keeled or crested, hooded or flat, mucronate in rare cases, orbicular to obcordate, brightly coloured, glabrous to tomentose. Lateral petals united to form single unit in some cases, inserted into spur rarely, variously lobed or without lobs, short to long dorsal auricle or auricle absent. Stamens 5 syngenesious, filiform to broad, free at base and united at tip; anthers 5. Ovary superior, with axile placentation, ovules 1 to many, style rudimentary or absent, stigma 5 toothed. Fruit loculicidal capsule, explosive mechanism to expel the seeds, valves open and incurve to release seeds. Seeds exalbuminous, smooth, warty or hairy; yellow to black.

Section *Epiphyticae*

Wight and Arnott, Prodr. Fl. Ind. Orient., 135. 1834; Hooker and Thomson in J. Proc. Linn. Soc. Bot., 4: 118. 1859; Dalzell and Gibson, Bombay Fl., 42. 1861; Hooker, Fl. Brit. India, 1: 440. 1874; Cooke, Fl. Bombay, 1: 168. 1901; Gamble, Fl. Madras, 1: 134. 1915; Manilal, Fl. Silent valley, 39. 1980; Mohanan and Henry, Fl. Thiruvanthapuram, 97. 1994; Sasidharan and Sivarajan Flo. Pla. Thrissur Dis., 77. 1996; Vivekananthan *et al*., in Hajra *et al*., Fl. India, 4: 99. 1997; Sasidharan, Study. Fl. Chinnar wil. San., 51. 1999; Mohanan and Sivadasan, Fl. Agasthyamalai, 128. 2002; Daniel Fl. Kerala, 1(2). 532. 2005

Perennial epiphytic herbs. Stem unbranched, monoliform, succulent with persistent leaf scare and woody at the base in some case. Leaf entire, ovate to lanceolate, base cuneate to obtuse, margins crenate with bristles on each crenation, acute to acuminate at apex, glabrous on both surface, 2 to 3 pairs of glands at base. Petiole long, translucent, channelled, glabrous, green to violet. Inflorescence panicle 2 flowered or 3–7 flowered, pedicle short to long, terete, translucent, glabrous, green to violet. Flowers complete, bisexual, zygomorphic thick and fleshy. Sepals 3, lateral sepals 2 small to large lanceolate to linear, thick, green to red. Lower sepals spured, large, laterally compressed or saccate, hook like projection at the opening, tip curved and blunt, brightly coloured, prominent markings on either side. Petals 3, dorsal petal hooded, thick, keeled, with nerves, yellow to green; lateral united petals 2, bilobed, basal lobe inserted in the spur, distal lobe projecting out of the spur, auricles absent. Stamens 5 syngenesious, filiform to broad, free at base and united at tip; anthers 5. Ovary superior, pentacarpellary, with axile placentation, ovules 1 to many, style rudimentary or absent, stigma 5 toothed. Fruit loculicidal capsule, Seeds exalbuminous, yellow to brown, with spirally coiled hair.

Key to the section *Epiphyticae*

1a. Inflorescence have more than 2 flowers, epiphytes ……..…….……..**2**

1b. Inflorescence have only 2 flowers, epiphytes……..……..……**3**

2a. Flowers (including spur, pedicel and petiole) violet, plant less than 10 cm, stem monoliform…….…….…….....***I. violaceae***

2b. Flowers other than violet, plant more than 25 cm long, stem not monoliform…….....***Impatiens* sp.1**

3a. Spur inflated or saccate, tip elongated dorsal petal yellow .....…. ***I. jerdoniae***

3b. Spur not inflated, laterally compressed, dorsal petal green……**4**

4a. Lateral sepals red, larger, obliquely ovate or oblong, much exceeding the spur…….....…… ***I. auriculata***

4b. Lateral sepals not red, smaller, linear-lanceolate or linear-ovate, acute to acuminate……...…...……**5**

5a. Distal lobe of lateral united petal is red, spur crimson red till the middle and yellowish white up to the tip……..…….....….....…..***I. viridiflora***

5b. Distal lobe of lateral united petal is other than red…….**6**

6a. Pedicel is red in colour, spur red, laterally compressed…….....….***I. parasitica***

6b. Pedicel is green, spur yellow till middle and red up to the tip……...…….....***I. sholayarensis***

1. ***Impatiens auriculata* Wight, Madras J. Lit. Sci. Ser. I, v. (1837) 8. Wight**, Madras J. Lit. Sci. ser. 1, 5: 8. t. 3. 1837; Hook. f., Fl. Brit. India, 1: 460. 1874; Gamble, Fl. Pres. Madras, 139 (99). 1915; Antony, Syst. Stud. Fl. Kottayam Dist., 90. 1989; M. Mohanan and Henry, Fl. Thiruvanthapuram, 97. 1994; Sasidh. and Sivar., Fl. Pl. Thrissur, For. 77. 1996; Vivek. *et al*., in Hajra *et al*., Fl. India, 4:121.1997; Muktesh, Epiphytic Fl. Western Ghats, 59. 1998; Gopalan and Henry, Endemic Pl. Agasthiyamalai, 267. 2000; Mohanan and Sivad., Fl. Agasthyamalai, 130. 2002; N. C. Rathakr. *et al*., in P. Daniel, Fl. Kerala, 1: 532. 2005 **(Figure 2)**

Type:—INDIA. Tamil Nadu: Tirunelveli district, Courtallum, September 1835, Wight 168; lectotype E00174019!; Isolectotypes E00174020!, E00174021! and K000694881!

Succulent epiphytes stem short, prostrate, swollen at internodes, 6–20 cm high, glabrous. Leaves alternate, fascicled at ends of branches, ovate-elliptic, obscurely crenulate with a few glands at base, obtuse or acute at apex, 3–10 × 1.5–6 cm, veins conspicuous, 4–6 lateral nerves, convergent, adaxial green, pale at abaxial, glabrous; petioles 1–5 cm long, light green, glabrous, stout. Pedicels 2–4 cm long, green, red at tip, glabrous; bracts ovate, red. Flowers axillary, zygomorphic, bisexual, complete, hypogynous, 1 or 2 in a cluster, scarlet red; peduncle about 2–4 cm long, green, glabrous. Lateral sepals much larger, obliquely ovate or oblong, much exceeding the spur, 1–1.2 cm long, red; Lower sepal spurred, 1–1.5 cm, thick, short, saccate, laterally compressed, furnished with 3–4 wrinkled thick markings, curved at apex, red at tip and light green at base; standard petal 0.8–0.9 × 1–1.2 cm, orbicular, crowned, prominently nerved, nerves light yellow, glabrous; keeled, keel 0.7–0.8 × 0.14–0.16 cm, yellowish green. Lateral united petal bilobed, inserted into the spur, distal lobe 0.5–0.8 cm spreading out of the spur, prominent yellow nerves, brownish red; basal lobe 0.5 × 0.7 cm, lower part thick, fleshy, light green, dark red towards the margin, glabrous. Anther 0.5 × 0.3 cm, exposed, filaments 0.5–0.7 cm, stout at base, filiform towards tip, pale yellow, glabrous. Ovary 0.65–0.7 cm, elliptic-ovate, glabrous; stigma with a pubescent tip.

Distribution: Courtellum, Kanyakumari, Agasthyamalai Biological Park and Peppara Wildlife Sanctuary.

Phenology: August-October.

Elevation: Above 1500 m.

Specimens examined: Kerala: Courtellum, 1835, *Robert Wight*, (MH!); Courtellum, 12.10.1975 *K.N Nair*, 70165 (CAL!); Courtellum, 1835, *H.B Griffith*, 1226 (K!); Kurisumala, 30.07.1985, *Fr. Kadavil,* 1214 (BSI!); Trivandrum, Way to Agasthyakudam top, 06.11.2016, *K. Prasad*, 8430 (BSID!); Athirumalai, 21.09.2019, *K. M Prabhuumar*, 1234 (CMPR!) **Tamil Nadu:** Thirunalvelli hills, 1885, *R.H Beddom*, 934 (BM!), Thirunalvelli hills, 1885, *R.H Beddom*, 935 (BM!), Muthukuzhi vayal, 09.09.1976, *A. N. Henry*, 48298 (MH!); Muthukuzhivayal, 09.09.1976, *A. N. Henry*, 48295 (MH!).

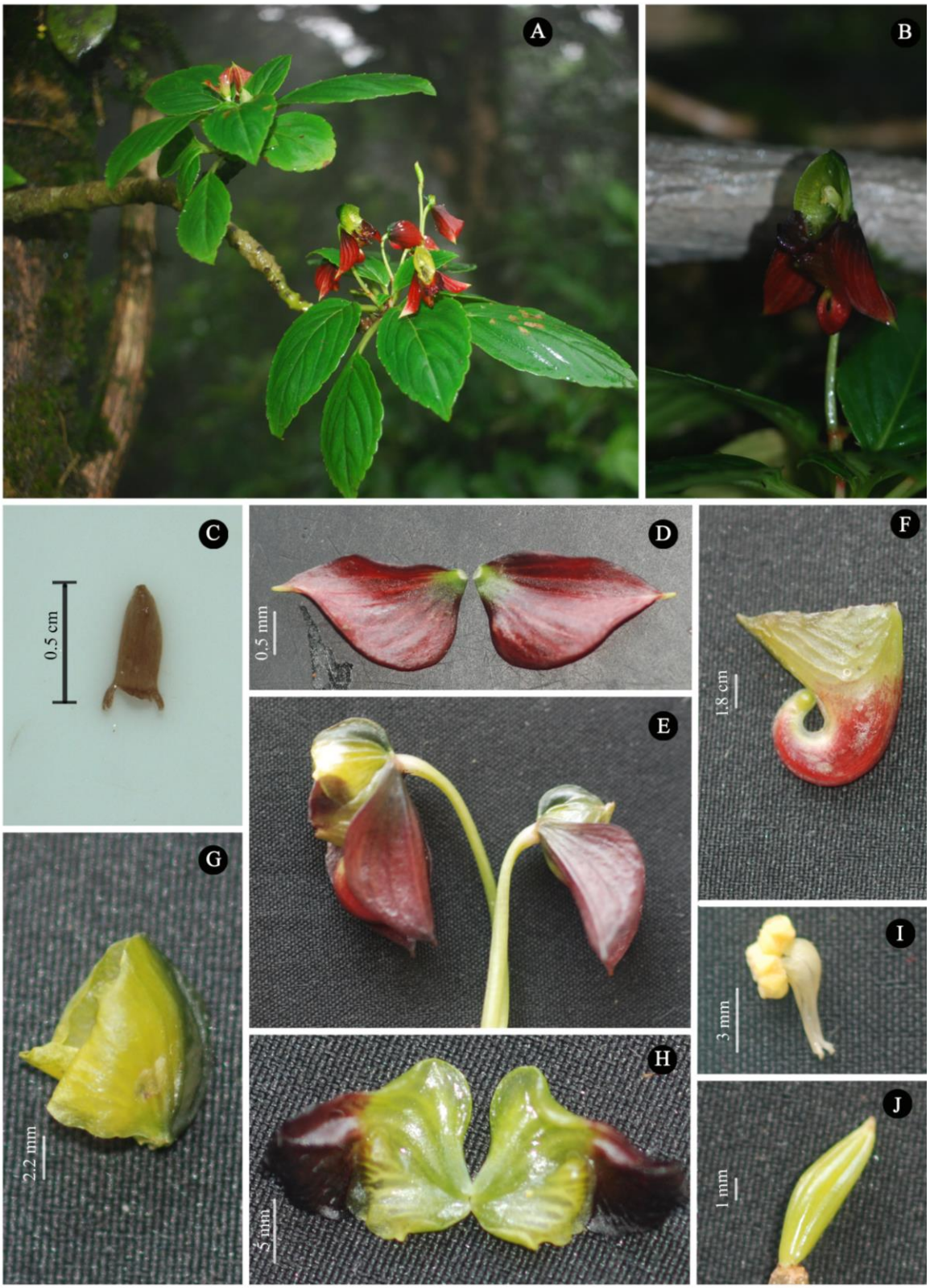

Figure 2: Floral parts of *Impatiens auriculata* **–A.** Habit; **B.** Front view of flower; **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal; **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium

2. ***Impatiens jerdoniae*** **Wight, Icon. Pl. Ind. Orient. (Wight) 1850.** Wight, Madras J. Lit. Sci. er. 1, 5: 8. 1850; Hook. F., Fl. Brit. India, 1: 460. 1874; Gamble, Fl. Pres. Madras, 139 (99). 1915; Manilal, Fl. Silent Valley, 40. 1988; Vivek. *et al*., in Hajra *et al*., Fl. India, 4: 159. 1997; Muktesh, Epiphytic Fl. Western Ghats, 60. 1998; Swarup. *et al*., Shola For. Kerala, 43. 1998; N.C. Rathakr. *et al*., in P. Daniel, Fl. Kerala, 1: 545. 2005; Ratheesh Narayanan, Fl. Stud. Wayanad Dist., 185. 2009 **(Figure 3)**

Type:—INDIA. Without precise locality, s.d., Wight s.n.; lectotype K000694885!

Residual syntype:—INDIA. Sispara Ghat, s.d., Wight 319 (K000694884!).

Epiphytic perennial herbs, 6–20 cm long, stem terete, unbranched, glabrous, light green at base and purple at apex; internodes 0.5–1 cm long, prominent leaf scares present. Leaves 10–11 × 3.5–4 cm, alternate, elliptic acute at apex, crenate, ciliate at each crenation, obtuse at base, glabrous on both surface, dark green adaxially and light green abaxially; nerves 4–5 pairs, prominent on abaxial surface; petiole 4–6 cm long, slender, glandular ciliate at base, glabrous, pale green with purple-coloured lines on surface. Inflorescence axillary, bearing two flowers; pedicel 4–4.5 cm terete, glabrous, red; flowers zygomorphic, complete, bisexual and hypogynous; lateral sepals 1 × 0.3 cm, thick, curved, tip touching each other, glabrous, dark purple coloured; lower sepal spured, spur 2.5 × 1.5 cm, large, saccate, ventricose, wrinkled, 3 prominent wrinkles present on spur, tip pointed, 2 cm long, curved up to middle of spur, scarlet red and yellowish green at mouth; dorsal petal 0.8 × 1 cm thick, orbicular, dorsally keeled, yellow, glabrous, keel prominent, 0.76 × 0.14 cm mucronate at apex, dark green; lateral united petals almost inserted to spur, 2 lobed, 0.15–0.2 × 0.1–0.16 cm, wrinkled, basal lobe small, distal lobe large with pointed end, yellow lines present on the surface, glabrous, yellowish green transparent near margins. Ovary superior, 1 cm long, elliptic, oblique at one side, slightly pubescent, light green, style absent, stigma broad, placed over a platform like structure. Ovules 10–25 in axile placentation. Anthers syngenesious 1.3 cm long, filaments 5, thick at the beginning and thin towards the end, anther lobes 5, yellow. Fruit elliptic, 1.5 cm long, light green, glabrous. Seeds 10–20, pear shaped, and spirally coiled hairs present on both ends.

Distribution: Sispara ghat of Nilgiris, Shola Forest of Wayanad district, Chooralmalai Wayanad district, Silent Valley National Park.

Phenology: July-October.

Elevation: 1000 to 2000 meters.

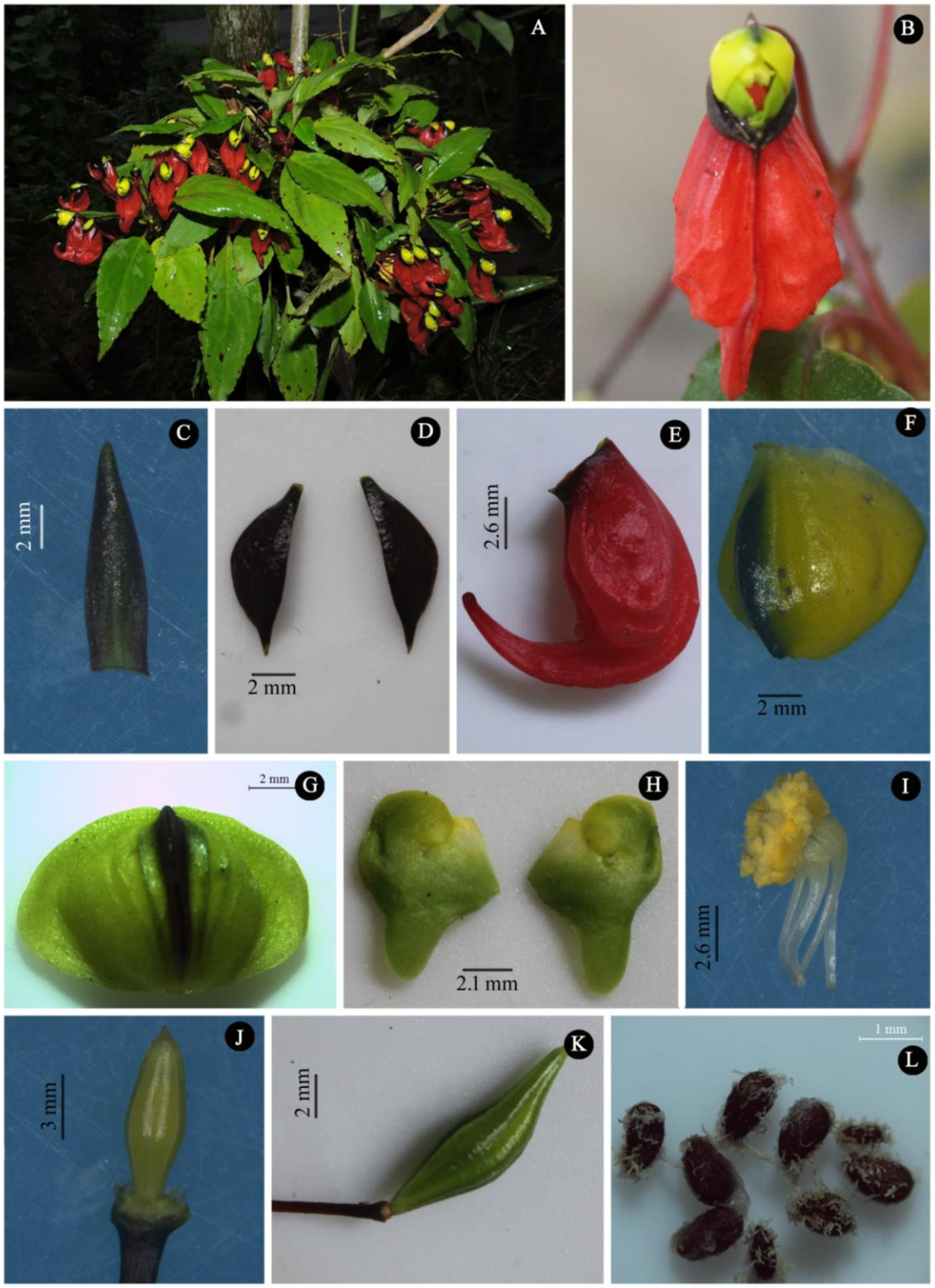

Figure 3: Floral parts of *Impatiens jerdoniae* –**A.** Habit **B.** Front view of flower **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium; **K.** Fruit **L.** Seed

Specimen examined: Kerala: Brahmagiri hills, 1852, *Robert Wight*, 7354 (MH!); Sispara Ghat, 1852, *Robert Wight* (K!); Malabar, 06.1859, *R. H. Beddome*, 57 (CAL!); Silent Valley, 26.09.1977, *R. Ansari*, 51488 (MH!); Chooralmalai, 15.08.2019, *Reshma Ashok*, 12554 (CMPR!); Chooralmalai, 07.09.2022, *Reshma Ashok*, 12715 (STC!) **Tamil Nadu:** Viralimalai, 30.10.1910, *C.E.C. Fischer*, 2384 (CAL!).

3. *Impatiens parasitica* Bedd., Madras J. Lit. Sci. Ser. II, xx. (1859) 66. *Impatiens parasitica* Bedd., Madras J. Lit. Sci. ser., 2, 20: 66. t.7. f.2. 1859 & Ic. t. 140. 1868–1874; Gamble, Fl. Pres. Madras, 139(99). 1915; Vivek. *et al*., in Hajra *et al*., Fl. India, 4: 191. 1997; Muktesh, Epiphytic Fl. Western Ghats, 61. 1998; Sasidh., Fl. Periyar Tiger Reserve, 49. 1998; Sasidh., Fl. Chinnar WLS, 53. 1999; Pradeep, Fl. Vellarimala, 35. 2000; Sasidh., Fl. Parambikulam WLS, 45. 2002; N.C. Rathakr *et al*., in P. Daniel, Fl. Kerala, 1: 554. 2005 **(Figure 4)**

Type:—INDIA Beddom, Annamallays, 5000–7000 ft. (1500–2120m), 1861, K000694777.

Epiphytic, annual, monoliform herbs; stem 5–25 cm long, branched, thick, fleshy, pale green. Leaves crowded towards the apex of stem; alternate, petiole 0.5–4.5 cm long, channelled, glabrous, pale green or pale red, with 2 prominent glands near the base of lamina; lamina 1–8 × 1–4 cm, ovate to elliptic-lanceolate, acute at apex, obtuse to cuneate at base, membranous, glabrous on both sides, green above and pale green to slight brownish beneath; lateral nerves 3–4 pairs, distinct, pale green or pale red, margins crenulate, crenules short, furnished with short bristles, pale green or pink. Inflorescence 2 flowered, axillary panicle; bracts 3 mm long, linear-lanceolate, acute, glabrous, pale red; peduncle1–1.5 cm, glabrous, pale red; pedicel 1– 4.8 cm, glabrous, pale red; greenish-yellow with crimson red tinge; flowers zygomorphic, bisexual, complete, hypogynous; lateral sepals 0.6–0.8 × 0.1–0.2 cm, linear-lanceolate or linear-ovate, acute to acuminate, glabrous, green above, greenish white below; lower sepal spurred, spur 1.6–2.3 × 0.8–1.2 cm, saccate, thick, laterally compressed, wrinkled, three prominent nerves on either side, tip curved, bright red coloured, brownish red at the tip; dorsal petal 0.6–0.7 × 0.45–0.5 cm, erect, greenish yellow, glabrous, with prominent dark green keel; lateral united petal 1–1.1 × 0.8–0.9 cm, bilobed, with small pouch in each lateral lobules, green or pale green, basal lobe 0.3–0.4 × 0.4–0.45 cm, distal lobe 0.2–0.25 × 0.3–0.4 cm; Anthers ca. 0.5 × 0.75 cm, pale yellow; filaments 1–1.5 × ca. 1.5 cm, white. Pistil ca. 0.4–0.5 × 0.17–0.2 cm, broadly ellipsoid, acute at apex, glabrous, yellowish-white, stigma silky pubescent.

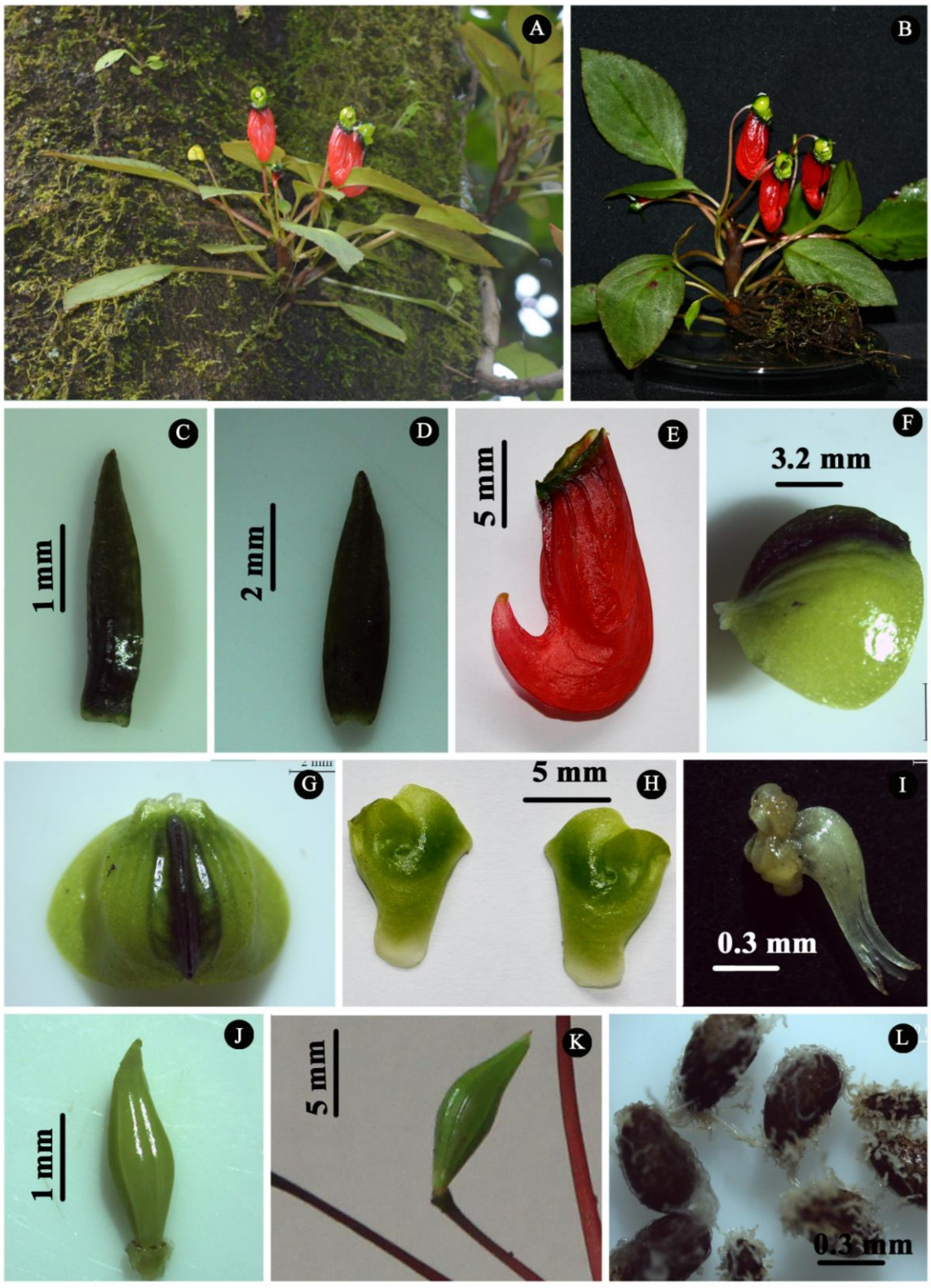

Figure 4: Floral parts of *Impatiens parasitica* – **A, B.** Habit; **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium; **K.** Fruit; **L.** Seed

Capsule 1.8–2 × 0.5–0.7 cm, elliptic-lanceolate, acute, glabrous, pale green. Seeds ellipsoid, numerous, brown, tip ciliate.

Distribution: Anamalai, Munnar, Pettimudi, Vellathuval, Nelliyampathy, Wayanad.

Phenology: July-October.

Elevation: 1500 to 2000 m.

Specimens examined: Kerala: Anamalai hills, 1861, *R. H Beddome*, (K!); Munnar, 10.14.2019, *Reshma Ashok*, 12598; Nelliyampathy, 09.27.2019, *Reshma Ashok*, 12580 (CMPR!); **Tamil Nadu:** Tamil Nadu, 06.1859, *R. H. Beddome*, 56 (CAL!); Italiyar River bank, 08.09.1983, *K. Ramamurthy*, 77524 (MH!)

4. *Impatiens sholayarensis* M. Kumar & Sequiera, Sida 19(4): 795 (2001). Muktesh and Stephen, Sida 19: 795. 2001; N.C. Rathnakr. *et al*., in P. Daniel, Fl. Kerala, 1: 557. 2005. **(Figure 5)**

Type:—INDIA. Kerala: Thrissur Dt., Sholayar, alt. 900m, 9 Oct 1998, Sequiera 20620 (holotype: KFRI; ISOTYPE: MH)

Epiphytic herbs, stem 2.5–5 cm long, terete, unbranched, glabrous, green. Leaf crowded towards the apex of the stem, alternate; petiole 2.5–4 cm long, channelled, reddish green, glabrous, 2–3 pairs of glands at the base of lamina; lamina 3–8 × 1.5–3 cm, ovate to elliptic, acute at apex, margins crenulate, short bristles found on each crenule; lateral veins 4; bright green on abaxial side and silvery green on adaxial side. Inflorescence axillary, two flowered clusters; peduncles 2–2.5 cm long, translucent, green, glabrous; pedicle 3–6 cm long, terete, translucent, green, glabrous. Flowers zygomorphic, bisexual, complete, up to 3.5 cm long. Lateral sepals 2, 0.6–1 × 0.2–0.4 cm, linear lanceolate, acute at tip, dark green, glabrous; lower sepal spurred, spur 1.5–3.2 × 0.5–0.9 cm, wide mouth with prominent hook at one end, lower side of the spur curved, yellowish green till the middle and crimson red till the tip; dorsal petal 0.5–0.9 × 0.5–0.9 cm, erect, thick, greenish yellow, glabrous, keeled, keel 0.3 cm wide and extend throughout dorsal petal; lateral united petals 2, 0.9 × 1 cm, inserted in the spur, bilobed, upper lobe project outside the spur; Androecium 0.6–1.1 cm long, anthers 5 yellow, filament 5 up to 1 cm long, yellowish white, glabrous; ovary superior, up to 1 cm long, elliptic lanceolate, slightly falcate, sparsely pubescent; stigma toothed and silky pubescent, ovules in axile placentation; capsule 0.9–1.1 cm long, elliptic, bright green, glabrous; seeds 15–20, pear shaped, hairs on both end.

Distribution: Sholayar forest ranges, Thrissur.

Elevation: 900 m.

Phenology: July-October.

Specimens examined: Kerala Sholayar, 1998, *Sequiera*, 20620; Sholayar, 10.09.2022, *Reshma Ashok,* 12778 (STC!).

5. *Impatiens violaceae* M. Kumar & Sequiera, Sida 19(4): 795 (2001). *Impatiens violaceae* Muktesh & Stephen, Sida 19: 795. 2001; N.C. Rathnakr. *et al*., in P. Daniel, Fl. Kerala, 1: 557. 2005. **(Figure 6)**

Type:—INDIA. Kerala: Idukki Dt., Munnar, Pettimudi, Way to Edamalakudy, alt. 2000m, 25 Aug 1998, Sequiera 20731 (HOLOTYPE: KFRI; ISOTYPE: MH).

Epiphytic on trees, monoliform herbs, up to 12 cm high; stem 0.5–2 cm diameter, moniliform, branched, stout, fleshy, rough, with persistent leaf scare, purple coloured; leaves 3–4 × 2–3 cm, crowded at apex, alternate, ovate to elliptic, apex acute, margins crenated, bristles present on each crenules, bristles dark violet coloured, 4-5 pairs of nerves, green with violet tinge on adaxial side, light green with violet tinge abaxially, glabrous; petioles up to 3.5 cm long, channelled, 1–3 pairs of glands at the base, light green with purple tinge; Inflorescence axillary, panicle, 3–5 flowers in a cluster, peduncle 2.5–3 cm long, green, glabrous; pedicel 3–3.5 cm, terete, violet, glabrous; bract 5 mm long, green; flowers up to 2 cm long, lateral sepals 0.7 × 0.2 cm, thick, elliptic, tip acute, green except at base, base violet, glabrous; lower sepal spurred, spur 1.5 × 0.8 cm, saccate, wrinkled, tip curved, blue coloured, glabrous; dorsal petal 0.69 × 0.6 cm, orbicular, keeled, thick nerves present, light green, glabrous; keel 0.69 × 0.11 cm dark green; lateral united petal inserted into spur, bilobed, basal lobe 0.53 × 0.46 cm, wrinkled, thick, light green, glabrous, distal lobe 0.95 × 0.6 cm, wrinkled, margin curved inward, light green; androecium syngenicious, filament 0.5 cm long, light yellow, anthers five, yellow; ovary 0.48 cm long, elliptic, light green, slightly pubescent; style absent, stigma slightly pubescent; ovule many axile placentation; capsule elliptic, 1–1.2 × 0.2– 0.4 cm, green with purple tinge, glabrous; seeds many, pear shaped, hairy throughout.

Distribution: Munnar, Pettimudi.

Phenology: August-October.

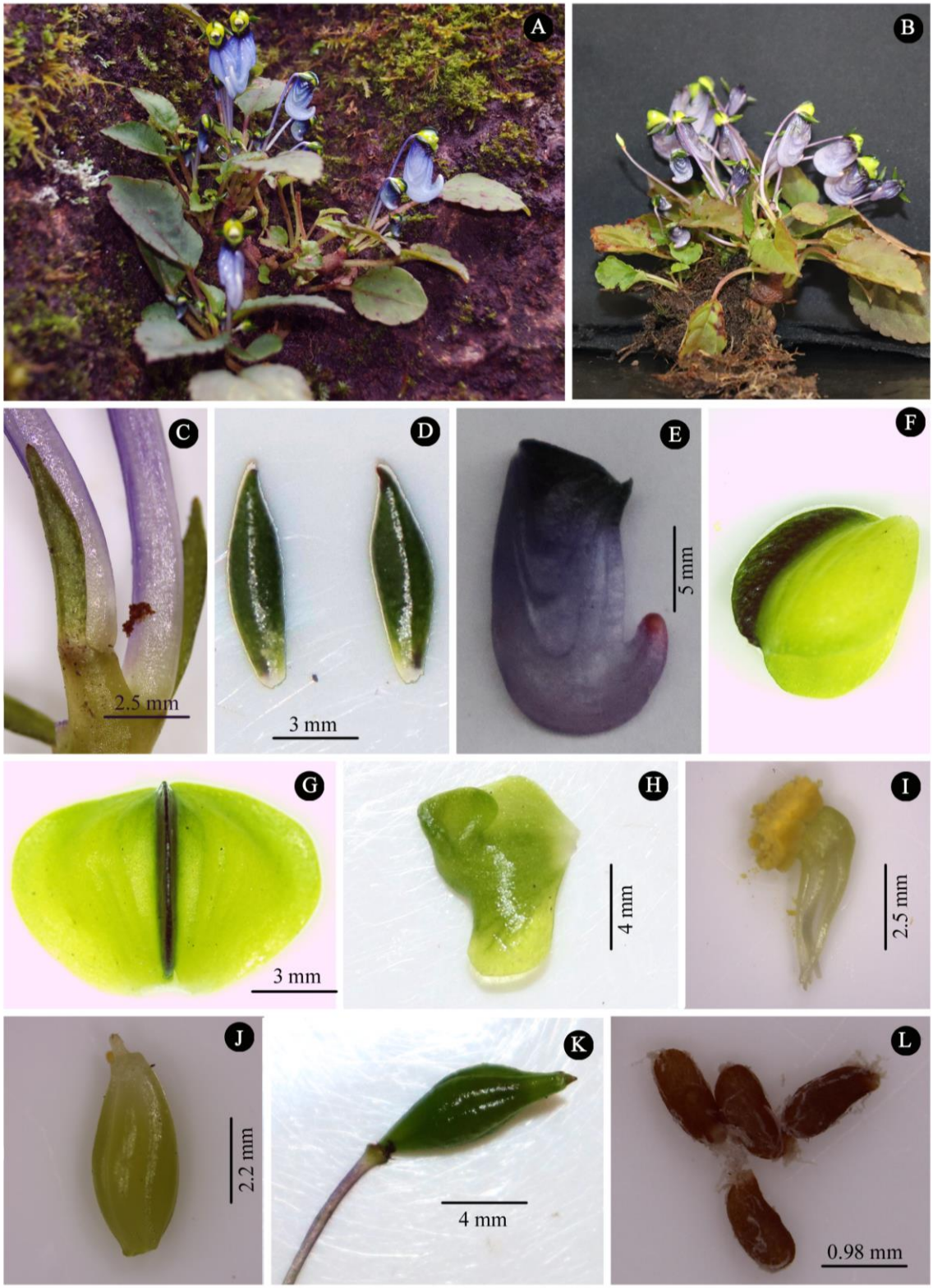

Figure 6: Floral parts of *Impatiens violacea* –A, B. Habit; **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal; **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium; **K.** Fruit; **L.** Seed

Elevation: 2000 m.

Specimens examined: Kerala Idamalakudi, 1998, *Sequiera*, 20731; Munnar, 10.14.2019, *Reshma Ashok*, 12596 (CMPR!).

6. *Impatiens viridiflora* Wight, Madras J. Lit. Sci. Ser. I, v. (1837) 9. Wight, Madras J. Lit. Sci. ser., 1, 5: 9. 1837; Hook. F., Fl. Brit. India, 1: 460. 1874; Gamble, Fl. Pres. Madras, 139(99). 1915; Vivek. *et al*., in Hajra *et al*., Fl. India, 4: 226. 1997; Muktesh, Epiphytic Fl. Western Ghats, 62. 1998; Sasidh., Fl. Periyar Tiger Reserve, 51. 1998; Sasidh., Fl. Parambikulam WLS, 45. 2002 **(Figure 7)**

Type:—INDIA. Tamil Nadu: Shevagerry (Sivagiri) hills, s.d., Wight 348; lectotype K000694879!

Epiphytic perennial, woody sub shrub up to 40 cm. Stem 2–3 cm diameter, erect, stout, fleshy with prominent leaf scare, brownish green, glabrous. Leaves crowded at the apex of stem, alternate, ovate to lanceolate, 2.5–6 × 1.8–3 cm, base cuneate, margin crenulate, each crenule furnished with pinkish green appendages, apex acute; 2–4 pairs of lateral nerves; petiole 2–4 cm long, channelled, translucent green with tinge of red. Inflorescence axillary, 2–3 flowered panicles; peduncle 2–3 cm long, terete, translucent green, glabrous. Flowers zygomorphic, bisexual, complete, hypogynous, up to 2.5 cm, faint red; bract ligulate 0.5– 0.7 cm, dark green, glabrous; lateral sepals 2; 0.5–1 cm long, lanceolate with acute tip, thick and fleshy, dark green, glabrous; lower sepal spurred, spur 1.8–2 cm long, saccate, wrinkled, hook like appendage at the opening, three prominent markings on either side, tip curved, crimson red till the middle and yellowish white up to the tip; dorsal petal 0.7–1 cm, orbicular, prominently nerved, strongly keeled, keel 0.12–0.14 cm thick, dark green; lateral united petals bilobed, inserted in the spur, basal lobe 0.5–0.8 cm, membranous with prominent nervous, wine red; anther 0.5–0.8 cm long, filaments 0.5–0.6 cm, broad at apex and filiform towards the tip, yellowish white, glabrous; ovary superior, 0.7–0.9 cm long, elliptic, falcate, greenish yellow, slightly pubescent; stigma slightly puberulous, ovules many, axile placentation; capsule 0.8–1.1 cm, lanceolate, narrow, bright green, glabrous; seeds many, pear shaped, hairy throughout

Distribution: Meghamalai, Srivilliputhur Wildlife Sanctuary, Vattaparai, Shivagiri hills, Periyar Tiger Reserve Kerala.

Phenology: August-October.

Elevation: 1500 m.

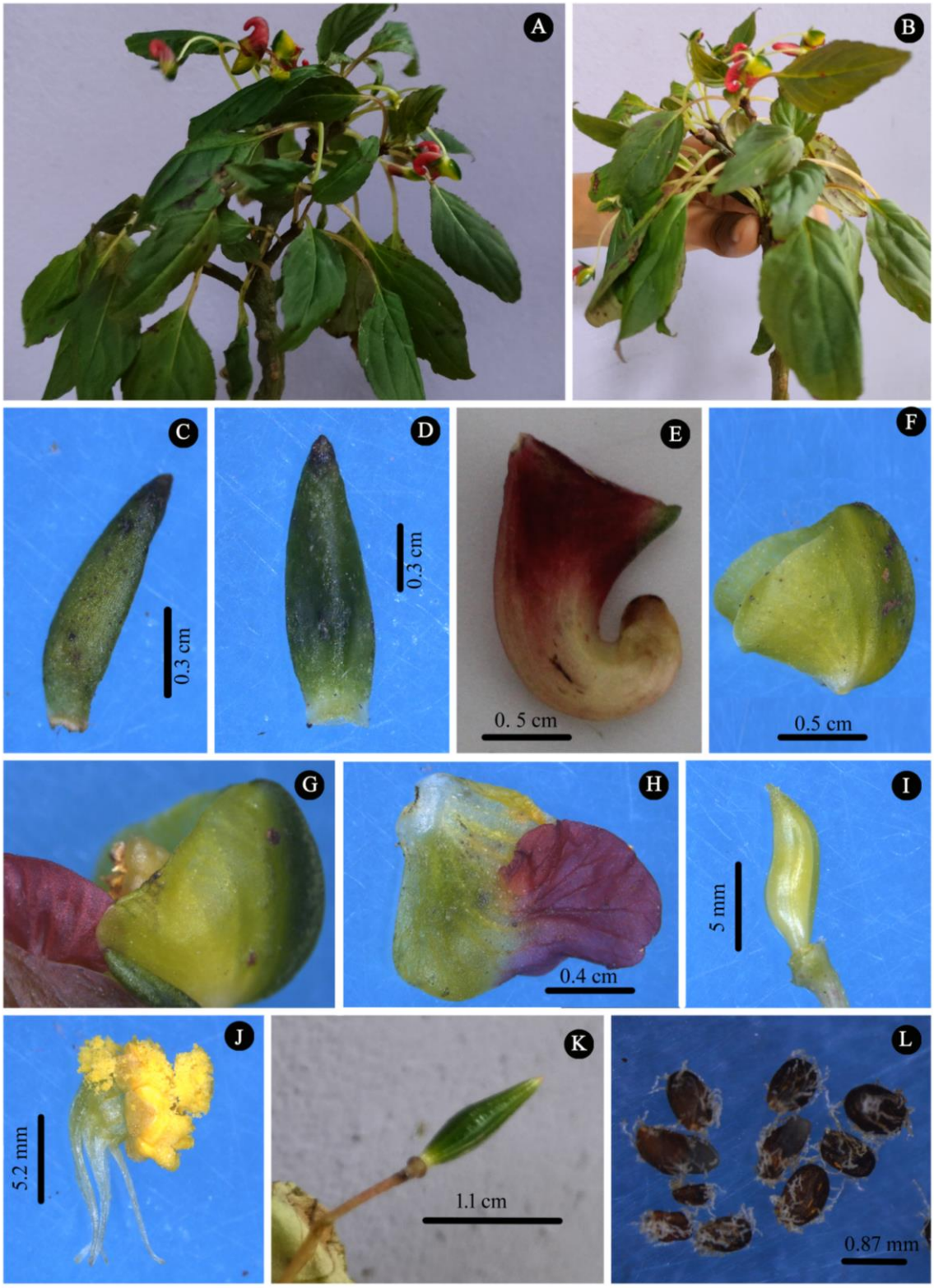

Figure 7: Floral parts of *Impatiens viridiflora* - **A, B.** Habit **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal; **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium; **K.** Fruit; **L.** Seed

Specimens examined: Kerala: Shevaghery hills, 1867, *Robert Wight*, 348(K!); **Tamil Nadu:** Sivagiri Ghats, Thirunelvelli hills, 1885, *R. H Beddome*, 938 (BM!), Thirunelvelli hills, 1885, *R. H Beddome*, 938 (BM!),Thirunelvelly, 1869, *R. H Beddome*, 7361(MH!); Near Deviar Estate, Forest boundary between Kerala and Tamil Nadu, 26.09.1991, *S. R. Srinivasan*, 98257 (MH!); Meghamalai, 10.21.2022, *Reshma Ashok*, 12800 (STC!).

7. *Impatiens* sp. 1 (Figure 8)

Type:— India. Kerala: Idukki, Wagamon, Kurisumala, ±1500 m, 21 September 2013, K.M. Prabhukumar 8478 (holotype, CMPR: isotype, MH, CATH).

Semi epiphytic or lithophytic sub shrub, up to 50 cm. Roots arising from the base of the stem, terete, glabrous, pale brown. Stem 2.5–3 cm diameter, stout, fleshy, leaves scar present, faint green, glabrous. Leaves simple, alternate, crowded towards the tip; petiole 2.5–6.5 × 0.2–0.5 cm, sub angular, canaliculated, pale purple, glabrous; lamina 6–16 × 3–9 cm, elliptic–oblanceolate, base attenuate, apex acute to apiculate, margin crenulate, crenulations 4–6 mm apart, furnished with fleshy, glossy, glabrous, small appendages; veins conspicuous, 4–6 lateral nerves, convergent, pair of stipitate glands at base, glabrous. Inflorescence sub umbellate, 3–7 flowers; peduncle 1.5–4 cm long, sub angular, pale green, glabrous; bract 0.4 × 0.1 cm, elliptic-lanceolate, base truncate, apex acute, veins faint. Flowers scarlet red; pedicels 3.5–4 cm, sub angular, base stout, filiform towards the apex, green, glabrous. Lateral sepals 1.1–1.6 cm long, lanceolate, with elongated base, thick, closely aligned with spur, glabrous, yellowish green. Lower sepal spurred, spur thick, saccate, laterally compressed, furnished with 3–4 wrinkled thick markings, curved at apex, scarlet red, greenish towards mouth, 1.5–1.8 × 1–1.1 cm at mouth, 0.7–0.9 cm towards the middle. Dorsal petal 0.85–0.9 × 1.05–1.09 mm, orbicular, crowned, prominently nerved, nerves light yellow, glabrous; deeply keeled, keel 0.85–0.92 × 0.14–0.16 cm, dark green. Lateral united petal bilobed, inserted into the spur, first lobule of the distal lobe spreading out of the spur, prominent yellow nerves, pale green; distal lobe 0.6–0.8 cm, with 2 lobules, first lobule orbicular, thin towards the margin, second lobule elongated, base truncate, margins curved inward; basal lobe 0.5 × 0.7 cm, lower part thick, fleshy, glabrous. Anther 0.7 × 0.3 cm, exposed, filaments 0.63–0.67 cm, stout at base, filiform towards tip, pale yellow, glabrous. Ovary 0.75–0.8 cm, elliptic-ovate, glabrous; stigma with a pubescent tip. Fruit 1.5–1.7 cm long, 5 lobed, elliptic-lanceolate, green, glabrous, apex apiculate. seed 60–70, ovate, densely villous.

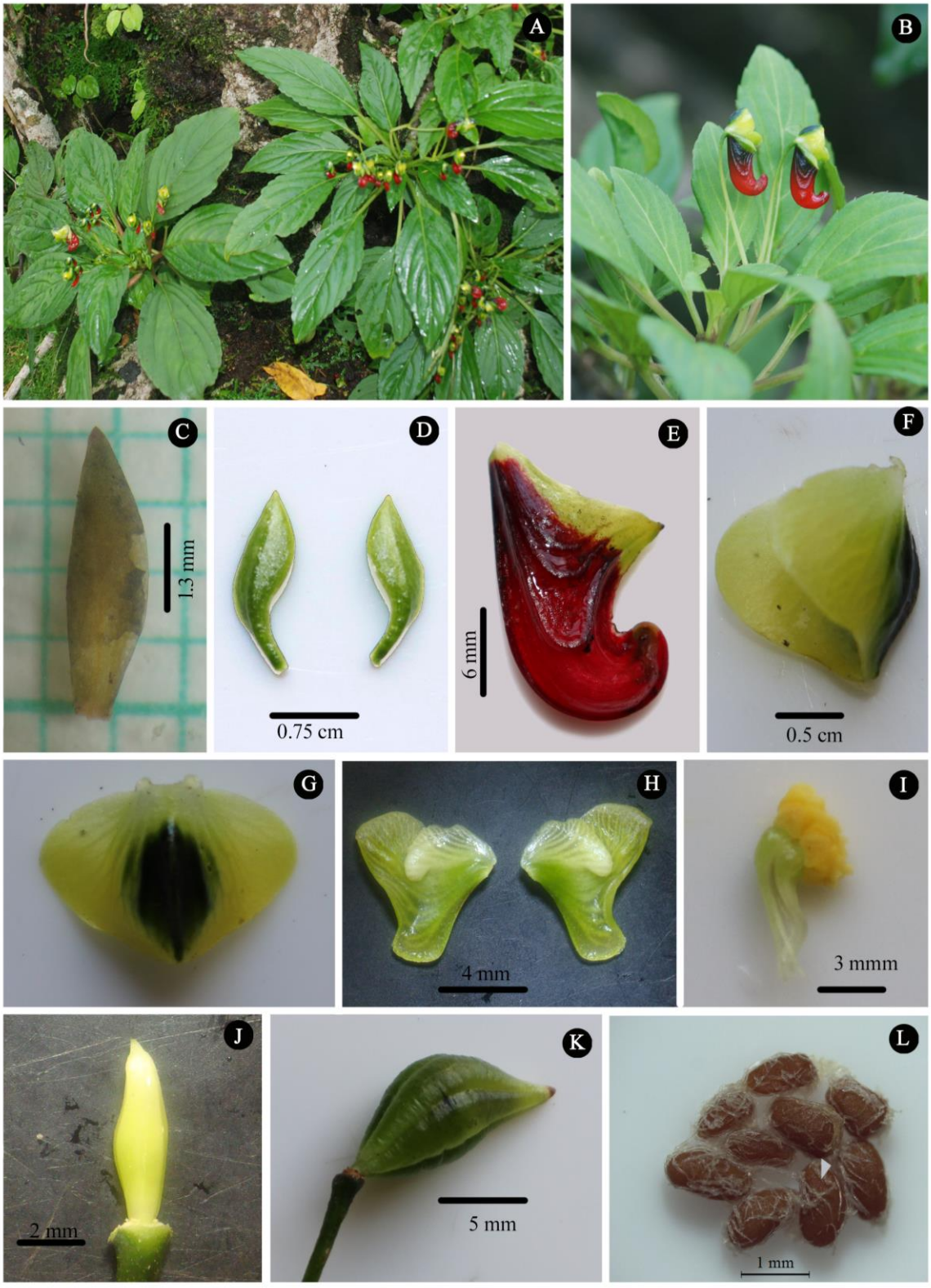

Figure 8: Floral parts of *Impatiens* sp. 1- A, B. Habit; **C.** Bract; **D.** Lateral sepal; **E.** Lower sepal; **F, G.** Dorsal petal; **H.** Lateral united petal; **I.** Androecium; **J.** Gynoecium; **K.** Fruit; **L.** Seed

Note: The new species is closely allied with *I. parasitica* (Table 3). The new taxon has been collected from Kurisumala (Wagmon) Idukki district, Kerala. Generally occurring on moss covered tree trunks and wet rock. It is observed that the plant is distributed throughout Kurisumala hills, both trees and rocks.

Distribution: Wagamon, Kurisumala, Idukki.

Phenology: August-October.

Elevation: 1500 m.

Specimens examined: Kerala: Idukki, Wagamon, Kurisumala, ±1500 m, 11.09.2014, *K. M. Prabhukumar* 8878 (CMPR!); 14 .10. 2015, *K. M. Prabhukumar* 9184 (CMPR!); 29.09. 2016, *K. M. Prabhukumar*, *R. Jagadeesan* and *P. M. Binu Prakash* 9578 (CMPR!); 24.08.2017, *K. M. Prabhukumar* 9888 (CMPR!); 2.10. 2018, *K. M. Prabhukumar* 9954 (CMPR!); 04.09.2019, *K. M. Prabhukumar* 9987 (CMPR!); 03. 11. 2019, *Reshma Ashok,* 12661 (CMPR!).

Table 3: Comparative account of *Impatiens* sp. 1and *I. parasitica*

Characters	***I. parasitica***	***Impatiens* sp. 1**
Habit	12–18 cm long	20–50 cm long
Stem	Monoliform, 5–6 mm diameter	Non monoliform, 25–30 mm diameter
Leaf scars	Obscure	Very prominent
Leaf	3.5–4 × 1.8–2.5 cm, obovate	6–16 × 3–9 cm, elliptic oblanceolate
Inflorescence	Umbel with1–2 flowers	Umbel with 3–6 flowers
Pedicel	Red	Green
Flower	1.6–2 cm long	2.4–3.2 cm long
Lateral sepals	0.75–1 × 0.1–0.13 cm, elliptic, tip acute, base truncate	1.1–1.7 × 0.25–0.3 cm, lanceolate, base linear elongated
Dorsal petal	0.79–0.81 cm long, nerves not forming a network	1–1.5 cm long, nerves forming network
Lateral united petal	Basal lobe without thick fleshy projection, second lobule of distal lobe shorter	Basal lobe with thick projection, second lobule of distal lobe elongated
Androecium	Filaments 0.5–0.52 cm long	Filaments 0.63–0.67 cm long

4.2 Variation in the floral morphology of *Impatiens parasitica* (Figure 9)

Key to the morpho types of *Impatiens parasitica*

1a. Colour of the spur is red……..…..**3**

1b. Colour of spur other than red……..…….**2**

2a. Pedicel more than 4 cm long, violet coloured……..……..….**Morpho type 8**

2b. Pedicel less than 4 cm, light rose coloured……...…..**Morpho type 7**

3a. Spur laterally compressed……..…….**4**

3b. Spur saccate inflated and broad at middle……...**Morpho type 1**

4a. Lateral sepals dark purple coloured broad elliptic.…….....…..**Morpho type 6**

4b. Lateral sepals green narrow and lanceolate…….…….**5**

5a. Ovary and filaments of anther pale white……..…...…..**Morpho type 3**

5b. Ovary and filament yellow…….……**6**

6a. Mouth of the spur and lateral sepals are perpendicular……...…**Morpho type 2**

6b. Mouth of the spur and lateral sepals are parallel……...……**7**

7a. Width of the keel equal throughout…….……..…..**Morpho type 4**

7b. Width of the keel higher at the middle…….…..……**Morpho type 5**

Morpho type 1

Epiphytic perennial herbs, 10–20 cm long, stem monoliform, terete, woody, wrinkled, unbranched, rough, Brown coloured; internodes 1 cm long, persistent leaf scare present. Leaves rosulate at tip, 4–5 × 3–3.5 cm, alternate, elliptic, acute at apex, crenate, small projections from each crenation, obtuse at base, glabrous, green adaxially and light purple abaxially, 4–5 pairs of nerves, petiole 1–2.5 cm long, slender, channelled, a pair of glands at base, green. Inflorescence axillary, cluster of two flowers, pedicel 3.5–4.5 cm, terete glabrous, scarlet red; flowers 2.5–3 cm long, scarlet red; lateral sepals 0.7 × 0.3 cm, thick, prominent vein present at centre, acute at tip, oblique at one side, dark green, glabrous; spur 2 × 1.5 cm large, inflated,

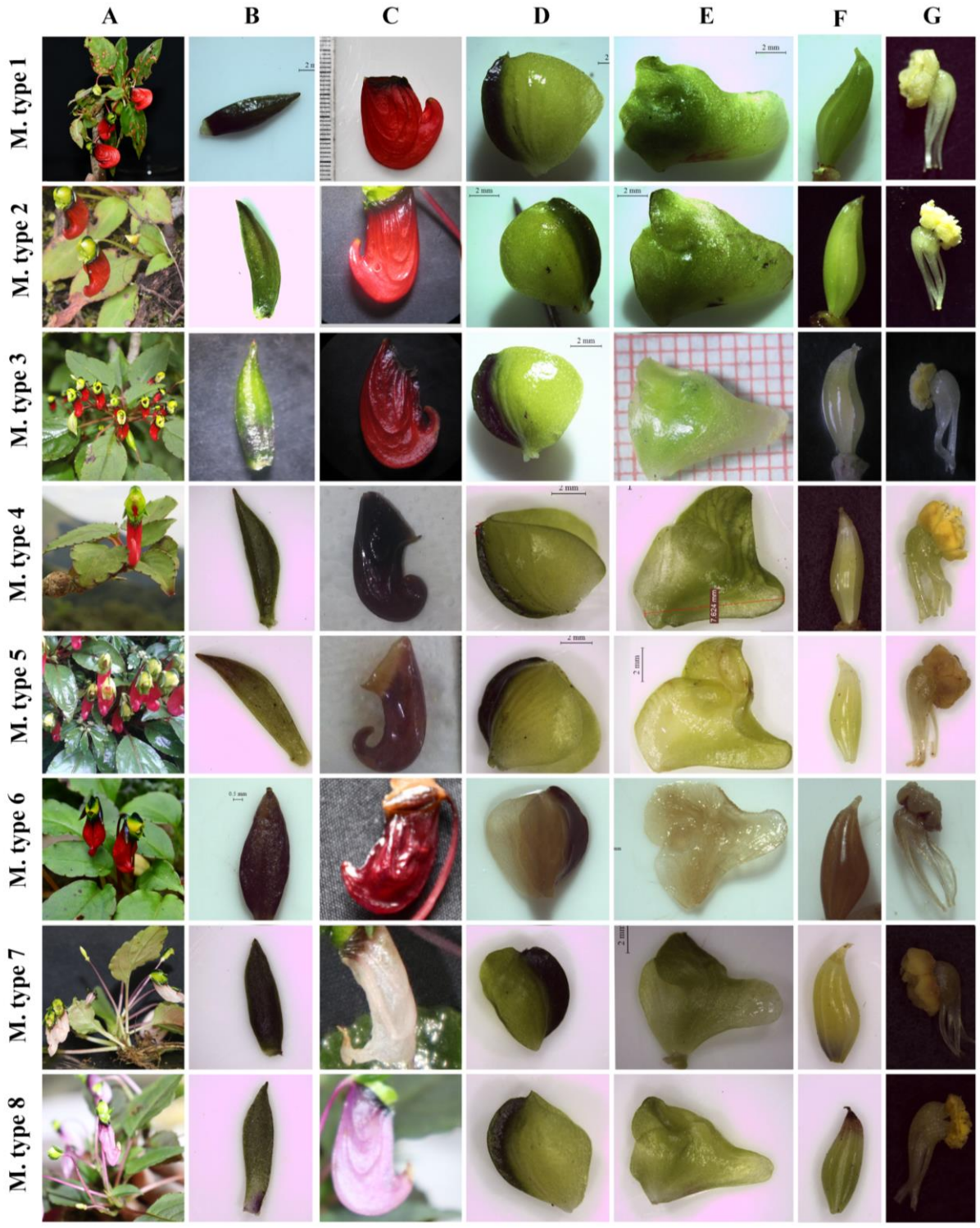

Figure 09: Floral parts of Morpho types 1- 8 of *I. parasitica*- **A.** Habit **B.** Lateral sepal **C.** Spur **D.** Dorsal petal **E.** Lateral united petal **F.** Gynoecium **G.**Androecium

wrinkled, saccate, tip very short, rounded, curvature of tip starting from middle of spur, scarlet red and maroon at mouth; standard petal 0.5 × 1 cm thick at middle and thin towards the margin, orbicular, keeled, yellow with light green nerves near the keel, keel 0.8 cm long and 1 mm thick, mucronate, dark green, glabrous; lateral united petals 1 × 0.7 cm, inserted into spur, 2 lobed, wrinkled, thick with prominent nerves, basal lobe dark green, distal lobe elongated, yellowish green with red tinge towards the margin. Style zero, stigma pointed, ovary elliptic 1 cm long, elliptic, yellowish green, glabrous. Anthers 5, syngenesious, filaments 1.5 mm long yellow.

Distribution: Cheriyaminnampara, Nelliyampathy, Kerala.

Phenology: August-October.

Elevation: 1500 m.

Specimens examined: Kerala: 12.07.2019, Cheriyaminnampara, Nelliyampathy, *Reshma Ashok* 12655 (CMPR!); 21.10.2020, *Reshma Ashok* 12720 (CMPR!).

Morpho type 2

Epiphytic perennial herbs, 2–12 cm long, stem very short monoliform, terete, fleshy, unbranched, rough, Brown coloured. Leaves rosulate at tip, 3–5.5 × 3–5 cm, alternate, elliptic, acute at apex, crenate, small projections from each crenation, obtuse at base, glabrous, green adaxially and reddish green abaxially, 1–2 pairs of nerves, petiole 2–3 cm long, slender, channelled, a pair of glands at base, green. Inflorescence axillary, cluster of two flowers, pedicel 2.5–3.5 cm, terete glabrous, scarlet red; flowers 1–2 cm long, scarlet red; lateral sepals 0.9 × 0.3 cm, thick, prominent vein present at centre, acute at tip, elliptic, dark green, glabrous; spur 1 × 1.5 cm small, laterally compressed, wrinkled markings at both side, tip very short, pointed, scarlet red and maroon at mouth; dorsal petal 0.8 × 1 cm thick, orbicular, keeled, yellow with light green nerves near the keel, keel 0.8 cm long and 1 mm thick, mucronate, dark green, glabrous; lateral united petals 1 × 1 cm, inserted into spur, 2 lobed, wrinkled, thick with prominent nerves, basal lobe dark green, distal lobe triangular, yellowish green. Style absent, stigma pointed, ovary elliptic 1 cm long, elliptic, yellowish green, glabrous. Anthers 5, syngenesious, filaments 0.15 cm long yellow.

Distribution: Govindhamalai, Nelliyampathy, Kerala.

Phenology: August-October.

Elevation: 1600 m.

Specimens examined: Kerala: Govindhamalai, Nelliyampathy, 12.07.2019, *Reshma Ashok* 12656 (CMPR!); 21.10.2020, *Reshma Ashok* 12724 (CMPR!).

Morpho type 3

Epiphytic perennial herbs, 10–18 cm long, stem monoliform, terete, fleshy, unbranched. Leaves crowded at tip, 3–6 × 3–5 cm, alternate, elliptic, acute at apex, crenate, small projections from each crenation, obtuse at base, glabrous, green adaxially and green with reddish tinge abaxially, 1–5 pairs of nerves, petiole 2–3 cm long, slender, channelled, 3–4 pairs of glands at base, green. Inflorescence axillary, cluster of two flowers, pedicel 3–4 cm, terete glabrous, green; flowers 1–2 cm long, scarlet red; lateral sepals 0.9 × 0.3 cm, thick, acute at tip, elliptic, dark green at base and light green towards the tip, glabrous; lower sepal spurred, spur 1 × 1.5 cm small, laterally compressed, wrinkled markings at both side, tip pointed, curved and touching the body of the spur, scarlet red and maroon at mouth; dorsal petal 1 × 1 cm thick, orbicular, keeled, yellowish green with light green nerves near the keel, keel 1 cm long and 1 mm thick, mucronate, dark green, glabrous; lateral united petals 1 × 0.7 cm, inserted into spur, 2 lobed, wrinkled, thick with prominent nerves, basal lobe light green, distal lobe elongated, white with slight green tinge. Style absent, stigma pointed, ovary elliptic 1 cm long, elliptic, yellowish green, glabrous. Anthers 5, syngenesious, filaments 1.5 mm long yellow.

Distribution: Cheriyaminnampara, Nelliyampathy, Kerala.

Phenology: August-October.

Elevation: 1600 m.

Specimens examined: Kerala: Cheriyaminnampara, Nelliyampathy, 12.07.2019, *Reshma Ashok* 12649 (CMPR!); 21.10.2020, *Reshma Ashok* 12730 (CMPR!).

Morpho type 4

Epiphytic perennial herbs, 12–15 cm long, stem monoliform, 0.5 cm diameter, intermodal length 1 cm, rough, woody; leaf scares present, green; Petiole 3–4 cm long, channelled, a pair of gland present, glabrous, green. Leaf crowded at tip 3.5–4 × 1.8–2.5 cm alternate, obovate, tip acute, crenate, ciliate, base obtuse, nerves 3–4 pairs, reddish green adaxially, silvery green abaxially; Inflorescence Axillary or terminal, 2 flowers in a cluster; Peduncle 1.3 cm, terete, glabrous, green; pedicel 3–3.5 cm, terete, glabrous, red; flowers

zygomorphic complete 1.8–2 cm long red, lateral sepals, 0.96 × 0.1 cm closely aligned with spur, straight elliptic, tip acute, base truncate, thick with prominent vein, dark green, lower sepal spurred, 1.5 cm long, mouth 0.9 cm, prominent hook at opening, green near mouth; tip rounded, curved and touching the body of spur, other parts scarlet red, dorsal petal 0.8 cm long, thick, prominent nerves, light green, keeled, keel 8x1mm dark green, lateral united petals 2 lobed, 0.76 × 0.9 cm long, distal lobe short, margins curved inward, light green with thick prominent nerves, basal lobe broad, with network like nerves, green; Androecium syngenesious, Filaments 0.52 cm long, light green, anthers 0.13 cm, yellow; Gynoecium, ovary superior 0.65 cm long, elliptic, light green, glabrous, style absent, stigma filiform.

Distribution: Pettimudi, Munnar, Idukki, Kerala.

Phenology: August-October.

Elevation: 1000 m.

Specimens examined: Kerala: Pettimudi, Munnar, 20.08.2019, *Reshma Ashok* 12667 (CMPR!); 11.10.2020, *Reshma Ashok* 12735 (CMPR!).

Morphotype 5

Epiphytic on trees, perennial herbs, 10–15 cm long, stem monoliform 0.5 cm diameter, thick, leaf scares present, green; petiole 3.5 cm long, channelled, single pair of gland, green with red lines; Leaves 3.5–4 × 2.5–3 cm long, alternate, elliptic, acute at apex, crenate, crenature short with incurved bristles, base obtuse, 3–5 pair of nerves, , glabrous, lamina dark green adaxially, purple abaxially ; Inflorescence axillary, cluster of two flowers, peduncle 3 cm long, terete, green; pedicel 4–4.5 cm long, terete, red, glabrous; flowers zygomorphic, complete, 1.5–1.8 cm long, lateral sepals 0.84 × 0.8 cm, thick, linear to elliptic, tip acute, margins entire, base truncate, green with reddish tip, glabrous; lower sepal spurred, spur 1.8 cm long, laterally compressed, wrinkled, mouth dark red, other part red, glabrous; dorsal petal 0.82 × 0.6 cm, orbicular, keeled, light green, keel 0.7 cm long, 0.3 cm thick, dark green; lateral united petal 8.5 mm long, petals bilobed, inserted into spur, basal lobe 0.5 × 0.7 cm, light green, distal lobe broad at base and pointed towards the tip, margins strongly curved inward, light green, glabrous; androecium syngenicious, filaments 5; ovary elliptic 0.5 cm long, tip light violet, other part light green, glabrous.

Distribution: Kadalar, Munnar, Idukki, Kerala.

Phenology: August-October.

Elevation: 1200 m.

Specimens examined: Kerala: Kadalar, Munnar, 20.08.2019, *Reshma Ashok* 12665 (CMPR!).

Morpho type 6

Epiphytic on trees, perennial herbs, 15–20 cm long, stem monoliform , thick, leaf scares present, green; petiole 4 cm long, channelled, single pair of gland, green with red tinge; Leaves 3–4.5 × 3–3.5 cm long, alternate, broadly elliptic, acute at apex, crenate, crenature short with incurved bristles, base obtuse, 3–5 pair of nerves, , glabrous, lamina dark green adaxially, reddish green abaxially ; Inflorescence axillary, cluster of two flowers, peduncle 3.5 cm long, terete, green; pedicel 4–4.5 cm long, terete, red, glabrous; flowers zygomorphic, complete, 1.5–2 cm long, lateral sepals 7 × 2 mm, thick, linear to elliptic, tip acute, margins entire, base truncate, dark purple, glabrous; lower sepal spurred, spur 1.8 cm long, slightly inflated, saccate, wrinkled, mouth dark red, other part red, glabrous; dorsal petal 9 × 6 mm, orbicular, keeled, light green, keel 8 mm long, 1 mm thick, dark green; lateral united petal 7.8 mm long, petals bilobed, inserted into spur, basal lobe 4.8 × 5 mm, light green, distal lobe broad at base and pointed towards the tip, margins slightly curved inward, light green, glabrous; androecium syngenicious, filaments 5; ovary elliptic 5 mm long, tip light violet, other part light green, glabrous.

Distribution: Chooralmalai, Wayanad, Kerala.

Phenology: August-October.

Elevation: 1500 m.

Specimens examined: Kerala: Chooralmalai, Wayanad, 23.08.2019, *Reshma Ashok* 12666 (CMPR!).

Morpho type 7

Epiphytic perennial herbs, 8–10 cm long, stem monoliform, leaf scares present, green with purple tinge at the tip; petiole 1.5–4 cm long, channelled, angled, glands absent or single pair, violet; Leaves 3–3.5 × 2–2.5 cm long, alternate, ovate, acute at apex, crenate, crenature short with incurved bristles, base obtuse, 3–5 pair of nerves, glabrous, lamina dark green adaxially, light green abaxially; Inflorescence axillary, cluster of two flowers, peduncle 2 cm long, terete, green; pedicel 2.8–3 cm long, terete, purple, glabrous; flowers zygomorphic,

complete, 1.8–2.3 cm long, lateral sepals 6 × 1 mm, thick, linear to elliptic, tip acute, margins entire, base truncate, greenish purple, glabrous; lower sepal spurred, spur 2 cm long, laterally compressed, wrinkled, mouth dark purple, other parts white with purple tinge, glabrous; dorsal petal 0.7 × 0.6 cm, orbicular, keeled, light green, keel 0.7 cm long, 0.15 cm thick, dark green; lateral united petal 0.75 cm long, petals bilobed, inserted into spur, basal lobe 0.5 × 0.5 cm, dark green, distal lobe elongated, light green, glabrous; androecium syngenicious, filaments 5; ovary elliptic 0.5 cm long, tip light violet, other part light green, glabrous.

Distribution: Idamalakudi, Munnar, Idukki, Kerala.

Phenology: August-October.

Elevation: 1800 m.

Specimens examined: Kerala: Idamalakudi, Munnar, 20.08.2019, *Reshma Ashok* 12668 (CMPR!).

Morpho type 8

Epiphytic on trees, perennial herbs, 12–15 cm long, stem 0.8–1 cm diameter, monoliform, thick, woody, terete, branched, rough, main stem green, branches purple; internodes 0.5 cm, persistent leaf scare present, Leaves 5–6 × 3.5–4 cm long, alternate, ovate, acute at apex, crenate, crenature short with incurved bristles, bristles violet, base truncate, 3–5 pair of nerves, nerves purple, glabrous, lamina dark green adaxially, purple abaxially ; petiole 4 cm long, channelled, 2 pair of glands at the base of lamina, glands purple coloured, light purple coloured, glabrous; Inflorescence axillary, cluster of two flowers, peduncle 2.5 cm long, terete, green; pedicel 4–4.5 cm long,, terete, violet coloured; flowers zygomorphic, complete, 1.5–2 cm long, lateral sepals 0.62 × 0.12 cm, thick, linear to elliptic, tip acute, margins entire, base truncate, green with violet base, glabrous; lower sepal spurred, spur 1.8 cm long, saccate, wrinkled, mouth dark violet, other part purple coloured, glabrous; dorsal petal 0.6 × 0.55 cm, orbicular, keeled, light green, keel 0.54 mm long, 0.77 mm thick, dark green; lateral united petals bilobed, inserted into spur, basal lobe 0.3 × 1.8 cm, distal lobe 0.82 × 0.4 cm, light green, glabrous; androecium syngenicious, filaments 5; ovary elliptic 0.46 cm long, tip light violet, other part light green, glabrous.

Distribution: Idamalaikudi, Munnar, Idukki, Kerala.

Phenology: August-October.

Elevation: 1800 m.

Specimens examined: Kerala: Idamalaikudi, Munnar, 20.08.2019, *Reshma Ashok* 12669 (CMPR!).

4.3 Resolving taxonomic discrepancy on the lobes of lateral united petals (Figure 10, 11)

The flowers of *Epiphyticae Impatiens* have two lateral united petals, which are inserted in the spur. The lateral united petals attached to the pedicel with a stalk and consists of a basal lobe and a distal lobe. Here these sepals are very rigid and thick unlike the fragile sepals found in most of the other species. The stalk of petal is broad and lobe like. In the descriptions and illustrations of first formed species viz, *I. auriculata, I. viridiflora, I. parasitica* and *I. jerdoniae* only two lobes are reported. Later in 1995 A. G Pandurangan and V. J Nair reported a new species from Meenmutty Idukki district. In the description of this species, the stalk of the lateral united petal is considered as a lobe, hence described that the petal consists of three lobes. A similar observation was reported by M. Kumar and Stephan Sequira (2001) while describing *I. violaceae* and *I. sholayarensis*. The key proposed by V. Bhaskar to identify *Epiphyticae Impatiens* divides these seven species into two, based on the number of lobes of lateral united petals; that is species with two lobes and species with three lobes.

On critical examination of all of these species it is understood that, the concept of third lobe of the lateral united petal was due to misinterpretation of stalk. The lateral united petals of *Epiphyticae Impatiens* contain only two lobes and a rigid stalk. The basal lobe is close to the stalk and sometime exposed out of the spur, the distal lobe is away from the stalk and always inserted in the spur. The illustrations provided by the authors of the species also show similarity in basic structure. The misinterpretation is also very evident from the illustrations. Hence the concept of three lobes should be discarded and the key proposed by V. Bhaskar is no longer acceptable.

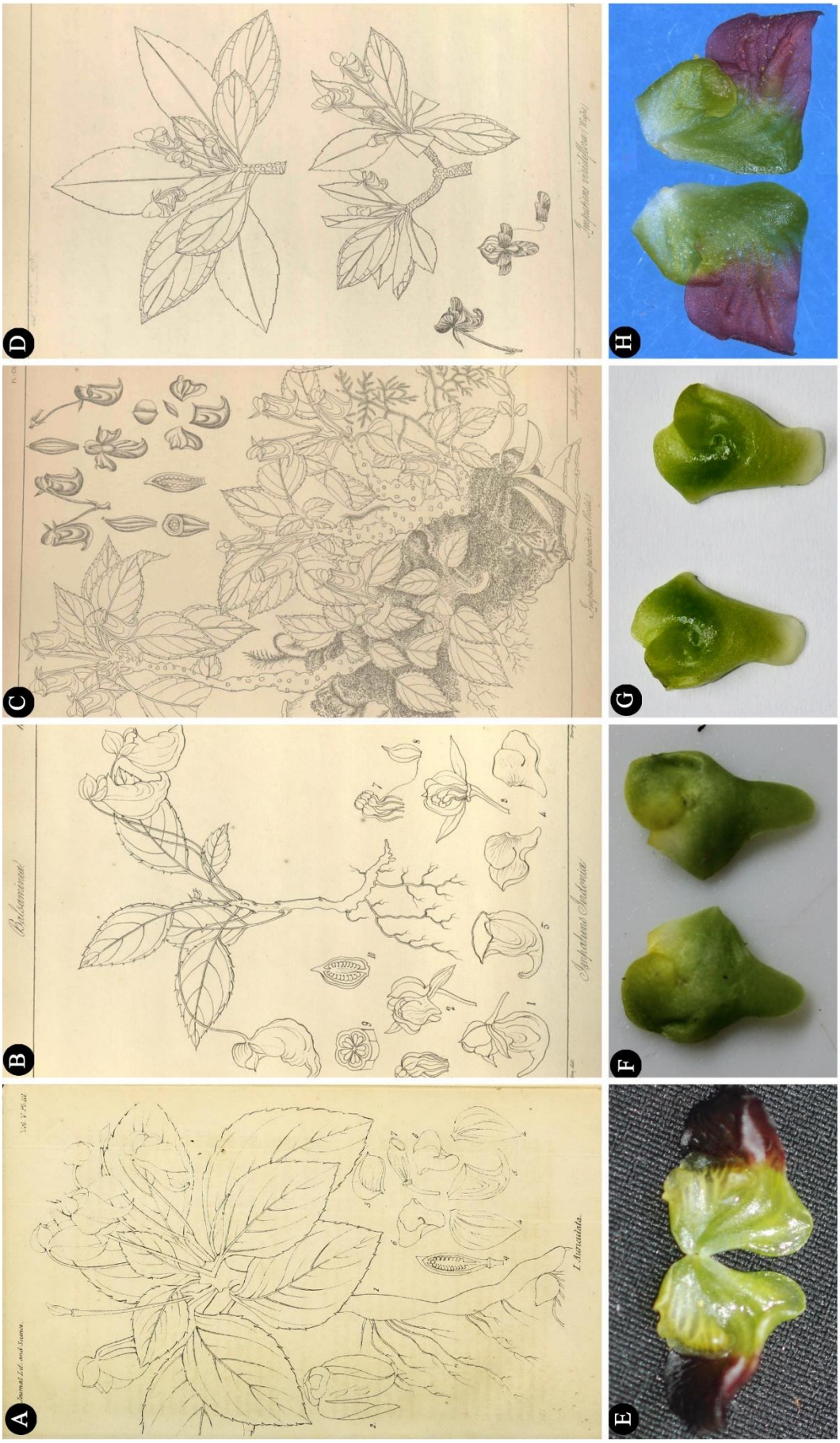

Figure 10: Illustrations of four *Epiphyticae Impatiens*- **A.** *I. auriculata*; **B.** *I. jerdoniae*; **C.** *I. parasitica*; **D.** *I. viridiflora*; Lateral united petals of **E.** *I. auriculata*; **F.** *I. jerdoniae*; **G.** *I. parasitica*; **H.** *I. viridiflora*

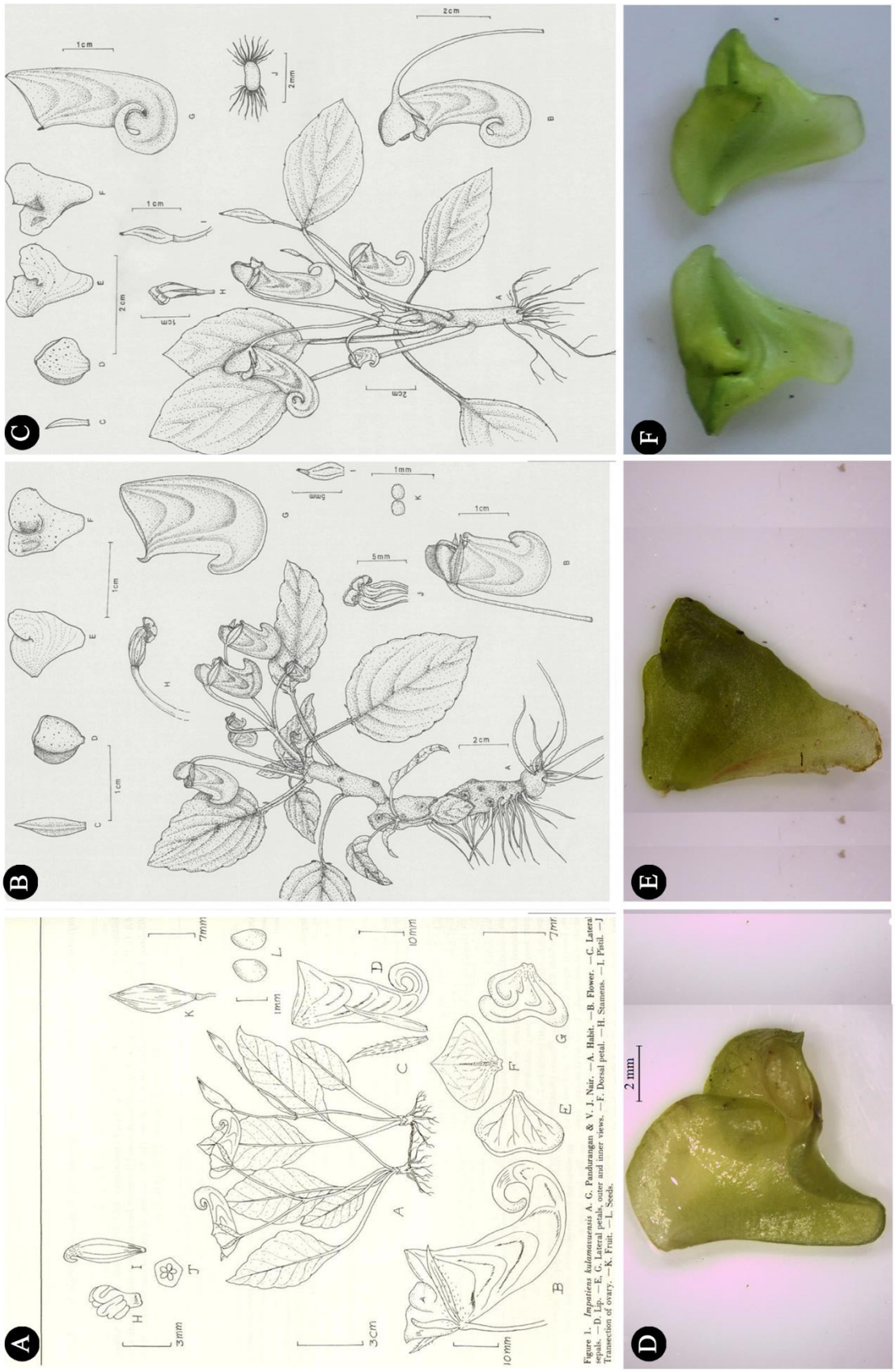

Figure 11: Illustrations of three *Epiphyticae Impatiens*- **A.** *I. kulamavuensis* ; **B.** *I. violaceae* ; **C.** *I. sholayarensis:* Lateral united petals of **D.** *I. kulamavuensis;* **E.** *I. violaceae*; **F.** *I. sholayarensis*

4. 4 Synonymizing *I. kulamavuensis* A. G Pandurangan and V. J. Nair with *I. parasitica* (Figure 12)

Impatiens Kulamavuensis is an epiphytic species described from Meenmutty, Kulamavu, Idukki district, Kerala. This species is closely allied to *I. parasitica*. On critical examination of holotype and other herbarium material, as well as the protologue, it is clear that *I. kulamavuensis* cannot be considered as an independent species, but it is a synonym of *I. parasitica.* According to the protologue *I. kulamavuensis* differ from *I. parasitica* by having stem less than 1 cm (vs. 10–12 cm long), leaves glanduliferous above (vs. glabrous on both surface), sepals hairy outside (vs. sepals glabrous outside), petals hairy at base (vs. petals glabrous at base), Stigma lobs not 5 toothed, silky pubescent (vs. stigma lobs 5 toothed, not pubescent), seeds pear shaped (vs. seeds ellipsoid) (Table 4).

Based on the extensive field trips conducted in these regions during the past years *I. parasitica* was found to be distributed throughout in these regions and showing many phenotypic variations. Plants with very short stems and stem trailing on the surface with new buds arising from the nodal regions are also frequently encountered. Hairy nature on the surface of certain floral parts cannot be considered as a stable character in plants like *Impatiens*. Stigmatic lobes show 5 toothed conditions and within the same plant itself 5 toothed conditions is found to be absent some times. The pubescent nature of stigmatic surface also varies between the flowers of the same plant or within the population. Hence, both these characters cannot be used for delimiting the species. The shape of the seed varies from round to pear shaped and colour from yellowish brown to dark brown. Hence, this character also does not support the independent existence of the new species.

Table 4: Comparative account of *Impatiens kulamavuensis* with *Impatiens parasitica*

Impatiens kulamavuensis	***Impatiens parasitica***
Stem less than 1 cm, stoloniferous, not monoliform	10–12 cm long, not stoloniferous, monoliform
Leaves glanduliferous above, glabrous beneath, lateral nerves indistinct	Glabrous on both surface, lateral nerves prominent
Lateral sepals hairy outside, glabrous inside	Lateral sepals glabrous outside, glandular inside at base
Petals hairy inside at base	Petals glanduliferous inside at base

Stigmas curved lobs not 5 toothed, silky pubescent	Stigma straight, stigmatic lobes 5 toothed, not pubescent
Seeds pear shaped	Seeds rounded to ellipsoid

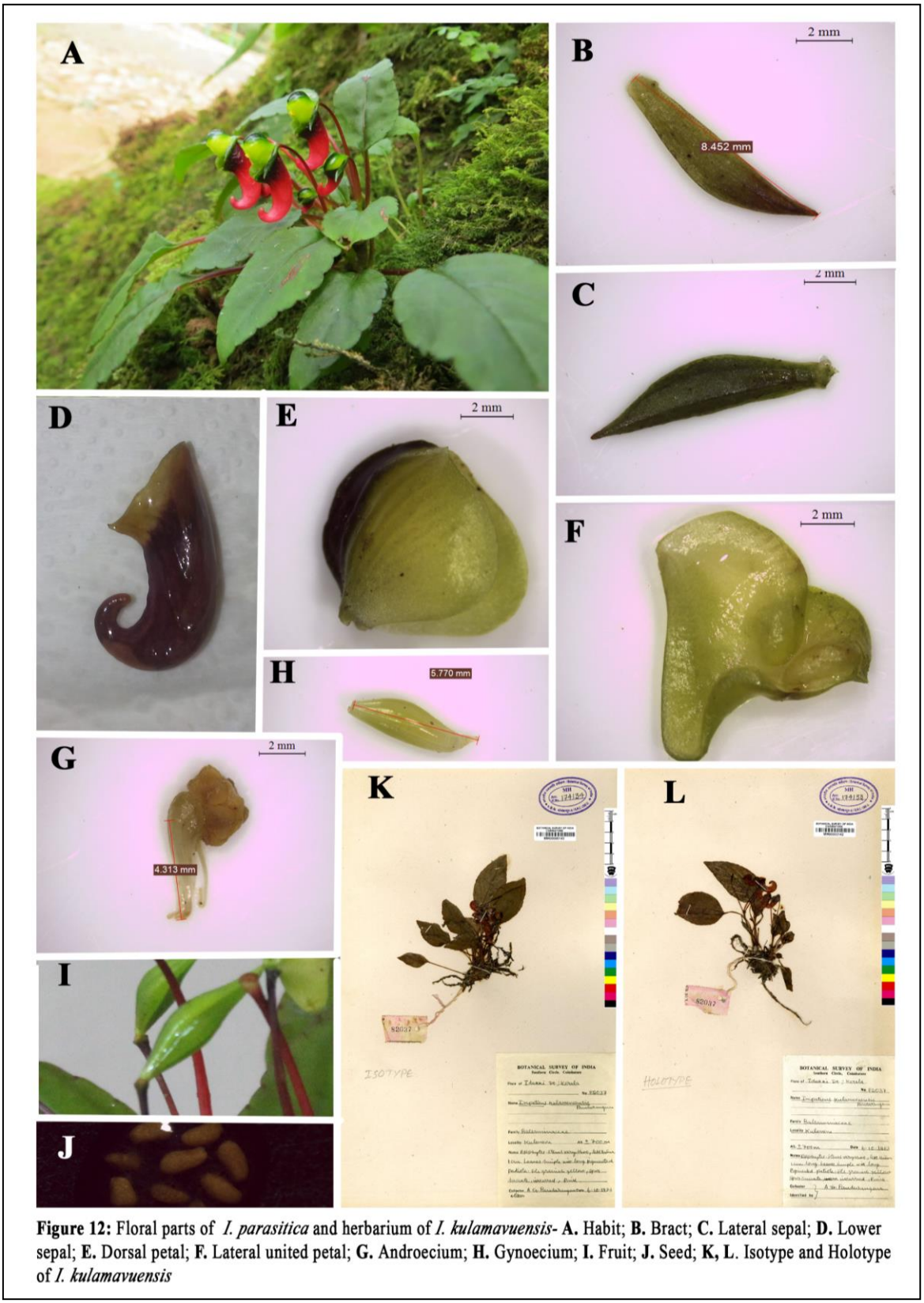

Figure 12: Floral parts of *I. parasitica* and herbarium of *I. kulamavuensis*- **A.** Habit; **B.** Bract; **C.** Lateral sepal; **D.** Lower sepal; **E.** Dorsal petal; **F.** Lateral united petal; **G.** Androecium; **H.** Gynoecium; **I.** Fruit; **J.** Seed; **K, L.** Isotype and Holotype of *I. kulamavuensis*

4.5 Anatomy of vegetative parts

Key to the species based on anatomy

1a. Epidermal cells of leaf have straight walls in surface view……***I. auriculata***

1b. Epidermal cells of leaf have wavy walls in surface view……..……**2**

2a. Vascular bundle of the leaf U shaped…….…….……..**3**

2b. Vascular bundles of the leaf crescent shaped…….…….……..**5**

3a. Palisade cells are arranged in a single layer…….……***I. jerdoniae***

3b. Palisade cells are arranged in two layers…….…..**4**

4a. Starch grains are present in the pith of stem also…….…..…..***Impatiens* sp. 1**

4b. Starch grains absent in the pith……...……...…***I. sholayarensis***

5a. Cortex of midrib have more than 3 layers of sclerenchyma ……..…..***I. viridiflora***

5b. Cortex of midrib have less than 2 layers of sclerenchyma.……...……**6**

6a. Raphides are evenly distributed in the hypodermis……...…..***I. violaceae***

6b. Rapphides are sparsely distributed in the hypodermis…….***I. parasitica***

4.5.1 Anatomy of Leaf

1. *Impatiens auriculata* (Figure 13)

Midrib: 600–607 µm thick. Epidermis: Adaxial epidermal cells 30–33 × 20–30 µm, rectangular, elongated, uniseriate; abaxial epidermal cells 28–34 × 20–31 µm, rectangular, uniseriate.

Adaxial hypodermis: Cells 294–300 µm thick, 2 layers of sclerenchyma cells just below the epidermis, 6–7 layers of parenchyma cells following sclerenchyma cells, mucilage canal present, 45–55 µm diameters.

Abaxial hypodermis: Cells 205–214 µm thick, single layer of sclerenchyma above epidermis, 5–7 layers of parenchyma cells following sclerenchyma cells, 5–9 mucilage canal present, circular outline with 55–65 µm diameter, surrounded by parenchyma cells which are broader than high.

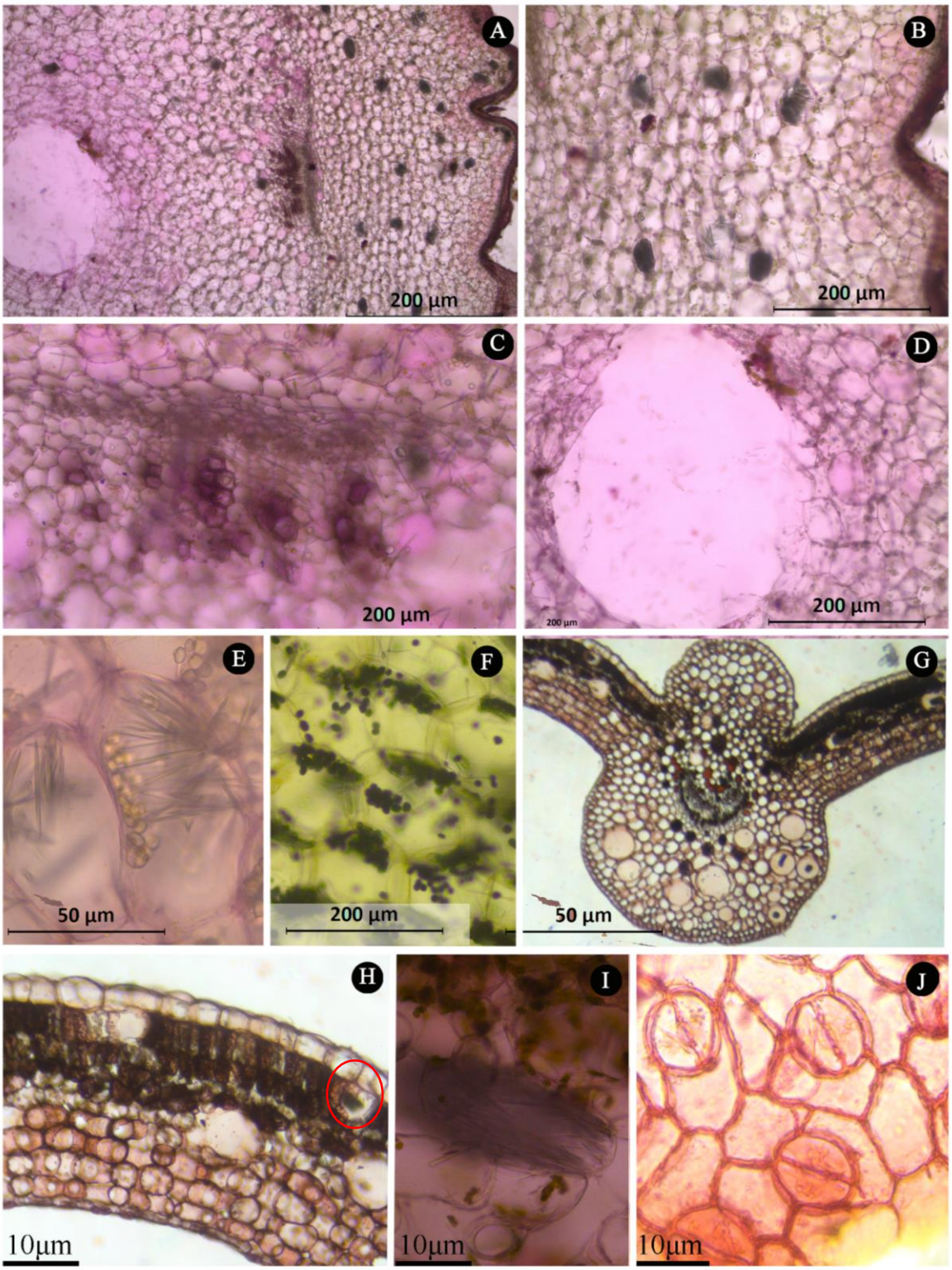

Figure 13: Anatomy of *Impatiens auriculata* – A. T.S of Stem; **B.** Cortex; **C.** Vascular bundle; **D.** Mucilage canal; **E.** Raphides in stem; **F.** Starch granules in cell of stem; **G.** C.S of leaf; **H.** Mesophyll **I.** Raphides in Leaf; **J.** Stomata

Vascular bundle: Single vascular bundle, 60–65 × 140–150 µm, U-shaped, 4–9 layers of phloem cells below the xylem, 5–10 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 418–428 µm thick. Epidermis: Adaxial epidermis 49–52 × 69–79 µm, rectangular broader than high, uniseriate; abaxial epidermis 11–20 × 25–32 µm, rectangular, broader than high uniseriate. Hypodermis: Divided into 2 layered palisade and 5–7 layers of spongy parenchyma cells; palisade 95–98 µm thick, chlorenchymatous, barrel shaped, 40–58 × 15–20 µm; spongy parenchyma 258–263 µm thick, isodiametric cells 40–48 µm diameter, chlorophyll present in first 2 layers of cells. Many mucilage canals and raphide sacs present.

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells polyhedral, anticlinal walls slightly wavy 8–15 × 6–11 µm. Abaxial surface stomatiferous, stomata anamocytic; guard cells 18–23 × 7.5–8.6 µm, stomatal opening 8–10 × 4–6 µm; subsidiary cells 4, polyhedral with straight to slightly wavy margin, 20–26 × 18–30 µm, subsidiary cells and epidermal cells are similar in shape and size, stomatal index 25.75%.

2. *Impatiens jerdoniae* (Figure 14)

Midrib: 975–981 µm thick. Epidermis: Adaxial epidermal cells 30–38 × 50–59 µm, rectangular, broader than high, uniseriate; abaxial epidermal cells 17–25 × 29–34 µm, rectangular, broader than high, uniseriate.

Adaxial hypodermis: 450–455 µm thick, single layer of sclerenchyma cells below the epidermis, following the sclerenchyma cells 3–5 layers of chlorenchyma cells, mucilage canal present, circular outline with 80–85 µm diameter.

Abaxial hypodermis: 310–320 µm thick, single layer of sclerenchyma cells above epidermis, 4–6 layers of parenchyma following sclerenchyma cells, mucilage canal present, circular outline with 80–86 µm diameter.

Vascular bundle: Single vascular bundle, 150–160 × 227–230 µm, U-shaped, 7–10 layers of phloem cells at the lower side, 7 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 470–475 µm thick. Epidermis: Adaxial epidermis 55–65 × 70–80 µm, rectangular broader than high, uniseriate; abaxial epidermis 21–23 × 22–25 µm, rectangular uniseriate.

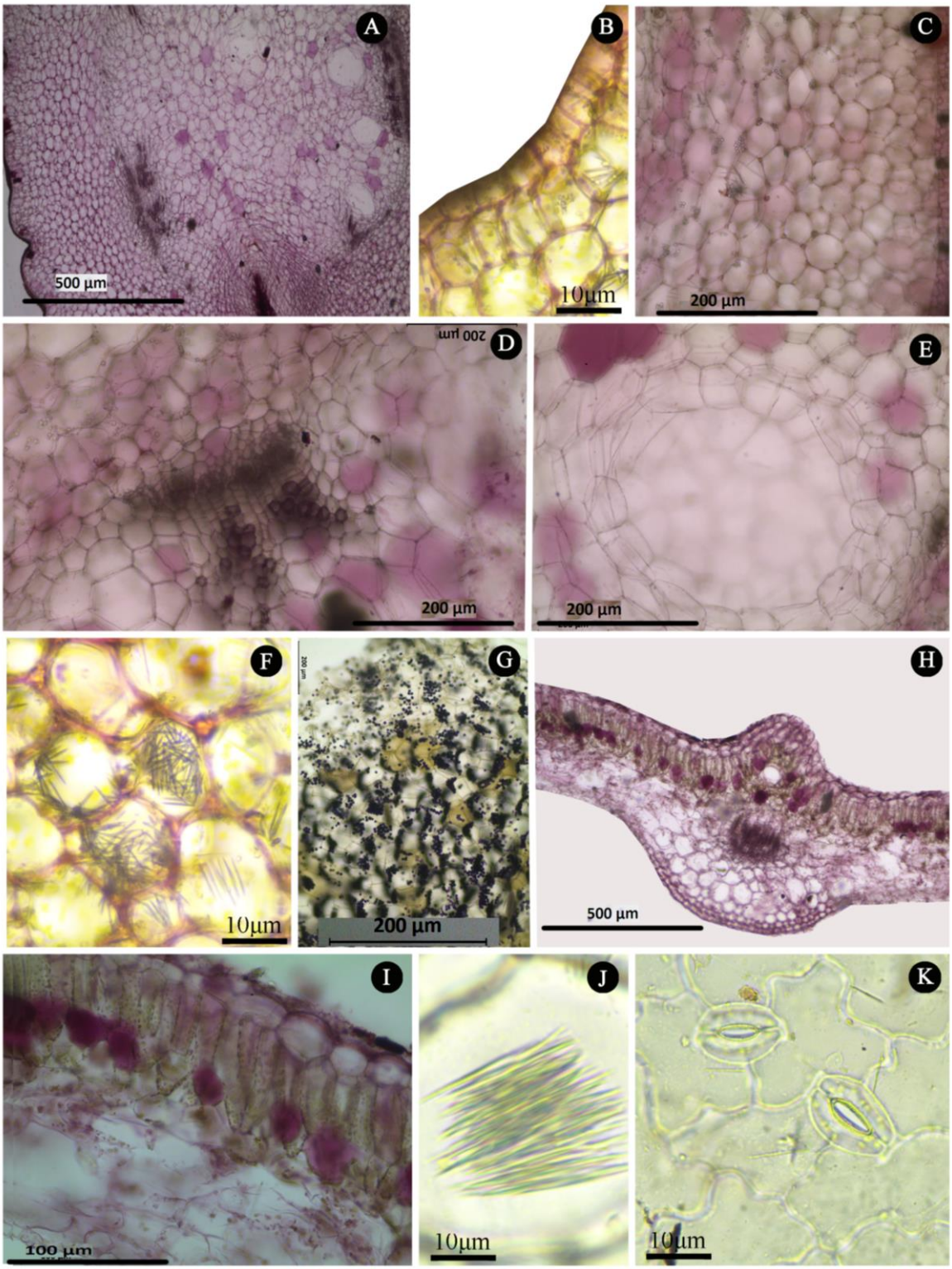

Figure 14:Anatomy of *Imptiens jerdoniae* - A. T.S of Stem; **B.** Epidermis; **C.** Cortex; **D.** Vascular bundle; **E.** Mucilage canal; **F.** Raphides in stem; **G.** Starch granules in cells of stem; **H.** C.S of leaf; **I.** Mesophyll; **J.** Raphides in Leaf; **K.** Stomata

Hypodermis: Divided into single layered palisade and 4 or 5 layers of spongy parenchyma cells; palisade 150–153 µm thick, chlorenchymatous, cells 150–153 × 45–48 µm; spongy parenchyma 240–248 µm thick, irregular shaped cells 45–60 × 20–37 µm. Raphide sac present.

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells elongated, margins wavy with 2–4 infoldings, 17–26 × 4–7 µm. Abaxial surface stomatiferous, stomata anamocytic; guard cells 29–32 × 8–10 µm, stomatal opening 14–18 × 5–7 µm; subsidiary cells 4, cells four sided with lobed and wavy anticlinal walls, 50–60 × 38–48 µm, stomatal index 22%.

3. *Impatiens parasitica* (Figure 15)

Midrib: 815–820 µm thick. Epidermis: Adaxial epidermal cells 30–35 × 50–60 µm, rectangular, higher than broad, uniseriate; abaxial epidermal cells 25–27 × 18–21 µm, rectangular, uniseriate.

Adaxial hypodermis: cells 306–315 µm thick, 1or 2 layers of sclerenchyma cells just below the epidermis, following the sclerenchyma cells 3–4 layers of chlorenchyma cells, up to 6 layers of parenchyma cells below, mucilage canal present, circular outline with 70–74 µm diameter.

Abaxial hypodermis 317–324 µm thick, single layer of sclerenchyma above epidermis, 5– 8 layers of parenchyma following sclerenchyma cells, 3–4 mucilage canal present, circular outline with 65–70 µm diameter.

Vascular bundle: single vascular bundle, 130–150 × 150–165 µm, crescent shaped, up to 10 layers of phloem cells at the lower side, 8 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 340–345 µm thick. Epidermis: Adaxial epidermis 25–35 × 100–110 µm, rectangular broader than high, uniseriate; abaxial epidermis 19–25 × 18–21 µm, rectangular uniseriate. Hypodermis: divided into 2 layered palisade and 5–8 layers of spongy parenchyma cells; palisade 110–117 µm thick, chlorenchymatous, upper layer of cells barrels shaped and more elongated than lower layer of cells, upper layer of cells 65–70 × 26–30 µm, lower layer of cells 50–55 × 26–30 µm; spongy parenchyma 165–175 µm thick, irregular shaped cells 35–70 × 25–35 µm. Raphide sacs present.

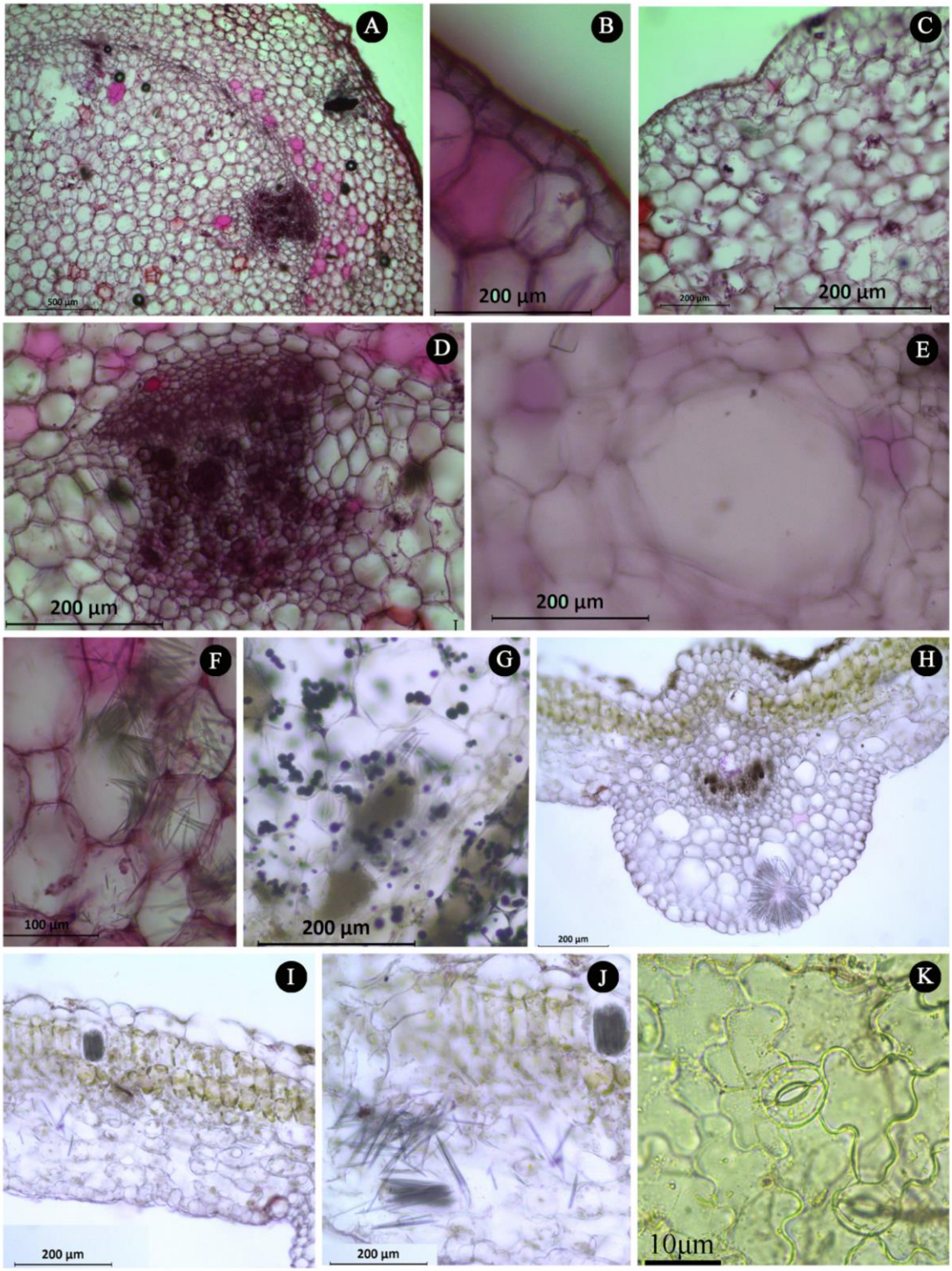

Figure 15: Anatomy of *Impatiens parasitica* - A. T. S of Stem; **B.** Epidermis; **C.** Cortex; **D.** Vascular bundle; **E.** Mucilage canal; **F.** Raphides in stem; **G.** Starch granules in cell of stem; **H.** C.S of leaf; **I.** Mesophyll; **J.** Raphides in Leaf; **K.** Stomata

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells 47–62 × 25–32 four sided, elongated, anticlinal wall wavy and lobed, number of lobes 5–8, abaxial surface stomatiferous, stomata anamocytic; guard cells 21–25 × 6–8 µm, stomatal opening 10–12 × 5– 8 µm; subsidiary cells 4, similar to adaxial cells in shape, 30–35 × 55–64 µm, stomatal index 20.5%.

4. *Impatiens sholayarensis* (Figure 16)

Midrib: 730–737 µm thick. Epidermis: Adaxial epidermal cells 25–34 × 24–32 µm, rectangular, broader than high, uniseriate; abaxial epidermal cells 30–45 × 28–34 µm, rectangular, uniseriate.

Adaxial hypodermis: cells 313–321 µm thick, 1or 2 layers of sclerenchyma cells just below the epidermis, following the sclerenchyma cells 4–7 layers of chlorenchyma cells, mucilage canal present, circular outline with 30–37 µm diameter.

Abaxial hypodermis: cells 245–250 µm thick, single layer of sclerenchyma above epidermis, 5–8 layers of parenchyma following sclerenchyma cells, 3–4 mucilage canal present, circular outline with 50–60 µm diameter.

Vascular bundle: single vascular bundle, 113–120 × 80–90 µm, U-shaped, up to 10 layers of phloem cells at the lower side, 6–8 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 331–340 µm thick. Epidermis: Adaxial epidermis 45–55 × 70–80 µm, rectangular broader than high, uniseriate; abaxial epidermis 20–27 × 18–21 µm, rectangular uniseriate. Hypodermis: divided into 2 layered palisade and 5–8 layers of spongy parenchyma cells; palisade 110–118 µm thick, chlorenchymatous, upper layer of cells barrel shaped and more elongated than lower layer of cells, upper layer of cells 57–82 × 27–45 µm, lower layer of cells 35–55 × 26–30 µm; spongy parenchyma 187–195 µm thick, irregular shaped cells 33–50 × 25–35 µm, chlorophyll present. Mucilage canal present, 60 µm diameter. Raphide sac present.

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells 40–60 × 20–43, irregular, margins wavy highly lobed, number of lobes 5–10, abaxial surface stomatiferous, stomata anamocytic; guard cells 20–24 × 4–6 µm, stomatal opening 9–11×5–8 µm; subsidiary cells 4, similar to adaxial cells in shape, 46–50 × 65–73 µm, stomatal index 20.25%.

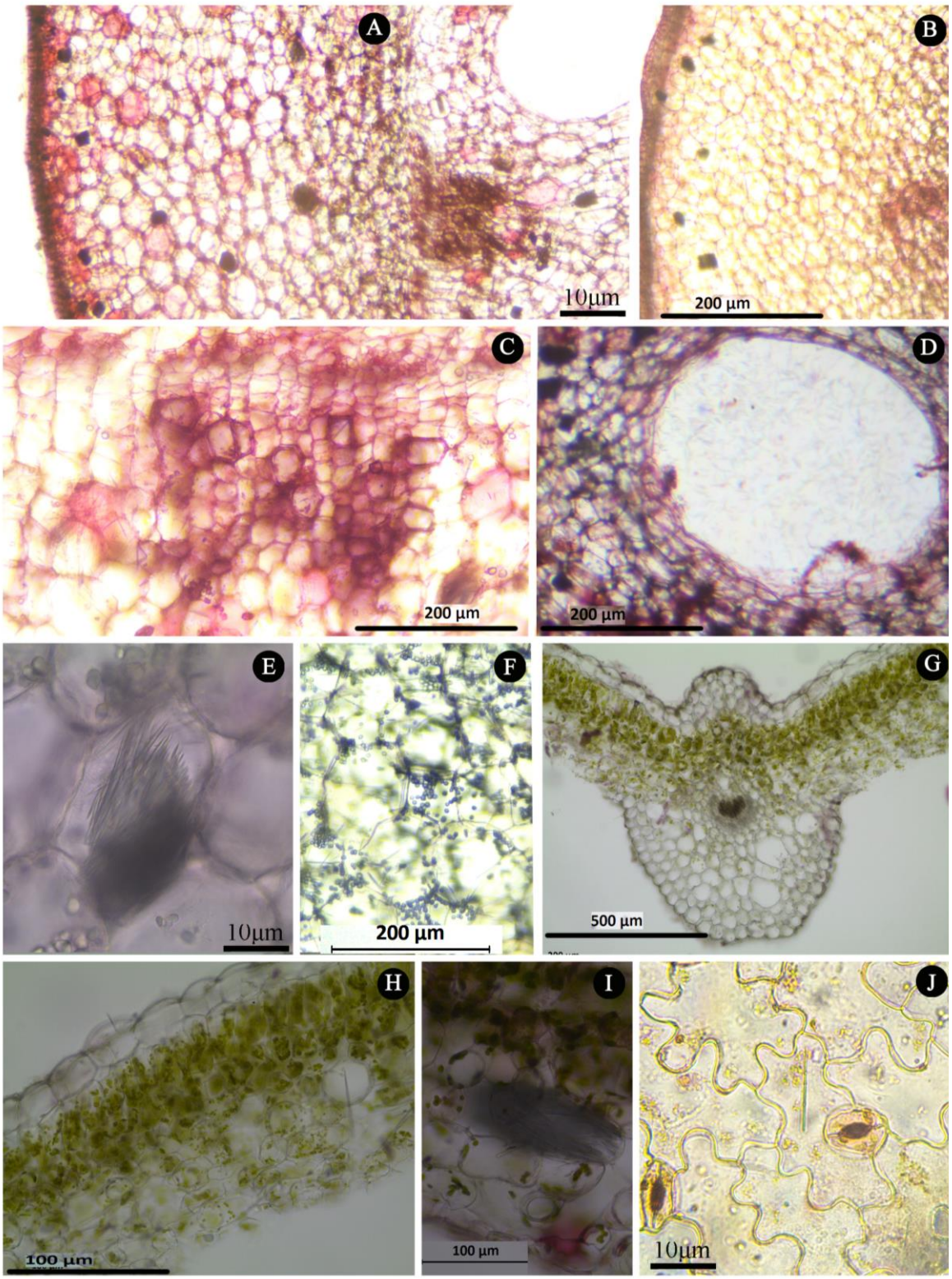

Figure 16: Anatomy of *Impatiens sholayarensis* -A. T.S of Stem; **B.** Cortex; **C.** Vascular bundle **D.** Mucilage canal; **E.** Raphides in stem; **F.** Starch granules in cell of stem; **G.** C. S of leaf; **H.** Mesophyll; **I.** Raphides in Leaf; **J.** Stomata

5. *Impatiens violaceae* (Figure 17)

Midrib: 759–761 µm thick. Epidermis: Adaxial epidermal cells 24–28 × 16–24 µm, rectangular, uniseriate; abaxial epidermal cells 40–50 × 45–52 µm, rectangular, uniseriate.

Adaxial hypodermis: cells 290–296 µm thick, 2–3 layers of sclerenchyma cells below the epidermis, following the sclerenchyma cells 2–4 layers of chlorenchyma cells, below these layers 3–4 layers of parenchyma cells, mucilage canal present, circular outline with 75–79 µm diameter.

Abaxial hypodermis: cells 238–240 µm thick, single layer of sclerenchyma above epidermis, 2–5 layers of parenchyma following sclerenchyma cells, mucilage canal present, circular outline with 65–71 µm diameter

Vascular bundle: single vascular bundle, 113–116 × 200–205 µm, crescent shaped, 5–9 layers of phloem cells around the xylem, 5–7 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 347–350 µm thick. Epidermis: Adaxial epidermis 36–42 × 69–78 µm, rectangular broader than high, uniseriate; abaxial epidermis 26–30 × 22–25 µm, rectangular uniseriate. Hypodermis: divided into single layered palisade and 7–9 layers of spongy parenchyma cells; palisade 80–85 µm thick, chlorenchymatous, 80–85 × 20–28 µm; spongy parenchyma 190–196 µm thick, isodiametric cells 35–50 × 20–37 µm. Raphide sac present.

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells 38–56 × 20–43, elongated, deeply lobed, number of lobes 2–5, abaxial surface stomatiferous, stomata anamocytic; guard cells 25–28 × 7–10 µm, stomatal opening 13–15 × 6–7.5 µm; subsidiary cells 4, broader than abaxial cells, anticlinal walls wavy and deeply lobed, 78–87 × 69–78 µm, stomatal index 20.5%.

6. *Impatiens viridiflora* (Figure 18)

Midrib: 460–467 µm thick. Epidermis: Adaxial epidermal cells 9–14 × 8–13 µm, rectangular, broader than high, uniseriate; abaxial epidermal cells 5–7 × 10–14 µm, rectangular, uniseriate. Adaxial hypodermis: cells 190–200 µm thick, 2–3 layers of sclerenchyma cells just below the epidermis, following the sclerenchyma cells 6–7 layers of chlorenchyma cells, mucilage canal present, circular outline with 30–35 µm diameter.

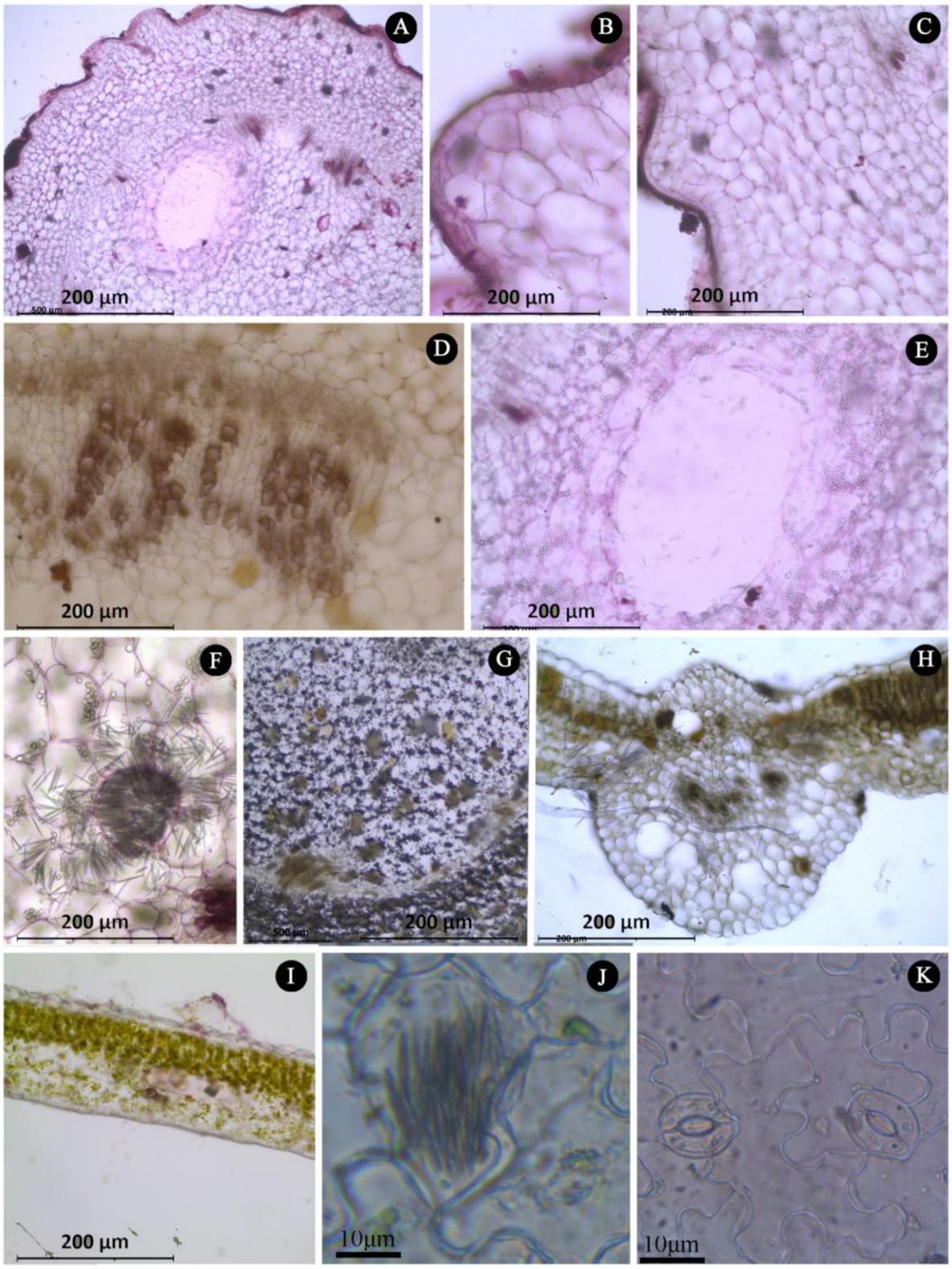

Figure 17: Anatomy of *Impatiens violacea* -A. T.S of Stem; **B.** Epidermis; **C.** Cortex; **D.** Vascular bundle; **E.** Mucilage canal; **F.** Raphides in stem; **G.** Starch granules in cell of stem; **H.** C. S of leaf; **I.** Mesophyll; **J.** Raphides in Leaf; **K.** Stomata

Abaxial hypodermis: cells 134–140 µm thick, 2–3 layers of sclerenchyma above epidermis, 5–7 layers of parenchyma following sclerenchyma cells, 1–3 mucilage canal present, circular outline with 40–45 µm diameter.

Vascular bundle: single vascular bundle, 185–192 × 50–60 µm, crescent shaped, up to 10 layers of phloem cells surrounding the xylem, 9–10 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

Mesophyll: 160–170 µm thick. Epidermis: Adaxial epidermis 10–15 × 20–29 µm, rectangular broader than high, uniseriate; abaxial epidermis 14–19 × 9–12 µm, rectangular, broader than high uniseriate.

Hypodermis: divided into single layered palisade and 4–6 layers of spongy parenchyma cells; palisade 29–38 µm thick, chlorenchymatous, barrel shaped, 27– 38 × 15–18 µm; spongy parenchyma 90–95 µm thick, elliptic shaped cells 20–26 × 15–18 µm, chlorophyll present. Raphide sac present.

Epidermal tissues and Stomata: Adaxial surface apostomatic, cells 40–60 × 20–40, irregular, margins wavy, lobed, number of lobes 5–8, abaxial surface stomatiferous, stomata anamocytic; guard cells 22–24 × 7–8.5 µm, stomatal opening 9–12 × 5.5–8 µm; subsidiary cells 4, irregular shaped 36–45 × 44–53 µm, stomatal index 22.5%.

7. *Impatiens* sp. 1 (Figure 19)

Midrib: 1426–1430 µm thick. Epidermis: Adaxial epidermal cells 27–36 × 38–44 µm, rectangular, broader than high, uniseriate; abaxial epidermal cells 36–45 × 50–60 µm, rectangular, broader than high, uniseriate.

Hypodermis: Adaxial hypodermal cells 600–606 µm thick, 2–3 layers of sclerenchyma cells just below the epidermis, following the sclerenchyma cells 4–6 layers of chlorenchyma cells, below this layer 3–6 layers of parenchyma cells present, mucilage canal present, circular outline with 130–134 µm diameter; Abaxial hypodermal cells 480–484 µm thick, 1 or 2 layers of sclerenchyma above epidermis, 5–7 layers of parenchyma following sclerenchyma cells.

Vascular bundle: single vascular bundle, 203–210 × 410–420 µm, U-shaped, 5–10 layers of phloem cells around the xylem, 6–9 rows of xylem, protoxylem towards the adaxial side and metaxylem towards the abaxial side.

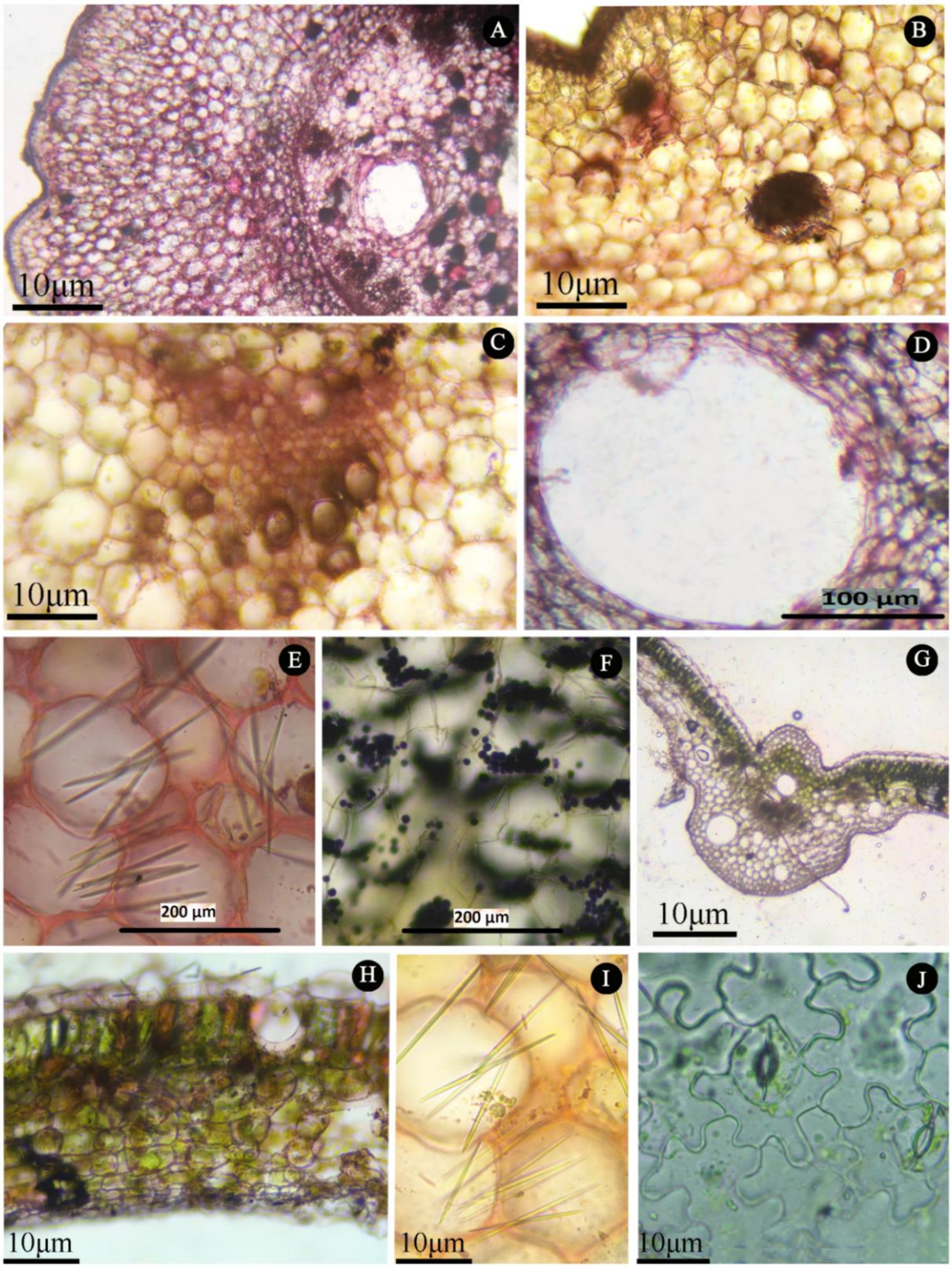

Figure 18: Anatomy of *Impatiens viridiflora* - A. T.S of Stem; **B.** Cortex; **C.** Vascular bundle; **D.** Mucilage canal; **E.** Raphides in stem; **F.** Starch granules in cell of stem; **G.** C.S of leaf; **H.** Mesophyll; **I.** Raphides in Leaf; **J.** Stomata

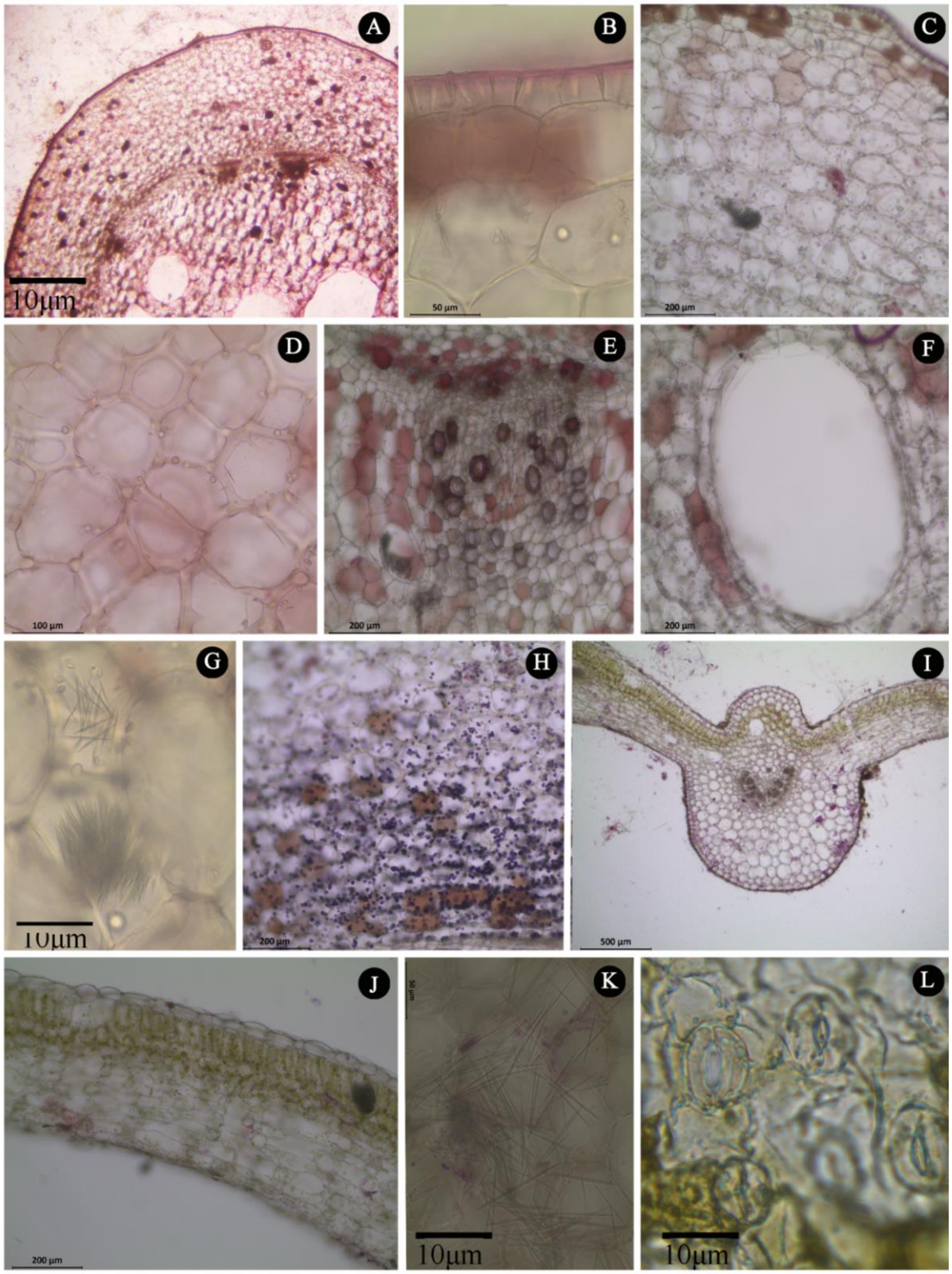

Figure 19: Anatomy of *Impatiens* species 1: A. T. S of Stem; **B.** Epidermis; **C.** Cortex; **D.** Sclerenchyma **E.** Vascular bundles; **F.** Mucilage canal; **G.** Raphides in stem; **H.** Starch granules in cell; **I.** C. S of leaf **J.** Mesophyll; **K.** Raphides in Leaf; **L.** Stomata

Mesophyll: 400–404 µm thick. Epidermis: Adaxial epidermis 36–40 × 88–92 µm, rectangular broader than high, uniseriate; abaxial epidermis 25–30 × 21–23 µm, rectangular uniseriate. Hypodermis: divided into 2 layered palisade and 8–10 layers of spongy parenchyma cells; palisade 128–130 µm thick, chlorenchymatous, upper layer of cells 86–90 × 23–28 µm, lower layer of cells 40–45 × 35–38 µm; spongy parenchyma 270–276 µm thick, cells broader than high 25–40 × 40–47 µm. Raphide sac present only in palisade layer.

Stomata: Present only in the abaxial surface, anamocytic; guard cells 20–26 × 7–10 µm, stomatal opening 8.5–12 × 5–7 µm; subsidiary cells 4, irregular shaped 55–65 × 58–68 µm, stomatal index 26.5%.

4.5.2 Anatomy of stem

1. *Impatiens auriculata* (Figure 13)

Epidermal cells 14–20 × 19–25 µm, rectangular, broader than high, uniseriate. Hypodermis 15–20 layered, following the epidermis 4–8 layers of collenchyma cells present, below the collenchyma 4–6 layers of chlorenchyma, following the chlorenchyma layer 6–9 layers of isodiametric parenchyma cells present, 5–6 layers of parenchyma near the endodermis carry more amounts of starch grains, starch grains and raphide sacs are present throughout hypodermis. Endodermis uniseriate, 16–20 × 25–27 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 220–228 × 355–364 µm, phloem 30–38 µm thick, 5–10 layered, cambium forming complete cambial ring, xylem 138–147 µm thick, metaxylem towards the epidermis 10–20 µm diameter, protoxylem towards the pith 5–10 µm diameter; medullary rays 10–15 layered, cells isodiametric. Mucilage canals present inside the pith, 3–5 in number, 740–750 µm diameters, surrounded by large parenchyma cells, 12–18 × 27–35 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells, starch grains and raphide sac present in the pith.

2. *Impatiens jerdoniae* (Figure 14)

Epidermal cells 22–30 × 25–35 µm, rectangular, broader than high, uniseriate. Hypodermis 12–18 layered, following the epidermis 2–4 layers of chlorenchyma cells present, below this 4–7 layers of collenchyma, following the collenchyma layer 3–5 layers of isodiametric parenchyma cells present, 2–4 layers of parenchyma near the endodermis carry starch grains. Endodermis uniseriate, 30–33 × 40–55 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 343–352 × 345–355 µm, phloem 65–67 µm thick, 10–20 layered,

cambium forming complete cambial ring, xylem 210–212 µm thick, metaxylem towards the epidermis 23–30 µm diameter, protoxylem towards the pith 10–14 µm diameter; medullary rays 10–20 layered, isodiametric cells. Mucilage canals present inside the pith, 3–4 in number, 708–716 µm diameter, surrounded by large parenchyma cells, 68–72 × 150–165 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells.

3. *Impatiens parasitica* (Figure 15)

Epidermal cells 27–33 × 19–25 µm, rectangular, uniseriate. Hypodermis 10–15 layered, following the epidermis 2–4 layers of collenchyma cells present, below the collenchyma 3–4 layers of chlorenchyma, following the chlorenchyma layer 6–9 layers of isodiametric parenchyma cells present, 2–4 layers of parenchyma near the endodermis carry starch grains. Endodermis uniseriate, 25–27 × 45–50 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 485–490 × 330–345 µm, phloem 85 µm thick, 15–25 layered, cambium forming complete cambial ring, xylem 351 µm thick, metaxylem towards the epidermis 10–30 µm diameter, protoxylem towards the pith 3–8 µm diameter; medullary rays 10–15 layered, isodiametric cells. Mucilage canals present inside the pith, 3–4 in number, 120–130 µm diameter, surrounded by large parenchyma cells, 45–60 × 120–145 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells, raphide sac sparsely distributed in hypodermis and pith.

4. *Impatiens sholayarensis* (Figure 16)

Epidermal cells 10–17 × 8–13 µm, rectangular, uniseriate. Hypodermis 10–15 layered, following the epidermis 2–4 layers of collenchyma cells present, below the collenchyma 3–4 layers of chlorenchyma, following the chlorenchyma layer 6–9 layers of isodiametric parenchyma cells present, 4–6 layers of parenchyma near the endodermis carry starch grains, raphides are present throughout hypodermis. Endodermis uniseriate, 11–25 × 7–13 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 65–80 × 114–134 µm, phloem 13–21 µm thick, 5–15 layered, cambium forming complete cambial ring, xylem 40–52 µm thick, metaxylem towards the epidermis 5–10 µm diameter, protoxylem towards the pith 2–5 µm diameter; medullary rays 10–15 layered, isodiametric cells. Mucilage canals present inside the pith, 4–6 in number, 45–60 µm diameters, surrounded by large parenchyma cells, 5–7 × 10–14 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells with few raphide sac.

5. *Impatiens violaceae* (Figure 17)

Epidermal cells 24–33 × 22–25 µm, rectangular, uniseriate. Hypodermis 10–12 layered, following the epidermis 1 or 2 layers of chlorenchyma cells present, below this 4–6 layers of collenchyma, following the collenchyma layer 4–5 layers of isodiametric parenchyma cells bearing starch grains present. Endodermis uniseriate, 25–32 × 45–51 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 412–415 × 508–510 µm, phloem 85–87 µm thick, 15–25 layered, cambium forming complete cambial ring, xylem 314–318 µm thick, metaxylem towards the epidermis 20–28 µm diameter, protoxylem towards the pith 8–13 µm diameter; medullary rays 10–20 layered, isodiametric cells. Mucilage canals present inside the pith, 1 or 2 in number, 744–750 µm diameter, surrounded by large parenchyma cells, 61–67 × 113–167 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells, numerous starch grains present. Raphides present throughout stem.

6. *Impatiens viridiflora* (Figure 18)

Epidermal cells 6–9 × 3–5 µm, rectangular, elongated, uniseriate. Hypodermis 10–15 layered, following the epidermis 1–2 layers of collenchyma cells present, below the collenchyma 4–6 layers of chlorenchyma, following the chlorenchyma layer 6–9 layers of isodiametric parenchyma cells present, 4–6 layers of parenchyma near the endodermis carry starch grains, starch bearing cells are larger than the rest, raphides are present in the first 5 layers of hypodermis. Endodermis uniseriate, 6–12 × 8–14 µm; vascular bundles: conjoint collateral and open, 6–7 in number, 45–50 × 45–53 µm, phloem 6–10 µm thick, 5–10 layered, cambium forming complete cambial ring, xylem 35–42 µm thick, metaxylem towards the epidermis 5–8 µm diameter, protoxylem towards the pith 2–5 µm diameter; medullary rays 6–12 layered, isodiametric cells. Mucilage canals present inside the pith, 3–5 in number, 74–81 µm diameters, surrounded by large parenchyma cells, 7–10 × 25–30 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells, starch grains present in the pith also.

7. *Impatiens* sp. 1 (Figure 19)

Epidermal cells 29–38 × 20–23 µm, rectangular, uniseriate. Hypodermis 20–30 layered, following the epidermis 2–5 layers of chlorenchyma cells present, below this 10–12 layers of collenchyma, following the collenchyma layer 5–10 layers of isodiametric parenchyma cells present. Endodermis uniseriate, 30–33 × 40–45 µm; vascular bundles: conjoint collateral and open, 8–9 in number, 737–740 × 430–433 µm, phloem 150–157 µm thick, 25–30 layered, cambium forming complete cambial ring, xylem 510–518 µm thick, metaxylem towards the

epidermis 50–78 µm diameter, protoxylem towards the pith 30–35 µm diameter; medullary rays 50–60 layered, isodiametric cells. Mucilage canals present inside the pith, 4 or 6 in number, 840–850 µm diameter, surrounded by large parenchyma cells, 71–77 × 135–147 µm, rectangular, broader than high; pith formed of isodiametric parenchyma cells. Starch grains and raphides present throughout stem, 7–10 layers of cells above the endodermis bear more amount of starch; similarly huge amount of starch grains is present in the pith also.

4.6 Pollen morphology of *Epiphyticae Impatiens*

Key to the species-based pollen morphology

1a. P/E ratio less than one ……..….***I. auriculata***

1b. P/E ratio greater than one……..…..……...….**2**

2a. In polar view dumbbell shaped……..…..***I. sholayarensis***

2b. In polar view pollen grains not dumbbell shaped……..…….….**3**

3a. Margins of the aperture simple and non-ornamented……..….***I. jerdoniae***

3b. Margins of aperture raised and ornamented……**4**

4a. Lumens on the surface always hexagonal……...…….**5**

4b. Lumens on the surface triangular to hexagonal……..…….**6**

5a. Surface uneven with shallow muri of the reticulation…….…. ***Impatiens* sp. 1**

5b. Surface smooth with deep muri of the reticulation……..….***I. violaceae***

6a. Muri closely packed and lumen narrow…….……***I. parasitica***

6b. Muri widely spaced and lumen large……..……..***I. viridiflora***

1. *Impatiens auriculata* (Figure 20)

Pollen 26–30× 26–34µm, P/E ratio 0.92, medium sized, oblate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, margin of aperture simple, non ornamented; reticulate ornamentation on pollen surface, lumens are hexagonal with granules inside.

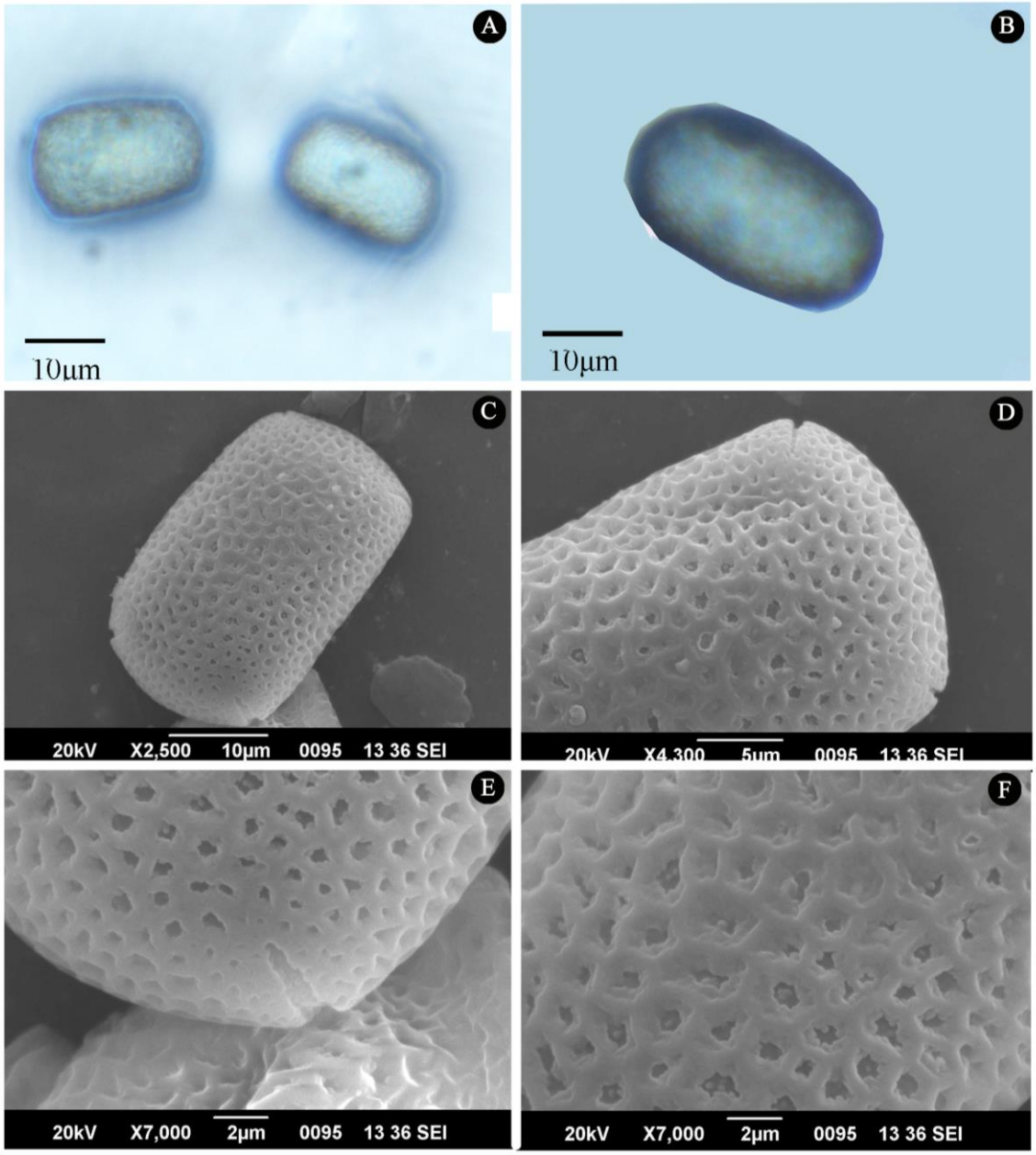

Figure 20: **Light microscopic and SEM images of pollen grain of *Impatiens auriculata*- A.** Polar view **B.** Equatorial view; **C.** Polar view; **D, E.** Aperture; **F.** Exine ornamentation

2. *Impatiens jerdoniae* (Figure 21)

Pollen 31–34 × 28–30µm, P/E ratio 1.10, medium sized, prolate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, margin of aperture simple, non-ornamented; reticulate ornamentation on pollen surface, lumens are pentagonal with granules inside

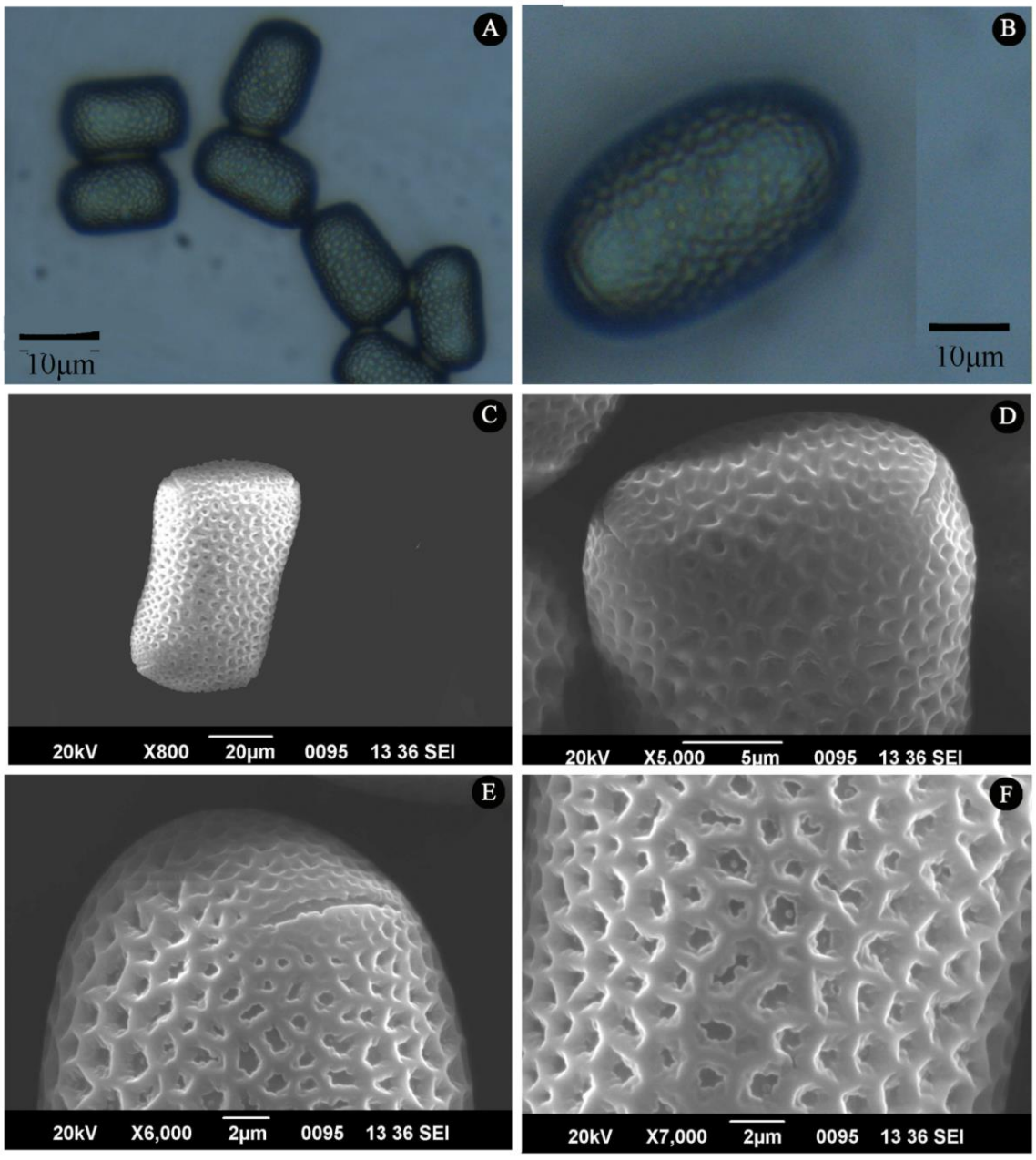

Figure 21:Light microscopic and SEM images of pollen grain of*Impatiens jerdoniae*- A. Polar view; **B.** Equatorial view; **C.** Polar view; **D, E.** Aperture; **F.** Exine ornamentation

3. *Impatiens parasitica* (Figure 22)

Pollen 30–34× 31–33µm, P/E ratio 1, medium sized Prolate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, and aperture wide with raised walls around; reticulate ornamentation on pollen surface, lumens 3–5 sided without granules inside.

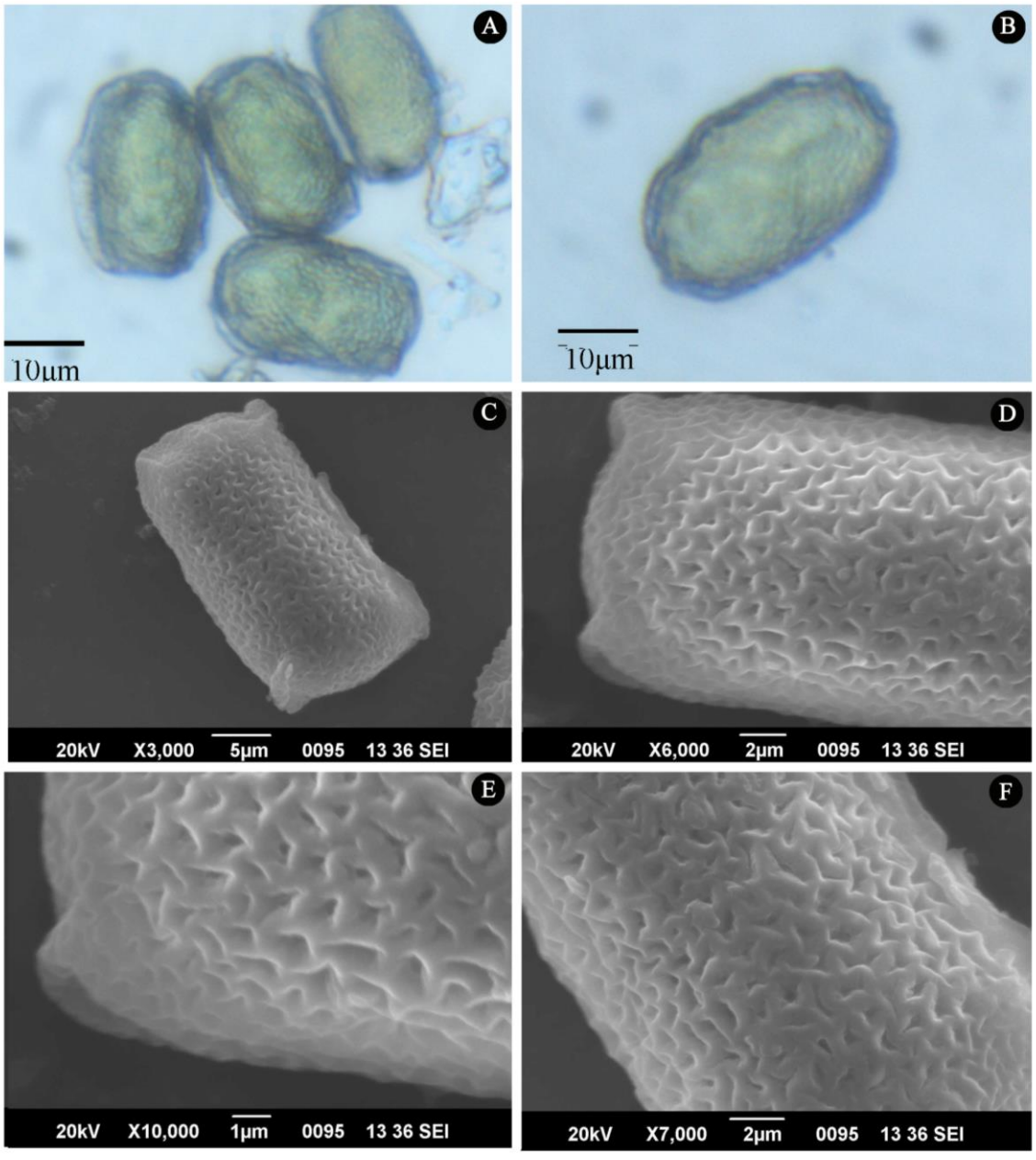

Figure 22: **Light microscopic and SEM images of pollen grain of *Impatiens parasitica*,-A.** Polar view; **B.** Equatorial view; SEM images-**C.** Polar view; **D, E.** Aperture; **F.** Exine ornamentation

4. *Impatiens sholayarensis* (Figure 23)

Pollen 33–36 × 31–35 µm, P/E ratio 1.03, medium sized, Prolate spheroidal, dumbbell shaped in polar view and elliptic in equatorial view, tetra zonocolpate, aperture simple, slit like, margins without ornamentation; pollen surface have reticulated ornamentation, lumens pentagonal or hexagonal, densely granulated inside.

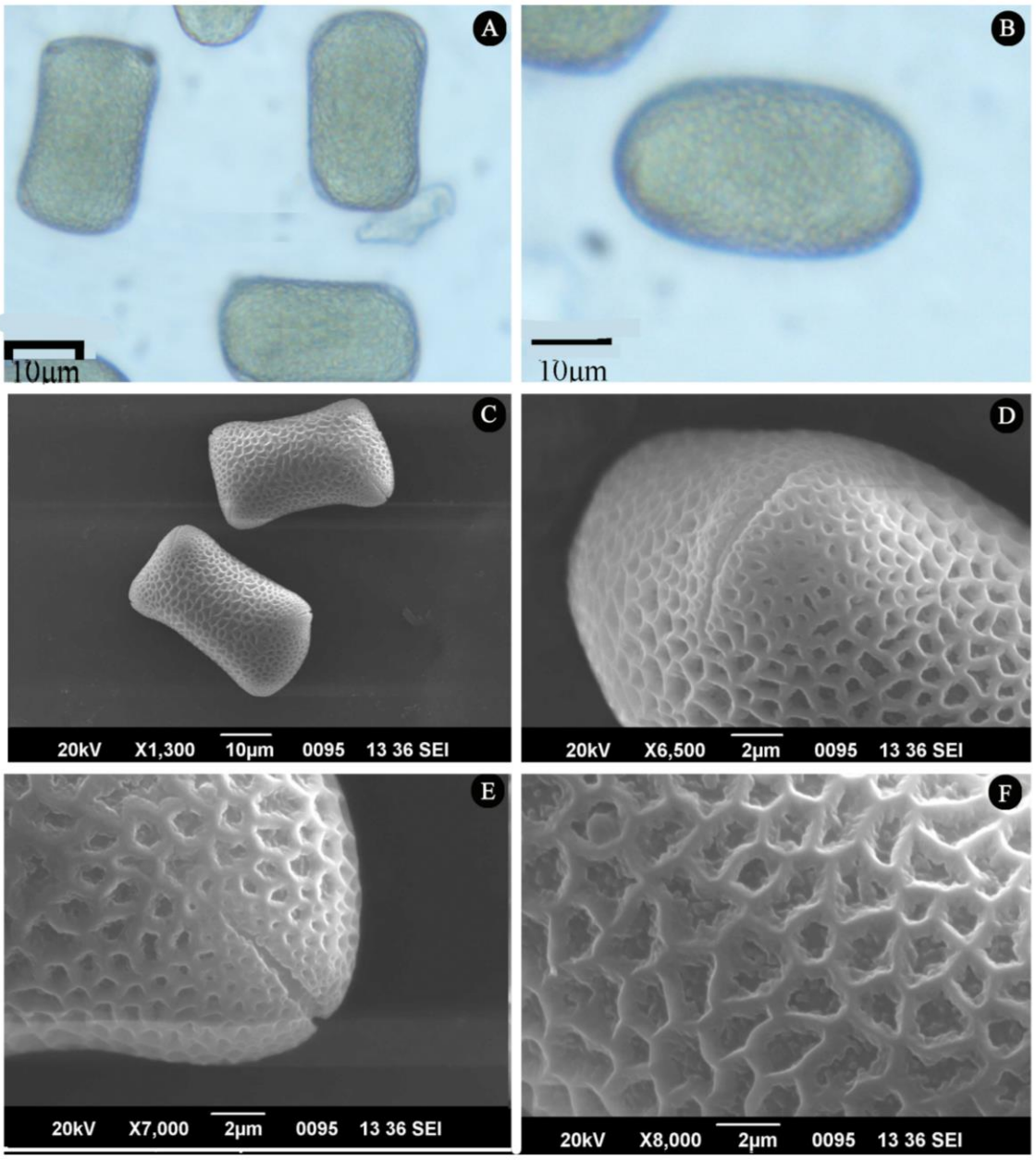

Figure 23: Light microscopic and SEM images of pollen grain of *Impatiens sholayarensis* - A. Polar view; **B.** Equatorial view; SEM images - **C.** Polar view; **D,E.** Aperture; **F.** Exine ornamentation

5. *Impatiens violaceae* (Figure 24)

Pollen 30–33 × 31–33µm, P/E ratio 1.01, medium sized, Prolate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, aperture wide and deep, with reticulate ornamentation; pollen surface has reticulated ornamentation, lumens hexagonal, non-granulated inside.

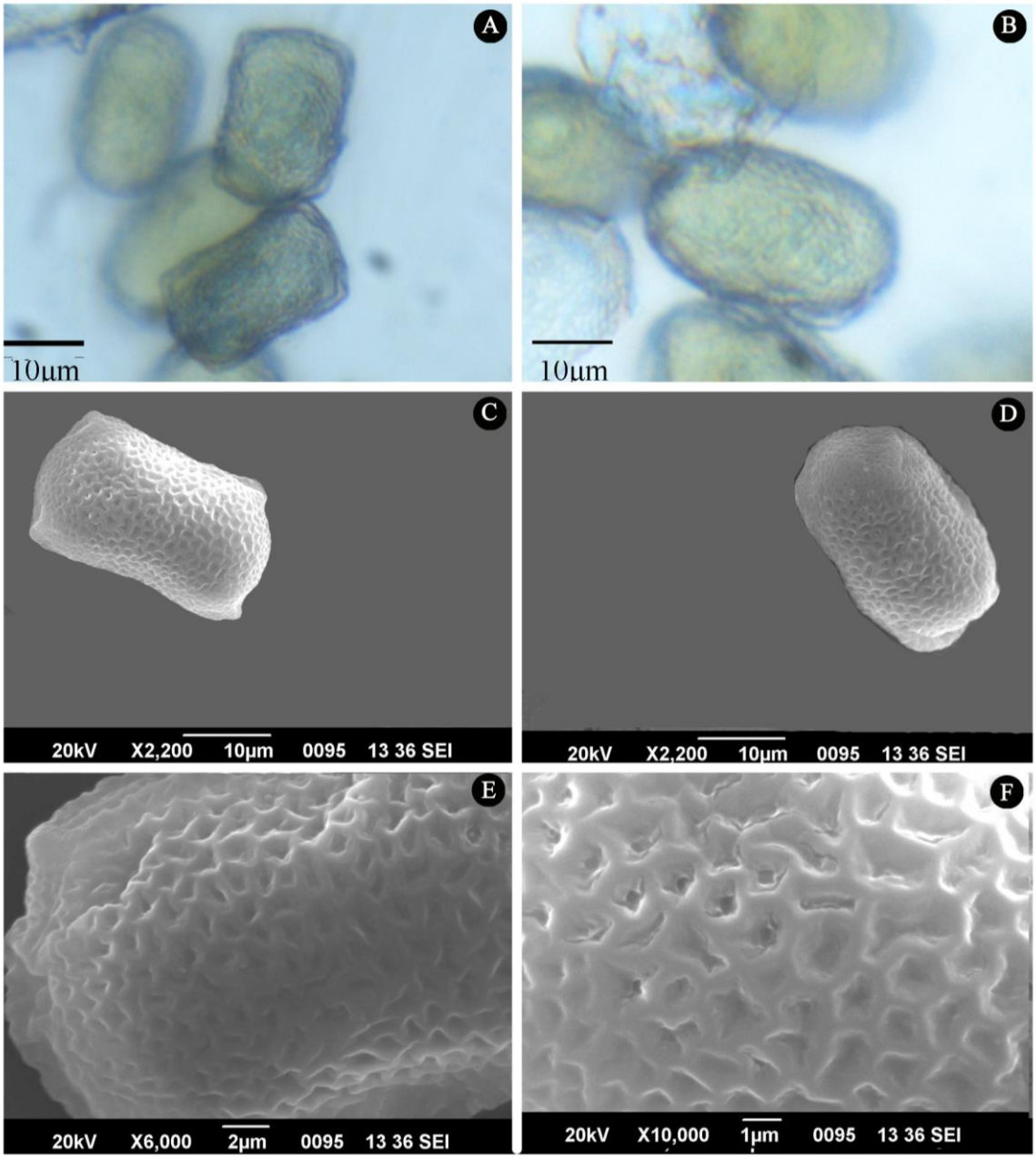

Figure 24: **Light microscopic and SEM images of pollen grain of *Impatiens violaceae*- A.** Polar view; **B.** Equatorial view; SEM images - **C.** Polar view; **D, E.** Aperture; F. Exine ornamentation

6. *Impatiens viridiflora* (Figure 25)

Pollen 34–37 × 33–35 µm, P/E ratio 1.04, medium sized, Prolate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, aperture wide with slightly raised margin having reticulate ornamentation; pollen surface has reticulated ornamentation, lumens triangular to hexagonal, non-granulated inside.

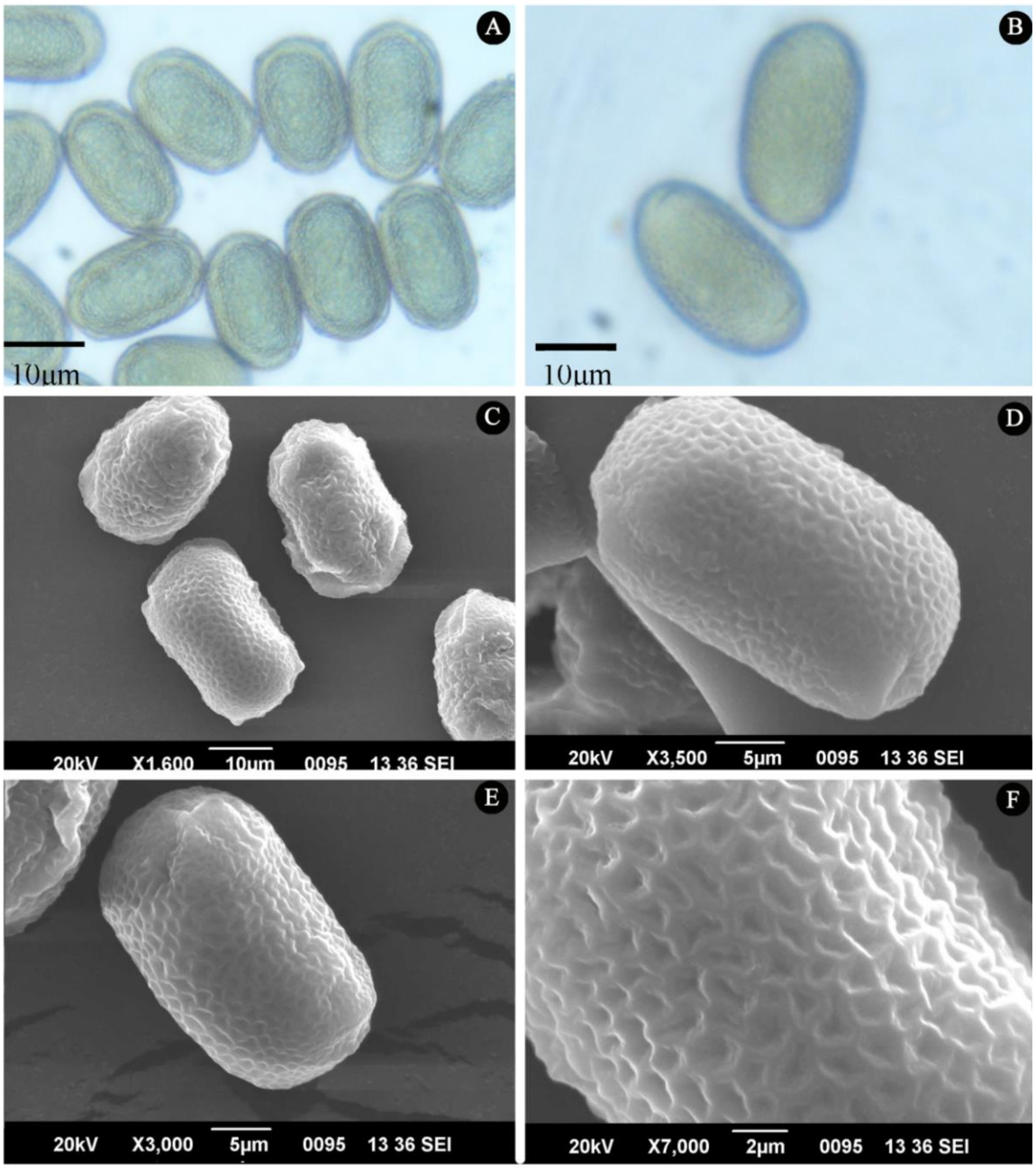

Figure 25:**Light microscopic and SEM images of pollen grain of *Impatiens viridiflora*- A.** Polar view **B.** Equatorial view; SEM images-**C.** Polar view; **D, E.** Aperture; **F.** Exine ornamentation

7. *Impatiens* sp. 1 (Figure 26)

Pollen 30–34 × 31–33µm, P/E ratio 1, medium sized, Prolate spheroidal, rectangular in polar view and elliptic in equatorial view, tetra zonocolpate, aperture wide, margins with reticulate ornamentation; pollen surface also have reticulate ornamentation, lumens hexagonal, non-granulated inside.

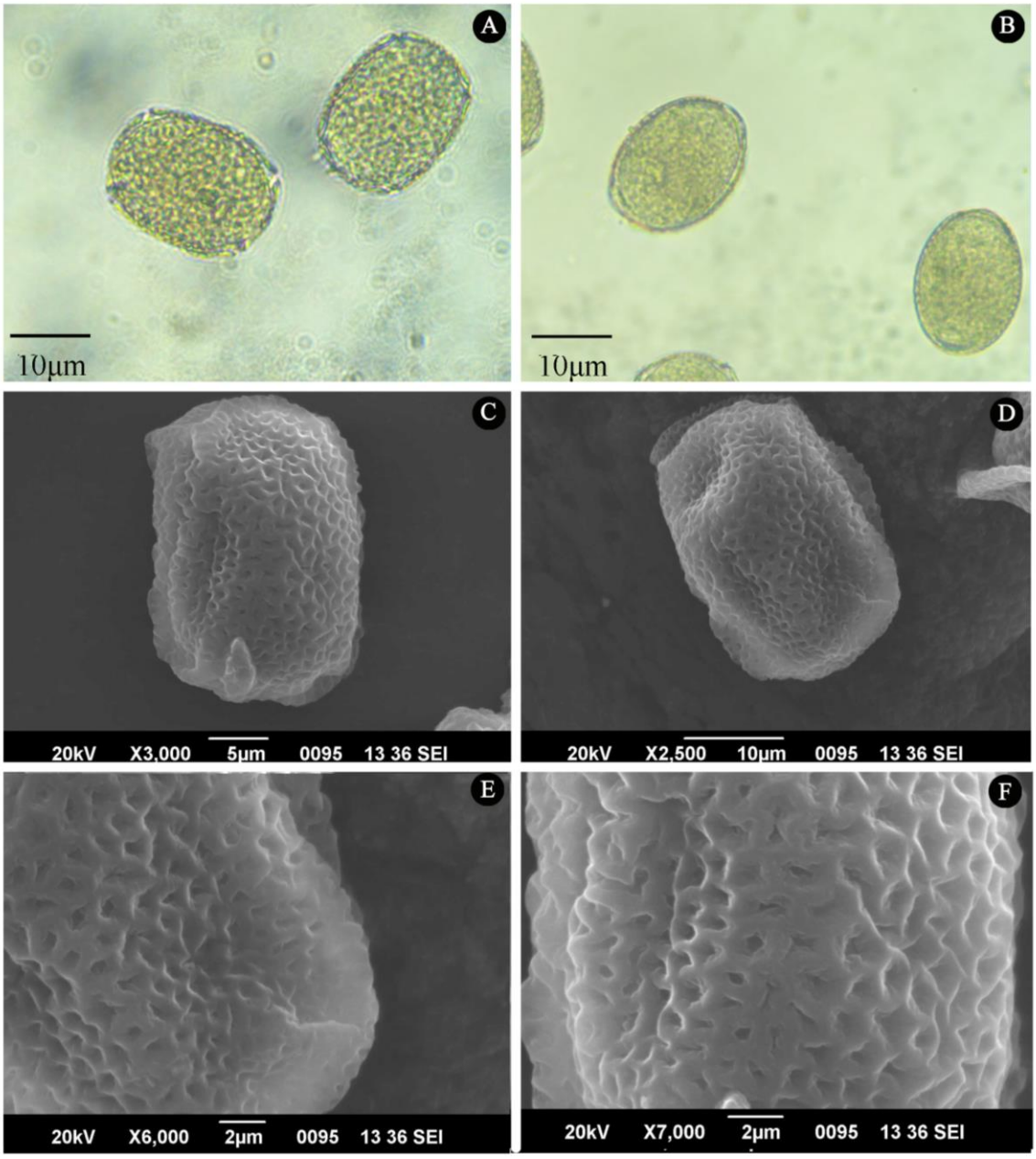

Figure 26: **Light microscopic and SEM images of pollen grain of *Impatiens* sp.1- A.** Polar view; **B.** Equatorial view; **C.** Polar view; **D, E.** Aperture; **F.** Exine ornamentation

4.7 Seed morphology

Key to the species based on seed morphology

1a. Hair distributed all over the seed……...……...……**2**

1b. Hair clustered at both ends……...……..……..**4**

2a. Surface of the seed reticulate with ribbon shaped hairs…….……..**3**

2b. Surface of the seed verucate with string like hairs……..… ***Impatiens* sp. 1**

3a. Reticulation shallow smooth striations with beaded projections……..…….…***I. viridiflora***

3b. Reticulation inconspicuous, striations and beaded projections absent…..…....***I. parasitica***

4a. Hair ribbon like, surface reticulate with striations……..…..……**5**

4b. Hair not ribbon shaped, reticulate without striations……..…..……...….***I. violaceae***

5a. Striations at the adjacent position merge to form reticulate pattern, seed broad Kidney shaped……..……...…..…….***I. jerdoniae***

5b. Striations smooth, narrow and continues, seed elliptic…….……***I. sholayarensis***

1. *Impatiens jerdoniae* (Figure 27)

Seeds broad kidney shaped, 795–800 × 486–490 µm, brownish black with yellow streaks, and hairy. Seed surface have striations all over, regular reticulate pattern formed by the merging of adjacent striations; reticulation absent at the notch. Seed hairs helically coiled compressed and twisted, at both ends.

2. *Impatiens parasitica* (Figure 28)

Seeds irregularly ovate, 945–950 × 518–522 µm, yellowish brown, hairy. Seed surface have reticulated ornamentation, with inconspicuous striations throughout; verrucose at one side. Seed hair ribbon like helically coiled, coils sometimes laterally compressed, throughout seed and more towards the tips.

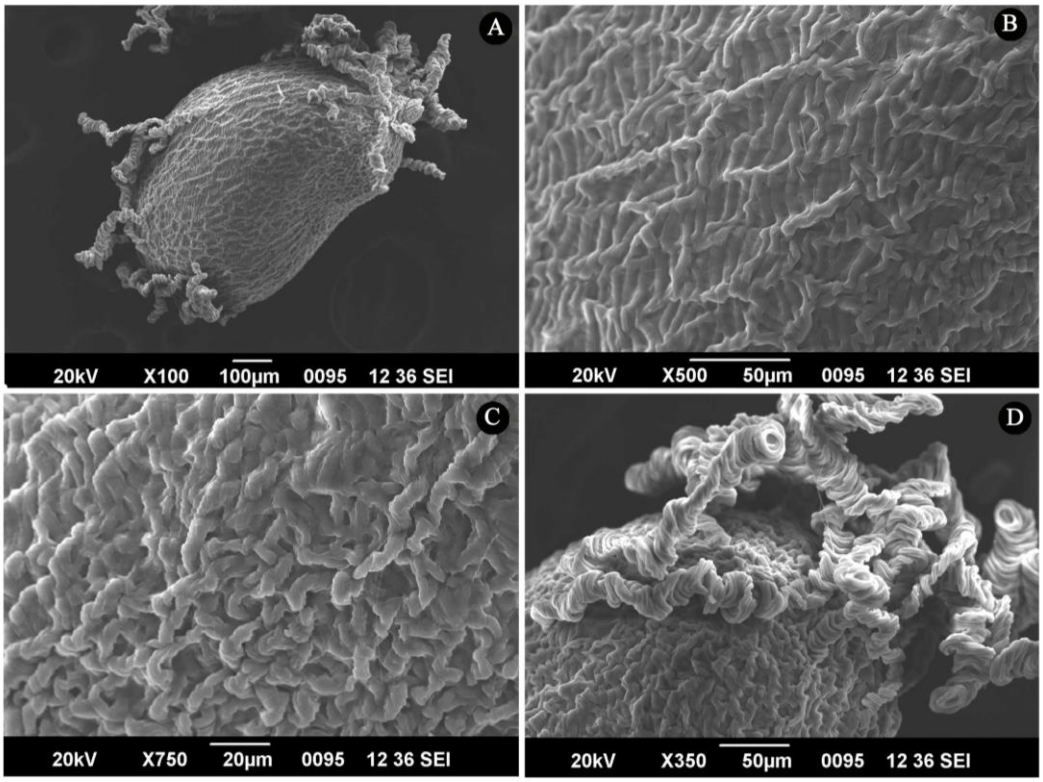

Figure 27: **SEM images of Seeds of *Impatiens jerdoniae*- A.** Entire view of seed; **B, C.** Surface of seed; **D.** Seed hair

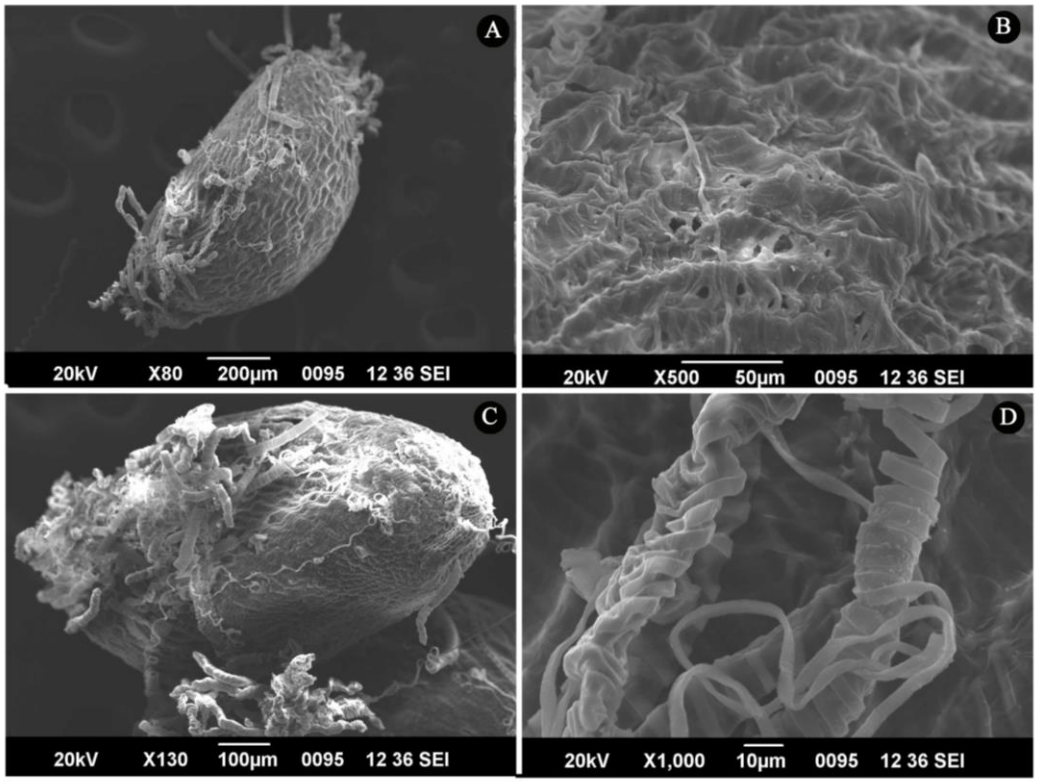

Figure 28: **SEM images of seeds of *Impatiens parasitica*- A.** Entire view of seed; **B, C.** Surface of seed **D.** Seed hair

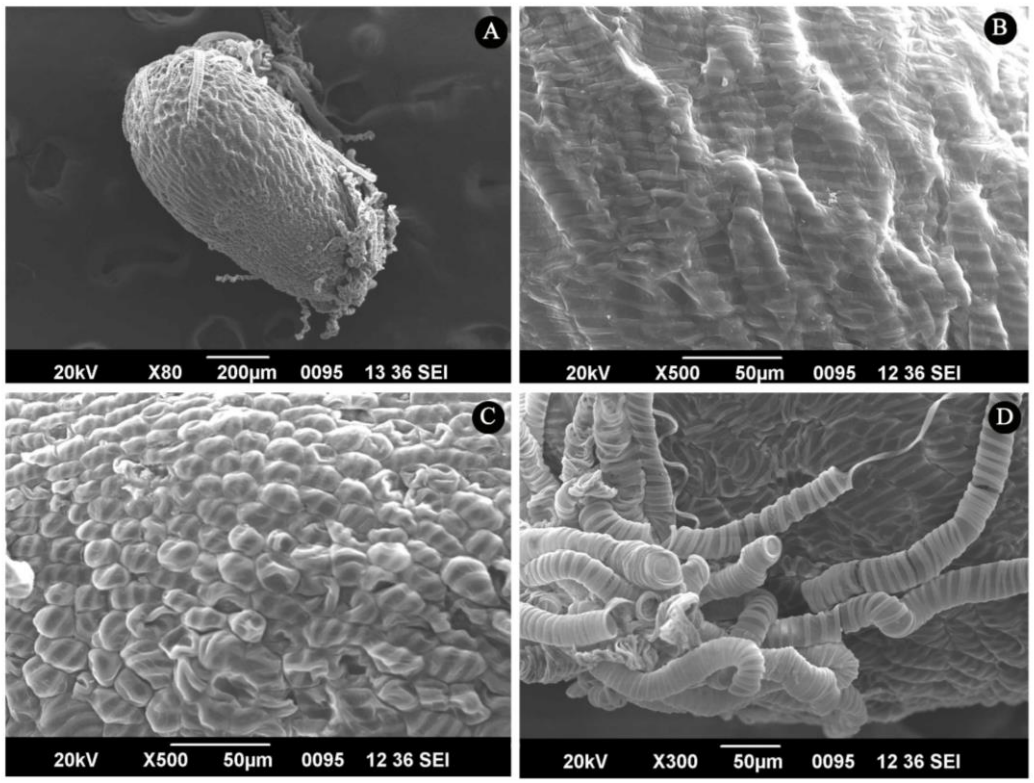

Figure 29: SEM images of seeds of *Impatiens sholayarensis*- A. Entire view of seed **B, C.** Surface of seed; **D.** Seed hair

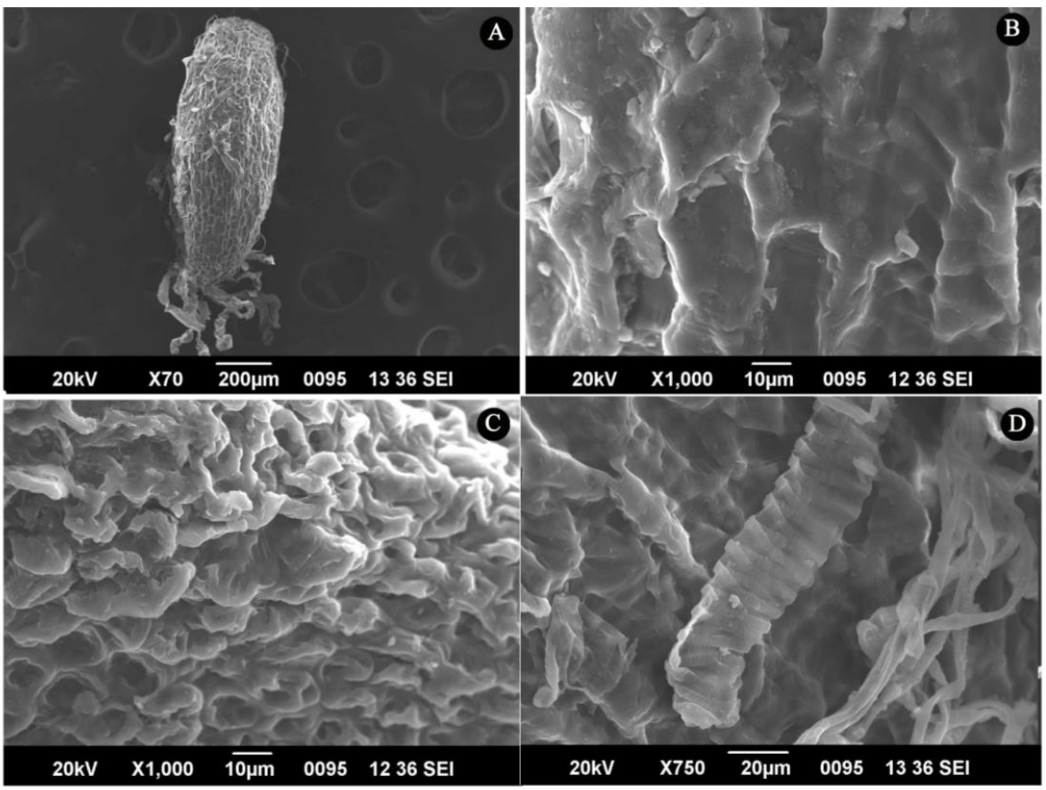

Figure 30: SEM images of seeds of *Impatiens violacea*- A. Entire view of seed; **B, C.** Surface of seed **D.** Seed hair

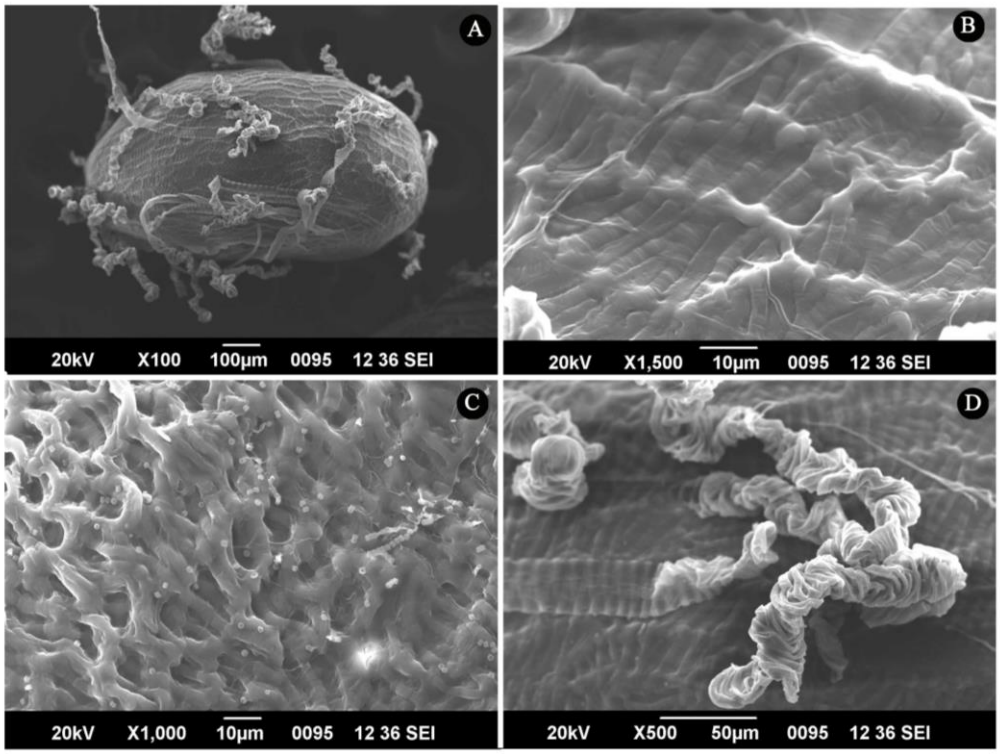

Figure 31: SEM images of seeds of *Impatiens viridiflora*- **A.** Entire view of seed; **B, C.** Surface of seed **D.** Seed hair

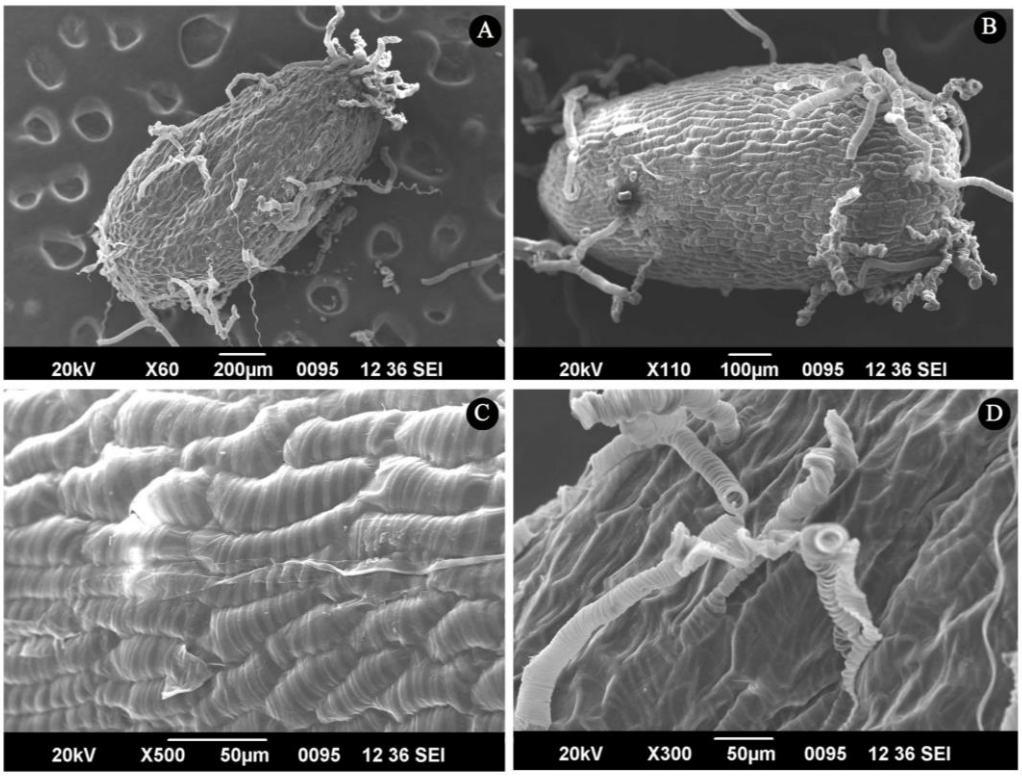

Figure 32: SEM images of seeds of *Impatiens* sp. 1- A. Entire view of seed **B, C.** Surface of seed; **D.** Seed hair

***3. Impatiens sholayarensis* (Figure 29)**

Seeds elliptic, 976–981 × 497–500 µm, brown, hairy. Seed surface have shallow reticulate ornamentation, with smooth narrow continues striations throughout; verrucose towards the tip. Seed hair ribbon like, helically coiled located at the ends.

4. *Impatiens violaceae* (Figure 30)

Seeds cuniform, 976–981 × 497–500 µm, brown, hairy. Seed surface have elongated reticulate ornamentation, striations absent. Seed hair ribbon like, helically coiled and compressed, at both ends of the seed.

5. *Impatiens viridiflora* (Figure 31)

Seeds oblong, 870–877 × 493–500 µm, brownish black, hairy. Seed surface have shallow reticulate ornamentation, smooth broad continues striations with beaded projections throughout, and reticulation is closely packed at one side. Seed hair ribbon like, helically coiled, compressed and twisted, found throughout seed surface.

6. *Impatiens* sp. 1 (Figure 32)

Seeds ovoid, 930–936 × 497–503 µm, brown, hairy. Seed surface verrucate, ornamented with striations, reticulate towards the end. Seed hair thin string like, helically coiled, throughout the seed and forming tuft at the end.

4.8 Prediction of Potential distribution of *Epiphyticae Impatiens*

Developments in the field of ecological niche modeling address many issues related to conservation biology. The Maximum entropy (MaxEnt) (Phillips *et al*., 2004) model is a general-purpose environmental model for predicting the potential distribution of species. This algorithm requires presence only (or occurrence) data and environmental information such as climate, topography, soil etc. for predicting the potential distribution of a species. The results obtained are very accurate and can be used to determine the possible range of distribution. The models goodness-of-fit was calculated using Area Under the Receiving Operator Curve (AUC), The value of AUC ranges from 0 to 1 and based on this value models are classified into 5 groups: Excellent (0.9), Good (0.8≤0.9), Bad (0.6≤0.7), Invalid (0.5≤0.6) (Haffman *et al*., 2008).

This algorithm was applied to all the species under study but the model having good performance was obtained only for four species vis *I. parasitica*, *I. jerdoniae*, *I. viridiflora* and

Impatiens sp. 1 for other species models' performance was poor hence discarded. The results of accepted species are the following:

1. *Imaptiens jerdoniae* (Figure 33)

The final model was build using 7 bioclimatic variables (Annual Mean Diurnal Range, isothermality, precipitation seasonality, precipitation of driest quarter, precipitation of warmest quarter and annual temperature range) and 3 topographic variables. The AUC value is 0.98, which is higher than 0.9 that means the model performance is excellent and the final model can be accepted. According to the jack knife test elevation is the most contributed variable and the suitability of the species under study increases with increasing elevation. Other variables show a steady contribution to the suitability of the species.

Moderate suitability is predicted throughout the Western Ghats for *I. jerdoniae*. The model shows high degree of suitability in some regions of Southern Western Ghats and some regions of Nilgiris in Central Western Ghats. In Southern Western Ghats these regions include Anamudi, Anamalai Tiger Reserve, Munnar and Kodaikanal regions whereas in Nilgiris region suitable regions are Ooty, Mudumalai Tiger Reserve and Vavul malai.

2. *Impatiens parasitica* (Figure 34)

The final model was created using 4 bioclimatic variables and 4 topographic variables, the are: Isothermality (Bio3), Temperature seasonality (Bio4), Precipitation of warmest quarter (Bio18), Precipitation of coldest quarter (Bio 19), slope, elevation, aspect, and TRI. The AUC value for training is 0.95 and for the test is 0.817 which is higher than 0.8, hence the model can be accepted and it justifies the construction of the final model based on the points available. Jackknife test illustrates temperature seasonality is the most contributed variable and TRI is the least contributed variable. The habitat suitability increases with increasing elevation, precipitation of the warmest quarter, and isothermality. At the same time, habitat suitability decreases with increasing temperature seasonality, and precipitation of coldest quarter; aspect, slope and TRI show steady trend on habitat suitability.

Impatiens parasitica (Figure 34) prefer evergreen and semi-evergreen forests in the southern Western Ghats. They are mainly distributed in forest having elevations from 800 m to 1500 m. Forest areas like Neyyar Wildlife Sanctuary, Agasthymalai Biosphere Reserve, Konni reserve forest, Ranni reserve forest, Idukki Wildlife Sanctuary, Eravikulam National Park,

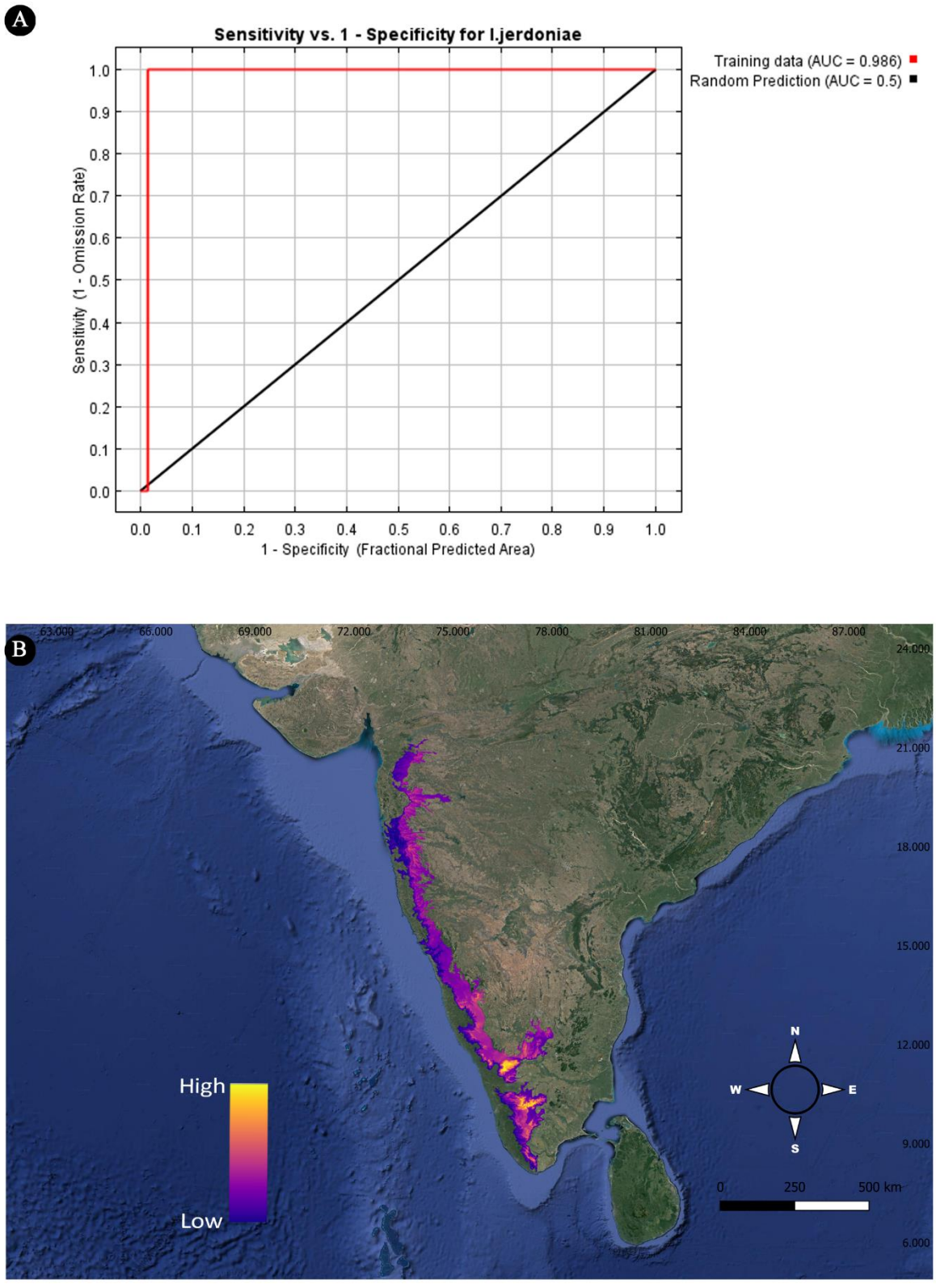

Figure 33: A. Receiver operating characteristic (ROC) curve for *I. jerdoniae;* **B.** Representation of the MaxEnt model for *I. jerdoniae*

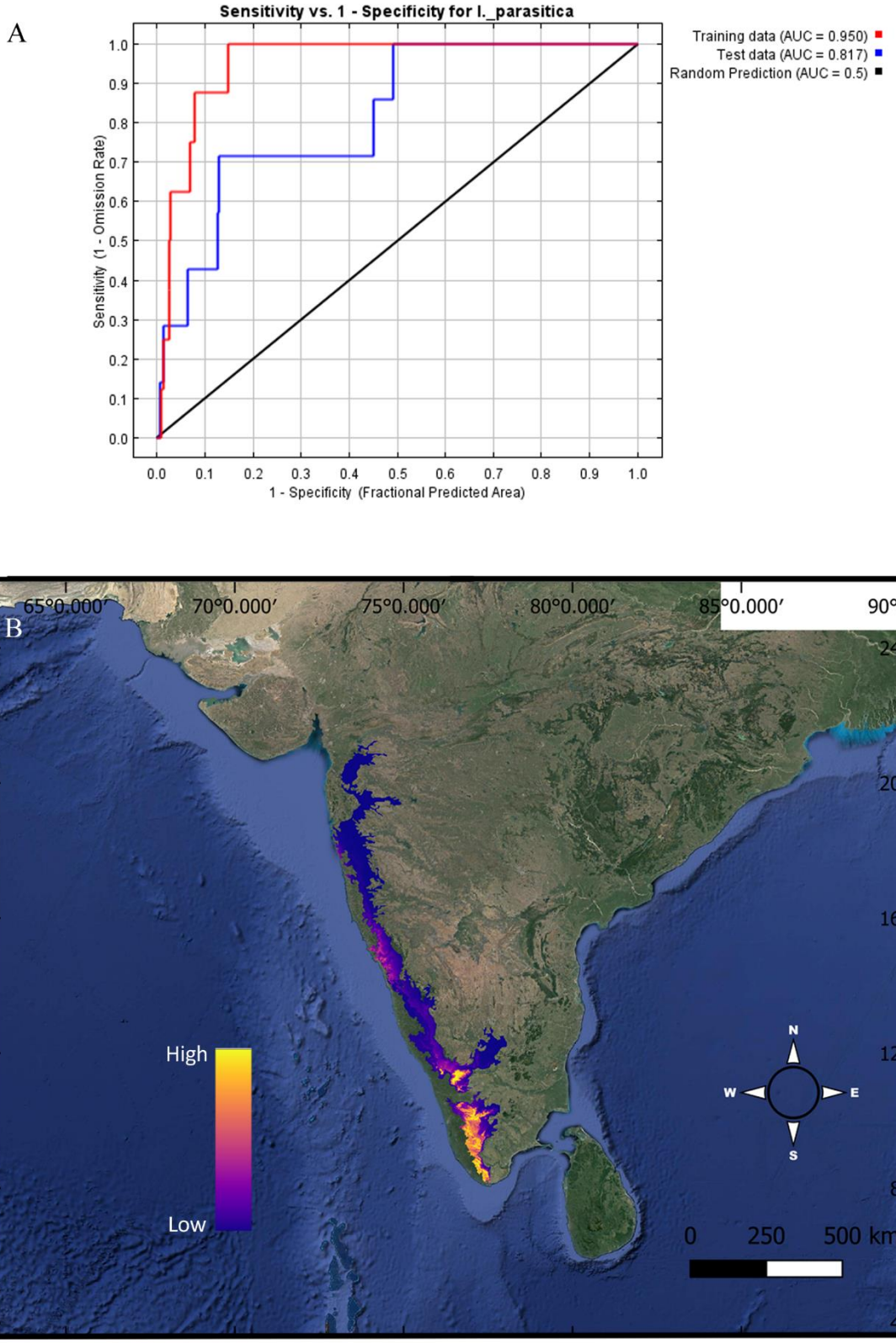

Figure 34: A. Receiver operating characteristic (ROC) curve for *I. parasitica;* **B.** Representation of the MaxEnt model for *I.parasitica*

Nelliyampathy reserve forest and Sholayar reserve forest, Silent valley National Park, New Amarambalam Reserve, Wayanad Wildlife Sanctuary and Malabar Wildlife Sanctuary shows high suitability. Certain parts of the Northern Western Ghats such as Mollem National Park, Cotigao National Park and Anashi National Park show moderate suitability to the species.

3. *Impatiens viridiflora* (Figure 35)

For creating final model 3 bioclimatic variables (Isothermality, minimum temperature of the coldest month, and precipitation of the wettest month) and 2 topographic variables (aspect and slope) are used. The AUC value is 0.91, which is higher than 0.9 that means the model performance is excellent and the final model can be accepted. The result of jack knife test shows that isothermality is the most contributed variable and aspect is the least contributed variable. The habitat suitability increases with increasing isothermality and slope whereas it decreases with precipitation of the wettest month and aspect; minimum temperature of the coldest month shows a steady trend.

The most suitable areas for this species according to the model are southern western ghats and regions of central western ghats that have elevation greater than 800 m. Following are the regions having highest suitability for I. *viridiflora*. Singapettai Zamindar forest, Papanasam reserve forest, Neyyar Wildlife Sanctuary, Ponmudi, Agasthymalai Biosphere reserve, Shendurini Wildlife Sanctuary, Tenmala reserve forest, Ranni reserve forest, Konni reserve forest, Periyar Tiger Reserve, Meghamalai, Vannathiparai reserve forest, Vellagavi forest, Pamapdumpara shoal National Park, Kurinjimala sanctuary, Kodaikanal, Anamudi, Anamalai Wildlife Sanctuary and Nelliyampathy reserve forest in the Southern Western Ghats. In the Central Western Ghats suitability areas includes Thadagam valley reserve forest, Attapadi reserve forest, Ooty, Kotagiri, Coonor and Bandhipur Tiger Reserve.

4. *Impatiens* sp. 1 (Figure 36)

For creating, the final model 3 bioclimatic variables (Minimum temperature of coldest month, Precipitation of driest period, Precipitation of warmest quarter) and 2 topographic variables (TRI and aspect) are used. The AUC value is 0.96, which is higher than 0.9 that means the model performance is excellent and the final model can be accepted. According to the result of Jackknife test precipitation of driest period is the most contributed variable and TRI is the least contributed variable. Habitat suitability increases with increasing temperature of the coldest month, precipitation of the driest month, precipitation of the warmest quarter, TRI and aspect.

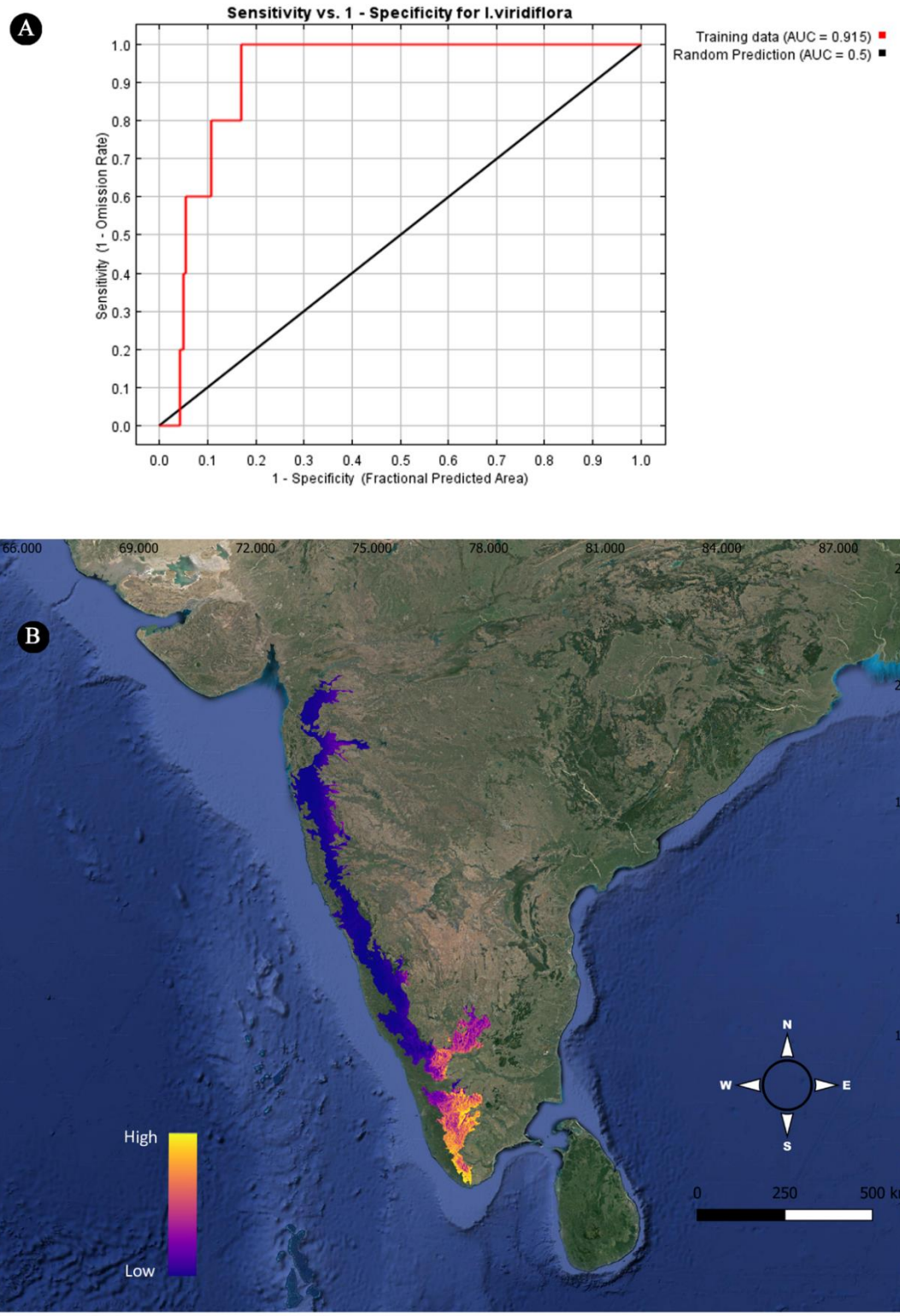

Figure 35: A. Receiver operating characteristic (ROC) curve for *I. viridiflora;* **B.** Representation of the MaxEnt model for *I.viridiflora*

This species shows high suitability in the evergreen forests of southern Western Ghats and certain regions of northern Western Ghats. According to the model developed most suitable habitats are found in Kalakad Mundanthurai Tiger Reserve, Kanyakumari Wildlife Sanctuary, Muthukuzhivayal, Singampatti zamindhar forest ranges, Agasthyamalai Biosphere.

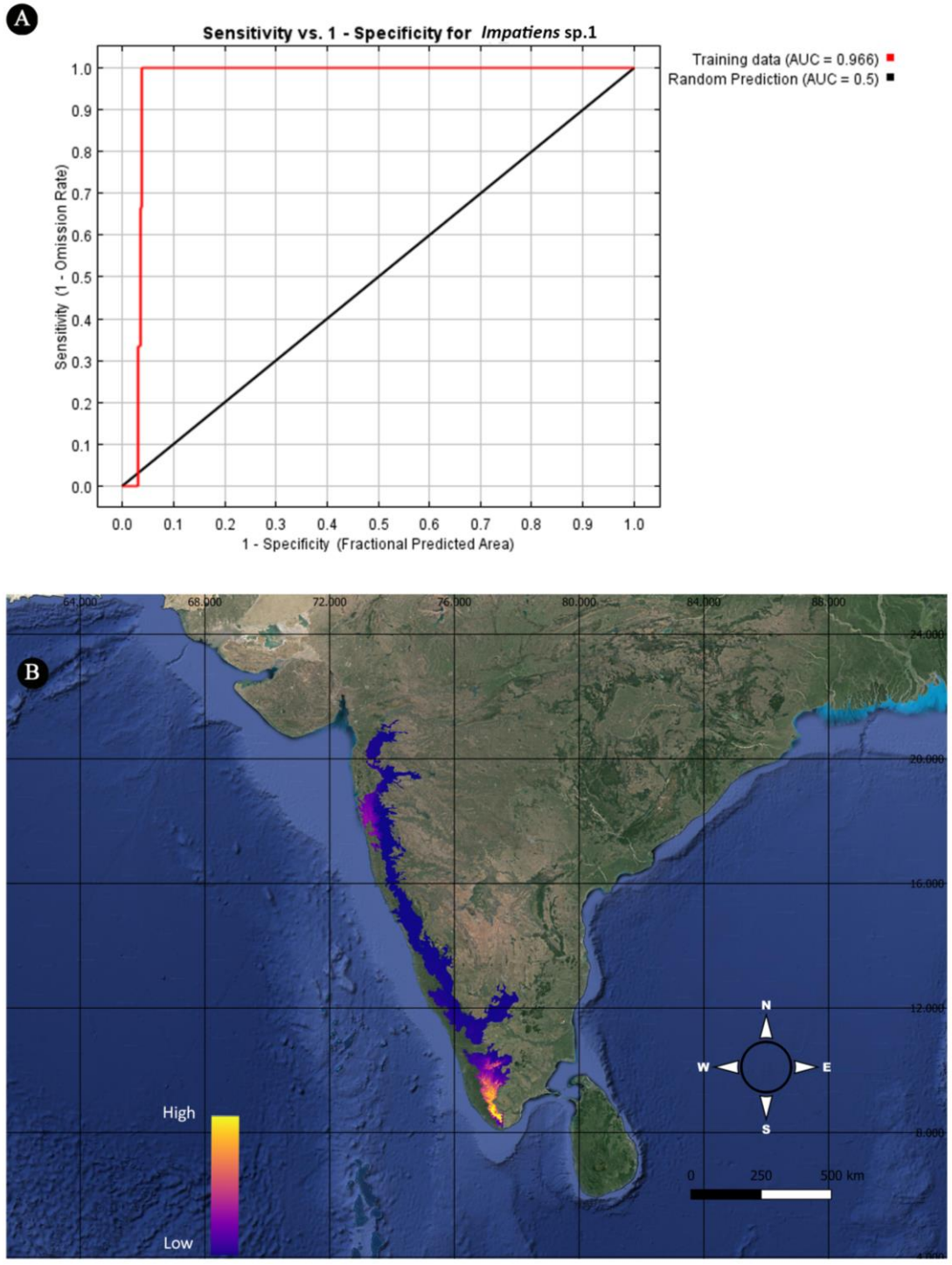

Figure 36: A. Receiver operating characteristic (ROC) curves for *Impatiens* sp. 1; **B.** Representation of MaxEnt model for *Impatiens* sp. 1

5.1 Systematic treatment

The classification system proposed by Hooker (1859) is followed in the present study. During the previous studies, seven species of *Epiphyticae Impatiens* species are reported and all of them are endemic to Southern Western Ghats. *I. auriculata* and *I. viridiflora* are the first reported species of the section *Epiphyticae*. These species do not show any specificity for the host plant. they are found in almost all trees at an elevation of 1000 meter. They are distributed just below the canopy to bottom of the trunk. *Impatiens* sp. 1 is also found growing in moist rocks, that means this species is not a strict epiphyte but also a lithophytic species. *I. viridiflora* and *Impatiens* sp. 1 are giant herbs with stout stem, the lower part of the stem is thick and woody and the upper part is fleshy. All other species are small succulent herbs. *I. parasitica* and *I. violaceae* posse's moniliform stem.

Leaves of *Epiphyticae Impatiens* are slightly succulent, thick, crenulate at margin and glabrous at both surfaces. All the species has an alternate phyllotaxy and leaf scares are prominent in the stem. In the case of stout species like *I. viridiflora* and *Impatiens* sp. 1 leaves form a tuft towards the tip of the stem. The colour of the leaf on the adaxial surface is green in all species and in the abaxial surface slight reddish green in *I. parasitica*, green with violet tinge in *I. violaceae* and silvery green in *I. sholayarensis*. Petiole is green except in *I. violaceae*, here a violet tinge is present in the petiole. The number of flowers in an inflorescence are 2 in most species, whereas in *Impatiens* sp. 1 and *I. violaceae* more than 3 flowers are found in an inflorescence. The colour of the pedicel is similar to the colour of spur in species like *I. jerdoniae, I. parasitica, I. violacea* and *I. viridiflora* whereas in other species it is green. The flowers of all the *Epiphyticae* species structurally similar but differ in the size, shape and colour of various floral parts.

The lateral sepals are green and thick in all the species except *I. auriculata* and *I. jerdoniae*. The lateral sepals of *I. auriculata* is very peculiar, it is remarkably different from other species due to the presence of highly elongated, broad and brightly coloured lateral sepals that almost covered the spur. This lateral sepal resembles the ears of a spaniel dog; the specific epithet "auriculata" is given due to this character. In *I. jerdoniae* lateral sepals are dark purple coloured, parallel to the opening of spur, tip curved and almost touching each other.

The lower sepal is the most attractive part of the species under study. It is modified into a rigid and brightly coloured spur. It is laterally compressed and curved at the tip in all species except *I. jerdoniae*. In this species spur is saccate and inflated at the middle portion and the tip

is longer than other species. In the case of *I. auriculata*, spur is small and not visible due to the large lateral sepals. Longest spur is found in *I. sholayarensis* and smallest spur in *I. auriculata*. The spur of *Impatiens* sp. 1 is very similar to *I. parasitica* at first glance; hence it is often confused with *I. parasitica*. On close examination remarkable differences like long and broad lateral sepals shorter spur and more than 3 flowers in a single inflorescence can be seen. The spur of *I. violaceae* is violet in colour, in *I. sholayarensis* yellow till the half part and orange red until the tip, in *I. auriculata* yellowish white until the middle and brownish red at the tip, and in *I. viridiflora* crimson red until the middle and yellowish white up to the tip. In all other species spur is bright red coloured. The mouth of the spur is broader than middle, boat shaped and straight in *I. auriculata*, whereas oblique in *Impatiens* sp. 1 and *I. viridiflora*. In *I. parasitica*, *I. jerdoniae* and *I. violaceae* mouth of the spur is shorter than the middle and oblique whereas in *I. sholayarensis* mouth width is same from mouth to middle of spur. The hook like structure is present at the tip of the mouth in all species. Prominent wrinkled arch like markings on either side of the spur is a characteristic feature of *Epiphyticae Impatiens*.

The dorsal petal is hood like in all the species and prominently keeled. The colour of the dorsal petal varies from yellow to yellowish green. Bright yellow coloured in *I. jerdoniae* and yellowish green in *I. viridiflora*. In the case of *Impatiens* sp. 1 nerves are very visible throughout the dorsal petal. Keel is visible through the entire length of dorsal petal and it is dark green in all species except *I. auriculata* where keel is yellowish green in colour.

The lateral united petal is characterized by the presence of fleshy hard stalk and lobes. In all *Epiphyticae* species lateral united petal consists of two lobes; distal lobe is inserted into the spur and basal lobe slightly projecting out of the mouth of the spur. In the previous works many authors (Pandurangan and Nayar (1995), Kumar and Sequira (2001)), consider the stalk of lateral united petal as a lobe and described as three lobs. But in the present study this concept is discarded. In *I. auriculata* and *I. viridiflora* basal lobe is maroon coloured, membranous towards the tip with prominent nervous and in all other species it is rigid and green coloured. In the above mentioned species, the distal lobe is smaller than others.

Ovary is superior and style is absent in all the species studied. Ovary elliptic and swollen at the middle in the case of *I. jerdoniae*, and in all other species it is elliptic and falcate. In the case of *I. viridiflora*, *I. violaceae*, *I. sholayarensis* and *I. jerdoniae* slight pubescent are observed throughout the ovary, whereas in others ovary is glabrous throughout. Stigma is silky pubescent in all the species studied. Anthers are syngenesious in all the species, filaments broad

at the tip and filiform towards the base. Longest filaments are found in *I. sholayarensis*. Fruit formation is a rare occurrence in *I. auriculata*, during the past 4 years different populations of *I. auriculata* was observed but fruit formation was not observed so far. Yet new individuals are found to be formed. Fruit is elliptic in *I. jerdoniae*, *I. parasitica*, broadly elliptic in *Impatiens* sp. 1, *I. violaceae* and *I. sholayarensis* whereas in *I. viridiflora* fruit is narrow and elliptic.

5.2 Variation in the floral morphology of *Impatiens parasitica*

The genus *Impatiens* is notorious among botanist due to the morphological variations. In section *Epiphyticae* the species *I. parasitca* show high degree of morphological variations. During the field studies 8 different morpho types of this species were collected from different regions. They are named as morpho types 1 to 8. Morpho type 1, 2, 3 are collected from different locations of Nelliyampathy, morpho type 4 collected from Munnar, morpho type 5 from Kadalar, Idukki district, morpho type 6 from Wayanad, Morpho type 7 and 8 from Idamalakudi, Idukki district.

The morpho type 7 is the shortest among them and attains a height up to 10 cm, morpho type 1 and 6 reach a height up to 20 cm. The pedicel of morpho type 1 and 2 is green, morpho type 3, 4, 5, 6 is red and violet in morpho type 7 and 8. The shape of leaf varies from elliptic to ovate. The colour on the adaxial surface of leaf is reddish green in morpho type 4 and green in all other morpho types. Whereas in the abaxial surface it is reddish green in morpho type 2, 3, 6; green with a purple tinge in morpho type 1, 5 and 8; silvery green in morpho type 4; light green in morpho type 7. The average length of pedicel is 3 in all the morpho types and the colour is red in morpho types 1 to 6; light rose in morpho type 7 and light violet in morpho type 8.

Lateral sepals are elliptic and dark green in all morpho types except morpho type 6, here it is broadly elliptic and dark purple coloured more allied to *I. jerdoniae*. The lateral sepals of morpho types collected from Nelliyampathy are spreading away from the mouth of the spur whereas in others it is remaining close to the spur. Variation in the morphological characters is most prominent in the nature of spur. The spur of morpho type 1 is broad saccate and laterally inflated like *I. jerdoniae*. tip of the spur is very short in morpho type 1, 2, 3, 6, 7 and 8; it is elongated, curved and touching the spur in morpho type 4 and 5. The colour of the spur is red in morpho type 1 to 6; light rose coloured in morpho type 7 and violet coloured in morpho type 8.

Much difference cannot be observed in other floral parts. The dorsal petal is crowned, keeled and green in all morpho types. The keel is dark green in all morpho types and width is highest in morpho type 7 and shortest in morpho type 4. In the case of lateral united petals, the distal lobe is elongated in morpho type 1, 3, 7 and 8; curved inwards in morpho type 4, 5 and 6; triangular in morpho type 2. There are no differences observed in the characters of androecium, gynoecium, fruit and seed. In the near future these morpho types may undergo other variations and eventually they may evolve to new species.

The plants belong to section *Epiphyticae* stands out from other *Impatiens* in many characters. The entire plant poses a semi succulent nature, floral parts are rigid and does not wilt easily just like other *Impatiens*. The dorsal petal is keeled and hooded in all the species belong to this section. The spurred lower sepal shows an exact similar pattern in all the *Epiphyticae* species, variation is observed only in colour, and size. The spur is rigid, brightly coloured, curved at tip, and prominent wrinkled markings are present on either side. This similarity is visible in the characters of lateral united petals also. They are bilobed attached to pedicel with a stalk and inserted in the spur. The anatomical characters of stem and leaf is also very much similar among the species and very unique among the genus. The pollen grains show slight variation in size and shape, surface is having reticulate pattern. The seeds are having hairs on the surface and surface sculpturing is very similar. All these uniqueness and stable characters propose the possible emergences of section *Epiphyticae* as a new genus.

5.3 Resolving taxonomic discrepancy on the lobes of lateral united petals

The lateral united petals are the floral parts of *Epiphyticae Impatiens* that create a huge confusion among the taxonomist. The stalk with which it is attached to the pedicel is some time confused as a lobe. Hence, some authors reported that the lateral united petals have three lobes. This misconception was observed in the protologue of *I. kulamavuensis*, *I. sholayarensis* and *I. violaceae*. Comparison of the floral parts of these species with other species proved without any confusion that the lateral sepals consist only two lobes. The illustrations provided by the authors also support this concept. The most recent key on section *Epiphyticae* was based on the number of lobes of lateral united petals. The key prepared by V. Bhaskar (2012) is confusing and cannot be accepted for identification.

5.4 Synonymizing *Impatiens kulamavuensis* with *Impatiens parasitica*

As mentioned earlier the genus *Impatiens* shows a high degree of morphological variations. As result, many authors reported such morphological variations as new species. One among them

is *I. kulamavuensis*, which is a morphological variation of *I. parasitica*. This species is allied to *I. parasitica* as per the protologue. Detailed examination of the type specimen and continues field visit in this region leads to the conclusion that *I. kulamavuensis* is a synonym of *I. parasitica*. Very strong and stable characters are required for delimiting a new species in a rapidly evolving genus like *Impatiens*. The trilobed condition in the lateral united petal of *I. kulamavuensis* is one of the major differences from *I. parasitica*, but this concept will no longer exist. More over eight morphotypes of *I. parasitica* is described above. This also justify the phenotypic plasticity of *I. parasitica*. The hairs and glands in various floral parts, length of the plant is not strong enough to delimit a new species. The fruit and seeds are very much similar to *I. parasitica*.

5.5 Anatomy of vegetative parts

The anatomy of stem and leaf shows some special features like mucilage canal and raphide sacs. The delicate nature of stem and leaf is due to the presence of mucilage canal. It provides a fleshy nature to the plant and allowing the plant to withstand quick drying. Mucilage canals present in the pith of stem and midrib of leaf. The size of mucilage canals is big enough to see with naked eyes. The presence of calcium oxalate crystals in the form of raphide sacs are observed throughout stem and leaf. Presence of mucilage and calcium oxalate crystals acts as a epiphytic modification and helps the plant to survive adverse conditions.

5.5.1 Anatomy of leaf (Figure 37; Table 5, 6, 7, 8)

All the species studied have considerable variations in the leaf anatomical traits. The width of midrib ranges from 460 to 981 µm, it was highest in *Impatiens* sp. 1 (1426–1430µm) and lowest in *I. viridiflora* (460–467 µm). Epidermal cells are uniseriate on adaxial and abaxial surface. Mucilage canals throughout mid rib in all species. Largest mucilage canals are present in *Impatiens* sp. 1 and smallest in *I. viridiflora*. Vascular bundles are U shaped in *I. jerdoniae* and *I. sholayarensis*, in others it is crescent shaped. Comparing to the size of midrib smallest vascular bundle is found in *I. sholayarensis* and largest in *I. viridiflora*. The number of phloem cells is much higher than the number of xylem cells, the phloem cells surround and forms a cap around the xylem. Mesophyll region vary from 150 to 475 µm, it was thickest in *I. jerdoniae* and thinnest in *I. viridiflora*. Mesophyll region is divided into palisade and spongy tissues. In *I. violacea* and *I. viridiflora* palisade tissues are made of single layer of elongated chlorenchyma cells whereas in other species 2 layers of palisade cells present. Raphide sacs present in the mesophyll region of all the species.

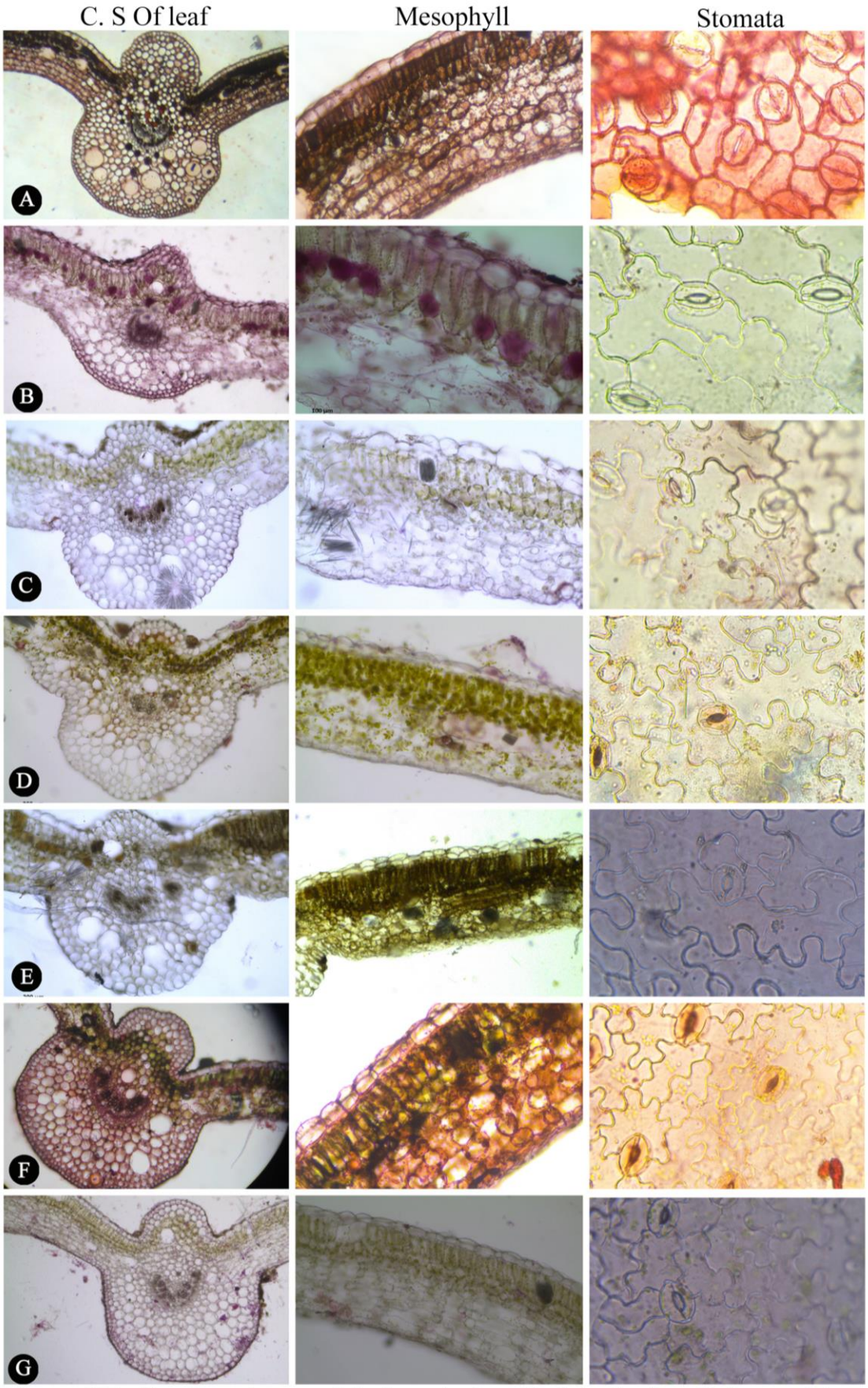

Figure 37 : Leaf anatomy of A. *I. auriculata*; **B.** *I. jerdoniae*; **C.** *I. parasitica*; **D.** *I. sholayarensis*; **E.** *I. violaceae*; **F.** *I. viridiflora*; **G.** *Impatiens* sp. 1

Table 5: Characteristic features of midrib of *Epiphyticae Impatiens*

Name of the species	Thickness (µm)		Adaxial epidermal cells Length		Adaxial epidermal cells Width		Abaxial epidermal cells Length		Abaxial epidermal cells Width		Adaxial hypodermal cells		Abaxial hypodermal cells		Mucilage canal Adaxial side		Mucilage canal Abaxial side		Vascular bundle Length		Vascular bundle Width	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE
Impatiens auriculata	600–607	607.25±1.55	30–33	31.25±0.54	20–30	25.25±1.34	28–34	30.75±1.37	20–31	26.8±2.0	294–300	295.6±1.04	205–214	209.75±1.84	45–55	49±1.7	55–65	58.6±1.97	60–65	62.25±1.1	140–150	146.2±1.71
Impatiens jerdoniae	975–981	977±1.41	30–38	34.6±1.62	50–59	53±2	17–25	21±1.82	29–34	31.25±1.1	450–455	452.5±1.19	310–320	314.25±2.0	80–85	82.5±1.19	80–86	82.75±1.37	150–160	155.5±2.1	227–230	228.5±0.64
Impatiens parasitica	815–820	818±1.0	30–35	32.75±1.1	50–60	55.25±2.1	25–27	25.75±0.47	18–21	19.5±0.64	306–315	309.25±2.1	317–324	320.25±1.43	70–74	71.75±0.85	65–70	67.75±1.1	140–150	140±1.16	150–165	158.25±3.49
Impatiens sholayarensis	730–737	733.5±1.55	25–34	28.75±2.05	24–32	27.75±1.75	30–45	38.25±3.32	28–34	31.25±1.25	313–321	316.5±1.7	245–250	246.75±1.18	30–37	34.5±1.55	50–60	55.5±2.1	113–120	113.5±2.1	80–90	85.25±2.1
Impatiens violaceae	759–761	759±0.47	24–28	26±0.91	16–24	20±1.68	40–50	44.75±2.1	45–52	48.5±1.55	290–296	293.5±1.32	238–240	239.25±0.47	75–79	76.5±0.86	65–71	68.25±1.25	113–116	114.25±1.03	200–205	220.5±1.19
Impatiens viridiflora	460–467	462±1.54	9–14	10.5±1.04	8–13	12±1.22	5–7	5.75±0.47	10–14	12.25±0.85	190–200	194.25±2.1	134–140	136.5±1.32	30–35	32.5±1.04	40–45	42.25±1.1	185–192	188.5±1.55	50–60	55.75±2.1
Impatiens sp. 1	1426–1430	1427.5±0.86	27–36	31.75±2.01	38–44	39.75±0.85	36–45	39.25±2	50–60	55.5±2.1	600–606	602.75±1.25	480–484	482.25±0.85	130–134	131.75±0.85	135–142	138.5±1.44	203–210	206.5±1.55	410–420	415.5±2.1

Table 6: Characteristic features of lamina of *Epiphyticae Impatiens*

Name of the species	Thickness (µm)		Adaxial epidermal cells Length		Adaxial epidermal cells Width		Abaxial epidermal cells Length		Abaxial epidermal cells Width		Width of palisade µm		Width of spongy parenchyma µm	
	Min-Max	Mean ±SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE
Impatiens auriculata	418–428	422.25 ±2.1	49–52	50.5±0.64	69–79	73.25±2.17	11–20	16±1.95	25–32	28.25±1.49	95–98	96.5±0.64	258–263	260±1.08
Impatiens jerdoniae	470–475	472.5±1.04	55–65	59.5±2.1	70–80	74.5±2.1	21–23	21.75±0.47	22–25	23.5±0.64	150–153	151.5±0.64	240–248	242.75±1.79
Impatiens parasitica	340–345	342.5±1.04	25–35	30.25±2.13	100–110	105.75±2.09	19–25	21.5±1.32	18–21	19.5±0.64	110–117	113.5±1.55	165–175	169.75±2.13
Impatiens sholayarensis	331–340	335.75±188	45–55	48.75±2.17	70–80	74.25±2.17	20–27	23.25±1.49	18–21	20±0.70	110–118	115.75±1.93	187–195	189.75±1.88
Impatiens violaceae	347–350	348.5±0.64	36–42	39.25±1.25	69–78	73±2.1	26–30	28±0.91	22–25	23.5±0.64	80–85	82±1.08	190–196	193.75±1.31
Impatiens viridiflora	160–170	165.25±2.17	10–15	13.5±1.19	20–29	25±1.95	14–19	17±1.08	9–12	11.25±0.75	29–38	34.75±2	90–95	93.5±1.19
Impatiens sp. 1	400–404	401.75±0.85	36–40	38±0.91	88–92	9±0.91	25–30	27.5±1.04	21–23	21.75±0.47	128–130	129±0.40	270–276	273.5±1.32

Table 8: Characteristic features of stomata of *Epiphyticae Impatiens*

Name of species	Guard cell Length		Guard cell Width		Stomatal opening Length		Stomatal opening Width		Length of subsidiary cell		Width of subsidiary cell	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE
Impatiens auriculata	18–23	20.5±1.04	7.5–8.6	8±0.20	8–10	8.87±0.42	4–6	4.87±0.42	20–26	23.75±1.31	18–30	24.5±2.5
Impatiens jerdoniae	29–32	30.5±0.64	8–10	8.87±0.42	14–18	15.75±0.85	5–7	6.12±0.42	50–60	54.25±2.1	38–48	42.5±2.1
Impatiens parasitica	21–25	23.25±0.85	6–8	6.87±0.42	10–12	10.87±0.42	5–8	6.5±0.64	30–35	32.75±1.10	55–64	59.5±1.84
Impatiens sholayarensis	20–24	22.25±0.85	4–6	5.12±0.42	9–11	9.87±0.42	5–8	6.25±0.66	46–50	49.75±1.65	65–73	68.5±1.7
Impatiens violaceae	25–28	26.5±0.64	7–10	8.62±0.80	13–15	14.12±0.42	6–7.5	6.75±0.322	78–87	81.75±2.05	69–78	71.5±2.17
Impatiens viridiflora	22–24	23.25±0.47	7–8.5	775±0.32	9–12	10.5±0.64	5.5–8	6.75±0.59	36–45	39.75±1.93	44–53	47.75±2.05
Impatiens sp. 1	20–26	23.25±1.25	7–10	8.5±0.64	8.5–12	1037±0.74	5–7	6±0.45	55–65	59.25±2.17	58–68	62.25±2.17

Table 8: Characteristic features of stomata of *Epiphyticae Impatiens*

Name of species	Stomatal type	Number of epidermal cells	Number of Stomata	Stomatal index	
Impatiens auriculata	Anamocytic	5–7	2	22–28	25.75±1.43
Impatiens jerdoniae	Anamocytic	10–11	2–3	21–23	22±0.57
Impatiens parasitica	Anamocytic	11–12	3	20–21	20.5±0.28
Impatiens sholayarensis	Anamocytic	8–9	2–3	18–25	20.25±1.65
Impatiens violaceae	Anamocytic	12–11	3	20–21	20.5±0.28
Impatiens viridiflora	Anamocytic	5–6	1–2	20–25	22.5±1.44
Impatiens sp. 1	Anamocytic	5–6	2	25–28	26.5±0.86

In all the species studied epidermal cells of abaxial surface and adaxial surface are similar in shape. Adaxial surface is apostomatic, abaxial surface is stomatiferous and stomata anamocytic in all species. The presence of anamocytic stomata in different species of *Impatiens* was confirmed in previous studies (Rahaman *et al*., 2016). The anticlinal walls of subsidiary cells are straight in *I. auriculata* and lobed in all other species. The number of lobes and depth of lobes vary in different species. Stomatal index ranges from 20.25% to 26.5%, highest value is observed in *Impatiens* sp. 1 and lowest in *I. sholayarensis*.

5.5.2 Anatomy of stem (Table 9)

The epidermis of all the species studied is single layered and rectangular in shape. Hypodermis is composed of chlorenchyma, collenchyma, sclerenchyma and parenchyma cells. The number of layers varies between 10 to 30. Presence of sclerenchyma cells in hypodermis was observed in *Impatiens* sp. 1 and this character is not observed in any other species. The presence of starch grains in 2 to 5 layers of parenchyma cells above the endodermis are found in all the species studied. The presence of starch is confirmed with iodine test. The size of the starch bearing cells and non-starch bearing cells are same. In *I. auriculata*, *Impatiens* sp. 1 and *I. violaceae* starch grains found throughout stem and higher amount in the above mentioned region. Endodermis is uniseriate in all the species studied.

The formation of cambium observed in all the species under study but secondary thickening is not occurring in any of the species. Intact vascular bundles are visible in all species. Number of vascular bundles varies from 6 to 9. The number of vascular bundles is highest in *Impatiens* sp. 1. The vascular bundles are thickest in *Impatiens* sp. 1 and broadest in *I. violaceae*. The thickness of phloem cell layer is highest in *Impatiens* sp. 1 and lowest in *I. viridiflora*. Similar trend is observed in the case of xylem cell layer also. In between vascular bundles 10 to 20 layers of medullary rays present. It is formed of isodiametric cells in all the species under consideration.

Mucilage canals are present in the pith of all the *Epiphyticae Impatiens*. The number of mucilage canal is half of the number of vascular bundles in every species except *I. viridiflora*. In this species 1 or 2 mucilage canal is observed. The broadest mucilage canal is observed in *Impatiens* sp. 1 and narrower in *I. sholayarensis*. Every mucilage canal is surrounded by a layer of highly elongate and large sized parenchyma cells. This feature is an epiphytic adaptation. The pith is formed of parenchyma cells. Another peculiar feature of these species is the presence of raphides in vegetative parts. In *I. jerdoniae* and *I. viridiflora,* raphide sacs are

confined to hypodermis whereas in other 5 species raphide sacs can be seen throughout stem. The presence

Table 9: Characteristic features of stem of *Epiphyticae Impatiens*

Name of species	Epidermal cells Length		Epidermal cells Width		Vascular bundle Length		Vascular bundle Width	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE
Impatiens auriculata	14–20	16.75±1.25	19–25	22±1.29	220–228	224.25±1.75	355–364	358.25±2.1
Impatiens jerdoniae	22–30	26.5±1.84	25–35	30±2.19	343–352	346.25±1.93	345–355	349.25±2.1
Impatiens parasitica	27–33	30.25±1.37	19–25	21.25±1.31	485–490	487±1.08	330–345	335..75±2.17
Impatiens sholayarensis	10–17	13.25±1.65	8–13	11±1.08	70–80	76±2.16	125–134	128.5±2.17
Impatiens violaceae	24–33	27.25±2	22–25	22.75±0.85	412–415	412.75±0.75	508–510	509.25±0.47
Impatiens viridiflora	6–9	8.25±0.75	3–5	4.5±0.5	45–50	47.5±1.04	45–53	50.75±2
Impatiens sp. 1	29–38	33.5±1.93	20–23	21±0.70	737–740	737.75±0.75	430–433	432.5±1.04

Name of species	Thickness of phloem cells µm		Thickness of xylem cells µm		Mucilage canal	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE		
Impatiens auriculata	30–38	34.25±1.93	138–147	142.75±1.84	740–750	745.5±2.1
Impatiens jerdoniae	65–67	65.75±0.47	210–212	211.25±0.47	708–716	710.5±1.89
Impatiens parasitica	78–85	82.5±1.55	343–351	346.5±1.7	120–130	124.75±2
Impatiens sholayarensis	13–21	17±1.82	42–52	47±2.19	50–60	54.25±2
Impatiens violaceae	85–87	86.25±0.47	314–318	315.75±0.85	744–750	747.25±1.25
Impatiens viridiflora	6–10	8.75±0.94	35–42	38.75±1.49	74–81	77.5±1.55
Impatiens sp. 1	150–157	154.5±1.55	510–518	514±1.68	840–850	845.5±2.1

of mucilage and raphides reduces the clarity of images. The raphides dislodge from their position immediately after sectioning and can be seen spreading throughout the section.

5.6 Pollen morphology (Figure 38; Table 10)

Pollen grains of all the species under study is medium sized according to the classification system of Erdtman. The size of pollen grains ranges from 27 to 35. Smallest size

is found in *I. auriculata* and largest in *I. viridiflora*. P/E ratio is highest in *I. jerdoniae* and smallest in *I. auriculata*. The shape of pollen grain is oblate spheroidal in *I. auriculata* and prolate spheroidal in all other 6 species under consideration. In polar view pollen grains have a rectangular shape in all species except *I. sholayarensis*; here it is dumbbell shaped. In equatorial view, all the pollen grains have elliptic shape.

The pollen grains are tetra zonocolpate in all the species studied. In earlier studies (Pechimuthu *et al*., 2020), this kind of aperture was reported in *I. walleriana*. The aperture of *I. auriculata, I. jerdoinae* and *I. sholayarensis* is simple, slit like without any ornamentation on the margin. The margin of aperture having slightly raised walls in *I. parasitica*, whereas in *Impatiens* sp. 1 a deep wedge connecting the two apertures is visible in the equatorial plain, furrow like structures throughout body.

Table 10: Characteristic features of pollen grains of *Epiphyticae Impatiens*

Name of the species	Polar diameter(P)		Equatorial diameter (E)		P/E	
	Min-Max	**Mean ±SE**	**Min-Max**	**Mean ±SE**	**Min-Max**	**Mean ±SE**
Impatiens auriculata	26–30	27.66 ±1.04	26–34	30 ±2	0.86–1.03	0.09 ±0.04
Impatiens jerdoniae	31–34	32 ±0.70	28–30	29.12 ±0.42	1.05–1.21	1.10 ±0.03
Impatiens parasitica	30–34	32 ±0.81	31–33	31.75 ±0.47	0.96–1.03	1.00 ±0.01
Impatiens sholayarensis	33–36	34.5 ±0.64	31–35	33.25 ±0.85	0.97–1.12	1.03 ±0.03
Impatiens violaceae	30–33	32.25 ±0.75	31–33	31.75 ±0.47	0.96–1.06	1.01 ±0.02
Impatiens viridiflora	34–37	35.25 ±0.62	33–35	33.75 ±0.47	1–1.12	1.04 ±0.02
Impatiens sp. 1	30–34	32.25 ±0.85	31–33	31 ±0.47	0.9–1.03	1 ±0.03

The surface of pollen grains has reticulate ornamentation. The lumens of reticulate ornamentation are hexagonal in *I. auriculata*, *Impatiens* sp. 1 and *I. violaceae*. In other species it is triangular to hexagonal in shape. The muri are closely packed in *I. parasitica* hence the lumen is very narrow, whereas in other species muri is widely spaced and the lumen is clearly visible. Lumen is deepest and widest in *I. shaolayarensis*. Thickness of muri is also least in *I. sholayarensis*. Muri is widest in the middle of the pollen and become closely packed near the

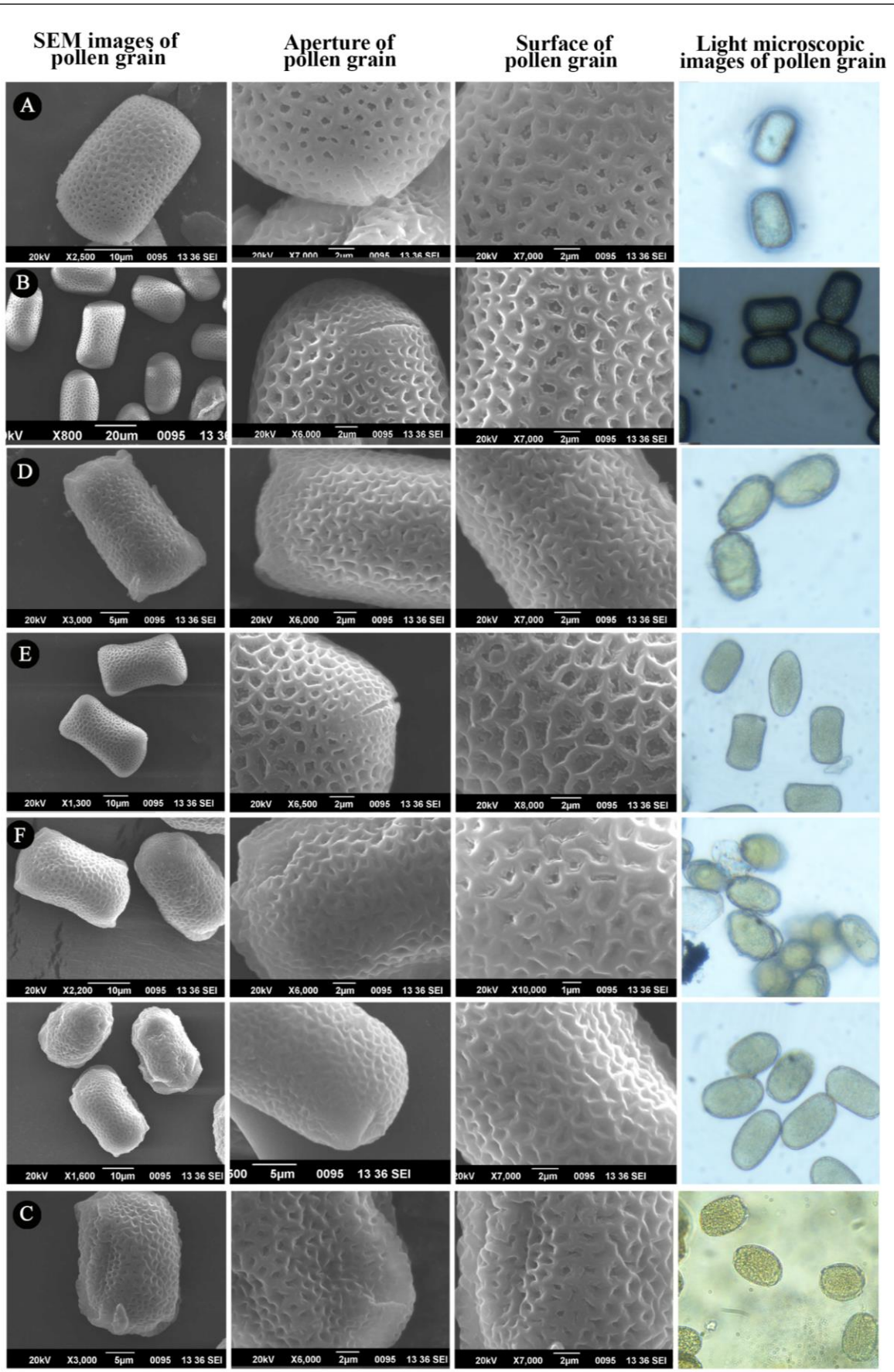

Figure 38: Pollen grains of **A.** *I. auriculata*; **B.** *I. jerdoniae*; **C.** *I. parasitica*; **D.** *I. sholayarensis* **E.** *I. violaceae*; **F.** *I. viridiflora*; **G.** *Impatiens* sp. 1

aperture; here the lumen is narrow. Inside the lumen numerous granules are found in *I. sholayarensis*, presence of granules is also observed in *I. auriculata* and *I. jerdoniae*. Whereas in other 4 species the surface of lumen is agranulated.

5.7 Seed morphology (Figure 39; Table 11)

The shape and size of seed is different in all the species under study. The largest seed is observed in *I. sholayarensis*; it is 976–981 µm long and the smallest one is found in *I. jerdoniae*. The colour of seed is brownish black in *I. jerdoniae* and *I. viridiflora*, yellowish brown in *I. parasitica* and brown in other species. Different type of ornamentation is found in the surface of seed. Seed surface is verrucate in *Impatiens* sp. 1 and reticulate in all other species under consideration.

Table 10: Characteristic features of seeds of *Epiphyticae Impatiens*

Name of species	Length of seed		Width of seed	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE
Impatiens jerdoniae	795–800	797.75 ±0.51	486–490	487.25 ±0.94
Impatiens parasitica	945–950	947.25 ±1.1	518–522	520 ±0.81
Impatiens sholayarensis	976–981	978.75 ±1.1	497–500	498.5 ±0.64
Impatiens violaceae	972–977	974.25 ±1.1	475–480	477.75 ±1.1
Impatiens viridiflora	870–877	873 ±1.47	493–500	496 ±1.47
Impatiens sp. 1	930–936	933.25 ±1.25	497–503	500.25 ±1.25

Continues striations are present in the surface of all the species and beads like projections are present in the surface of *I. viridiflora*. According to Song *et al*., (2005) reticulate ornamentation is the most common type among *Impatiens*. The species with these characters usually found at the base of phylogenic tree hence considered as an ancestral and primitive character.

Seeds of *Epiphyticae Impatiens* are hairy, as an adaptation for epiphytic mode of life. These hairs are helically coiled in all the species under study. With the help of these hairs seed can remain attached to the moss on the tree trunk. Seed hairs are helically coiled and each coil is laterally compressed in *I. jerdoniae*, *I. violaceae* and *I. viridiflora*; in the case of *I. violaceae*

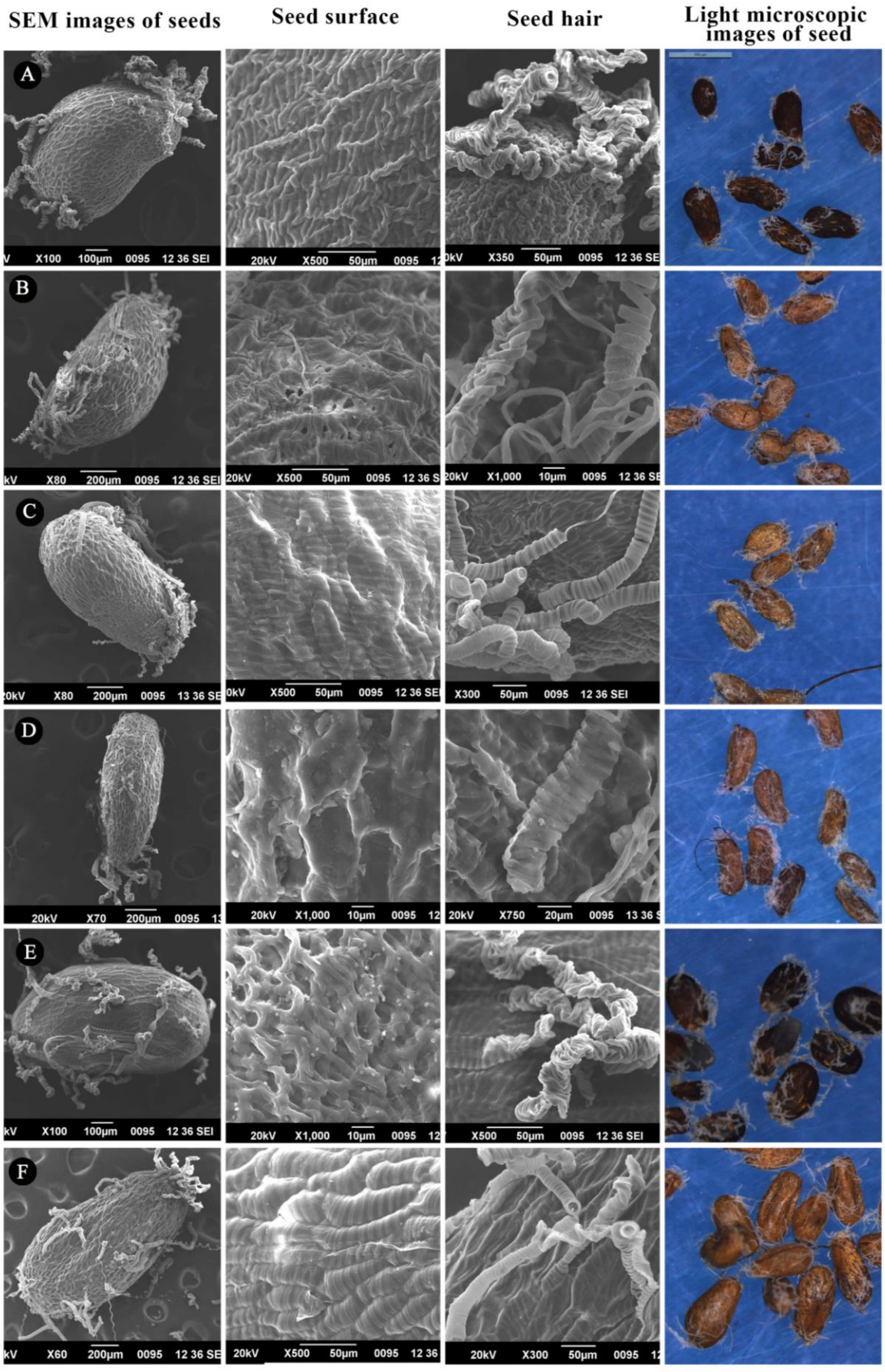

Figure 39: Seeds of - A. *I. jerdoniae*; **B.** *I. parasitica*; **C.** *I. sholayarensis*; **D.** *I. violaceae*; **E.** *I. viridiflora*; **F.** ***Impatiens*** sp. 1

compression is at it extreme hence the coils look like ribbon. In *Impatiens* sp. 1 seed hairs are thin like a string, and ribbon like in all other species. Seed hairs are located either at both ends of the seed or it is distributed throughout the seed surface. In Sp.1, *I. parasitica* and *I. viridiflora* it is at the ends and in other 3 species it is found throughout the surface.

Seed dispersal mechanism of the members of genus *Impatiens* is peculiar and ensures the spread of seeds to distant locations. The forceful breaking of fruit results in the ejection of seeds to far distances. The hairs on the seeds hold to the surface of host tree. Both these characters are epiphytic adaptation and seed hairs are reported only in epiphytic species.

5.8 Prediction of Potential geographical distribution of *Epiphyticae Impatiens*

MaxEnt algorithm is very useful in determining the distribution of plant species. This algorithm can be applied to identify the new populations of endemic species like *Impatiens*. While applying this algorithem to *Epiphyticae* species under study four species (*I. parasitica, I. jerdoniae, I. viridiflora* and *Impatiens* sp. 1) out of the seven-show good result and the AUC value was more than 0.9 hence it is accepted. But for three species (*I. auriculata, I. violaceae* and *I. sholayarensis*) the performance of the model was poor hence discarded.

I. jerdoniae is commonly found at an altitude higher than 900 m. The model predicts a moderate suitability throughout Western Ghats. The habitat suitability depends only on elevation and it increases with increasing elevation. High suitability was predicted in some regions of both Southern Western Ghats and Nilgiris.

I. parasitica is commonly found in higher altitudes with thick canopy and humid conditions. The model predicts a profound and almost continuous distribution in the southern parts of the Palghat gap and limited distribution in the northern part. High suitability was expected in different regions of Nilgiris also. The habitat suitability largely depends on temperature seasonality and areas with lower values show higher suitability. This trend is common among species that prefer stable climatic conditions for their survival. The regions with higher elevations usually have a stable climate. This might be the reason that *I. parasitica* prefers higher altitude regions of the Western Ghats. According to the model developed by MaxEnt, most of the suitable habitat of *I. parasitica* is the evergreen and semi-evergreen forest of Western Ghats and most of the regions are protected areas.

I. viridiflora was so far reported only from southern Western Ghats but the model predicts suitability areas in central Western Ghats also. This model is mostly influenced by

isothermality. That means fluctuations in the temperature are the factor that determine the distribution of this species. Areas with high isothermality have an equal diurnal temperature range and annual temperature range. Such stable temperature range is required for *I. viridiflora*. In the case of *Impatiens* sp. 1 precipitation is the factor that contributes to its distribution. Water availability in the driest months determines the distribution of this species. So far, this species is available only from Wagmon but the model shows many suitable areas in Southern Western Ghats and central Western Ghats.

According to the model all, the species under study show high suitability in Southern Western Ghats especially Idukki district Agasthyamalai Biosphere Reserve and associated regions. Idukki district was truly a paradise of all kind of *Impatiens*. When it comes to *Epiphyticae* species three (*I. parasitica, I. violaceae* and *Impatiens* sp. 1) out of the seven species are already reported from Idukki district and according to the model the probability of occurrence of *I. jerdoniae* and *I. viridiflora* in this region is also predicted. In the previous year's many authors informally consider that *I. parasitica* was distributed only southern Western Ghats up to Palakkad gap and *I. jerdoniae* in central Western Ghats. Nevertheless, in our study I could identify *I. parasitica* from Wayanad district contradictory to this view. The performance of MaxEnt model also confirms this.

For all the species, studied most of the suitable areas are protected areas. Hence, threat due to direct anthropogenic activities is less likely to occur. At the same time, various natural calamities taking place in this region is a constant threat to the species. The torrential rainfall that occurred in the southwest monsoon of 2018 triggered 4728 landslides (Hao *et al*., 2020). In the following year also a huge number of cataclysmic landslides occurred in different regions of the Western Ghats. This may result in the habitat destruction of endemic species like Impatiens which adversely affect their survival.

The genus *Impatiens* belongs to the family Balsaminaceae, is one of the species rich genus distributed in five major hot spots around the world. This genus is notorious among the botanists due to delicate nature of the flowers, variations in morphological characters, rapid hybridization, and high degree of endemism. Due to these intricacies, the classification of genus *Impatiens* is still incomplete. The intergeneric classification proposed by Hooker divides this genus into 7 sections and one among them is section *Epiphyticae*. This section is a narrow endemic, distributed only in Southern Western Ghats. The section includes 7 species located at various locations of Southern Western Ghats. The floral parts are rigid and remain fresh for long time unlike the other *Impatiens*. The present study deals with the taxonomy, anatomy, palynology, seed morphology and potential distribution of Impatiens belongs to the section *Epiphyticae*.

Standard procedure for systematic investigation was followed during the study. The original publication of all the species under study was obtained from various sources. The type specimens also examined from various herbaria. The fresh specimens are collected from various regions of Southern Western Ghats. All the specimens are identified using protologues and type specimens. Morphology of the specimens collected studied using Leica s8 APO Stereomicroscope and photographs were taken. Herbarium prepared as per the standard protocol. Anatomy of the vegetative parts such as stem and leaf studied following standard procedure and photographs taken using Micaps digital cameras attached to Labomed Microscope. Morphology of seed and Pollen studied with help of Scanning Electron Microscope. Potential geographical distribution of Epiphytic species was done with the help of MaxEnt Software version 3.2.

All the species belongs to section *Epiphyticae* are epiphytes on trees and do not show any preference to the host tree. Their vegetative parts are fleshy in nature and the leaves are thick with persistent leaf scares on stem. The flowers are very attractive due to the presence of brightly coloured spur. Due to the unique nature of the spur they are also known as, Parrot billed *Impatiens*.

Critical examination of a specimen collected from Wagamon confirmed as novelty and have been recognized as new species. This species is closely aligned with *I. parasitica* and known only from the type locality. The variation in morphology of *I. parasitica* collected from different localities confirmed the rapid evolution-taking place in this genus. During the studies 8 different morpho types of *I. parasitica* was collected. They show variations in floral

characters but the seed and fruit are similar. In the future, these morpho types may develop to new species. These morpho types some time confused as new species and are reported as new species. This is what happened in the case of *I. kulamavuensis*. On critical examination of the type specimen of this taxon it is concluded that *I. kulamavuensis* is a synonym of *I. parasitica* hence merged under *I. parasitica*.

The ambiguity remained in the structure of floral parts especially lateral united petal of *Epiphyticae* Impatiens was resolved here. The lateral united petals consist of two lobes and attached to pedicel with the help of a stalk. The key proposed by. Bhaskar (2012) based the trilobed and bilobed condition of lateral united petal was unacceptable and a new key for the identification of *Epiphyticae* species based on revised characters are proposed here.

Negligible literature is available about the anatomy of the genus *Impatiens*. This is the first attempt to elucidate the anatomical features of *Epiphyticae Impatiens*. This attempt resulted in significant data on the anatomy of leaf and stem. The vegetative anatomy does not show much variation; indeed, it provides additional evidences for delimiting the taxa. Since these plants are epiphytes, they show adaptations for such mode of life. Presence of mucilage canal is one of the epiphytic adaptations. It helps the plant to store water and to prevent desiccation. Presence of raphide sacs in leaf and stem is another character observed in the species under study. The presences of starch grains are confirmed in the cells of stem. Starch grains either may found throughout the stem or confined to few layers of parenchyma cells above the endodermis. The shape of the epidermal cells of leaf on abaxial and adaxial surface are similar but vary in size. The leaf epidermal cell wall is wavy in nature. The depth and number of infoldings vary from species to species and it is straight in *I. auriculata*. Adaxial surface is apostomatic, abaxial surface is stomatiferous and stomata anamocytic in all species.

The pollen grains of all the species under study have a medium size and shape is oblate spheroidal in *I. auriculata* and prolate spheroidal in all other 6 species under consideration. The surface of the pollen grains consists of reticulate ornamentation. The number of sides and the distance between the muri varies from species to species. All the pollen grain under study is tetrazonocolpate.

The seeds of *Epiphyticae Impatiens* are adapted to their epiphytic mode of life. The seeds are furnished with spirally coiled hair. The hairs may find throughout the seed or it may cluster at both ends. These hairs help the seed to cling on mosses on the tree trunk and germinate there. The hairs may be ribbon like or string like. Surface of the seed is verrucate in *Impatiens*

sp. 1 and reticulate in all other species under study. Seeds are the most peculiar epiphytic adaptation found in these plants. The matured fruit forcefully open even with a slight touch and disperse the seeds to long distances.

The MaxEnt algorithm helps to predict the potential distribution of species under study. Only four species (*I jerdoniae, I parasitica, I. viridiflora* and *Impatiens* sp. 1) out of the seven species reported a good result hence the final model is accepted. The performance of the model for other three species (*I. auriculata, I. violaceae* and *I. sholayarensis*) is not good due to the narrow endemism of hence final model is discarded. In the previous studies *I. parasitica* was reported only in the southern parts of Palghat gap. However, the model predicted suitability areas in the northern parts also. It was proven true by collecting *I. parasitica* from Wayanad district. According to the model all the studied species show distribution in Idukki district as well as Agasthyamalai regions. Probable locations of these species were obtained from the algorithm and it is very useful for further studies and developing conservation measures for these narrow endemic species.

Future Prospective

In this study the taxonomy, anatomy, seed morphology, and palynology of all the E*piphyticae Impatiens* are completed. In the future the molecular taxonomic studies of these plants need to be done. Especially all the eight morphotypes of *I. parasiticae*. Molecular evidence may ascertain the view that all of them are *I. parasitica*. Or it might also lead to a new conclusion that they may be new species. Molecular evidences would also provide additional strength to the synonymizing of *I. kulamavensis* and *I. parsitica.*

The potential distribution of four *Epiphyticae* species was done in this work. In the forthcoming years a detailed ecological study to find out new populations using this result can be conducted. This would be an added advantage for conservation of these fragile plants. The molecular evidences combined with ecological studies may provide an insight to the evolution of *Epiphyticae Impatiens*. Along with molecular level studies, cytogenetic studies of these plants are also relevant. So, in the near future this will also be conducted.

Epiphyticae Impatiens are plants having curious flowers. It will be interesting if some data about the pollination mechanism of these plants are available. No such studies are conducted so for. Hence in the future the pollination biology of *Epiphyticae Impatiens* is planning to execute. Pollen viability and related studies are also there in plan.

The biochemical aspects of *Epiphyticae Impatiens* is also unknown. So, such studies also have a relevance. Since these plants are endemic and facing many environmental issues utilizing plants collected from the wild for biochemical studies are practically impossible. At this point, growing them using tissue culture method will be a good idea. In this way it is possible to increase the population of these plants and can be used for biochemical studies also.

Abid, R., Ather, A., & Qaiser, M. (2011). The seed atlas of Pakistan–V. Balsaminaceae. *Pakistan Journal of Botany*, *43*(5), 2451–2456.

Abrahamczyk, S., Janssens, S., Xixima, L., Ditsch, B., & Fischer, E. (2016). *Impatiens pinganoensis* (Balsaminaceae), a new species from Angola. *Phytotaxa*, *261*(3), 240–250.

Antony V.T., (1989). *Systematic Studies on the Flora of Kottayam District*, Kerala. Ph.D. Thesis, Bharathiyar University, Coimbatore.

Arigela, R. K., Singh, R. Kr., & Kabeer, K. A. A. (2019). *Impatiens tanyae* (Balsaminaceae), a new species from Western Ghats, India. *Kew Bulletin*, *74*(3). https://doi.org/10.1007/s12225–019–9831–4

Arigela, R. K., & Ahamed Kabeer, K. A. (2022). New Synonyms in Three Southern Indian Endemic Species of *Impatiens* (Balsaminaceae). *Annales Botanici Fennici*, *59*(1). https://doi.org/10.5735/085.059.0138

Arnott, G. A. W. (1835). New species of Indian Balsamineae. *Companion to the Botanical magazine, 1,* 320–325.

Arya, S., Govind, M. G., Suresh, V., Vishnu, W. K., & Kumar, V. N. S. A. (2021). Three new species of *Impatiens* (Balsaminaceae) from southern Western Ghats, Kerala. *PhytoKeys*, *180,* 157–171. https://doi.org/10.3897/phytokeys.180.66748

Barooah, C. & Ahmed, I. (2014) Plant diversity of Assam: A checklist of Angiosperms and Gymnosperms. Assam Science Technology and Environment Council, Assam, pp 599.

Barnes, E. (1939). The species of Geraniaceae occurring on the Travancore High Range including the description of a new balsam. *Journal Indian Botanical Society. 18*(3), 95–105.

Beddome, R. H. (1858). The genus *Impatiens.* Description of new species from the Anamalai hills. *Madras journal of Literature and Science 4*, 66–70.

Beddome, R. H. (1874). *Icones Plantarum Indiae Orientalis.* Grantz Brothers, Madras.

Bexon, D., & Wood, A. E. (1930). Observations on the Anatomy of Teratological Seedlings: VII. The Anatomy of some Polycotylous Seedlings of *Impatiens Roylei*, Walp. *Annals of Botany*, *44*(174), 297–309. https://www.jstor.org/stable/43237234

Bhaskar, V. (1981) The genus *Impatiens* in South India: Endemism and affinities. *Indian Forester, 107*, 368–376.

Bhaskar, V. (2006) *Impatiens clavata* Bhaskar *sp. nov*.-a new scapigerous balsam (Balsaminaceae) from Bisle Ghat, Western Ghats, South India. *Current Science, 91*, 1138–1140.

Bhaskar, V. (2012) *Taxonomic Monograph on Impatiens L. (Balsaminaceae) of Western Ghats, South India: The Key Genus for Endemism.* Pp 1–283. Centre for plant taxonomic studies, Bangalore.

Bhaskar, V. & B. A. Razi (1978). Studies in South Indian *Impatiens* L. -General. *Indian Journal of Forestry*, *1*, 191–198.

Bhaskar, V. & B. A. Razi. (1982). Two more new species of *Impatiens* L. from South India. *Journal of Bombay Natural History Society, 79*(2), 382–384.

Bhaskar, V. & Sringeswara, A. N. (2017). Two new species of *Impatiens* L. under the section: 'Annuae' (Balsaminaceae) from Western Ghats, India. *Webbia*, *72*, 1–6. https://www.jstor.org/10.1080/00837792.2017.1370208.

Bhaskar, V. & Sringeswara, A. N. (2018). *Impatiens bhimgadensis* (Balsaminaceae), a New Species from Karnataka, India. *Current Science*, *114*, 443–445. https://www.jstor.org/10.18520/cs/v114/i03/443–445.

Biju, P., Arya, S., Augustine, J., Josekutty, E. J., & Kumar, V. N. S. A. (2022). *Impatiens thulunadensis* (Balsaminaceae), a new species from northern Kerala, India. *Annales Botanici Fennici*, *59*(1), 207–212.

Blatter, E. (1933). Revision of the Flora of the Bombay Presidency: Balsaminaceae. *Journal of Bombay Natural History Society, 36*, 307–320

Brown, Hill, Dolan, Carnaval & Haywood (2018) PaleoClim, high spatial resolution paleoclimate surfaces for global land areas. *Nature – Scientific Data*, *5*,180–254

Candolle, A. P. D. (1824) *Prodromus systematis naturalis regni vegetabilis. 1*, 685– 688.

Caris, P. L., Geuten, K. P., Janssens, S. B., & Smets, E. F. (2006). Floral development in three species of *Impatiens* (Balsaminaceae). *American Journal of Botany*, *93*(1), 1–14. https://www.jstor.org/stable/4125468

Chandrabose, M. (1978) A new species of *Impatiens* L. (Balsaminaceae) from South India. *Journal of Bombay Natural History Society*, *75*, 901–902.

Chandrabose, M., Chandrasekharan, V. & N. C. Nair (1984) A new species of *Impatiens* L. (Balsaminaceae) from South India. *Journal of Bombay Natural History Society*, *81*, 676–677.

Chen, Y. L., (2001). *Balsaminaceae. In: Flora Reipublicae Popularis Sinica*, Vol. 47, pp. 1–243, Science Press, Beijing.

Chen, Y. L., Akiyama, S. & Ohba, H., (2007). *Balsaminaceae. In: Wu, Z.Y., Raven, P.H. (Eds.), Flora of China*, vol. 12, pp. 43–113. Science Press and Missouri Botanical Garden Press, Beijing and St. Louis.

Chinnaiyan, R., S. Jeevith & Kottaimuthu, R. (2018). *Impatiens pendula* B. Heyne ex Wight and Arn. (Balsaminaceae): A Jewel Weed New to Tamil Nadu, Western Ghats. *International Journal of Current Research in Biosciences and Plant Biology*, *5*, 44–49. 10.20546/ijcrbp.2018.511.004.

Ching S., (1977). New Medical College (ed), "*Dictionary of Chinese Materia Medica*," Shanghai Scientific Tecnological Publishers, Shanghai, 2096.

Cooke, T. (1901). *The Flora of the Presidency of Bombay.* (Vol 1, pp. 169–175) Tailor and Francis. London.

Dalzell, N. A. & A. Gibson. (1861). *The Bombay Flora.* (pp. 42–44) Education Society's Press, Byculla, Maharashtra.

Daniel, P., Murthy, G. V. S. & Venu, P., (2005). *Flora of Kerala volume 1, Ranunculaceae—Connaraceae*. Botanical Survey of India.

Dessai, J. R. N. & Janarthanam, M. K. (2008). Taxonomy and distribution of *Impatiens talbotii* – a rare endemic balsam from Western Ghats. *The Journal of Economic and Taxonomic Botany*, *32*(3), 624–627.

Dessai, J. R. N., Joseph, L. & Janarthanam, M. K. (2009) A new species of epiphytic *Impatiens* (Balsaminaceae) from the Western Ghats, India. *Taiwania, 54*, 149–151.

Dessai, J. R. N. & Janarthanam, M. K. (2011). The genus *Impatiens* (Balsaminaceae) in the northern and parts of central Western Ghats. *Rheedea*. *21*, 23–80.

Dessai, J. R. N. (2011) Taxonomic studies on the genus *Impatiens* L. (Balsaminaceae) of Northern and Central Western Ghats with special reference to endemic species, Ph.D. thesis submitted to University of Goa, Goa, India, 169p

Drury Herber. (1864) *Hand Book of the Indian Flora: Being a Guide to All the Flowering Plants Hitherto Described as Indigenous to the Continent of India* Vol. I, 605p

Elias, T. S., & Gelband, H. (1977). Morphology, Anatomy, and Relationship of Extrafloral Nectaries and Hydathodes in Two Species of *Impatiens* (Balsaminaceae). *Botanical Gazette*, *138*(2), 206–212. doi:10.1086/336916

Fosberg, F.R. & Sachet, M. (1965). *Manual for Tropical Herbaria. International Association for Plant Taxonomy, Regnum Vegetabile* Vol. 39.

Fyson, P. F. (1915). *The Flora of Nilgiri and Pulney hill tops.* Vol. 1, 2 and 3. pp. 59–71 (Vol. 1), 47–5 (Vol.2), 13–20 (Vol. 3) Today and Tomorrow Printers Publication, New Delhi.

Gamble, J. S. (1915). *Impatiens*, In: *Flora of the Presidency of Madras*. pp. 134–145. Adlard & Sons Ltd., London.

Gavit, C. G., (1990). *A contribution to the Study of Systematic Seed Morphology of South Gujrat Plants*. Ph. D. thesis, South Gujrat University, Surat, India.

Grey Wilson, C. (1980a). *Impatiens of Africa*. A. A. Balkema, Rotterdam.

Grey Wilson, C. (1980b). Some observations on the floral vascular anatomy of *Impatiens*: studies in Balsaminaceae: VI. *Kew Bulletin*, 221–227.

Hajra, P. K., Nair, V. J. & Daniel, P. (1998). *Flora of India* Vol. 4: Malpighiaceae–Dichapetalaceae, Botanical Survey of India.

Hao, L., Van Westen, C., KS, S., Martha, T. R., Jaiswal, P., & McAdoo, B. (2020). Constructing a complete landslide inventory dataset for the 2018 monsoon disaster in Kerala, India, for land use change analysis. *Earth System Science Data Discussions*, *2020*, 1–32.

Hoffman, J. D., Narumalani, S., Mishra, D. R., Merani, P., & Wilson, R. G. (2008). Predicting potential occurrence and spread of invasive plant species along the North Platte River, Nebraska. *Invasive Plant Science and Management*, *1*(4), 359–367.

Hooker, J. D. & T. Thomson. (1859). Praecursoresad Floram Indicam – Balsamineae. *Journal of the Proceedings of the Linnean Society of London, Botany* *4*, 106–157.

Hooker, J. D. (1874). *Balsamineae.* In *Flora of British India,* (Vol. 1, pp. 440–483). London.

Hooker, J. D. (1904). An epitome of the British Indian species of *Impatiens. Records of Botanical Survey of India, 4*(1), 1–10.

Hooker, J. D. (1905). An epitome of the British Indian species of *Impatiens. Records of Botanical Survey of India, 4*(2), 11–35.

Hooker, J. D. (1906). An epitome of the British Indian species of *Impatiens. Records of Botanical Survey of India, 4*(3), 37–58.

Hooker, J. D. (1910a). Indian species of *Impatiens.* Generis *Impatiens* species Indicae novae et minus rite cognitae a cl. A. Meebolddetectae. *Bulletin of Miscellaneous Information Kew,* 291–300.

Hooker, J. D. (1910b). *Icones Plantarum,* t. 2901–2925. 4th series. London.

Hooker, J. D. (1911). *Icones Plantarum,* t. 2951–2975. 4th series 10(1), London.

Hooker, W. J. (1850). *Journal of botany and Kew garden miscellany*, Vol 2, pp. 37–38

Hu, Tian., Peng, S., Zhou, X. X., Zheng, Y. M., Cong, Y. Y., & Hu, G. W. (2022). Two new species of *Impatiens* (Balsaminaceae) from Gaoligong Mountains, Yunnan, China. *Phytotaxa*, *566*(3), 268–278.

Irfan-Ullah, M., Amarnath, G., Murthy, M. S. R., & Peterson, A. T. (2006). Mapping the geographic distribution of *Aglaia bourdillonii* Gamble (Meliaceae), an endemic and threatened plant, using

ecological niche modeling. In *Plant Conservation and Biodiversity*. pp. 343–351, Springer, Dordrecht.

Jain, S.K. & Rao, R.R. (1977). *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers and Publishers, New Delhi.

Jalal, J. S., & Singh, P. (2017). Ecological niche modelling for conservation of *Habenaria Suaveolens* Dalzell, an endangered orchid species endemic to Western Ghats: A case study. *Journal of Orchid Society of India*, *31*, 77–83.

Janssens, S., Geuten, K., Yuan, Y. M., Song, Y., Küpfer, P., & Smets, E. (2006). Phylogenetics of *Impatiens* and *Hydrocera* (Balsaminaceae) using chloroplast atpB–rbcL spacer sequences. *Systematic Botany*, *31*(1), 171–180.

Janssens, S. B., Wilson, Y. S., Yuan, Y. M., Nagels, A., Smets, E. F., & Huysmans, S. (2012). A total evidence approach using palynological characters to infer the complex evolutionary history of the Asian *Impatiens* (Balsaminaceae). *Taxon*, *61*(2), 355–367.

Joe, A., Bhaskar, V., & Sabu, M. (2017). *Impatiens agastyamalayensis* stat. Nov. (Balsaminaceae)-A reassessment of Impatiens rufescens var. Agastyamalayensis and rediscovery of the plant from the Western Ghats, India, *Phytotaxa*, *326*(2), 144. https://doi.org/10.11646/phytotaxa.326.2.6

Jeevith, S., Arigela, R. K., Singh, R. K., Kabeer, K. A. A., Rajasekhar, C., & Kunhikannan, C. (2022). The checklist of Impatiens Riv. ex L. (Balsaminaceae) in Nilgiri and Palani Hills of southern Western Ghats (India). *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae*, *7*, 1–16.

Karuppusamy, S., Ravichandran, V., & Kumar, M. U. (2021). Rediscovery and taxonomic notes of an endemic species, *Impatiens viridiflora* wight (Balsaminaceae) from southern western ghats, India, *International Journal of Botany Studies*, *6*(6), 1040–1042. https://www.botanyjournals.com/archives/2021/vol6/issue6/6–6–167

Kallappa, K.S. (2015). Studies on reproductive dynamics and conservation strategies of three rare and endemic balsams of Western Ghats, Ph.D. thesis submitted to university of Kannur, Kannur, Kerala, India, 167p

Klimko, M., Antkowiak, M., & Nowinska, R. (2009). The influence of habitat conditions on anatomical structure of *Impatiens parviflora* DC. (Balsaminaceae). *Roczniki Akademii Rolniczej w Poznaniu. Botanika-Steciana*, *13*.

Kumar, M. & Sequiera, S. (1996) *Impatiens sivarajanii*: A new species of Balsaminaceae from Silent Valley National Park, Kerala, India. *Rheedea, 6*(2)**,** 51–54

Kumar, M., & Sequiera, S. (2001). Two new species of *Impatiens* (Balsaminaceae) from India. *SIDA, Contributions to Botany*, 795–801.

Kumar, N. A., Sivadasan, M., & Ravi, N. (2005). *Flora of Pathanamthitta (Western Ghats, Kerala, India)*. Daya Books

Lamarck, J. B. A. P. de M. (1785). *Encyclopedie methodique: botanique.* Vol. 1, pp. 363. Paris.

Lens, F., Dressler, S., Jansen, S., van Evelghem, L., & Smets, E. (2005). Relationships within balsaminoid Ericales: A wood anatomical approach. *American Journal of Botany*, *92*(6), 941–953. https://doi.org/10.3732/ajb.92.6.941

Lindely John. (1836). A natural system of botany; or, a systematic view of the organisation, natural affinities, and geographical distribution, of the whole vegetable kingdom; together with the uses of the most important species in medicine, the arts, and rural or domestic economy. 138–139

Linnaeus, C. (1753). *Species Plantarum.* Vol. 2, pp. 937–938. Stockholm.

Mabberley, D. J. (2008). *Mabberley's Plant-Book: A portable dictionary of Plants, their classification and uses*, Third Edition, Cambridge University Press, London: 384– *Habenaria* & 429– *Impatiens*.

Maciejewska-Rutkowska, I., & Janczak, B. (2016). Variability of seeds of the invasive species Impatiens glandulifera Royle (Balsaminaceae) and their micromorphology. *Steciana*, *20*(4).

Mandle, L., Warren, D. L., Hoffmann, M. H., Peterson, A. T., Schmitt, J., & von Wettberg, E. J. (2010). Conclusions about niche expansion in introduced *Impatiens walleriana* populations depend on method of analysis. *PLoS One*, *5*(12), e15297.

Mani, B., & Thomas, S. (2017). *Impatiens brittoi* (Balsaminaceae) sp. nov. from the southern Western Ghats, India. *Nordic Journal of Botany, 35*(4), 440–444. doi:10.1111/njb.01485

Mani, B., Thomas, S., & Britto, S. J. (2018). Two new species of *Impatiens* (Balsaminaceae) from the Western Ghats, India. *Phytotaxa*, *334*(3), 233. https://doi.org/10.11646/phytotaxa.334.3.4

Mani, B., Thomas, S., & Britto, S. J. (2020). A new species of *Impatiens* (Balsaminaceae) and rediscovery of *Impatiens aliciae* from the Western Ghats of India. *Taiwania*, *65,* 451–455. 10.6165/tai.2020.65.451

Manilal, K. S. (1988). *Flora of Silent Valley tropical rain forests of India*. The Mathrubhumi Press, Calicut, Kerala. pp. 39–42.

Manilal, K. S. & Sivarajan, V. V. (1982). *Flora of Calicut: The Flowering Plants of the Greater Calicut Area Consisting of the Western Sectors of Calicut and Malappuram Districts*, Bishen Singh Mahendra Pal Singh.

Manudev, K. M., Robi, A. J., & Nampy, S. (2017). *Impatiens stolonifera* (Balsaminaceae): A new scapigerous species from the southern Western Ghats, Kerala, India. *Phytotaxa*, *295*(1), 71. https://doi.org/10.11646/phytotaxa.295.1.6

Markov, M. V., & Yusufova, V. Z. (2013). Initial stages of the root system development in three *Impatiens* species (Balsaminaceae family). *Russian Journal of Developmental Biology*, *44*(4), 206–210. https://doi.org/10.1134/S1062360413040061

McClatchie Isabel. (1917). Observations on the Root-System of *Impatiens Roylei*, Walp.. *Journal of the Linnean Society of London, Botany*, *43*, 493–516. 10.1111/j.1095–8339.1917.tb00615_493.x.

Meyer, R. R., & Walker, E. R. (1931). The Vegetative Anatomy of *Impatiens pallida*. *Transactions of the American Microscopical Society*, *50*(1), 1–19. https://doi.org/10.2307/3222472

Mohanan, M. & A. N. Henry. 1994. *Flora of Thiruvananthapuram Kerala*. pp. 96–100. Botanical Survey of India, Howrah.

Mohanan, N. & Sivadasan, M. (2002). *Flora of Agasthyamala*. Bishen Singh Mahendra Pal Singh.

Mohan, V., Venugopal, D. K., Francis, D. & Nampy, S. (2020). Two new scapigerous species of *Impatiens* (Balsaminaceae) from southern Western Ghats, India. *Taiwania*, *65*(2). https://doi.org/10.6165/tai.2020.65.187

Mohan, V., Francis, D., Nampy, S., & Venugopal, D. K. (2021). *Impatiens raktakesara* (Balsaminaceae), a new species from the southern Western Ghats, India. *Brittonia, 73*(3), 316–322. https://doi.org/10.1007/s12228–021–09676–7

Muktesh Kumar, (1998). Studies on Epiphytic Flora in the Tropical Ecosystem of Western Ghats with Special Reference to Nilgiri Biosphere Reserve. KFRI Research Report No. 139. Kerala Forest Research Institute, Peechi.

Nair, N. C. (1991). Endemism on the Western Ghats with special reference to *Impatiens* L. Proceedings of the Symposium on rare, endangered and endemic plants of Western Ghats, Kerala Forest Dept. (Wildlife wing), Thiruvananthapuram, Spl. Publ. No: III: 93–102.

Narayana, L. L., (1974) A contribution to the floral, anatomy of Balsarninaceae. *Japanese journal of Botany, 49*, 315–320

Narayanan, M. K. R., (2009) *Floristic study of Wayanad District with special emphasis on conservation of rare and threatened flowering plants.* Ph.D thesis submitted to Department of Botany, Calicut University

Narayanan, M. K. R., Anilkumar, N., Raj, R. M., Sivadasan, M., & Alfarhan, A. H. (2011). A new scapigerous species of *Impatiens* (Balsaminaceae) from India. *Bangladesh Journal of Plant Taxonomy*, *18*(2), 141–148. https://doi.org/10.3329/bjpt.v18i2.9299

Narayanan, M. K. R., Joseph, J. P., Kumar, N. A., Sivadasan, M., & Alfarhan, A. H. (2013). *Impatiens theuerkaufiana* (Balsaminaceae), a new scapigerous species from the western ghats, India. *Phytotaxa*, *83*(1), 54–60. https://doi.org/10.11646/phytotaxa.83.1.3

Palkar, R. S., Janarthanam, M. K., & Sellappan, K. (2020). Prediction of potential distribution and climatic factors influencing Garcinia indica in the Western Ghats of India using ecological niche modeling. *National Academy Science Letters*, *43*(6), 585–591.

Pandurangan, A. G. & Nair, V. J (1995) *Impatiens kulamavuensis*, a New Species of Balsaminaceae from India. *Novon a journal of botanical nomenclature from the Missouri Botanical Garden* 5: 57–58

Pavlova, D. K., & Glogov, P. S. (2021). Pollen Morphology and Pollen Production of Invasive and Native Impatiens Species Growing in Bulgaria. *Ecologia Balkanica*, *13*(1).

Pechimuthu, M., Arumugam, R. and Ponnusamy, S. (2021) "Pollen morphology of the genus Impatiens L. (Balsaminaceae) and its systematic implications", *Acta Biologica Szegediensis*, 64(2), pp. 207–219. doi: 10.14232/abs.2020.2.207-219.

Perry, M. L., (1980), *Medicinal Plants of East and Southeast Asia*, The MIT Press, Cambridge, 53.

Phillips, S., (2006). A brief tutorial on Maxent. AT&T Research. Available at: http://www.cs.princeton.edu/~schapire/maxent/tutorial/tutorial.doc.

Phillips, S.J. and Dudik, M. (2008) Modeling of Species Distributions with MaxEnt: *New Extensions and a Comprehensive Evaluation. Ecography, 31*, 161–175. http://dx.doi.org/10.1111/j.0906-7590.2008.5203.x

Prabhukumar, K. M., Hareesh, V. S., Bhaskar, V., Sreekumar, V. B., Nirmesh, T. K., & Balachandran, I. (2016). *Impatiens glabrata* (Balsaminaceae)–A new species from southern Western Ghats, India. *Phytotaxa*, *266*(1), 33. https://doi.org/10.11646/phytotaxa.266.1.5

Prabhukumar, K. M., Jagadeesan, R., Prasad, G., Nagaraj, B. A. N. A., Kumar, V. V. N., Veeralinga, B., & Balachandran, I. (2017). Two new taxa of *Impatiens* (Balsaminaceae) from southern parts of Western Ghats, India. *Phytotaxa, 296*(3), 281. https://doi.org/10.11646/phytotaxa.296.3.7

Pradeep A.K., (2000). *Floristic Studies on Vellarimala on the Western Ghats of Kerala*. Department of Botany, University of Calicut, Calicut.

Pownitha, K. V., Hulegaru, Nagaraja, P. B., Charles, B., Vasudeva, R., Aravind, N. A., & Ravikanth, G. (2022). Ecological niche modelling to identify suitable sites for cultivation of two important medicinal lianas of the Western Ghats, India. *Tropical Ecology*, *63*(3), 423–432. https://doi.org/10.1007/s42965–021–00207–9

Prasad, G. (2019) Population and spatial distribution assessment of three exclusive endemic to Kerala and rare category Balsams (*Impatiens*) in and around hamilton plateau of Idukki district Kerala. Ph.D. thesis submitted to Bharathiar University

Priti, H., Aravind, N. A., Shaanker, R. U., & Ravikanth, G. (2016). Modeling impacts of future climate on the distribution of Myristicaceae species in the Western Ghats, India. *Ecological Engineering*, *89*, 14–23.

R. Gopalan and A. N. Henry. (2000) *Endemic Plants of India- Endemics of Agasthiyamalai Hills,* Bishen Singh Ma- hendrapal Singh publications, Dehradun.

Rahman, F., Ahmad, M., Zafar, M., Mumtaz, A. S., & Shah, S. A. (2016). Taxonomic implications of foliar epidermis in *Impatiens* (Balsaminaceae): Investigating 12 Pakistani taxa as an example. *Plant Biosystems – An International Journal Dealing with All Aspects of Plant Biology*, *151*(4), 642–648. https://doi.org/10.1080/11263504.2016.1193068

Raju, R. (2009) Reproductive Biology of three endemic and endangered Balsams (*Impatiens coelotropis* Fischer, *I. phoenicea* Bedd. and *I. platyadena* Fischer) of Western Ghats. Ph.D. thesis submitted to University of Kerala, Thiruvananthapuram, Kerala, India, 18 pp.

Raju, D. R., Dhanraj, F. I., Arumugam, M., & Ag, P. (2015). *Impatiens matthewiana*, a new scapigerous balsam from Western Ghats, India. *Phytotaxa*, *227*(3), 268. https://doi.org/10.11646/phytotaxa.227.3.6

Raju, R., Surendran, A. & Ayyathurai, C. P. (2020a). A new species *Impatiens* (Balsaminaceae) From kodaikkanal wildlife sanctuary, India. *Taiwania*, *65*(4). https://doi.org/10.6165/tai.2020.65.426

Raju, R., Surendran, A., & Ayyathurai, C. P. (2020b). Two new species of *Impatiens* (Balsaminaceae) from the Western Ghats of Tamil Nadu, India. *Phytotaxa, 460*(4), 249–258. https://doi.org/10.11646/phytotaxa.460.4.2

Raju, R., Manikandan, G., Mehalingam, P. & Pandurangan, A.G. (2015) *Impatiens courtallensis* (Balsaminaceae), a new species of *Impatiens* from Western Ghats, Tamil Nadu, India. *Phytotaxa, 203* (2), 199–204.

Raju, R. & Kamalabai, S. A. (2020c). How distinct is *Impatiens hookeriana* Arnott from *I. grandis* Heyne (Balsaminaceae)? *Feddes Repertorium*, *131*(4), 225–232. doi:10.1002/fedr.201900027

Raju, R. & Pandurangan, A. G. (2015). Rediscovery of *Impatiens munnarensis* Barnes: A strict endemic balsam of Southern-Western Ghats. *Bangladesh Journal of Botany*, *43*. 10.3329/bjb.v43i2.21678.

Ramaswami M. S. (1912). *A Botanical tour in the Tinnevely Hills.* Part 1. pp. 106–171

Rama Devi (1991). "Floral Anatomy of Six Species of *Impatiens*." *Feddes Repertorium*, *102,* 395–98. https://doi.org/10.1002/fedr.19911020511

Ravikumar, K., Subramani, S. B, Udayan, P. S. & Karnat, M. (2000). Note on a few rare and endemic plants from the Western Ghats of Coorg District, Karnataka, India. *Journal of Economic and Taxonomic Botany, 24,* 334–338.

Rahelivololona, E. M., Fischer, E., Janssens, S. B., & Razafimandimbison, S. G. (2018). Phylogeny, infrageneric classification and species delimitation in the Malagasy *Impatiens* (Balsaminaceae). *PhytoKeys*, *110*, 51.

Rewicz, A., Adamowski, W., Borah, S., & Gogoi, R. (2020). New data on seed coat micromorphology of several *Impatiens* spp. from Northeast India. *Acta Societatis Botanicorum Poloniae*, *89*(3).

Rewicz, A., Myśliwy, M., Rewicz, T., Adamowski, W., & Kolanowska, M. (2022). Contradictory effect of climate change on American and European populations of *Impatiens capensis* Meerb. - Is this herb a global threat? *Science of The Total Environment*, *850*, 157959. https://doi.org/10.1016/j.scitotenv.2022.157959

Richard, A. (1822). Dictionnaire Classique d'histoire Naturelle, Tome Second, Paris, Rey et Gravier, Libraries-Editeurs, Auai des Augustins, no. 55; Baudouin Frèrer, Libraries-Editeurs, Imprimeurs de la société D'Histoire Naturelle, Rue de Vaugirard, no. 36: 173.

Richard, P. S. S., Karuppusamy, S., & Ravichandran, V. (2021). *Impatiens godfreyi* (Balsaminaceae), a new species of Balsam from the southern Western Ghats, India. *Journal of Asia-Pacific Biodiversity*, *15*(1), 138–144. https://doi.org/10.1016/j.japb.2021.12.001

Roth, A. G. (1821). *Novae Plantarum Species Praesertim Indiae Orientalis.* Halberstadii. pp. 164.

Royle, J. Forbes. (1839). *Illustrations of the botany and other branches of the natural history of the Himalayan Mountains: and of the flora of Cashmere*, (Vol. 1, Pp. 150–151). London.

Roxburg, W. (1824). *Flora Indica.* (Vol. 2, pp. 452–465). William Carey Ed. Serampore.

Salisbury, E.J. (1927) On the Cause and Ecological Significance of Stomatal Frequency with Special Reference to the Woodland Flora. Philosophical Transactions of the Royal Society of London: *Biological Sciences*, *216*, 1–65. http://dx.doi.org/10.1098/rstb.1928.0001

Salish, M. J., Hareesh, V. S., Arun, L., Sandeep, S. & Rajan, P. (2019). A new species of *Impatiens* (Balsaminaceae) from eravikulam national park, southern western ghats, India. *Webbia*, *74*(2), 271–274. https://doi.org/10.1080/00837792.2019.1637176

Santapau, H. (1953). The flora of Khandala on the Western Ghats of India. 3 rd Ed. *Records of Botanical Survey of India 16*(1), 30–31.

Saravanan, T. S., & Kaliamoorthy, S. (2022). Two new epiphytic species of *Impatiens* L. (Balsaminaceae) from the southern Western Ghats, India. *Phytotaxa*, *552*(1), 107–114.

Sasidharan N., (2002). *Floristic Studies in Parambikulam Wildlife Sanctuary*. KFRI Research Report No. 246. Kerala Forest Research Institute, Peechi.

Sasidharan, N. (2004) *Biodiversity Documentation for Kerala Part 6: Flowering Plants.* Kerala Forest Research Institute, Peechi.

Sasidharan N., (1998). *Studies on the flora of Periyar Tiger Reserve*. KFRI Research Report No. 150. Kerala Forest Research Institute, Peechi.

Sasidharan, N. & V. V. Sivarajan (1996). *Flowering Plants of Thrissur Forests*. Scientific Publishers, Jodhpur, 579pp.

Sasidharan, N. (1999). *Study on the flora of Chinnar wildlife sanctuary*., Kerala Forest Research Institute Peechi, Thrissur

Sedgwick, L. J. (1919). A new Indian *Impatiens. Records of Botanical Survey of India 6*, 351.

Sen, S., Gode, A., Ramanujam, S., Ravikanth, G., & Aravind, N. A. (2016). Modeling the impact of climate change on wild *Piper nigrum* (Black Pepper) in Western Ghats, India using ecological niche models. *Journal of plant research*, *129*(6), 1033–1040.

Sharma, B. D., Shetty, B. V., Vivekananthan, K. & Rathakrishnan, N. C. (1978) *flora of Mudumalai wildlife sanctuary*, Tamilnadu. *Journal of Bombay Natural History Society, 75*(1), 13–42

Sivarajan V.V. and Philip Mathew, (1996). *Flora of Nilambur*. Bishan Singh Mahendrapal Singh, Dehra Dun.

Song, Y. I., Yuan, Y. M., & Küpfer, P. (2005). Seedcoat micromorphology of *Impatiens* (Balsaminaceae) from China. *Botanical Journal of the Linnean Society*, *149*(2), 195–208.

Song, Y. X., Peng, S., Mutie, F. M., Jiang, H., Ren, J., Cong, Y. Y., & Hu, G-W. (2022). Evolution and taxonomic significance of seed micromorphology in *Impatiens* (Balsaminaceae). *Frontiers in Plant Science*, *13*, 835943. https://doi.org/10.3389/fpls.2022.835943

Subbiah, K., & Vellingiri, R. (2019). *Impatiens flavescens* sp. Nov. (Balsaminaceae), a first yellow flowered balsam from the southern Western Ghats of India. *Webbia*, *74*(2), 265–269. https://doi.org/10.1080/00837792.2019.1659547

Subramaniyan K.N., (1995). *Flora of Thenmala Division*. International Book Distributors, Dehra Dun.

Sumangala, R. C., Rosario, S., Charles, B., Ganesh, D., & Ravikanth, G. (2017). Identifying conservation priority sites for *Saraca asoca*: an important medicinal plant using ecological Niche models. *Indian Forester*, *143*(6), 531–536.

Sunil C.N., (2016). *Flowering Plants Diversity of Ernakulam District*. Project Report. S.N.M. College, Malienkara.

Sunil C.N. and M. Sivadasan, (2009). *Flora of Alappuzha District, Kerala, India*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Swarupanandan, K., Sasidharan, N., & Basha, S.C. (1998). *Studies on the shola forests of Kerala*.

Tharani, R., Murugesan, M., Ravichandran, V., Karthik, B., & Anusuba, V. (2021). Rediscovery of *Impatiens laticornis* CEC Fisch. (Balsaminaceae), a stenoendemic and critically endangered species from Nilgiri Biosphere Reserve, southern India. *Nelumbo*, *63*(2), 32–36.

Tarun, C., Ramneek, S., Prabhukumar, K.M. & Hareesh, S. (2016). Three new taxa of *Impatiens* (Balsaminaceae) from southern Western Ghats, India. *Nordic Journal of Botany*, *34*. 10.1111/njb.01139.

Utami, N., & Shimizu, T. (2005). Seed morphology and classification of *Impatiens* (Balsaminaceae). *Blumea–Biodiversity, Evolution and Biogeography of Plants*, *50*(3), 447–456.

Van Rheede, H. A. (1689). *Hortus Malabaricus.* Vol. 9. Amsterdam.

Vajravelu E., (1990). *Flora of Palghat District. Botanical Survey of India*, Calcutta.

Vivekananthan, K., N. C. Rathakrishnan, M. S. Swaminathan & L. K. Ghara. (1997). Balsaminaceae. In: P. K. Hajra, V. J. Nair & P. Daniel (Eds) *Flora of India*, Vol. 4, pp. 95–229. Botanical Survey of India, Howrah.

Warburg, O. & K. Reiche. (1895). Balsaminaceae. In: A. Engler & K. Prantl (Eds) *Die naturlichenPflanzenfamilien. 5*, 383–392. Engelmann, Leipzig.

Wei, Chen., Ke–Ming, Lu., Xiu–Zhen, Cai., Yi–Yan, Cong. (2007). Micromorphology features of seed surface of fourteen species in *Impatiens* (Balsaminaceae) in relation to their taxonomic significance. *Acta Botanica Yunnanica, 29*, 625–631.

Wight, R. (1837). On the genus *Impatiens. Madras journal of Literature and Science, 1*(5), 1–15.

Wight, R. (1844). *Icones plantarum IndiaeOrientalis.* Madras.

Wight, R. (1845). *Icones plantarum IndiaeOrientalis.* Madras.

Wight, R. (1846). *Icones plantarum IndiaeOrientalis.* Madras.

Wight, R. (1850). *Icones plantarum IndiaeOrientalis.* Madras.

Wight, R. & G. A. Arnott. (1834). *Prodromus florae Peninsulae Indiae Orientalis*. Parbury Allen & Co. London. pp. 134–140.

Yao, N., JinRui, L., XiQiang, S., ShuMei, H. & YunFang, Z., (2018). Modeling the potential suitable habitat of *Impatiens hainanensis*, a limestone – endemic plant. *Chinese Journal of Plant Ecology*, *42*(9) pp.946–954

Yoganarasimhan S.N. (2000) *Medical plants of India*, 2nd ed., pp. 109-110, Tamilnadu, International Book Publishers., Print Cyber Media., Bangalore

Yu, S.X., (2012). Balsaminaceae of China. Peking University Press, Beijing.

Yuan, Y., M., Y. Song, K. Geuten, E. Rahelivololona, S. Wohlhauser, E. Fischer, E. Smets, & P. Ku¨ Pfer. (2004). Phylogeny and biogeography of Balsaminaceae inferred from ITS sequence data. *Taxon, 53*, 391–403.

List of papers published

- Ashok, R., Varghese, A.P. and Antony, I., 2023. Predicting the geographical distribution of *Impatiens parasitica* (Balsaminaceae), an epiphytic species endemic to the Southern Western Ghats, India. *Indian Journal of Forestry,* 46(1), pp.1-7. https://doi.org/10.54207/bsmps1000-2023-V2134U
- A new spurless species of *Impatiens* sect. Microsepalae (Balsaminaceae) from south India K.M. Prabhukumar, Reshma Ashok, P.M. Binu Prakash, Indira Balachandhran, *Phytotaxa* 616(1): 109 (2023).

List of Presentations

- International seminar on plant science research, conducted by Mahatma Gandhi College Thiruvanthapuram on 3rd and 4th March 2022 on the topic "The genus Impatiens in the Western Ghats of Kerala"
- National Seminar "Species the Passion7" organized by the Research and Post-Graduate Department of Botany, St. Thomas' College (Autonomous), Thrissur on March 9th 2022 on the topic" Floral biology and phenology of *Impatiens violaceae*, an endemic balsam of Western Ghats
- National Seminar "Species the Passion8"organized by the Research and Post-Graduate Department of Botany, St. Thomas' College (Autonomous), Thrissur on February 3rd 2023 on the topic "Predicting the geographical distribution of *Impatiens parasitica* Bedd. (Balsaminaceae), an *Impatiens* endemic to the Western Ghats,India"

APPENDIX

Indian Journal of Forestry 46(1), pp.1-7, 2023
RESEARCH ARTICLE

Predicting the geographical distribution of *Impatiens parasitica* (Balsaminaceae), an epiphytic species endemic to the Southern Western Ghats, India

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ABSTRACT

Impatiens parasitica Bedd. is an epiphytic balsam, endemic to the southern Western Ghats region of India. Maximum entropy distribution modelling (MaxEnt) was used for predicting the potential habitat suitability for this species. The Area Under the receiver operating characteristics Curve (AUC) value for training and test (0.95 and 0.817) is higher than 0.8, hence the model can be accepted. Jackknife test illustrates that temperature seasonality is the most contributed variable and Terrain Ruggedness Index (TRI) is the least contributed variable. The model predicted high suitability in the evergreen and semi-evergreen forests of the southern Western Ghats.

INTRODUCTION

Western Ghats are globally recognized due to the immense diversity of flora and fauna. Even though it covers only a few parts of the country, the Western Ghats are home to nearly 30% of the biodiversity (Ramachandra & Suja, 2006). The present condition of these unique mountain ranges is disastrous due to various anthropogenic factors. Deforestation, rampant stone quarrying and huge constructions in the fragile regions make this area more prone to frequent landslides. The changing monsoon pattern in India has a direct connection to the destruction of the Western Ghats. Due to the ever-increasing human population, vast areas are being converted to agricultural lands (Ajin et al., 2022).

Developments in the field of ecological niche modelling address many issues related to conservation biology. The systematic conservation planning and management of biodiversity requires information on the spatial distribution of species. Conventional methods used for obtaining this information were costly and time-consuming. Ecological niche modelling is a good alternative to this conventional method. The Maximum entropy (MaxEnt) (Phillips, Anderson & Schapire, 2006) model is a general-purpose environmental model for predicting the potential distribution of species. This algorithm requires presence only (or occurrence) data and environmental information such as climate, topography, soil, etc. for predicting the potential distribution of a species. The results obtained are very accurate and can be used to determine the possible range of distribution.

The genus *Impatiens* commonly known as "Jewel weeds" are plants bearing beautiful flowers that belong to the family Balsaminaceae. This genus is mainly distributed in the tropical and subtropical regions of the old world as well as in the Northern temperate regions (Grey-Wilson, 1980). In India, the genus is represented by 326 taxa, includes 302 species plus 24 subspecies/varieties (Prabhukumar et al., 2022). More

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than 106 species of *Impatiens* are endemic to the Western Ghats, and nearly 90 taxa are endangered (Bhaskar, 2012). The genus *Impatiens* in south India is classified into seven informal sections by Bhaskar (2012). Section "*Epiphyticae*" is one among them and it is endemic to southern Western Ghats. So far seven species belonging to this section have been identified from different regions of Western Ghats. The flowers of this section are very rigid and fleshy, and remain fresh for a long time unlike the other species. *Impatiens parasitica* Bedd. (Figure 1) is one of the species that belong to section "*Epiphyticae*". This species was described by Beddome in 1859 based on collections from the Anamalai hills of Western Ghats. This species is found between an altitude of 1500-2000 m in moss-covered trees and is strictly endemic to the southern Western Ghats. The species is famous for its beautiful flowers and has a high potential as a garden plant. Limited information is available about the current distribution pattern of this species and it is essential for further *in-situ* and *ex-situ* conservation. Threat status of this species is not studied yet and the results of this study are useful for threat assessment.

MATERIALS AND METHODS

Study area

The Western Ghats is a continuing chain of mountain ranges that extend between Gujarat and the Kanyakumari district of Tamil Nadu in the Indian peninsula. The mountain chain possesses a varied range of habitats and is recognized for its biodiversity richness and endemism (Myers et al., 2000). Palghat gap is about 22 km long natural pass that separates the Western Ghats in two parts. The vegetation in the high altitude of these mountain chains especially of southern Western Ghat is weird with the shola grassland complex (Ramachandra & Suja, 2006). The sholas are unique primitive montane short stunted semi-evergreen vegetations considered as living fossil (Jose, 2012). The present study was conducted in the southern parts of Western Ghats, as the literature indicates the strict endemism of *I. parasitica* in the southern Western Ghats.

Species occurrence data and Environmental Variables

Distribution data of *I. parasitica* was obtained from both primary and secondary sources. Eight non-overlapping occurrence points were collected from the field during 2019-2021. The occurrence points are obtained from different locations in Nelliyampathy, and Idukki district including Munnar, Pettimudi, Vellathuval, Kadalar and Wagmon. Seven occurrence points were obtained by retrieving data and information from the Global Biodiversity Information Facility (GBIF, https://www.gbif.org). A total of 15 non-overlapping occurrence points were used in this study.

Environmental variables used for the study were obtained from the WorldClim dataset (www.worldclim.org). Nineteen bioclimatic variables (Hijmans et al., 2005) with a spatial resolution of 30 seconds were downloaded. Topographic variables such as slope, elevation, aspect, and terrain ruggedness index (TRI) were generated using the Digital Terrain Model (DTM) of Shuttle Radar Topographic Mission (SRTM) with 90 m resolution. These are computed with the help of QGIS algorithm and DTM images were downloaded from the www.srtm.usgs.gov website. A total of 23 predictor variables were used for the model building (Table 1). Multi co-linearity among the variables was checked by calculating Pearson's correlation (r) and the variables having a coefficient value of >±0.7 were highly correlated and hence excluded (Table 2). Four bioclimatic variables and four topographic variables were used for creating the final model and they are: Isothermality (Bio3), Temperature seasonality (Bio4),

Figure 1. *Impatiens parasitica* Bedd.

Table 1. Environmental variables are used for the model building

Code	Environmental variables	Unit
Bio1	Annual mean temperature	°C
Bio2	Mean diurnal range (mean of monthly max. and min. temp.)	°C
Bio3	Isothermality ((Bio2/Bio7) × 100)	-
Bio4	Temperature seasonality (standard deviation × 100)	C of V
Bio5	Maximum temperature of warmest month	°C
Bio6	Minimum temperature of coldest month	°C
Bio7	Temperature annual range (Bio5–Bio6)	°C
Bio8	Mean temperature of wettest quarter	°C
Bio9	Mean temperature of driest quarter	°C
Bio10	Mean temperature of warmest quarter	°C
Bio11	Mean temperature of coldest quarter	°C
Bio12	Annual precipitation	mm
Bio13	Precipitation of wettest period	mm
Bio14	Precipitation of driest period	mm
Bio15	Precipitation seasonality (CV)	C of V
Bio16	Precipitation of wettest quarter	mm
Bio17	Precipitation of driest quarter	mm
Bio18	Precipitation of warmest quarter	mm
Bio19	Precipitation of coldest quarter	mm
TRI	Terrain Ruggedness Index	m
elevation	Elevation	m
aspect	Aspect	o
slope	Slope	o

Precipitation of warmest quarter (Bio18), Precipitation of coldest quarter (Bio 19), slope, elevation, aspect, and TRI.

Spatial modelling

Maximum Entropy Modelling implemented in the software MaxEnt was used to predict the potential distribution. It predicts the environmental niche of a species by finding a probability distribution of a species occurrence that is based on a distribution of maximum entropy (regarding a set of environmental variables) (Philips, Anderson & Schapire, 2006). This model works well, even with a small number of occurrence points. The number of iterations used was 500 with a convergence threshold of 0.00001 and a maximum of 10,000 background points, algorithm parameters were set to auto features (Phillips & Dudik, 2008) and all other parameters were set at default settings. 50% of the data were selected for training and the rest for testing. To evaluate the model's goodness-of-fit, Area Under the receiving operator characteristics Curve (AUC) was used. The value of AUC ranges from 0 to 1 and based on this value, models were classified into 5 groups: Excellent (0.9), Good (0.8≤0.9), Bad (0.6≤0.7), Invalid (0.5≤0.6) (Hoffman et al., 2008). To compute the percentage of variable importance, Jackknife procedure was used.

Table 2. Multi – collinearity test using Pearson correlation coefficients (r) among environmental variables

	Bio1	Bio2	Bio3	Bio4	Bio5	Bio6	Bio7	Bio8	Bio9	Bio10	Bio11	Bio12	Bio13	Bio14	Bio15	Bio16	Bio17	Bio18	Bio19	aspect	slope	TRI	elevation
Bio1	1																						
Bio2	-0.61	1																					
Bio3	0.12	0.04	1																				
Bio4	0.26	0.23	-0.58	1																			
Bio5	0.99	-0.54	0.04	0.35	1																		
Bio6	0.99	-0.67	0.14	0.19	0.97	1																	
Bio7	-0.61	0.87	-0.44	0.49	-0.5	-0.67	1																
Bio8	0.99	-0.63	0.16	0.21	0.97	0.98	-0.64	1															
Bio9	0.99	-0.62	0.09	0.25	0.99	0.99	-0.6	0.98	1														
Bio10	0.99	-0.6	0.07	0.3	0.99	0.99	-0.57	0.98	0.99	1													
Bio11	0.99	-0.65	0.13	0.2	0.98	0.99	-0.64	0.98	0.99	0.99	1												
Bio12	0.38	-0.53	-0.23	-0.07	0.38	0.41	-0.36	0.33	0.43	0.39	0.43	1											
Bio13	0.45	-0.49	-0.36	0.13	0.47	0.47	-0.26	0.38	0.5	0.47	0.49	0.97	1										
Bio14	-0.44	0.24	0.56	-0.46	-0.51	-0.42	-0.05	-0.36	-0.49	-0.48	-0.46	-0.77	-0.87	1									
Bio15	0.46	-0.43	-0.45	0.22	0.5	0.47	-0.16	0.4	0.52	0.49	0.5	0.91	0.97	-0.94	1								
Bio16	0.43	-0.51	-0.34	0.07	0.44	0.45	-0.29	0.36	0.48	0.45	0.47	0.98	0.99	-0.86	0.96	1							
Bio17	-0.35	0.1	0.66	-0.59	-0.43	-0.31	-0.23	-0.28	-0.39	-0.39	-0.35	-0.65	-0.77	0.97	-0.86	-0.75	1						
Bio18	0.45	-0.5	0.58	-0.42	0.37	0.49	-0.73	0.49	0.46	0.43	0.49	0.46	0.33	0	0.2	0.34	0.15	1					
Bio19	0.58	-0.38	-0.25	0.48	0.6	0.57	-0.22	0.54	0.66	0.6	0.57	0.62	0.71	-0.59	0.64	0.66	-0.56	0.41	1				
aspect	-0.13	0.05	-0.24	0.04	-0.13	-0.14	0.14	-0.15	-0.13	-0.12	-0.13	0.22	0.17	-0.11	0.11	0.2	-0.16	-0.04	0.13	1			
slope	0	0.35	-0.01	0.21	0.04	-0.03	0.33	-0.05	0.02	0.01	0.004	0.31	0.33	-0.46	0.35	0.34	-0.45	0.02	0.15	-0.04	1		
TRI	-0.28	0.15	-0.2	0.04	-0.25	-0.27	0.24	-0.33	-0.25	-0.27	-0.26	0.38	0.37	-0.33	0.32	0.38	-0.29	-0.01	0.1	0	0.64	1	
elevation	-0.98	0.63	-0.049	-0.27	-0.98	-0.98	0.58	-0.98	-0.99	-0.99	-0.98	-0.45	-0.52	0.51	-0.54	-0.5	0.42	-0.48	-0.62	0.09	-0.01	0.24	1

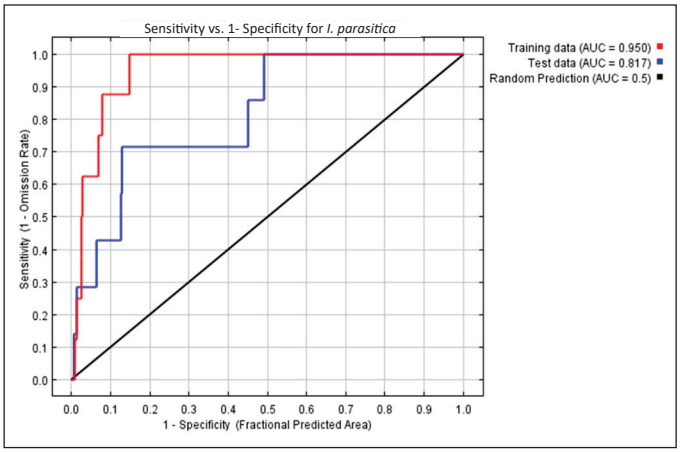

Figure 2. Receiver operating characteristic (ROC) curve for *I. parasitica*

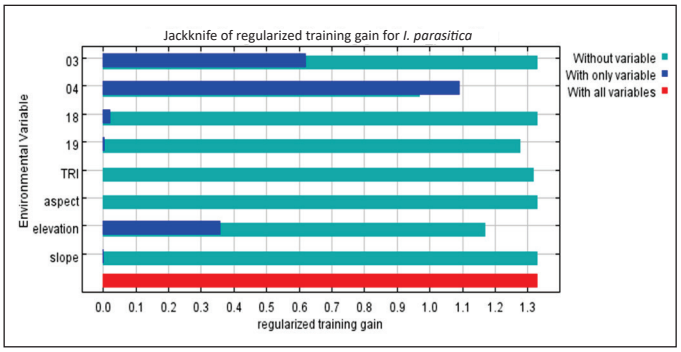

Figure 3. The Jackknife test for evaluating the relative importance of environmental factors for *I. parasitica*

RESULTS

The best model included 3 bioclimatic variables (Isothermality, Temperature Seasonality, and Precipitation of Coldest Quarter) and 2 topographic factors (Elevation and TRI). All the variables used here are continuous. The AUC value for training is 0.95 and for the test is 0.817 which is higher than 0.8, hence the model can be accepted and it justifies the construction of the final model based on the points available (Figure 2). Jackknife test illustrates that temperature seasonality is the most contributed variable and TRI is the least contributed variable (Figure 3; Table 3). The response curves (Figure 4) illustrate the change in occurrence probability values of *I. parasitica* with respect to key climatic and topographic variables. The habitat suitability increases with increasing elevation, precipitation of the warmest quarter, and isothermality. At the same time, habitat suitability decreases with increasing temperature seasonality, and precipitation of coldest quarter; aspect, slope and TRI show steady trend in habitat suitability.

Table 3. Relative contributions of the environmental variables to the Maxent model

Variable	Percent contribution	Permutation importance
Temperature seasonality (Bio4)	62.2	73
Elevation	16.4	5.7
Isothermality (Bio3)	16.3	0
Precipitation of coldest quarter (Bio 19)	4.7	20.6
TRI	0.3	0.8
Precipitation of warmest quarter (Bio18)	0	0
Aspect	0	0
Slope	0	0

After the visual inspection of the MaxEnt map (Figure 5), it is clear that the species under study prefer evergreen and semi-evergreen forests in the southern Western Ghats. According to the model they are mainly distributed in forest having elevations from 800 m to 1500 m. Forest areas like Neyyar Wildlife Sanctuary and Agasthymalai Biosphere Reserve of Trivandrum district, Kerala, Konni reserve forest and Ranni reserve forest of Pathanmthitta district (Kerala), Idukki Wildlife Sanctuary and Eravikulam National Park of Idukki district (Kerala), Nelliyampathy reserve forest of Palakkad district (Kerala), Silent valley National Park Palakkad (Kerala), Sholayar reserve forest Thrissur, (Kerala), New Amarambalam Wildlife Sanctuary Malappuram (Kerala), Wayanad Wildlife Sanctuary, Wayanad (Kerala) and Malabar Wildlife Sanctuary, Kozhikode (Kerala) show high suitability. Certain parts of the Northern Western Ghats such as Mollem National Park (Goa), Cotigao National Park (Goa) and Anshi National Park (Karnataka) show moderate suitability to the species.

DISCUSSION

Impatiens parasitica is commonly found in higher altitudes with thick canopy and humid conditions. This is the first attempt to study the potential distribution of an *Impatiens* species in the Western Ghats. The model predicts a profound and almost continuous distribution in the southern parts of the Palghat gap and limited distribution in the northern part. High suitability was expected in different regions of Nilgiris also. According to the literature available the species is distributed at an elevation of 1500-2000 meter, but the model predicts suitable at an elevation from 800 m to 1500 m. The habitat suitability largely depends on temperature seasonality and areas with lower values show higher suitability. This trend is common among species that prefer stable climatic conditions for their survival. The regions with higher elevations usually have a stable climate. This might be the reason that *I. parasitica* prefers higher altitude regions of the Western Ghats.

According to the model developed by MaxEnt, most of the suitable habitat of *I. parasitica* is the evergreen and semi-evergreen forest of Western Ghats contradicting the natural distribution in shola forests. Most of the regions are protected areas; hence threats due to direct anthropogenic activities are least likely to occur. At the same time, various natural calamities taking place in this region are a constant threat to

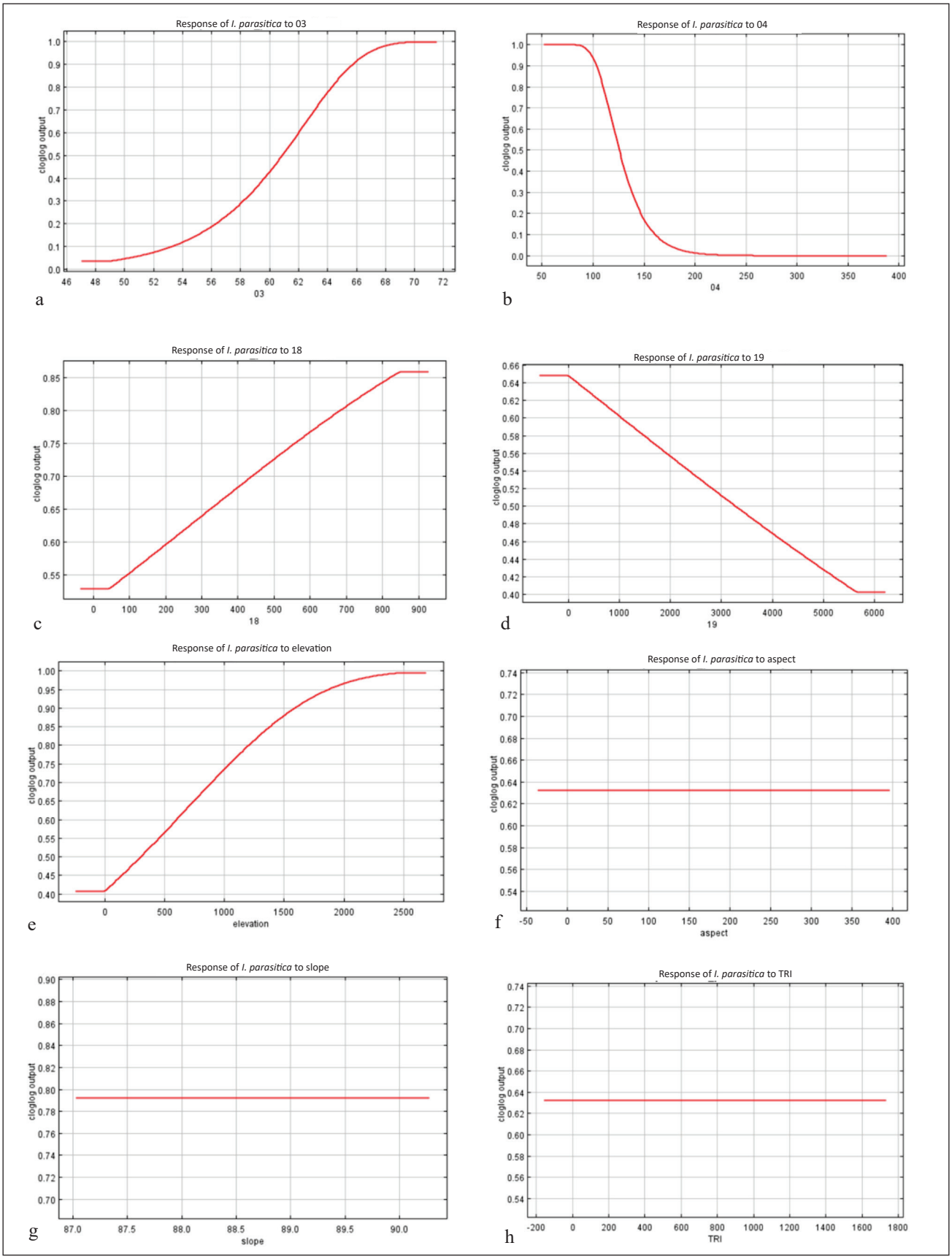

Figure 4. Response curves of the most influential predictors for *I. parasitica*; **a.** Isothermality (Bio3); **b.** Temperature seasonality (Bio4); **c.** Precipitation of warmest quarter (Bio18); **d.** Precipitation of coldest quarter (Bio19); **e.** Elevation; **f.** Aspect; g. Slope; **h.** TRI

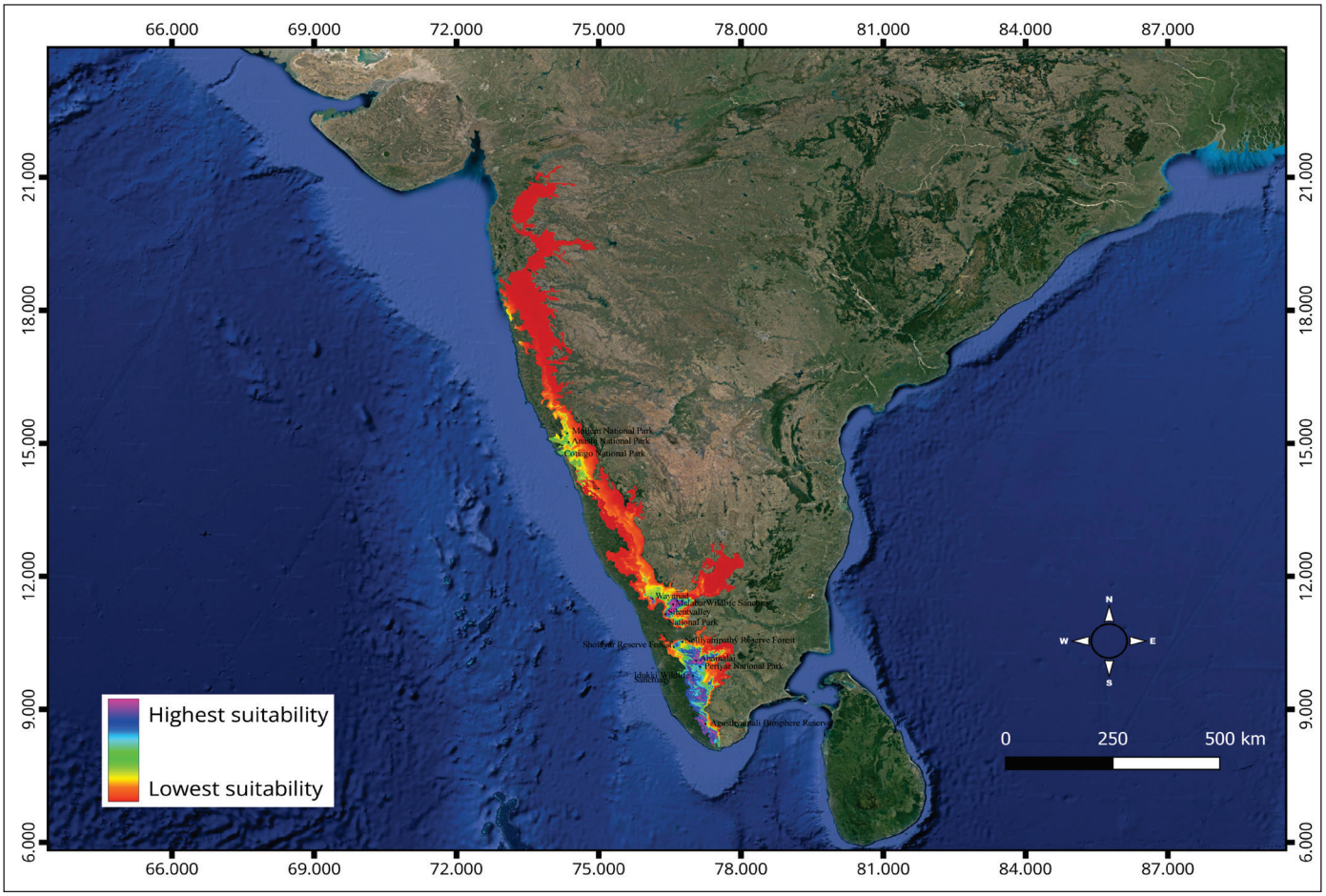

Figure 5. Prediction of potential distribution of *I. parasitica*

the species. The torrential rainfall that occurred in the south-west monsoon of 2018 triggered 4728 landslides (Hao et al., 2020). In the following year, a huge number of cataclysmic landslides occurred in different regions of the Western Ghats. This may result in the habitat destruction of endemic species like *I. parasitica* which adversely affect their survival.

CONCLUSION

Ecological Niche Modelling is a highly acceptable tool for predicting the suitable habitat of endemic species using a small number of sample records. The result obtained for *I. parasitica* is highly useful for designing conservation measures and for identifying the new populations of this plant. The changing climate pattern and frequent natural calamities taking place in the Western Ghats emphasize the importance of studies like this.

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REFERENCES

Ajin, R.S., Nandakumar, D., Rajaneesh, A., Oommen, T., Ali, Y.P. and Sajinkumar, K.S., 2022. The tale of three landslides in the Western Ghats, India: Lessons to be learnt. *Geoenvironmental Disasters*, **9**. https://doi.org/10.1186/s40677-022-00218-1

Anderson, R.P., Lew, D. and Peterson, A.T., 2003. Evaluating predictive models of species' distributions: Criteria for selecting optimal models. *Ecological Modelling*, **162**(3), pp.211-232. https://doi.org/10.1016/S0304-3800(02)00349-6

Bhaskar, V., 2012. *Taxonomic Monograph on Impatiens L. (Balsaminaceae) of Western Ghats, South India: The Key Genus for Endemism*. Centre for plant taxonomic studies, Bangalore.

Elith, J., Phillips, S.J., Hastie, T., Dudík, M., Chee, Y.E. and Yates, C.J., 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, **17**(1), pp.43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

Gamble, J.S., 1935. *Flora of the Presidency of Madras*. Reprint, 2004, Bishen Singh Mahendra Pal Singh, Dehradun.

Gopalakrishnan, R., Jayaraman, M., Bala, G. and Ravindranath, N.H., 2011. Climate change and Indian forests. *Current Science*, **101**(3), pp.348-355.

Grey-Wilson, C., 1980. *Impatiens of Africa*. A.A. Balkema, Rotterdam.

Hoffman, J.D., Narumalani, S., Mishra, D.R., Merani, P. and Wilson, R.G., 2008. Predicting potential occurrence and spread of invasive plant species along the North Platte River, Nebraska. *Invasive Plant Science and Management*, **1**(4), pp.359-367. https://doi.org/10.1614/IPSM-07-048.1

Hao, L., Rajaneesh, A., Van Westen, C., Sajinkumar, K.S., Martha, T.R., Jaiswal, P. and McAdoo, B.G., 2020. Constructing a complete landslide inventory dataset for the 2018 monsoon disaster in Kerala, India, for land use change analysis. *Earth System Science Data*, **12**(4), pp.2899-2918. https://doi.org/10.5194/essd-12-2899-2020

Hijmans, R.J., Cameron, S., Parra, J., Jones, P., Jarvis, A. and Richardson, K., 2005. *World Clim*, version 1.3. University of California, Berkeley.

Hooker, J.D., 1906. An epitome of the British Indian species of Impatiens. *Records of Botanical Survey of India*, **4**(3), pp.37-58.

Jose, F.C., 2012. The 'Living fossil' shola plant community is under threat in upper Nilgiris. *Current science*, **102**(8), pp.1091

Kujala, H., Moilanen, A., Araújo, M.B. and Gabeza, M., 2013. Conservation planning with uncertain climate change projections. *PLoS ONE*, **8**(2), e53315. https://doi.org/10.1371/journal.pone.0053315

Kumar, S. and Stohlgren, T.J., 2009. MaxEnt modelling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment*, **1**(4), pp.94-98.

Moisen, G.G. and Frescino, T.S., 2002. Comparing five modelling techniques for predicting forest characteristics. *Ecological Modelling*, **157**(2/3), pp.209-225. https://doi.org/10.1016/S0304-3800(02)00197-7

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**, pp.853-858. https://doi.org/10.1038/35002501

Pramanik, M., Paudel, U., Mondal, B., Chakraborti, S. and Deb, P., 2018. Predicting climate change impacts on the distribution of the threatened *Garcinia indica* in the Western Ghats, India. *Climate Risk Management*, **19**, pp.94-105. https://doi.org/10.1016/j.crm.2017.11.002

Prabhukumar, K.M., Hareesh, V.S, Gogoi, R, and Sabu, M., 2022. Family Balsaminaceae - An Indian Scenario. *Conspectus on Realms of Biodiversity*, pp.151-184.

Phillips, S.J., Anderson, R.P. and Schapire, R.E., 2006. Maximum entropy modelling of species geographic distributions. *Ecological modelling*, **190**(3/4), pp.231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Phillips, S.J. and Dudik, M., 2008. Modelling of Species Distributions with MaxEnt: New Extensions and a Comprehensive Evaluation. *Ecography*, **31**(2), pp.161-175.

QGIS Development Team, 2019. QGIS geographic information system. Open Source Geospatial Foundation. http://qgis.osgeo.org.

Ramachandra, T.V. and Suja, A., 2006. *Sahyadri*: *Western Ghats biodiversity information system, Biodiversity in Indian scenarios.* Daya Publishing House, New Delhi.

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A new spurless species of *Impatiens* sect. *Microsepalae* (Balsaminaceae) from south India

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Abstract

An interesting balsam with spurless lower sepal is described here as a new species to the *Impatiens* Sect. *Microsepalae* (Balsaminaceae) from southern parts of Western Ghats, India. Detailed notes on description, ecology, and distribution are provided along with a comparison of its morphologically similar species and colour photographs.

Key words: *Impatiens dasysperma*, India, Wayanad, Western Ghats

Introduction

Balsaminaceae family comprises two genera, a monotypic *Hydrocera* Blume (1825: 241) ex Wight & Arnott (1834: 140) and *Impatiens* Riv. ex Linnaeus (1753: 937) represented by 1113 taxa all over the world (POWO 2023). The genus *Impatiens* is mainly distributed to five distinct areas of the world: eastern Himalaya, southern India, Sri Lanka, Southeast Asia, tropical Africa, and Madagascar (Grey-Wilson 1980). India consists of 340 taxa (314 species and 26 varieties/subspecies) of *Impatiens* mainly distributed in the Eastern Himalayas, the neighbouring North-Eastern states, and the Western Ghats (Richard & Ravichandran 2023, Prabhukumar *et al.* 2022). In recent years, several new species have been added from India (Narayanan *et al.* 2011, 2012, 2013, Hareesh *et al.* 2015, Prabhukumar *et al.* 2015 a,b, 2016, 2017, Ramasubbu *et al.* 2015 a,b, Mani & Thomas 2017, Manudev *et al.* 2017, Mani *et al.* 2018, Salish *et al.* 2019, Vishnu *et al.* 2020, Karuppusamy *et al.* 2021, Richard *et al.* 2022, Borah *et al.* 2022, Biju *et al.* 2022, Saravanan & Kaliamoorthy 2022, Singh *et al.* 2022, Tiwari 2022, 2023, Khanal *et al.* 2023, Ravichandran *et al.* 2023, Richard & Ravichandran, 2023).

During the floristic exploration in the Wayanad district of Kerala, the authors found an interesting species of *Impatiens* from the Thollayiram forest of the Meppady range. Detailed taxonomic studies with the perusal of relevant literature (Hooker 1875, 1904, 1905, 1906, 1910, Vivekananthan *et al.* 1997, Dessai & Janarthanam 2011, Bhaskar 2012, Yu 2012, Prabhukumar *et al.* 2022) proved that, this species is belonging to sect. *Microsepalae* due to the presence of minute lateral sepals and which is hitherto unknown to science. Hence, they are described here as *Impatiens salimii sp. nov.*

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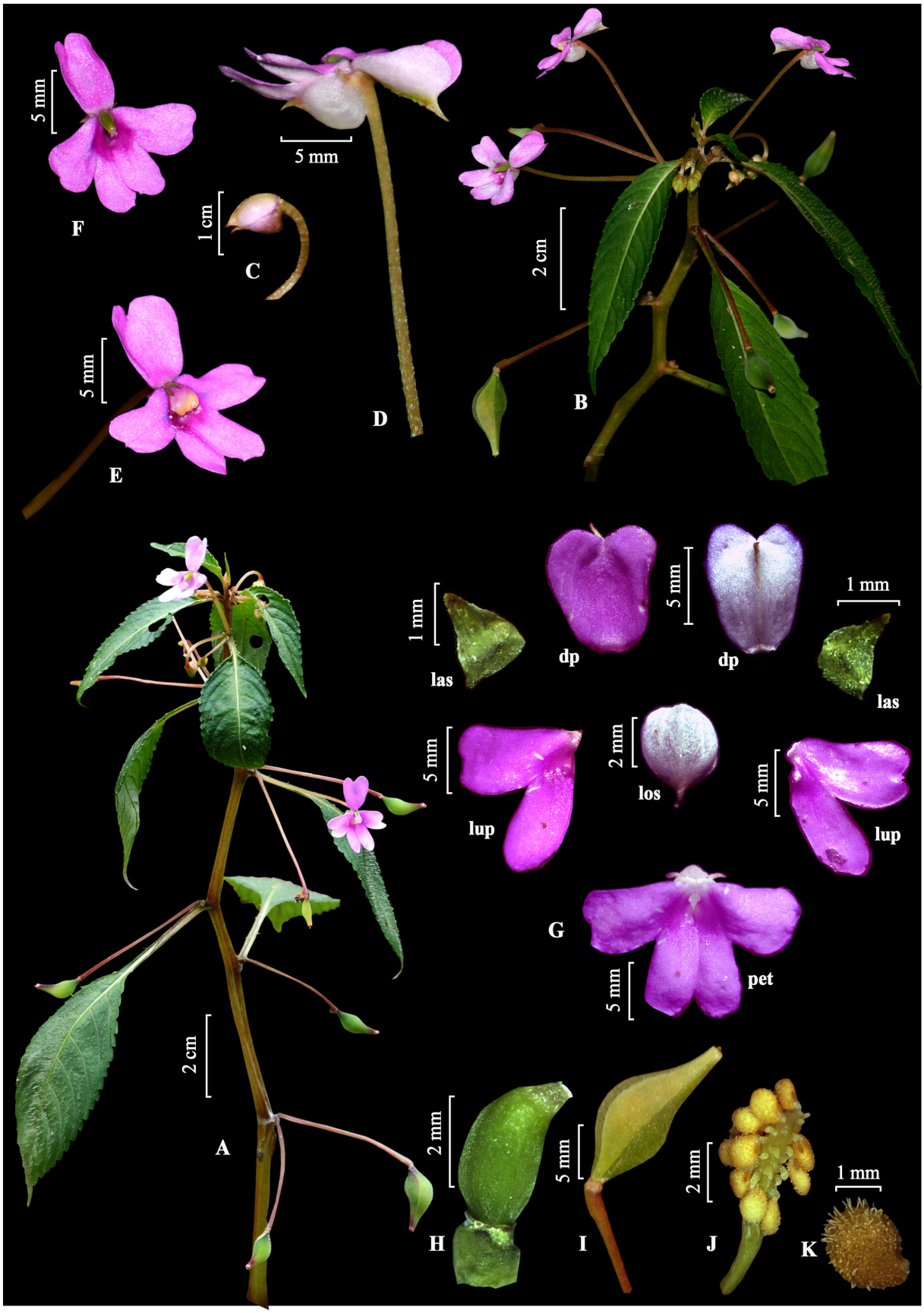

FIGURE 1. ***Impatiens salimii*** *sp. nov.* **A. & B.** Twigs bearing flowers and fruits; **C.** Bud; **D–F.** Different views of **s**ingle Flower; **G.** Floral parts: dorsal petal (dp), lateral sepal (las), lateral united petal (lup), lower sepal (los); wing petals (pet); **H.** Ovary; **I.** Single fruit; **J. & K.** Seeds (Photos: KM Prabhukumar).

Taxonomy

Impatiens salimii K.M.P. Kumar & A. Reshma *sp. nov.* (Fig. 1)

Type:—India. Kerala: Wayanad, Meppadi, Kalladi, Thollayiram forest, ±1500 m, 21 September 2013, *K.M. Prabhukumar & P.M. Binu Prakash 8478* (holotype, LWG: isotype, CMPR, MH, CATH).

Diagnosis: The new species, *Impatiens salimii* shows morphological similarities with *I. dasysperma* Wight (1837: 7) by means of its small sepals, alternately arranged leaves, flowers without peduncle and brown seeds but distinct in many attributes *viz*. glabrous stem (vs. puberulose or densely hairy at growing points), pubescent lower sepal (vs. glabrous or puberulent), absence of spur (vs. present, 1.5–1.8 cm long), obcordate standard petal with mucronate apex (vs. obovate or obcordate petal with cuneate apex), basal lobe and distal lobe wide from each other, distal lobe spathulate (vs. basal lobe and distal lobe close to each other, distal lobe with acute tip), absence of dorsal auricle (vs. present) and pubescent capsule (vs. glabrous), Table 1.

Terrestrial, erect annual herb, 20–35 cm tall; stem quadrangular, branched; internodes 4–5 cm long, green, sparsely pubescent on young shoots and glabrous on mature; nodes purple. Leaves simple, alternate, petiolate; lamina 4–8 × 2–4 cm, elliptic, cuneate at base, margins crenate with spines at each crenation, apex acuminate, whitish green at abaxial side and green at adaxial side, veins are pubescent at lower surface and pubescent throughout on upper surface; petiole 1.5–2.5 cm long, channelled, 2 or 3 pairs of glands at base, green, sparsely pubescent. Flowers axillary, usually solitary, rarely in pair or three, pedicellate; pedicel 2.5–3.5 cm long, canaliculate, green with a purple tinge, pubescent. Lateral sepals 2, 1–3 × 1–3 mm, ovate, acute, pale green with purple tip, pubescent; lower sepal 3–5 × 3–5 mm, boat-shaped, apex acuminate, base broad, 3-nerved, white, pubescent; spur absent. Standard petal 5–8 × 4–5 mm, obcordate, apex mucronate, base truncate to obtuse, pink, inside white, keeled; keel tip elongated, green; wing petals bi-lobed, basal lobe and distal lobe wide from each other; distal lobe short, 6–8 × 2–3 mm, spathulate, pink, glabrous; basal lobe 7–9 × 4–6 mm, apex notched, ovate, pink, base slightly protruding; dorsal auricle absent. Stamens 5, 4–5 × 2–3 mm, cohering, yellow; filaments short, upper 2 light purple, lower 3 white. Ovary 3–4 × 4–5 mm, ellipsoid, apex acuminate, 5-celled, green, glabrous; stigma hairy. Capsule ellipsoid, 13–18 × 5–8 mm, apex acuminate, green, pubescent; fruiting pedicel 2.5–3.5 cm, pubescent. Seeds many, 20–25, c. 10 × c. 10 mm, globose with oblique tip, thick short hairs throughout, creamy yellow.

Phenology:—July to November.

Etymology:—The species is named to honour Mr. Pichan M. Salim, M.S. Swaminathan Research Foundation, Kalpatta, Wayanad, Kerala, India, for his contribution to plant taxonomy and conservation. The author, PKM found this new species for the first time in the *ex-situ* conservatory of P.M. Salim, labelled as '*Impatiens dasysperma'* and the next day PKM found the same plants from the type locality.

Distribution and Ecology:—The new taxon has been collected from Thollayiram forest in Meppadi range of Wayanad district. Generally occurring on margins of evergreen forests as undergrowth at an elevation range of 1450–1600 m asl.

TABLE 1. Comparative account of *Impatiens salimii* K.M.P. Kumar & A. Reshma *sp. nov.* with *I. dasysperma* Wight.

Character	***Impatiens salimii***	***I. dasysperma***
Stem	glabrous throughout	puberulose or densely hairy at growing points
Lower sepal	pubescent, spur absent	glabrous or puberulent, spurred, spur 1.5–1.8 cm long
Standard petal	obcordate, apex mucronate	obovate or obcordate, apex cuneate
Wing petals	basal lobe and distal lobe wide from each other, distal lobe spathulate	basal lobe and distal lobe close to each other, distal lobe with acute tip
Dorsal auricle	absent	present, round
Capsule	13–18 mm long, pubescent	8–12 mm long, glabrous

FIGURE 2. **A. & B.** *Impatiens salimii sp. nov.*; **C. & D.** *Impatiens dasysperma* (D. showing the long spur) (Photos: KM Prabhukumar).

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References

Bhaskar, V. (2012) *Taxonomic Monograph on Impatiens L. (Balsaminaceae) of Western Ghats, South India: The Key Genus for Endemism.* Centre for plant taxonomic studies, Bangalore, pp. 1–283.

Biju, P., Arya, S., Augustine, J., Josekutty, E.J. & Kumar, V.N.S.A. (2022) *Impatiens thulunadensis* (Balsaminaceae), a new species from northern Kerala, India. *Annales Botanici Fennici* 59 (1): 207–212. https://doi.org/10.5735/085.059.0132

Bince, M., Sinjumol, T. & John Britto, S. (2018) Two new species of *Impatiens* (Balsaminaceae) from the Western Ghats, India. *Phytotaxa* 334 (3): 233–240. https://doi.org/10.11646/phytotaxa.334.3.4

Bince, M. & Sinjumol, T. (2017) *Impatiens brittoi* (Balsaminaceae) *sp. nov.* from the southern Western Ghats, India, *Nordic Journal of Botany* 35 (4): 440–444.
https://doi.org/10.1111/njb.01485

Borah, D., Singh, R.K. & Taram, M. (2022) *Impatiens pasighatensis* (Balsaminaceae), a new species from Arunachal Pradesh, northeast India. *Indian Forester* 148 (2): 233–235.
https://doi.org/10.36808/if/2022/v148i2/156569

Dessai, J.R.N. & Janarthanam, M.K. (2011) The genus *Impatiens* (Balsaminaceae) in the northern and parts of central Western Ghats. *Rheedea* 21: 23–80.

Grey-Wilson, C. (1980) *Impatiens of Africa: morphology; pollination and pollinators; ecology; phytogeography; hybridisation; keys and a systematic treatment of all African species; with a note on collecting and cultivation*. Rotterdam: A.A. Balkema, pp. 1–235.

Hareesh, V.S., Sreekumar, V.B., Dantas, K.J. & Sujanapal, P. (2015) *Impatiens sahyadrica sp. nov.* (Balsaminaceae)—a new species from southern Western Ghats, India. *Phytotaxa* 207 (3): 291–296.
https://doi.org/10.11646/phytotaxa.207.3.8

Hooker, J.D. (1910) *Indian species of Impatiens. Generis Impatiens species Indicae novae et minus rite cognitae a Cl. A*. Meebolddetectae. Bulletin Miscellaneous Information, Kew, pp. 291–300.
https://doi.org/10.2307/4111723

Hooker, J.D. (1908b) *Impatiens*. *Hooker's Icones Plantarum*, 4th series 9. London: Dulau & Co., pp. 2851–2875.

Hooker, J.D. (1904, 1905, 1906) An Epitome of the British Indian species of *Impatiens*. *Records of Botanical Survey of India* 4: 1–58.

Hooker, J.D. (1875) *Impatiens* L. *In*: Hooker, J.D. (Ed.) *Flora of British India,* vol. 1. L. Reeve & Co., London, UK, pp. 440–464.
https://doi.org/10.5962/bhl.title.54393

Karuppusamy, S., Ravichandran, V. & Kumar, U.M. (2021) A new species of *Impatiens* (Balsaminaceae) from the Eastern Ghats of Tamil Nadu, India. *Species* 22 (70): 342–347.

Khanal, M., Chettri, M., Chettri, B., Rai, S.K., Kumar, D. & Sherpa, N. (2023) A new species of *Impatiens* Riv. ex L. (Balsaminaceae) from Sikkim, India. *NeBIO* 14 (1): 1–4.

Linnaeus, C. (1753) *Species plantarum, exhibentesplantasritecognitas, ad generarelatas, cum differentiisspecificis, nominibustrivialibus, synonym is selectis, locisnatalibus, secundrumsystemasexualedigestas.* Vols. 1–2. L. Salvii, Holmiae, 1200 pp.
https://doi.org/10.5962/bhl.title.669

Mabberley, D.J. (2008) *The Plant Book: A portable dictionary of the vascular plants*, 3rd Ed—Cambridge University Press, UK, 858 pp.

Manudev, K.M., Robi, A.J. & Nampy, S. (2017) *Impatiens stolonifera* (Balsaminaceae): A new scapigerous species from the southern Western Ghats, Kerala, India *Phytotaxa* 295 (1): 71–76.
https://doi.org/10.11646/phytotaxa.295.1.6

Mohan, V., Francis, D., Nampy, S. & Venugopal, D.K. (2021) *Impatiens raktakesara* (Balsaminaceae), a new species from the southern Western Ghats, India. *Brittonia* 73 (3): 316–322.
https://doi.org/10.1007/s12228-021-09676-7

Narayanan, M.K.R., Joseph, J.P., Anil Kumar, N., Sivadasan, M. & Ahmed, H.A. (2013) *Impatiens theuerkaufiana* (Balsaminaceae), a new scapigerous species from the Western Ghats, India. *Phytotaxa* 83 (1): 54–60.
https://doi.org/10.11646/phytotaxa.83.1.3

Narayanan, M.K.R., Anil Kumar, N., Jayesh, P.J., Sunil, C.N. & Shaju, T. (2012a) *Impatiens johnsiana* (Balsaminaceae), A new scapigerous balsam from Western Ghats, India. *J. Bot. Res. Inst. Texas* 6 (1): 113–118.

Narayanan, M.K.R, Sujana, K.A., Balakrishnan, V., Meera Raj, R. & Anil Kumar, N. (2012b) *Impatiens mohana* (Balsaminaceae), a new scapigerous balsam from Wayanad, Western Ghats, India. *Edinburgh Journal of Botany* 69 (2): 281–285.
https://doi.org/10.1017/S096042861200008X

Narayanan, M.K.R., Anil Kumar, N., Meera Raj, R., Sivadasan, M. & Alfarhan, A.H. (2011) A new scapigerous species of *Impatiens* (Balsaminaceae) from India. *Bangladesh Journal of Plant Taxonomy* 18: 141–148.
https://doi.org/10.3329/bjpt.v18i2.9299

Prabhukumar, K.M., Hareesh, V.S., Gogoi, R. & Sabu, M. (2022) *Family Balsaminaceae: Indian Scenario*. *In*: Seethalakshmi, K.K., Haridasan, K., Maya, C. Nair & Rekha, V.A. (Eds.) *Conspectus of Realms of Biodiversity*. *Commemorative volume to Prof. R. Vasudevn Nair*. Vibha, Palakkad, India, pp 151–184.

Prabhukumar, K.M.R., Jagadeesan, G., Prasad, B.N., Nagaraj, B.A.N.A., Kumar, N.V.V, Veeralinga, B. & Balachandran, I. (2017) Two new taxa of *Impatiens* (Balsaminaceae) from southern parts of Western Ghats, India. *Phytotaxa* 296 (3): 281–286.
https://doi.org/10.11646/phytotaxa.296.3.7

Prabhukumar, K.M., Hareesh, V.S., Bhaskar, V., Sreekumar, V.B., Nirmesh, T.K. & Indira, B. (2016) *Impatiens glabrata* (Balsaminaceae)—A new species from southern Western Ghats, India. *Phytotaxa* 266 (1): 33–39.
https://doi.org/10.11646/phytotaxa.266.1.5

Prabhukumar, K.M., Hareesh, V.S., Sreekumar, V.B., Nirmesh, T.K. & Indira, B. (2015a) *Impatiens neo-modesta* (Balsaminaceae)—A new species from Western Ghats, India. *Webbia: Journal of Plant Taxonomy and Geography* 70: 231–235. https://doi.org/10.1080/00837792.2015.1074792

Prabhukumar, K.M., Omalsree, M., Hareesh, V.S., Bhaskar, V., Nirmesh, T.K., Sreekumar, V.B. & Indira, B. (2015b) Two new taxa of *Impatiens* L. (Balsaminaceae) from Western Ghats of India. *Phytotaxa* 238 (3): 255–264. https://doi.org/10.11646/phytotaxa.238.3.4

Ramasubbu, R., Felix, I.D., Mohanraj, A. & Pandurangan, A.G. (2015a) *Impatiens matthewiana*, A new scapigerous balsam from Western Ghats, India. *Phytotaxa* 227 (3): 268–274. https://doi.org/10.11646/phytotaxa.227.3.6

Ramasubbu, R., Manikandan, G., Mehalingam, P. & Pandurangan, A.G. (2015b) *Impatiens courtallensis* (Balsaminaceae), A new species of *Impatiens* from Western Ghats, Tamil Nadu, India. *Phytotaxa* 203 (2): 199–204. https://doi.org/10.11646/phytotaxa.203.2.10

Ravichandran, V., Murugesan, M., Tharani, R., Karthik, B. & Premkumar, M. (2023) *Impatiens neo-orchioides*, a striking new balsam (Balsaminaceae: Scapigerae) from Nilgiri Biosphere Reserve, Western Ghats, India. *Taiwania* 68 (2): 161–165. https://doi.org/10.6165/tai.2023.68.161

Richard, P.S.S. & Ravichandran, V. (2023) *Impatiens karuppusamyi* (Balsaminaceae), a new species from the southern Western Ghats, India. *Annales Botanici Fennici* 60 (1): 131–135. https://doi.org/10.5735/085.060.0121

Richard, P.S.S., Karuppusamy, S. & Ravichandran, V. (2022) *Impatiens godfreyi* (Balsaminaceae), a new species of Balsam from the southern Western Ghats, India. *Journal of Asia-Pacific Biodiversity* 15 (1): 138–144.

Salish, M.S., Hareesh, V.S., Lekshmi, A., Sandeep, S. & Rajan, P. (2019) A new species of *Impatiens* (Balsaminaceae) from Eravikulam National Park, southern Western Ghats, India. *Webbia*. 74 (2): 271–274. https://doi.org/10.1080/00837792.2019.1637176

Saravanan, T.S., & Kaliamoorthy, S. (2022) Two new epiphytic species of *Impatiens* L. (Balsaminaceae) from the southern Western Ghats, India. *Phytotaxa* 552 (1): 107–114. https://doi.org/10.11646/phytotaxa.552.1.10

Singh, H., Sharma, A. & Adamowski, W. (2022) *Impatiens glauca* Hook. f. *et* Thomson—A little known Himalayan species with augmented description and a new spurless variety. *Phytotaxa* 539 (3): 280–286. https://doi.org/10.11646/phytotaxa.539.3.7

Tiwari, U.L. (2022) A new variety of *Impatiens jurpia* (Balsaminaceae) from Arunachal Pradesh, India. *Phytotaxa* 530 (3): 280–286. https://doi.org/10.11646/phytotaxa.530.3.3

Tiwari, U.L. (2023) *Impatiens tajoensis* (Balsaminaceae): A new species from Arunachal Pradesh, India. *Taiwania* 68 (1): 39–43. https://doi.org/10.6165/tai.2023.68.39

Vivekananthan, K., Rathakrishnan, N.C., Swaminathan, M.S. & Ghara, L.K. (1997) *Balsaminaceae*. *In*: Hajra, P.K., Nair V.J. & Daniel, P. (Eds.) *Flora of India*, vol. 4. Botanical Survey of India, Kolkata, pp. 99–229.

Wight, R. & Arnott, G.A.W. (1834) *Prodromus florae peninsula Indiaeorientalis*. Parbury, Allen, & Co., London, 480 pp.

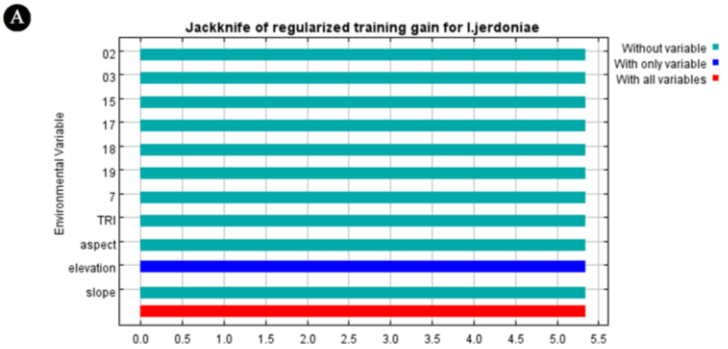
Wight, R. (1837) Contributions to Indian Botany, No.1. On the Genus *Impatiens*. *Madras Journal of Literature and Science* 5: 1–15.

Yu, S.X. (2012) *Balsaminaceae of China*. Beijing: Peking University Press, 215 pp.

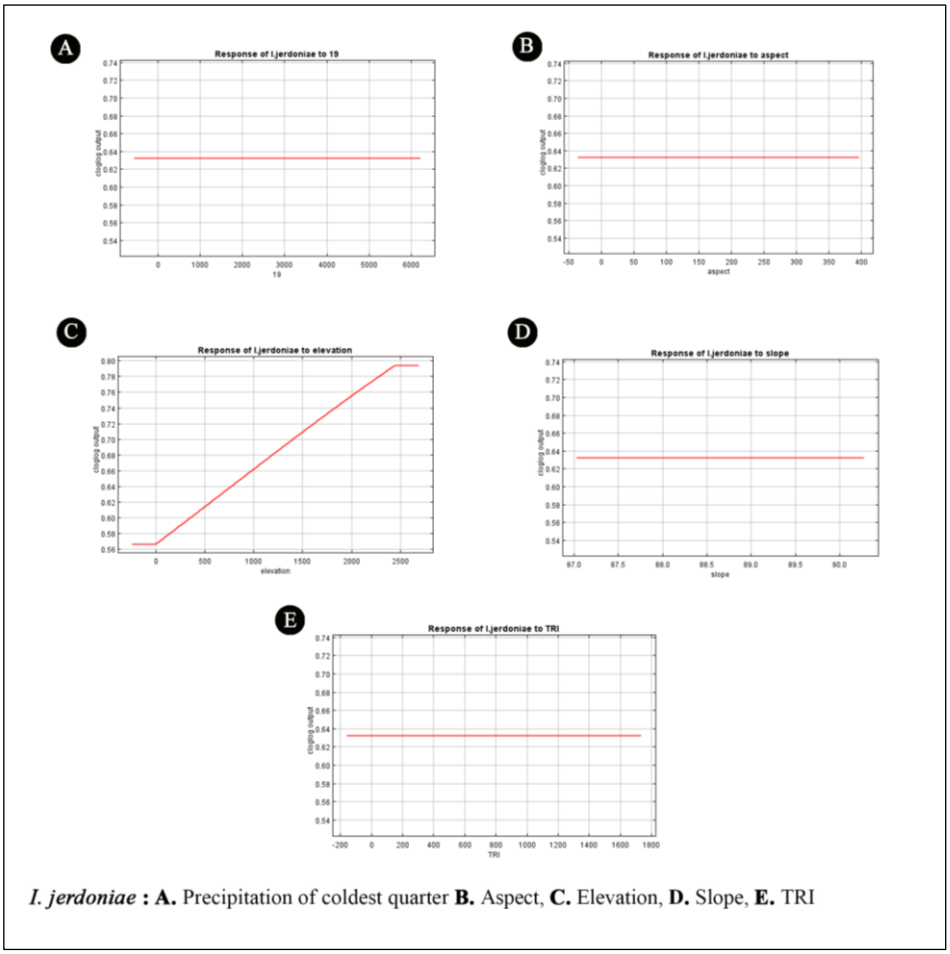
Additional data for identifying potential distribution of *Impatiens jerdoniae*

Occurrence points

Longitude (E)	Latitude (N)
76.08889	11.5125
76.09778	11.51917
76.09611	11.51083
76.08889	11.50389
76.12583	11.43944
76.69083	10.98444
75.47861	12.41528



I. jerdoniae **: A.** Jackknife test of variable importance; Response curves to different enviromental variables
B. Mean diurnal range, **C.** Isothermality, **D.**Temperature annual range, **E.** Precipitation of seasonality
F. Precipitation of driest quarter, **G.** Precipitation of warmest quarter



***I. jerdoniae* : A.** Precipitation of coldest quarter **B.** Aspect, **C.** Elevation, **D.** Slope, **E.** TRI

Pearson correlation of different variables of *I. jerdoniae*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	elevation	tri	slope	aspect
1	1																						
2	-0.21	1																					
3	0.15	0.54	1																				
4	0.88	-0.13	0.12	1																			
5	0.99	-0.24	0.08	0.88	1																		
6	0.99	-0.23	0.16	0.88	0.99	1																	
7	-0.32	0.006	-0.83	-0.24	-0.27	-0.35	1																
8	0.98	-0.1	0.29	0.89	0.96	0.97	-0.43	1															
9	0.99	-0.19	0.11	0.84	0.99	0.98	-0.27	0.96	1														
10	0.99	-0.22	0.11	0.87	0.99	0.99	-0.29	0.97	0.99	1													
11	0.99	-0.22	0.11	0.83	0.99	0.99	-0.28	0.96	0.99	0.99	1												
12	0.52	-0.62	-0.46	0.37	0.58	0.55	0.12	0.35	0.55	0.54	0.56	1											
13	0.61	-0.59	-0.46	0.45	0.67	0.64	0.15	0.45	0.65	0.64	0.66	0.98	1										
14	-0.52	0.58	0.67	-0.3	-0.57	-0.51	-0.41	-0.36	-0.58	-0.55	-0.58	-0.81	-0.86	1									
15	0.6	-0.53	-0.55	0.38	0.65	0.6	0.30	0.43	0.65	0.62	0.65	0.92	0.96	-0.96	1								
16	0.55	-0.62	-0.49	0.4	0.61	0.58	0.17	0.38	0.58	0.57	0.59	0.99	0.99	-0.85	0.94	1							
17	-0.55	0.61	0.68	-0.36	-0.59	-0.54	-0.41	-0.40	-0.59	-0.58	-0.6	-0.77	-0.84	0.99	-0.93	-0.93	1						
18	0.31	0.48	0.9	0.36	0.28	0.34	-0.76	0.42	0.27	0.29	0.27	-0.18	-0.19	0.52	-0.34	-0.22	0.54	1					
19	0.81	-0.39	0.05	0.83	0.84	0.84	-0.33	0.77	0.78	0.81	0.79	0.60	0.64	-0.42	0.53	0.61	-0.46	0.37	1				
elevation	-0.98	0.27	-0.03	-0.83	-0.98	-0.97	0.22	-0.94	-0.99	-0.99	-0.99	-0.58	-0.67	0.63	-0.68	-0.61	0.65	-0.18	-0.76	1			
tri	-0.37	-0.24	-0.49	-0.49	-0.35	-0.38	0.42	-0.45	-0.32	-0.35	-0.31	0.16	0.11	-0.25	0.19	0.15	-0.21	-0.68	-0.59	0.25	1		
slope	-0.59	-0.43	-0.22	-0.64	-0.59	-0.58	-0.02	-0.61	-0.59	-0.59	-0.57	-0.11	-0.2	0.14	-0.22	-0.14	0.14	-0.45	-0.51	0.54	0.67	1	
aspect	0.70	-0.22	0.4	0.44	0.67	0.71	-0.63	0.71	0.71	0.69	0.72	0.37	0.4	-0.26	0.36	0.36	-0.25	0.34	0.	-0.72	-0.008	-0.12	1

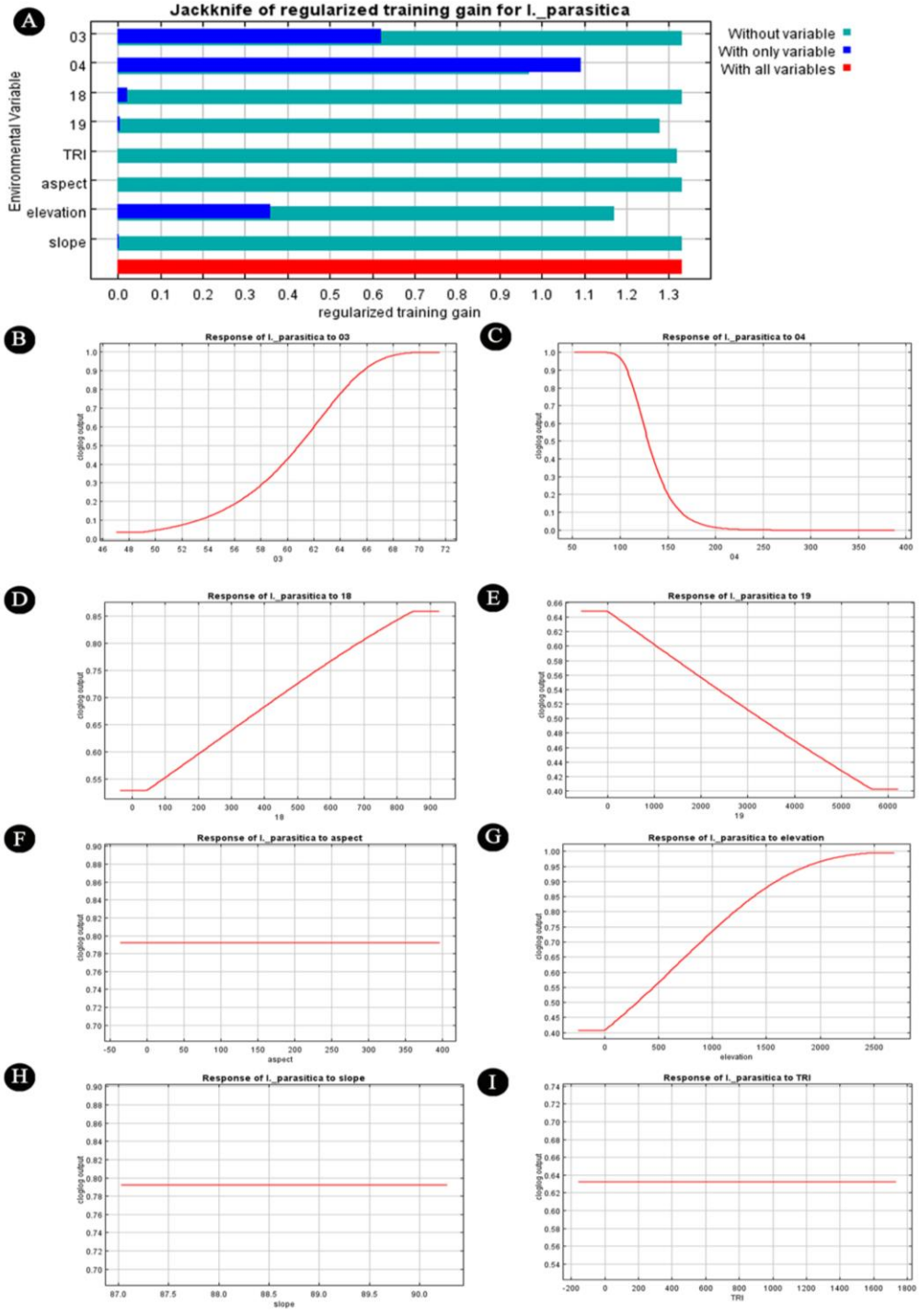
Additional data for identifying potential distribution of *Impatiens parasitica*

Occurrence points

Longitude (E)	Latitude (N)
75.85817	11.61118
75.85137	11.8542
77.39992	9.7281
77.16747	9.434987
76.7181	10.5524
76.87878	10.36092
76.90953	10.2072
76.99179	10.3881
76.98252	10.39077
77.01312	10.16319
77.03569	10.11475
77.23459	10.12036
77.21475	9.341245
76.86741	9.64936
76.08485	11.48875

Pearson correlation of different variables of *I. parasitica*

	Bio1	Bio2	Bio3	Bio4	Bio5	Bio6	Bio7	Bio8	Bio9	Bio10	Bio11	Bio12	Bio13	Bio14	Bio15	Bio16	Bio17	Bio18	Bio19	aspect	slope	TRI	elevation
Bio1	1																						
Bio2	-0.61	1																					
Bio3	0.12	0.04	1																				
Bio4	0.26	0.23	-0.58	1																			
Bio5	0.99	-0.54	0.04	0.35	1																		
Bio6	0.99	-0.67	0.14	0.19	0.97	1																	
Bio7	-0.61	0.97	-0.44	0.49	-0.5	-0.67	1																
Bio8	0.99	-0.63	0.16	0.21	0.97	0.98	-0.64	1															
Bio9	0.99	-0.62	0.09	0.25	0.99	0.99	-0.6	0.98	1														
Bio10	0.99	-0.6	0.07	0.3	0.99	0.99	-0.57	0.98	0.99	1													
Bio11	0.99	-0.65	0.13	0.2	0.98	0.99	-0.64	0.98	0.99	0.99	1												
Bio12	0.38	-0.53	-0.23	-0.07	0.38	0.41	-0.36	0.33	0.43	0.39	0.43	1											
Bio13	0.45	-0.49	-0.36	0.13	0.47	0.47	-0.26	0.38	0.5	0.47	0.49	0.97	1										
Bio14	-0.44	0.24	0.56	-0.46	-0.51	-0.42	-0.05	-0.36	-0.49	-0.48	-0.46	-0.77	-0.87	1									
Bio15	0.46	-0.43	-0.45	0.22	0.5	0.47	-0.16	0.4	0.52	0.49	0.5	0.91	0.97	-0.94	1								
Bio16	0.43	-0.51	-0.34	0.07	0.44	0.45	-0.29	0.36	0.48	0.45	0.47	0.98	0.99	-0.86	0.96	1							
Bio17	-0.35	0.1	0.66	-0.59	-0.43	-0.31	-0.23	-0.28	-0.39	-0.39	-0.35	-0.65	-0.87	0.97	-0.86	-0.85	1						
Bio18	0.45	-0.5	0.58	-0.42	0.37	0.49	-0.83	0.49	0.46	0.43	0.49	0.46	0.33	0	0.2	0.34	0.15	1					
Bio19	0.58	-0.38	-0.25	0.48	0.6	0.57	-0.22	0.54	0.66	0.6	0.57	0.62	0.81	-0.59	0.64	0.66	-0.56	0.41	1				
aspect	-0.13	0.05	-0.24	0.04	-0.13	-0.14	0.14	-0.15	-0.13	-0.12	-0.13	0.22	0.17	-0.11	0.11	0.2	-0.16	-0.04	0.13	1			
slope	0	0.35	-0.01	0.21	0.04	-0.03	0.33	-0.05	0.02	0.01	0.004	0.31	0.33	-0.46	0.35	0.34	-0.45	0.02	0.15	-0.04	1		
TRI	-0.28	0.15	-0.2	0.04	-0.25	-0.27	0.24	-0.33	-0.25	-0.27	-0.26	0.38	0.37	-0.33	0.32	0.38	-0.29	-0.01	0.1	0	0.64	1	
elevation	-0.98	0.63	-0.049	-0.27	-0.98	-0.98	0.58	-0.98	-0.99	-0.99	-0.98	-0.45	-0.52	0.51	-0.54	-0.5	0.42	-0.48	-0.62	0.09	-0.01	0.24	1



I. parasitica : **A.** Jackknife test of variable importance; Response curves to different enviromental variables **B.** Isothermality, **C.** Temperature seasonality, **D.** Precipitation of warmest quarter, **E.** Precipitation of coldest quarter, **F.** Aspect, **G.** Elevation, **H.** Slope **I.** Terrain Ruggedness Index

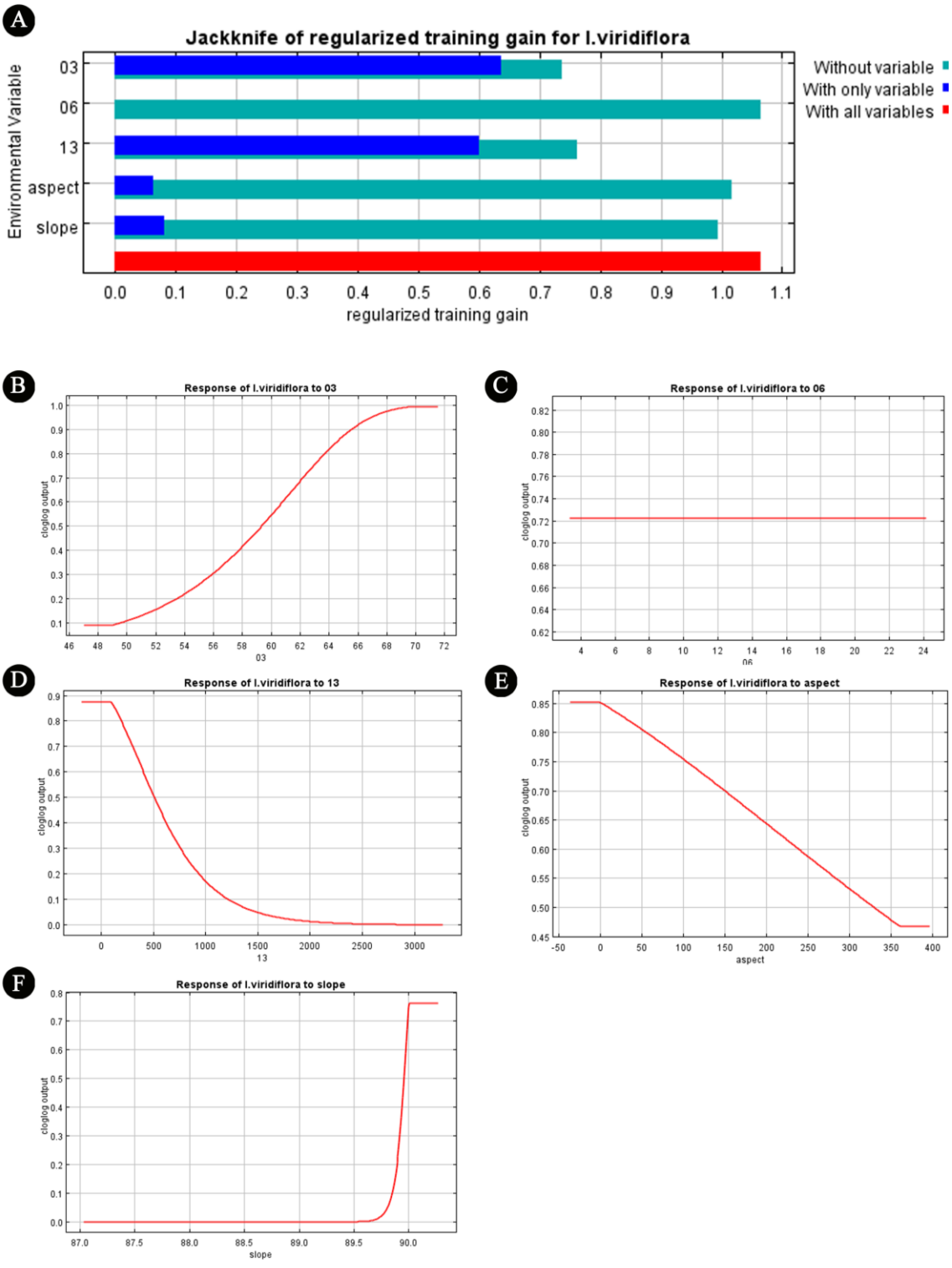
Additional data for identifying potential distribution of *Impatiens viridiflora*

Occurrence points

Longitude (E)	Latitude (N)
77.32547	9.586948
77.33167	9.588888
77.33444	9.595472
77.52862	9.533614
77.54452	9.550552
77.12611	9.568882

Pearson correlation of different variables of *I. parasitica*

	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Elevation	Aspect	Slope	TRI
19	1																						
18	0.95	1																					
17	0.98	0.99	1																				
16	0.61	0.82	0.742	1																			
15	-0.96	-0.84	-0.91	-0.4	1																		
14	0.99	0.98	0.99	0.71	-0.92	1																	
13	0.53	0.75	0.66	0.99	-0.3	0.63	1																
12	0.89	0.98	0.95	0.9	-0.75	0.94	0.85	1															
11	-0.99	-0.93	-0.97	-0.57	0.97	-0.98	-0.48	-0.86	1														
10	-0.99	-0.94	-0.98	-0.59	0.97	-0.98	-0.51	-0.88	0.99	1													
9	-0.99	-0.93	-0.97	-0.56	0.97	-0.98	-0.47	-0.86	0.99	0.99	1												
8	-0.99	-0.93	-0.96	-0.55	0.98	-0.97	-0.46	-0.85	0.99	0.99	0.99	1											
7	-0.97	-0.99	-0.99	-0.76	0.88	-0.99	-0.69	-0.96	0.95	0.96	0.95	0.95	1										
6	-0.99	-0.94	-0.97	-0.58	0.97	-0.98	-0.49	-0.87	0.99	0.99	0.99	0.99	0.96	1									
5	-0.99	-0.94	-0.98	-0.6	0.96	-0.98	-0.51	-0.88	0.99	0.99	0.99	0.99	0.96	0.99	1								
4	-0.95	-0.99	-0.98	-0.82	0.84	-0.98	-0.76	-0.98	0.93	0.94	0.93	0.92	0.98	0.93	0.94	1							
3	-0.15	-0.16	-0.15	-0.14	0.09	-0.16	-0.14	-0.18	0.16	0.16	0.16	0.16	0.13	0.17	0.16	0.17	1						
2	-0.96	-0.98	-0.98	-0.76	0.87	-0.98	-0.69	-0.96	0.95	0.96	0.95	0.95	0.99	0.96	0.96	0.98	0.23	1					
1	-0.99	-0.94	-0.98	-0.6	0.97	-0.98	-0.51	-0.88	0.99	0.99	0.99	0.99	0.96	0.99	0.99	0.94	0.16	0.96	1				
Elevation	0.99	0.93	0.97	0.56	-0.98	0.98	0.47	0.86	-0.99	-0.99	-0.99	-0.99	-0.95	-0.99	-0.99	-0.92	-0.16	-0.95	-0.99	1			
Aspect	0.22	0.11	0.16	-0.1	-0.3	0.17	-0.14	0.04	-0.23	-0.22	-0.23	-0.24	-0.07	-0.23	-0.22	-0.12	-0.14	-0.08	-0.22	0.23	1		
Slope	-0.05	0.1	0.04	0.4	0.16	0.01	0.44	0.18	0.09	0.07	0.09	0.1	0.007	0.08	0.07	-0.12	0.11	0.02	0.07	-0.1	0.09	1	
TRI	-0.07	0.11	0.03	0.47	0.21	0.07	0.51	0.21	0.12	0.1	0.12	0.13	-0.007	0.11	0.1	-0.13	0.15	0.01	0.09	-0.13	-0.06	0.98	1

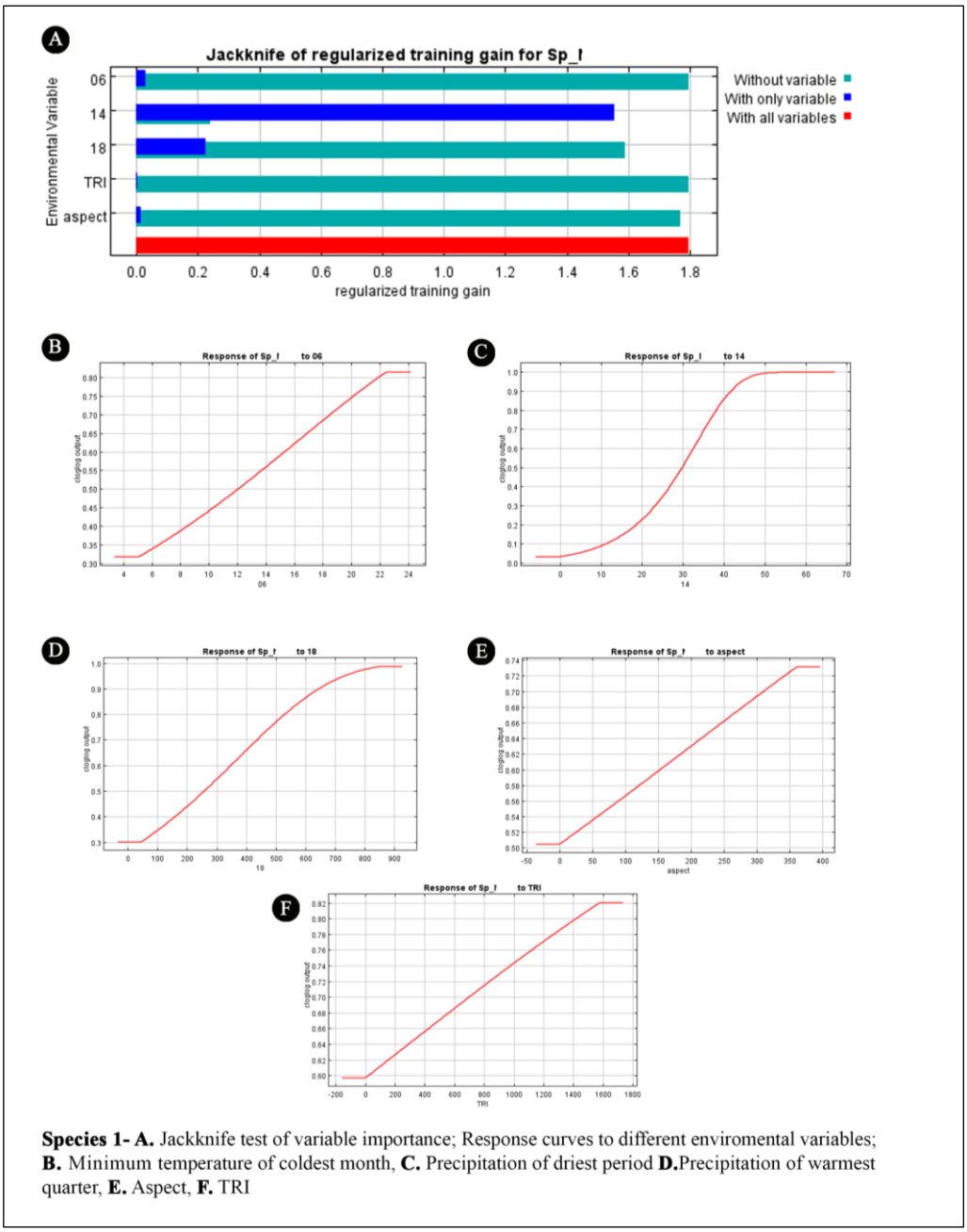


I. viridiflora **: A.** Jackknife test of variable importance; Response curves to different enviromenta variables; **B.** Isothermality, **C.** Minimum temperature of coldest month, **D.** Precipitation of wette

Additional data for identifying potential distribution of Species 1

Occurrence points

Longitude (E)	Latitude (N)
76.88972	9.676389
76.89167	9.677222
76.89111	9.675278
76.89389	9.674167



Species 1- A. Jackknife test of variable importance; Response curves to different enviromental variables; **B.** Minimum temperature of coldest month, **C.** Precipitation of driest period **D.**Precipitation of warmest quarter, **E.** Aspect, **F.** TRI