MICROMORPHOLOGICAL AND MOLECULAR TAXONOMY OF GENUS *PARTHENOCISSUS* PLANCHON IN INDIA

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CERTIFICATE

This is to certify that the thesis entitled **"MICROMORPHOLOGICAL AND MOLECULAR TAXONOMY OF GENUS *PARTHENOCISSUS* PLANCHON IN INDIA"** is an authentic record of research work carried out by **Ms. Nimmi C Dominigose** under my supervision in fulfilment of the requirement for the degree of Doctor of Philosophy, in Botany of University of Calicut. The results 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 contents of the thesis have been checked using anti-plagiarism data base and no unacceptable similarity was found through the software check.

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DECLARATION

I, **Nimmi C Dominigose**, hereby declare that the thesis entitled **"MICROMORPHOLOGICAL AND MOLECULAR TAXONOMY OF GENUS *PARTHENOCISSUS* PLANCHON IN INDIA"** 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. Anto P V, Assistant Professor, Department of Botany, St. Thomas College (Autonomous), Thrissur and that it has not been submitted earlier either in part or full for the award of any degree/diploma to any candidate of any University.

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ABSTRACT

Vitaceae, the grape family, consists of 17 genera and about 950 species widely distributed in tropical regions and partially in temperate regions. This is an economically well known family as it contains grape species and ornamentals. It has been considered a difficult taxonomic group with unclear generic boundaries and nomenclatural problems.

Parthenocissus is one of the least revised genera in the family Vitaceae. It can be easily distinguished from the other genera by its highly branched tendrils, adhesive discs at tendril apices, and appendages on the inner side of the petal. This genus consists of 13 species mainly distributed in Asia and North America. This study aims to revise the genus *Parthenocissus* for the first time in India. A combined morphological and molecular analysis was carried out in this study to solve the nomenclatural problems within the genus and to trace the evolutionary relationship among them. Extensive field explorations were conducted during 2017-2022. Each specimen with vegetative and reproductive parts was collected. The field observations, such as habit, habitat, nature of leaves, colour, and the shape of the flowers, were noted in the field book. Morphological analysis includes both micromorphology and macromorphology. Micromorphology mainly focuses on tendril morphology, palynology and seed coat morphology. Plant materials with vegetative and reproductive parts were dried and mounted on standard herbarium sheets. Herbarium sheets of each species, including type specimen, were deposited at St. Thomas College herbarium. Distribution maps of each species were prepared for future study. Molecular analysis was carried out using plastid DNA sequences. Newly generated sequences were deposited on NCBI. A phylogenetic tree of genus *Parthenocissus* was constructed with a newly generated sequence and sequence retrieved from GenBank. The tree was divided into three major clades. It strongly supports the continental disjunction and evolutionary relationship within the genus.

The present study reports eight taxa in India, including varieties of the genus *Parthenocissus*. Among them, *Parthenocissus quinquefolia* and *Parthenocissus tricuspidata* are grown as ornamentals. During the study, three new species were reported; *Parthenocissus renukae*, *Parthenocissus wallichianus. Parthenocissus sasii* and one species were reinstated; *Parthenocissus subferruginea.* Based on morphological and molecular analysis, the genus *Parthenocissus* was classified into three sections in this study: Cissoparthe, Causoparthe and Euparthe. Evaluation of the medicinal properties of newly reported species is a future aspect of this study.

സംഗ്രഹം

മുന്തിരിവള്ളിയുടെ കുടുംബമായ വൈറ്റേസിയിൽ, 17 ജീനസ്സുകളും 950 ഓളം ഇനങ്ങളും ഉൾക്കൊള്ളുന്നു. ഇത് വ്യാപകമായി ഉഷ്ണമേഖലാ പ്രദേശങ്ങളിലും ഭാഗികമായി മിതശീതോഷ്ണ പ്രദേശങ്ങളിലും സ്ഥിതിചെയ്യുന്നു. മുന്തിരിഇനങ്ങളും, അലങ്കാരചെടികളും അടങ്ങിയിരിക്കുന്നതിനാൽ ഇത് സാമ്പത്തികമായി പ്രാധാന്യമുള്ള സസ്യ ഇനമാണ്. വ്യക്തമല്ലാത്ത സ്പീഷീസ് വേർതിരിവും, നാമകരണപ്രശ്നങ്ങളും ഉള്ള വളരെ ബുദ്ധിമുട്ടുള്ള ടാക്സോണമിക് ഗ്രൂപ്പായി ഇത് കണക്കാക്ക പ്പെടുന്നു.

വൈറ്റേസി കുടുംബത്തിലെ ഏറ്റവും കുറവ് പഠനം നടത്തിയ ജീനസ്സുകളിൽ ഒന്നാണ് പാർത്തിനോസിസസ്. വളരെയേറെ ശാഖകളുള്ള ടെൻഡ്രലുകൾ, ടെൻഡ്രിൽ അഗ്രങ്ങളിൽ ഒട്ടിപ്പിടി ക്കാൻ കഴിവുള്ള ഡിസ്കുകൾ, ദളത്തിന്റെ ഉൾഭാഗത്തുള്ള അപന്റേജുകൾ (അനുബന്ധങ്ങൾ) എന്നിവയാൽ ഇതിനെ മറ്റ് ജീനസ്സുകളിൽനിന്ന് എളുപ്പത്തിൽ വേർതിരിച്ചറിയാൻ കഴിയും. ഈ ജീനസ്സിൽ പ്രധാനമായും ഏഷ്യയിലും വടക്കേ അമേരിക്കയിലും സ്ഥിതിചെയ്യുന്ന 13 സസ്യ ഇനങ്ങൾ ഉൾപ്പെടുന്നു. ഇന്ത്യയിൽ ആദ്യമായി പാർത്തിനോസിസസ് ജീനസ്സിനെ പഠിച്ച് പരിഷ്കരിക്കാനാണ് ഈ ഗവേഷണം ലക്ഷ്യമിടുന്നത്. ജീനസ്സിലെ നാമകരണ പ്രശ്നങ്ങൾ പരിഹരിക്കുന്നതിനും അവ തമ്മിലുള്ള പരിണാമപരമായ ബന്ധം കണ്ടെത്തുന്നതിനും ഒരു സംയോജിത രൂപഘടനയും, തന്മാത്രാ വിശകലനവും നടത്തി. 2017-2022 കാലയളവിൽ വിപുലമായ ഫീൽഡ് പര്യവേക്ഷണങ്ങൾ നടത്തി. ഓരോ ചെടിയും ശേഖരിച്ചു. ആവാസവ്യവസ്ഥ, ഇലകളുടെ സ്വഭാവം, നിറം, പൂക്കളുടെ ആകൃതി എന്നിവ ഫീൽഡ് ബുക്കിൽ രേഖപ്പെടുത്തി. മോർഫോളജിക്കൽ വിശകലനത്തിൽ മൈക്രോമോർഫോ ളജിയും മാക്രോമോർഫോളജിയും പഠനവിഷയമാക്കി. മൈക്രോമോർഫോളജിയിൽ ടെൻഡ്രിൽ മോർഫോളജി, പാലിനോളജി, സീഡ്കോട്ട് മോർഫോളജി എന്നിവയ്ക്ക് കൂടുതൽ പ്രാധാന്യം നൽകി. ചെടിയുടെ ഭാഗങ്ങൾ ഉണക്കി ഹെർബേറിയം ഷീറ്റുകളിൽ ഒട്ടിച്ചു. ഓരോ ഇനത്തിന്റെയും ഹെർ ബേറിയം ഷീറ്റുകൾ, ടൈപ്പ് സ്പെസിമൻ ഉൾപ്പെടെ സെന്റ് തോമസ് കോളേജ് ഹെർബേറിയ ത്തിൽ നിക്ഷേപിച്ചു ഭാവി പഠനത്തിനായി ഓരോ സസ്യത്തിന്റെയും ലൊക്കേഷൻമാപ്പുകൾ തയ്യാറാക്കി. ക്ലോറോപ്ലാസ്റ്റ് ഡിഎൻഎ സീക്വൻസുകൾ ഉപയോഗിച്ചാണ് തന്മാത്രാവിശകലനം നടത്തിയത്. പുതുതായി സൃഷ്ടിച്ച സീക്വൻസുകൾ എൻ.സി.ബി.ഐ.യിൽ നിക്ഷേപിച്ചു. ജെൻബാങ്കിൽ നിന്ന് വീണ്ടെടുത്തതും പുതുതായി ജനറേറ്റ് ചെയ്തതുമായ സീക്വൻസിന്റെ സഹായത്തോടെ പാർത്തിനോ സിസസ് ജീനസ്സിലെ ഫൈലോജെനെറ്റിക് ട്രീ നിർമ്മിച്ചു. ഇതിനെ മൂന്ന് പ്രധാന ക്ലേഡുകളായി തിരിച്ചിരിക്കുന്നു. ജീനസ്സിനുള്ളിലെ ഭൂഖണ്ഡാന്തര വിഭജനത്തെയും, പരിണാമബന്ധത്തെയും ഇത് ശക്തമായി പിന്തുണയ്ക്കുന്നു

ഇന്ത്യയിലെ പാർത്തിനോസിസസ് ജീനസ്സിലെ എട്ട് ടാക്സകളെയാണ് ഇപ്പോഴത്തെ ഗവേ ഷണപഠനം റിപ്പോർട്ട് ചെയ്യുന്നത്. അവയിൽ, പാർത്തിനോസിസസ് ക്വിൻക്യൂഫോളിയ, പാർത്തിനോ സിസസ് ട്രൈക്കസ്പിഡാറ്റ എന്നിവ അലങ്കാരസസ്യങ്ങളായി വളർത്തുന്നു. പഠനത്തിനിടയിൽ, മൂന്ന് പുതിയ സ്പീഷീസുകൾ റിപ്പോർട്ട് ചെയ്യപ്പെട്ടു; പാർത്തിനോസിസസ് രേണുകേ, പാർത്തിനോസിസസ് വല്ലിച്ചിയാനസ്, പാർത്തിനോസിസസ് ശശൈ ഇതിൽ ഉൾപെടുന്നു. പാർത്തിനോസിസസ് സബ്ഫെറു ജീനിയ എന്ന പേരിലുള്ള സ്പീഷീസ് പുനഃസ്ഥാപിച്ചു. രൂപശാസ്ത്രപരവും, തന്മാത്രാവിശകലനവും അടിസ്ഥാനമാക്കി, ഈ പഠനത്തിൽ പാർത്തിനോസിസസ് ജീനസ്സിനെ മൂന്ന് വിഭാഗങ്ങളായി തരം തിരിച്ചിട്ടുണ്ട്: സിസ്സോപാർത്തി, കൗസോപാർത്തി, യൂപാർത്തി. പുതുതായി റിപ്പോർട്ട് ചെയ്യപ്പെട്ട സസ്യങ്ങളുടെ ഔഷധഗുണങ്ങളെക്കുറിച്ചുള്ള വിലയിരുത്തൽ ഈ പഠനത്തിന്റെ ഭാവി വശമാണ്.

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ABBREVIATIONS

° C	Degree Celsius
µL	Microliter
µg	Microgram
µm	Micrometre
mL	Milliliter
mg	Milligram
M	Molar
g	Gram
m	metre
mm	millimeter
cm	Centimeter
nm	Nanometer
%	Percentage
~	Approximately
>	Greater than
rpm	Revolutions per minute
kV	Kilovolt
pg	picograms
ca.	Circa (Latin), around
var.	Variety
spp.	Species
sp.nov	New species
QGIS	Quantum Geographic Information System
LM	Light Microscopy
cs	cross section
viz.	Videlicet (Latin), namely

Dedicated to my family

Chapter-1

Introduction

1.1. General Introduction

Vitaceae is an important family, well known among commercial fruits for the economic importance of grapes (Karkamkar *et al*., 2010). According to Bentham and Hooker classification the family was treated under order Rhamnales, comprised of 17 genera and 950 species distributed widely in tropical, subtropical, and partially temperate regions. Characterised mainly by woody creepers or lianas, few are herbaceous or erect shrubs, rarely succulent trees categorised primarily as a source of food, wine, resins, and also as ornamental (Manchester *et al*., 2013; Lu *et al*., 2013). Family members can be easily recognised by their leaf opposed tendrils and unique seed characteristics (Chen *et al*., 2007; Wen, 2007; Zhang *et al*., 2015). Vitaceae are commonly found in lowland tropical forests, mountainous areas in temperate regions or montane forests in the subtropics and tropics. The major genera of Vitaceae include *Acareosperma*, *Afrocayratia*, *Ampelocissus*, *Ampelopsis*, *Causonis*, *Cayratia*, *Cissus*, *Clematicissus*, *Cyphostemma*, *Nothocissus*, *Parthenocissus*, *Pterisanthes*, *Pterocissus*, *Rhoicissus*, *Tetrastigma*, *Vitis* and *Yua*. This study mainly focuses on the genus *Parthenocissus*.

1.1.1. Genus *Parthenocissus* Planchon.

According to the recent APG system of classification, the systematic position of the genus *Parthenocissus* includes the order Vitales, and the family Vitaceae. This genus comprises 13 species distributed mainly in Eastern Asia and North America. There are approximately ten Old World species distributed primarily in the east of Asia, with one species in the Western Ghats of India and Sri Lanka, one in Java to northern Thailand, and three in North America (Soejima & Wen, 2006; Wen, 2007; Chen *et al*., 2007). *Parthenocissus* is derived from two Greek words: ' *Parthenos*', which means virgin or maiden and '*Kissos,*' which means ivy. Later, the word '*Kissos*' was Latinized. Planchon (1887) established two closely related genera, *Parthenocissus* and *Landukia*, based on differences in floral disk morphology. Earlier names of this genus include *Landukia* Planch., *Psedera* Neck., and *Quinaria* Raf. Planchon reported seven species of *Parthenocissus*, *P. quinquefolia*, *P. himalayana*, *P. neilgherriensis*, *P. cuspidifera*, *P. semicordata*, *P. anamalayana*, and *P. tricuspidata*. He also mentioned *P. thomsonii* Lawson in the genus with a question mark. Rheder (1905) renamed the species *Hedera quinquefolia* L. as *P. quinquefolia* (L) Planch. a species

of *Parthenocissus* having tendril with an attaching pad. Contrary to Rheder, Graebner (1908) used the name *P. quinquefolia* to the species without attaching the pad known at present a *P. vitacea* (Knerr) Hitchc. Most American and European botanists followed Rheder's view (Brizicky, 1965; Soejima & Wen, 2006; Wen *et al*., 2007), but few botanists supported Graebner's opinion. Gagnepain (1911) merged *Landukia* as a synonym for *Parthenocissus* because one and only one species of *Landukia* is most likely similar to *P. semicordata*. This opinion was followed by later botanists (Suessenguth, 1953; Latiff, 1982; Li, 1998; Shetty & Singh, 2000; Wen, 2007; Chen *et al*., 2007). Gleason (1947) placed *V. inserta* as a synonym of *P. quinquefolia*. Suessenguth (1953) divided the genus into two groups, the Asian group or Old World (Africa, Asia, Australia) and American group or New World. Galet (1967) proposed three series in this genus: series Tricuspidatae with simple leaves, series Trifoliolae with trifoliolate leaves, and series Quinquefoliolae with palmate penta to hepta foliolate leaves. Based on taxonomic studies, Singh (1986) solved the nomenclatural issue regarding *P. thomsonii* Lawson. Furthermore, they were treated as a species of the *Parthenocissus* genus from the Indian subcontinent. Nevertheless, later, Li (1990) separated two species, *P. austro-orientalis* (Metcalf) C.L and *P. thomsonii,* from this genus and placed them in a new genus called Yua based on tendril morphology and the nature of inflorescence. Later, Li (1996) divided the Chinese species of *Parthenocissus* into three sections based on tendril morphology: (1) section *Parthenocissus* with young tendril apices slender, curving and slightly expanded as fist shaped adhesive discs; (2) section Margaritaceae C.L. Li with young tendril apices expanded into ball like structures; and (3) section Tuberculiformes C.L.Li with palmate, pentafoliolate leaves, and young tendril apices expanded into tubercles. Li (1998) reported nine species and one variety from China: *P. chinensis* C.L.Li, *P. cuspidifera* (Miq.) Planch. var. *pubifolia* C.L. Li, *P. dalzielii* Gagnep., *P. feddei* (H. Lév.) C.L.Li, *P. henryana* (Hemsl.) Diels & Gilg, *P. laetevirens* Rehd., *P. quinquefolia* (L.) Planch., *P. semicordata* (Wall.) Planch., *P. suberosa* Hand. Mazz. and *P. tricuspidata* (Sieb. & Zucc.) Planch. This classification was accepted by Chen *et al*., (2007) with slight modification, such as *P. cuspidifera* var. *pubifolia* was treated as a synonym of *P. semicordata*.

However, in the case of the Asian species of *Parthenocissus,* species determination has been highly complex and controversial. Because more than six names of the same

species and infra specific taxa have existed in these regions. In the case of *P. semicordata,* five other names include *P. anamalayana* Planch. and *P. cuspidifera* (Miq.) Planch., *P. heterophylla* (Blume) Merr., *P. himalayana* (Royle) Planch., *P. neilgherriensis* (Wight) Planch. King (1896) described *P. semicordata* Planch as a synonym of *V. semicordata*. Here, he cited Wallich specimen catalogue no. 6020. In this work, he also placed *P. cuspidifera as* a synonym of *V. semicordata* var. *roylei*. He added that *V. semicordata* is not confined to the Himalayan region. On the contrary, its type and variety are found in Sikkim, Khasia, Neilgherries, and upper Burma. This may be why more than six names for the same species and species delimitation become controversial. *P. heterophylla* was derived from *Blume's Ampelopsis heterophylla* from Java. Rheder (1939) treated *P. feddei* as conspecific with *P. heterophylla*. Raizada (1967) described *P. semicordata* var. *semicordata*. Anto *et al.,* (2018) added a new species, *P. renukae,* into the *Parthenocissus* genus. Dominigose *et al.,* (2023) recently described a new species, *P. wallichianus* Anto, Nimmi & Pradeep.

1.1.2. Distribution and Ecology

The genus *Parthenocissus* shows an intercontinental disjunct distribution between Asia and North America (Rossetto *et al*., 2001). Most species are located in Asia, and the rest are in America. However, it extends to Central America and the Caribbean region (Chen *et al*., 2007). Most of the Indian species are found in South India's northeastern parts. In India, Kerala has the maximum diversity of *Parthenocissus* species.

1.1.3. Economic Importance

The members of *Parthenocissus* form a fascinating group of plants due to their ornamental and medicinal values. The brilliant crimson coloured leaves and climbing or clinging tendrils with pink coloured finger adhesive pad cover the side of a brick or stone building add glory to cottage gardens with arches and fences. Several species of the genus are grown as ornamentals. *P. tricuspidata* and *P. quinquefolia* are examples.

Medicinal properties are reported to many species. For example, sap collected from aerial parts and roots of *P. semicordata* is used to remedy various ailments, including leucorrhoea and piles (Uniyal *et al*., 2006). A hot decoction of *P. quinquefolia* is used

as a poultice to help reduce swellings (Moerman, 1998). A glycoside from *P. tricuspidata* was found to have antimalarial activity in mice (Park *et al*., 2008).

Other uses include the sap of *P. tricuspidata* as a sugar substitute and *P. quinquefolia* for watershed protection and erosion control. Fruit of both *P. quinquefolia* and *P. semicordata* are edible.

1.2 Objectives

1. Field exploration, collection, documentation and preparation of herbarium specimens for future reference.
2. To prepare a distribution map for *Parthenocissus* spp.
3. To identify the collected specimens using a micromorphological technique.
4. To characterise *Parthenocissus genera* using molecular taxonomy.
5. To find out the evolutionary relationship using the Phylogenetic tree.

1.3 Area of the present study

The present study spreads over the entire political boundary of India, which lies between 8°4' and 37°6' North latitudes and between 68°7' and 97°25' East longitudes. It comprises 29 states and seven union territories. Being the largest Peninsula of Asia, it measures 3219 km from north to south and about 2977 km from east to west. The natural boundaries are the Great Wall of the Himalayas in the north, the Thar desert of Rajasthan in the northwest, the Indian Ocean in the south, the Bay of Bengal (wherein lie Andaman Nicobar Islands) in the eastern side of the Peninsula, the Arabian Sea (wherein lie Lakshadweep islands) south western side of Peninsula and the mountain ranges in the east separating Myanmar from India. The countries that touch India's border from west to east are Pakistan, Afghanistan, Nepal, Bhutan, China, Tibet, Bangladesh, and Myanmar (Murthy *et al*., 1996).

Biogeography

Biogeography India can be divided into three major physiographic zones: a. The Peninsula, a triangular plateau encircled by the Vindhyan ranges in the north. The

Western Ghats (Sahyadri) and the Eastern Ghats are the major ranges in the Peninsula along the western and eastern coasts. b. The Extra Peninsula, which constitutes the Himalayas and other mountains in the northern extremity, consists of the Hindukush, the Karakoram, and the Himalayas. c. The North Indian Plains, located between the Peninsula and Extra Peninsula, comprises extensive plains of Assam, West Bengal, Bihar, Uttar Pradesh, and Punjab (Murthy *et al*., 1996).

Soil

Soils in India are classified into eight categories: Lateritic soil, Black cotton soil, Red soils, Alluvial soils, Alkaline soils, Saline soils, Peaty soil, Desert soil or Arid soil, and Scanty soils of mountains and hills (Venu *et al*., 1996). The lateritic soils are generally reddish or yellowish red and turn black on exposure to the sun. They are well developed hilltops and have a higher content of humus. The black soils are primarily dark grey to black and formed by the decomposition trap rucksacks. The red soils are mainly found in the peninsular regions and are low in humus and other organic nutrients. Alluvial soil, India's largest and most crucial soil group is derived from the silt of numerous Indus, the Ganges, and Brahmaputra systems tributaries. The alkali and saline soils have more salts, while the peaty soils, characterised by excessive organic matter, accumulate in poorly decomposed conditions. The desert soils in arid and semiarid zones are salty and contain a good amount of alkali. The mountain soils, which are young or immature, are distributed in the north from the east to the eastern part of the country (Murthy *et al*., 1996).

Forest

Forests in India encompass 67.83 million hectares of land, which represents 20. 64% of the nation’s geographical territory. Different types of forests are found in the Indian subcontinent, varying from arid zone forests to Himalayan temperate forests. There are six major types of forests, namely, moist tropical, dry tropical, montane subtropical, montane temperate, subalpine, and alpine. These are further divided into 16 major types of forests. The eastern part of India consists of moist, deciduous and wet evergreen forests; the western part comprises thorn and dry deciduous forests. The northern and central area consists of primarily dry and moist deciduous forests,

and the southern parts include characteristics of both central and western zones (Murthy *et al*., 1996).

Rivers

Rivers of India fall into two major groups. 1. The Extra Peninsular rivers or Himalayan rivers comprise 19 significant rivers, of which the Indus, the Ganges, and the Brahmaputra are the largest. Among the 19 rivers, six belong to the Indus system, nine belong to the Ganges system, and four belong to the Brahmaputra system. 2. The Peninsular Rivers: These rivers are entirely fed by monsoon and are often more or less dry in summer. They fall into two groups. a. The coastal rivers are relatively small stretches that drain the western side of the Western Ghats, pass through the Narrow Plain, and flow into the Arabian Sea. There are over 600 on the west coast, from Gujarat in the north to Kanyakumari in the south. b. The inland rivers include the west flowing Narmada and Tapti and the east flowing Mahanadi, Godavari, Krishna and Kaveri (Murthy *et al*., 1996).

Climate

The climate is one of the essential components of the natural environment. The Himalayan ranges act as a tremendous climatic divide. They obstruct the southwest monsoon winds to shed their moisture as heavy rainfall along the sub mountain areas north of the Indo-Gangetic plains and as snowfall further north. It also blocks the direct entry of extreme continental winds from the Tibet Plateau into India. Up to 30º north, the plains experience a warmer climate in winter; other parts of the world at the same latitude experience cold winters. Peninsular India is flanked by the Bay of Bengal on the east, the Arabian Sea on the west, and the Indian Ocean on the south. The Peninsular region is also flanked by Western Ghats along the west coast and Eastern Ghats along the east coast. These two mountain ranges significantly ensure rain on their windward slopes (Murthy *et al*., 1996). India's climate is affected by two seasonal winds, the southwest monsoon and the northeast monsoon. The southwest monsoon (summer monsoon) blows from the sea to land, whereas the northeast monsoon (winter monsoon) blows from land to sea. Though India is often called a tropical country, half is in the tropics and half in the North Temperate Zone. However, there is some form of unity in the climatic conditions. This is due to the influence of

the Himalayas and the monsoons. The climate may be broadly described as tropical monsoon type. Four seasons in India are Summer or Pre monsoon, Monsoon, Post monsoon, and Winter.

Temperature

The mean annual temperature in India exceeds 24^{o}C, except in hilly areas and the extreme North West. The latitude, altitude, humidity, winds, etc., influence the temperature. Hill stations, coastal areas, and plateau regions have different temperature conditions. The hill stations have the lowest temperature, averaging between 15.7^{o}C and 16.9^{o}C. In coastal areas, the west coast has an average temperature of 30.5^{o}C (Mumbai) while the east coast goes up to 33.4^{o}C (Chennai).

Rainfall

The southwest monsoon and the northeast monsoon bring good rains into India. It varies from place to place. There are four broad climatic regions based on rainfall. 1. Areas like the west coast lying at the foothills of the Western Ghats, Assam gets the heaviest rainfall, over 200 cm annually. 2. States like Maharashtra, Madhya Pradesh, and Bihar along the Vindhyan mountains receive 100 – 200 cm rainfall. 3. South coastal plains, northwestern Deccan, and the upper Gangetic plain have 50 – 100 cm rainfall. 4. The Rajasthan desert, extending to Kutch, the high Ladakh plateau in Kashmir constituting the arid zone, receives only nominal rainfall of 15 cm annually. Thus, in India, about 30% of the country receives 15 – 80 cm, 40% of the area gets 80 – 120 cm, 20% of the area gets 120 – 200 cm, and only 10% of the area receives over 200 cm of annual rainfall (Murthy *et al*., 1996).

Chapter-2

Review of Literature

2.1. Taxonomy and Floristics

Planchon (1887) proposed the genus *Parthenocissus* in a famous work known as Monographiæ phanerogamarum. He reported seven species of *Parthenocissus*, *P. quinquefolia*, *P. himalayana*, *P. neilgherriensis*, *P. cuspidifera*, *P. semicordata*, *P. anamallayana*, *P. tricuspidata*.

Jelliffe (1899) reported *P. quinquefolia* from Long Island, commonly distributed on the Island, especially over the sands at the western end. Saunders (1899) said the same species was from South Dakota. Lounsberry (1899) narrates the beauty of *P. quinquefolia,* a beautiful vine that climbs using tendrils and rootlets. It accommodates almost every kind of soil, and in the autumn, the leaves change into a brilliant crimson that enhances the beauty of a garden. However, the author suggests that, unfortunately, this species is misidentified as poison ivy, with three leaflets and whitish fruit.

Gattinger (1901) documented two species, *P*. *quinquefolia* and *P. tricuspidata,* in Tennessee flora. Porter (1903) reported *P. quinquefolia* in 'Flora of Pennsylvania.' He mentions two names for this species: Virginia creeper and American ivy. Habitat is confined to woods and thickets.

Rydberg (1906), while dealing with Flora of Colorado, recorded two species of *Parthenocissus* from there, *P. quinquefolia* and *P. laciniata.* The former has aerial rootlets, but the latter lacks them. Nelson (1906) introduced a new combination of *P. laciniata* to contribute to rocky mountain plants.

Bergen (1908) documented three species of *Parthenocissus*: *P. quinquefolia, P. tricuspidata,* and *P. vitacea in* 'Bergen's botany key and flora. Northern and central states,' According to him, these species are woody vines, climbing by tendrils and rootlets. Leaves palmately compound and flowers in compound cymes. Robinson and Fernald (1908) enumerated two species and two varities of *Parthenocissus*, *P. quinquefolia, P. vitacea, P. quinquefolia* var. *hirsuta, P. quinquefolia* var. *saint-paulii*.

During their expedition to China, Sargent (1913) recorded five species and one variety of *Parthenocissus*. The species include *P. henryana, P. thomsonii, P. himalayana, P. landuk, P. tricuspidata, and P. himalayana* var. *rubrifolia*. Two of

these species are new combinations to the genus *Parthenocissus*. They discussed their habits and localities. Kerr (1911) reported one species, *P. semicordata,* in Contribution to the Flora of Siam. Petersen (1911) reported *P. quinquefolia* from Nebraska, like Banner County, Natick, Pine Ridge, and Valentine.

Britton and Brown (1913) described *P. quinquefolia* in 'An Illustrated Flora of the Northern United States, Canada, and the British Possessions. In this work, the *Parthenocissus* genus is differentiated from other genera, having a hypogynous disk and digitately compound leaves. He also gave the name "False Grape" to this species. Harper (1913) describes *P. quinquefolia* as a 'Handsome vine'. He also mentions this plant's economic importance, such as primarily cultivated as an ornamental plant that covers buildings. Then, the bark and shoots show some medicinal properties. Small (1913 a,b) describes one species, *P. quinquefolia,* from Miami and Lancaster County. According to him, *Parthenocissus* is a genus consisting of vines with disk bearing tendrils. In the same year, he documented four species of *Parthenocissus* from the Southeastern United States: *P. quinquefolia, P. hirsutus, P. laciniata, and P. heptaphylla.* He also prepared a key for the identification of these species.

Fyson (1915) in his monumental work 'The Flora of the Nilgiri and Pulney Hill tops', describes *P. neilgherrensis* as climbing shrubs with much branched tendrils and attaching themselves by discs. He also points out that *V. anamalayana,* expressed in volume one, is *P. neilgherrensis*.

Britton and Millspaugh (1918) documented two species of *Parthenocissus*, *P. quinquefolia* and *P. tricuspidata,* in the Flora of Bermuda. *P. quinquefolia* is a typical species in North America. Gamble (1918), a British forester and botanist, reported species in The Flora of the Presidency of Madras. He describes the genus *Parthenocissus* and mentions *P. neilgherrensis,* a vast climber with large leaves.

Bailey (1919) proposed the cultivation of three species of *Parthenocissus*. According to him, *P. quinquefolia and P. vitacea are* propagated by seeds, hardwoods, or layers. However, *P. tricuspidata* and its varieties are propagated only by greenwood cuttings. All these species require humid and good soil for their propagation.

Britton (1920) reported ten species in 'The Bahama Flora', eastern North America and Asia. He also describes the typical species in Bahama, such as *P. quinquefolia*.

Tendrils are numerous with terminal adhering expansions. Clements and Clements (1920) described and illustrated *P. quinquefolia,* Virginia creeper and American ivy. This species separated from the *Vitis* with its key character like leaves with five leaflets. It is a trailing woody vine with adhering disks.

Fitting *et al*., (1921) illustrated *P. tricuspidata* with stem and branched tendrils. According to him, branched tendrils of both *P. tricuspidata* and *P. quinquefolia* bearing attaching disc at their tip help to fasten its attachment to flat surfaces.

House (1924) listed two species of *Parthenocissus* along with one variety. In this work, he mentions the synonyms of these species. The first species, *P. quinquefolia*, is mainly located in a habitat like woods and thickets, most preferably along streams and moist or damp thickets. But in the case of *P. vitacea,* habitat mainly like low or wet thickets. *P. vitacea* differs from the former species by having less branched tendrils without discs, inflorescence showing distinctly cymose corymbs, and leaflets having deeper and sharper serrations. *P. quinquefolia* var. *hirsuta* is the only variety in this work.

Wiegand and Eames (1925) recorded two species and two varieties of *Parthenocissus* from the Cayuga Lake basin in New York: *P. quinquefolia, P. quinquefolia* var. *hirsuta*, *P. vitacea,* and *P. vitacea* var. *dubia*. They prepared genus and species level key considering floral disk, corolla, leaves, and tendrils for easy identification.

House and Alexander (1927) described *P. quinquefolia* from the Allegany state park region. He mentions the habitat variation in this species from the rocky slope to the valleys and streams of the area. McCurdy (1926) enumerated *P. tricuspidata*, commonly known as Boston or Japanese ivy. According to him, this vine is an exciting garden plant that will attract every person, especially in the autumn, because the leaves change into a brilliant crimson colour. He also mentions this ivy's older name, *Ampelopsis veitchii*.

Makins (1937) recorded five *Parthenocissus* species native to the north temperate zone: *P. tricuspidata*, *P*. *quinquefolia*, *P. henryana, P. himalayana, and P. thomsonii.* He discussed the older names of each species and critical characteristics for recognising these species without any previous knowledge.

Rheder (1939) introduced new combinations in the genus *Parthenocissus*, *P. inserta* f. *macrophylla*, *P. inserta* f. *dubia* and *P. inserta* var. *laciniata.* He also lists out all the possible synonyms of these. Fernald (1939) gave critical notes on the species *P. quinquefolia.* He addressed some nomenclatural about this species.

Deam (1940) prepared a key for identifying two species of *Parthenocissus*, *P. quinquefolia* and *P. inserta.* In 'Flora of Indiana', he used multiple characters such as a leaf, tendril, inflorescence, fruit, and seed in this taxonomic key.

Tehon (1942), while working on the 'Fieldbook of native Illinois shrubs', describes two species, *P. quinquefolia* and *P. inserta*. He mentioned that the genus is mainly distributed in eastern North America and Asia. Two species occur in Illinois. He provided the key to the species of *Parthenocissus* based on the character, such as leaves and inflorescence.

Wyman (1944) reported three species of *Parthenocissus*, *P. quinquefolia, P. tricuspidata,* and *P. heptaphylla* in 'Available rapid growing vines in the United States. It is mainly located in Northcentral United States, Central United States, Great Plains, Northwest Pacific Coast, San Francisco, Southern California, Southern Texas, and Southern Florida. The former two species cling to stone or wood by rootlets, and the latter climb by tendrils or twisted leaf stalks.

Gagnepain (1946) described the new species *P. pedata*. He stated that this species is a climbing shrub with five leaflets. Gleason (1947) studied the existence of two names of *P. quinquefolia*. He concluded that *V. inserta* is just a synonym of the species mentioned above and another name, *P. vitacea,* displaced due to the absence of an adhesive disc.

Bailey and Bailey (1949) reported one species, *P. inserta*, commonly known as the thicket creeper. It is a trailing vine with long, branched tendrils. Rehder (1949) documented four species of *Parthenocissus* and their varieties in his work 'Bibliography of cultivated trees and shrubs hardy in the cooler temperate regions of the Northern Hemispheretitle.' *P. inserta, P. inserta* var. *laciniata*, *P. heptaphylla*, *P. quinquefolia, P. quinquefolia* var. *murorum*, *P. quinquefolia* var. *hirsuta*.

Freeman (1953) listed *P. quinquefolia* as one of the plants growing naturally at the National Arboretum of the United States. Chandler (1957) described two new species, *P. britannica* and *P. boveyana*. He addressed the remarks and affinities of these species with other relative species. Based on the distinctive characters, he retained the specific name.

Jones (1963) reported two species of *Parthenocissus*, *P. quinquefolia* and *P. vitacea* in Flora of Illinois. He gave the detailed taxonomic key for identifying these two species considering characters such as leaf, tendril, adhesive tip, inflorescence, fruit, and seed. According to him, palmately compound leaves with five leaflets are the critical characteristics of the *Parthenocissus* genus.

Brizicky (1965) extensively studied the genera of Vitaceae in the Southeastern United States. Based on this modern revision work of the North American species, he stated that *Parthenocissus* is closely related to *Ampelocissus* and *Vitis*. Ohwi (1965) describes one species of *Parthenocissus*, *P. tricuspidata,* in the Flora of Japan. It is a woody vine, widely planted in hedges for covering walls.

Holmgen and Reveal (1966) reported *P. inserta* from the intermountain regions of the United States. They place *P. vitacea* as its synonym.

Raizada (1967) in 'Additions to the Flora of Mussoorie Hills' reported one species, *P. semicordata* var. *semicordata*. He also mentions its difference from *P. semicordata* var. *roylei,* like the hispid nature of young branches, petioles, and nerves on the lower surface of the leaves.

Moul (1973) describes *P. quinquefolia* in the Northeastern United States marine flora. He also made illustration of leaves with five leaflets for easiness of identification.

Eaton (1974) reported two species, *P. quinquefolia* and *P. inserta,* in Flora of Concord. In his work, Siskin and Bobrov (1974) reported three species of *Parthenocissus*: *P. quinquefolia, P. tricuspidata, and P. inserta.* These three species are economically important as ornamentals.

Nair (1977) in his famous work 'Flora of Bashahr Himalayas' recorded two species of *Parthenocissus*, *P. semicordata* var. *semicordata* and *P. semicordata* var. *roylei*.

Gillet and White (1978) recorded *P. vitacea* in the checklist of vascular plants of the Ottawa-Hull region of Canada. Scoggan (1978) reported two species of *Parthenocissus* in Flora of Canada, *P. quinquefolia* and *P. inserta.* He also gave the taxonomic key for the identification of these two species.

Nazimuddin and Qaiser (1983) enumerated three species viz. *P. quinquefolia, P. tricuspidata* and *P. semicordata* from Pakistan. Seymour (1982) prepared a detailed key for identifying the species located in New England based on multiple characteristics such as leaves, pith, inflorescence, and tendrils. *P. quinquefolia, P. tricuspidata, P. vitacea, and P. hirsuta* were documented in Flora of New England.

Mitchell (1986) documented three species of *Parthenocissus*, *P. inserta*, *P. quinquefolia,* and *P. tricuspidata* in A checklist of New York state plants. Singh and Shetty (1986) prepared some Nomenclatural notes on the Vitaceae of the Indian subcontinent; He gave notes on the species *P. thomsonii*. He stated the correct name of the species along with its synonyms.

Manilal (1988) reported *P. neilgherriensis* from the proposed dam site in Silent Valley in his famous work Flora of Silent Valley tropical rain forests of India.

Green (1993) extensively studied the Nature reserves of the Himalayas and the mountains of Central Asia. In this work, he reported *P. himalayana*, commonly known as the Himalayan creeper, from the Sagarmatha National Park and Jiangcun nature reserve.

Mathew (1996) described one species of *Parthenocissus*, *P. neilgherriensis,* in Flora of Palni Hills. According to him, the species is an extensive liana that can see above 1600 m above from sea level. He also mentions specimens examined by him during describing the taxa.

Shetty and Singh (2000) described two Species of *Parthenocissus* along with two varieties, *P. semicordata* var. *semicordata* and *P. semicordata* var. *roylei*. They also mention the cultivated varieties *P*. *quinquefolia* and *P. tricuspidata*. They also provide a key to the species as well as a key to the varieties. Swarupanandan *et al*., (1998) documented a large climber, *P. neilgherriensis,* along the roadsides in Mannavan

shola. He also mentions the three synonyms of this species: *V. neilgherriensis* Wight, *V. himalayana* Brandis, and *V. anamallayana* Bedd.

In Flora of Jammu and Kashmir, Singh *et al*., (2002) reported one species *P. semicordata*. The specimens are collected from Jammu, Baganga, Ardhkumari, Udhampur, Latidhuna, and Kashmir. He also made the illustration of *P. semicordata* for easiness of identification.

Kumar *et al*., (2005) documented 'Flora of Pathanamthitta', which belongs to the Western ghats region of Kerala state. He also describes *P. neilgherriensis* from this area. Daniel *et al*., (2005) reported one species, *P. semicordata* var. *roylei,* in the book 'Flora of Kerala'. He also mentions the economic importance of the species. The wood is used for making picture frames, as it is a liana. The young wine is used as rope for tying bundles of grass. Leaves are taken as fodder, and fruit is also edible.

Chen *et al*., (2007) contributed the Vitaceae in monumental works such as Flora of China. He enumerated nine species of *Parthenocissus*. Among them, six were endemic to China, and one species was introduced. *P. feddei*, *P. semicordata*, *P. chinensis*, *P. tricuspidata*, *P. suberosa*, *P. dalzieii*, *P. laetevirens*, *P. henryana*, *P. quinquefolia*. He also reported one variety, *P. henryana* var. *hirsuta*. Among these, *P. tricuspidata* and *P. quinquefolia* are ornamental climbers in this genus. The taxonomic key provided by him mentions multiple characters for easy identification. He used characters such as leaf shape, leaf surface, tendril tip, inflorescence type, and stem structure to discriminate the species.

Wen *et al*., (2013) documented eight species viz. *P. chinensis, P. dalzielii, P. henryana*, *P. laetevirens, P. quinquefolia, P. suberosa, P. tricuspidata,* and *P. vitacea* based on the collection housed in US (United States National Herbarium, Washington, D.C).

Fatma (2016) extensively studied the phytogeographical distribution of Indian Vitaceae. She documented the occurrence of *P. semicordata* var. *semicordata*, *P. semicordata* var. *roylei*, *P. thomsonii*, *P. quinquefolia*, and *P. tricuspidata*. She concluded that *Parthenocissus* is mainly restricted to the mountainous regions of the temperate zone.

Trias Blasi *et al*., (2017) reported one species from Nepal in the 'Flora of Nepal' *P. semicordata*. The species are mainly distributed in the eastern and western Himalayas and the Tibetan plateau. She also mentioned that *Parthenocissus* and *Yua* are more closely related. In the same year, she carried out the lectotypifications, neotypifications, epitypifications, and nomenclatural corrections of some Vitaceae species in the Asian continent. She designated the isotype and isolectotype of *P. semicordata* in this work.

Anto *et al*., (2018) described a new species, *P. renukae,* from the Thrissur district of Kerala state. Wen *et al*., (2018) documented two species, *P. tricuspidata* and *P. vitacea,* as part of integrative systematic studies. He used the voucher specimen housed at the US herbarium and gave Genbank accession numbers and the DNA sequence used in this study.

Pramanick *et al*., (2020) documented three species and one variety from India, *P. renukae, P. semicordata*, *P. thomsonii,* and *P. semicordata* var. *roylei*.

2.2. Morphological studies

Ckitchfield (1970) studied the shoot growth and leaf dimorphism in *P. tricuspidata*. He proposed that these species produce two types of leaves during their growing season. Through this study, he concluded that *P. tricuspidata* resembles several tree species because of its seasonal type leaf dimorphism and shoot system with long and short shoots.

Morphological and anatomical studies in some selected species of Vitaceae, such as *V. riparia*, *P. inserta*, *A. brevipedunculata,* and *Cissus antarctica,* were extensively studied by Gerrath *et al.*, (1988,1994,1998). They also studied the vegetative and floral development of some species like *P. inserta* and *A. brevipedunculata*. Based on their study, tendril growth of *P. inserta* is sympodial and develops an adhesive disc at each tip, but tips may disintegrate. They observed two types of shoot architecture in the *Parthenocissus*, interrupted axillary buds at two or three nodes in *P. inserta* and interrupted axillary buds at one of three nodes in *P. tricuspidata*.

Gerrath *et al.*, (2001) reported the primary vascular patterns in the Vitaceae. They classified the Vitaceous shoot into five distinct architectural designs based on a three

node sequence of tendril and axillary bud presence. In this work, he concluded that the number of leaf traces in fertile shoots of *P. quinquefolia* was reduced to two. In the case of *P. tricuspidata* stipule, vascular bundles are derived from foliar traces.

Yim and Kim (2002) observed that at the early development of aerial root tissue of *Parthenocissus* filled with electron dense substances, their distribution varied within the tissue. This study suggested the capability of electron dense substances for the attachment of the plant.

Novel variation in the floral development of two species of *Parthenocissus* was done by Wilson and Posluszny (2003b). This study compares the development of the two species of *Parthenocissus* such as *P. quinquefolia* and *P. tricuspidata.* The calyx is cup like in *P. quinquefolia* and ring like in *P. tricuspidata.* He also noted that the *P. tricuspidata* flower develops a strong gynoecial disc and stigma.

Soejima and Wen (2006) reported that the *Parthenocissus* floral disk is not morphologically recognisable but produces some amount of nectar. Gerrath and Posluszny (2007) examine the shoot architectural patterns of Vitaceae. They found five shoot architectural patterns in the family and concluded that the monopodial pattern present in most species today is derived and unique to the Vitaceae. He also studied the shoot architectural patterns of three species of *Parthenocissus*: *P. quinquefolia, P. tricuspidata,* and *P. inserta.* He says the bud at the tendril less node will be the largest. Timmons *et al*., (2007) supported the presence of outgrowths or knobs at the tip of tendrils of *P. quinquefolia,* but they failed to explain its function.

Najmaddin (2014) compared leaf anatomy and palynological differences among selected *V. vinifera* and *P. quinquefolia* cultivars. Based on this study, leaf epidermal cells of *P. quinquefolia* were polygonal or irregular. The stomatal apparatus is mainly located in the abaxial epidermis. The stomata type is anomocytic. Ickert-Bond *et al*., (2014) studied the gynoecial structure of Vitales, and they revealed that the gynoecial disk in the *Parthenocissus* genus is almost indistinct from the ovary then through various degrees of lobing, it forms a complete ring.

Dang *et al*., (2016) compared the genus *Parthenocissus* with its closely related species *Yua* based on the collection housed in different herbaria (A, CDBI, HN, IBK, K,

KUN, P, PE, and VNM). He used the characters such as old stems, tendrils, leaves, inflorescence, and seeds.

Zafar *et al*., (2020) studied the foliar micromorphology of two species, *P*. *semicordata* and *P. tricuspidata*. Their study found that two types of stomata, paracytic and anomocytic, with elliptical guard cells, occur in these species. They also studied the quantitative parameters of stomata, guard cells, and subsidiary cells. Both qualitative and quantitative helped in the identification of taxa.

2.2.1. Tendril morphology

Millington (1966) observed that the tendril of *P. inserta* is lateral in origin and develops from meristematic cells on the flank of the shoot apex. Shah and Dave (1970) studied the tendrils' origin and development of the tendrils in 16 species of Vitaceae species. He investigated four species of *Parthenocissus* in this work, such as *P. inserta*, *P. tricuspidata*, *P. quinquefolia,* and one other species. He found that the tendril is an extra axillary branch.

Ultrastructural and Cytochemical studies on the developing adhesive disc of Boston ivy tendrils Endress and Thomson (1976,1977) showed that peripheral cells contain varied vacuoles filled with electron dense aggregates. Insoluble carbohydrates also occur in these vacuoles but contain no protein or lipid. He carried out the electron microscopic examination of the tendrils of Boston Ivy (*P. tricuspidata*), revealing that adhesive secretion occurs from the peripheral cells at the contact face of the discs. They also conclude that adhesive is a mucopolysaccharide. Junker (1976) reported a scanning electron microscopic study on the surface of developing tendrils of *P. tricuspidata*. Epidermal cells of mature branchlets are densely covered with minute corrugations called microplicae.

Wilson and Posluszny (2003a) studied the complex tendril branching in two species of *Parthenocissus, P. quinquefolia* and *P. tricuspidata*. Tendril development in the *Parthenocissus* genus can be demonstrated as sympodial.

Kim and Kim (2007) examined the epidermal changes of adhesive disks of *P. tricuspidata* at the time of attachment to the substrate. He found that the upper and lower epidermis deteriorate due to electron dense substances release.

Bowling and Vaughn (2008) did structural and immunocytochemical characterisation of the adhesive tendril of *P. quinquefolia*, known as Virginia creeper. The adhesive appears as a highly heterogeneous, raftlike structure and consists of pectinaceous, rhamnogalacturonan (RG) I-reactive components surrounding a callosic core. Deng (2008) studied the superadhesive properties of *P. tricuspidata and* measured the average mass of a single mature adhesive disk. He proposed that *P. tricuspidata* has evolved as a versatile plant that can stick to different types of surfaces.

He *et al*., (2010, 2011) conducted experimental studies on the morphology and mechanics of the adhesive disc of liana *P. tricuspidata* and revealed that it has super adhesive properties. They proposed a new hypothesis and model to elucidate the mechanism of adhesion. They also propose a new theory through this study. He proposed a two stage model of biological adhesion in *P. tricuspidata.* The first is structural contact, and the second is adhesive action.

Morphology and ontogenetic changes of attachment pads in the *P. tricuspidata* during the attachment process investigated by Steinbrecher *et al*., (2011). They observed that cell size, cell orientation, and grade of lignification vary over the pad cross section typical to the interface. Based on SEM and X-ray spectroscopy, Lee and Kim (2011) confirmed that the adhesive disks of *P. tricuspidata* adhered to the substrate surface by secreting adhesive materials.

Structural changes of adhesive discs during attachment of Boston ivy (*P. tricuspidata*) were investigated by Kim (2014). According to his findings, four phases of attachment are suggested for its climbing behaviour.

2.2.2. Pollen morphology

Perveen and Qaiser (2008) documented details of the pollen morphology of six species of the family Vitaceae using Light microscopy (LM) and Scanning Electron Microscopy (SEM). The result showed that pollen grains are mostly radially symmetrical, isopolar, and tricolporate. They described pollen grains of *P. semicordata* var. *roylei* as prolate.

The use of both Light microscopy (LM) and Scanning Electron Microscopy (SEM) to investigate surface view and exine ornamentation was used by Najmaddin (2014) to

study the pollen of *P. quinquefolia* and *V. vinifera* found that pollen grains range from tricolpate prolate-spheroidal to spheroidal and exine ornamentation are reticulate to micro reticulate.

2.2.3. Seed morphology

Brizicky (1965) compared the seeds of the Vitaceae family. The comparison reveals that in the seeds of *P. quinquefolia* adaxial surface shows variation in raphe and grooves. The fruit is slightly poisonous.

Tiffney and Barghoorn (1976) investigated the fruits and seeds of Brandon lignite with consideration of the Vitaceae deposit. The study reveals that seeds borne two to the berry often have one flattened, common in the *Parthenocissus* genus.

Chen (2009), while working on their PhD thesis on 'History of Vitaceae Inferred from morphology based Phylogeny and the fossil record of Seeds.' He enumerated the features of *Parthenocissus* seeds. They are typically long and divergent ventral infolds with a deep, sharp apical notch. He also found that *P. heptaphylla* is the only sampled seed with endotesta of regular thickness. Seed morphological study based on the shape and position of ventral infolds and chalaza, the shape of ventral infold cavities, and testa anatomy of some genera of Vitaceae conducted by Chen and Manchester (2011). They reported that *Parthenocissus* seeds have long and divergent ventral infolds and a deep and sharp apical notch compared to other species.

A detailed study on the seed morphology of six species of *Parthenocissus* and ten species of *Ampelopsis* was carried out by Latiff (2012). Their results showed that the external morphology of both species is variable in size, shape, and other notable features. He added that contrary to other species, Malaysian species of the genus mentioned above could be differentiated by seed size. He also provided a generic key based on seed morphology.

Seed morphology of Vitaceae based on morphometric methods was performed by Martín-Gómez *et al*., (2020). They found that in *P. tricuspidata,* the number of seeds varies from one to three, and the difference in seed shape is based on the number of seeds per fruit. Cervantes *et al*., (2021) reviewed the seed geometry in Vitaceae. They described ten morphological types, of which seven were general, and three were

specific. He stated that seeds of *Parthenocissus* show typical shapes of water drops and heart curves, the squared heart curve.

2.3. Molecular phylogeny

Lodhi and Reisch (1995) estimated the nuclear DNA content in *Vitis* species and some genera of Vitaceae using the flow cytometry technique. They revealed that genotypes of both *Vitis* and *Parthenocissus* were similar in nuclear DNA content. This study disagreed with the finding of Shetty (1959) that the chromosome of *Parthenocissus* is more significant than those of *Vitis*. Di gaspero *et al*., (2000) investigated the conservation of microsatellite loci within the 14 species of the genus *Vitis* and one species, *P. quinquefolia,* as its related genus. Based on the investigation, they proposed that speciation in the family Vitaceae has occurred recently.

Ingrouille *et al*., (2002) conducted molecular phylogeny of 20 species of Vitaceae based on plastid *rbcL* DNA sequences. They compared these species ontogeny, floral and vegetative morphology with the phylogenetic tree produced. The *rbcL* tree links showed that *Vitis* is closely related to *Parthenocissus*. The morphological features like elongated bud form and hooded petals proved the similarity between these two species. They concluded that *Vitis* is paraphyletic to *Parthenocissus* and is closely related.

Soejima and Wen (2006) conducted a phylogenetic analysis of 12 genera and 79 species of Vitaceae based on three chloroplast markers. The species were sequenced for the *trnL-F* spacer, *atpB-rbcL* spacer, and the rps16 intron. They concluded that *Parthenocissus* and *Ampelocissus* demonstrate an Asian new world disjunct distribution. Through phylogenetic analysis, they found that *Parthenocissus* forms a clade with one species of *Yua*. It suggested that there is a close relationship between these two genera.

Concerning the molecular phylogeny of Vitaceae, Wen *et al*., (2007) studied the phylogenetic position of *Parthenocissus*. They used 105 nuclear GAI1 sequences for the phylogenetic analysis. The phylogenetic tree showed that *Parthenocissus* was included in the first significant clade. The result proved the monophyly and sister relationships between *Parthenocissus* and *Yua*. However, the results reported that *Vitis* paraphyletic with *Parthenocissus,* but this relationship has no bootstrap support.

Nie *et al*., (2010) conducted a detailed phylogenetic analysis of the *Parthenocissus* genus. Also, they investigated its s intercontinental disjunction between Asia and North America using parsimony, likelihood, and Bayesian inference. The phylogenetic analysis was mainly based on plastid such as *trnL-F*, rps16, and *atpB-rbcL* and nuclear GAI1 sequences of 12 *Parthenocissus* species. The result showed that *Parthenocissus* is monophyletic, and *Yua* is its sister group. They recognised two major clades within the *Parthenocissus* genus. They concluded that the inter-continental distribution estimated early in the Miocene period and leaflet numbers in the *Parthenocissus* genus could not be used for infrageneric classification. Ren *et al*., (2011) studied the evolution of the Vitaceae using three noncoding plastid markers: *trnC-petN*, *trnH-psbA*, and *trnL-F*. They reported five major clades in the family, i.e., the Ampelocissus-Vitis-Nothocissus-Pterisanthes clade, the *Parthenocissus*-*Yua* clade, the core Cissus clade, the Cayratia-Cyphostemma-Tetrastigma clade, and the Ampelopsis-Rhoicissus-Clematicissus clade. They provided a generic relationship within the grape family. The study concluded that *Parthenocissus* and *Yua* are well-supported and closely related to *Vitis*.

Trias Blasi *et al*., (2012) conducted a phylogenetic analysis of 34 species of Vitaceae using parsimony and the Bayesian method. Phylogenetic trees were estimated using four plastid sequences since regions such as *trnL* intron, *trnL-trnF* space, *atpB-rbcL* spacer, and rps16 intron. The outcome showed that the North American species *P. quinquefolia* formed a strongly supported clade with the Asian species *P. tricuspidata*. This study gave light on the fact that disjunct distribution of *Parthenocissus* in Asia and North America. But the result unresolved the position of *Parthenocissus* about other Vitaceae members. They also suggested that species of both *Parthenocissus* and *Yua* could be congeneric. Recently Lu *et al.*, (2012) published a combined morphological and molecular phylogenetic analysis of the *Parthenocissus* genus based on 27 morphological and 4137 molecular characters throughout the genus. They explored the inflorescence structure, calyx morphology, appendages on the inner side of petals, leaf epidermis, pollen, and seed characters of species through Asia and North America. Through the combined analysis, they recognised clades within the genus *Parthenocissus* according to their distribution.

Zhang *et al*., (2015) reconstructed the phylogeny of Vitaceae using plastomes and mitochondrial genes. Detailed phylogenetic analyses were conducted using maximum likelihood and the Bayesian method. They identified five major monophyletic clades: the *Ampelopsis-Rhoicissus* clade, the *Cissus* clade, the *Cayratia-Cyphostemma-Tetrastigma* clade, the *Parthenocissus-Yua* clade, the *Vitis-Ampelocissus* clade.

The study on genome size variation and genome evolution in four significant tribes of Vitaceae was carried out by Chu *et al*., (2018). Tribes include Ampelopseae, Parthenocisseae, Viteae, and Cisseae. They used flow cytometry for genome size calculation, five plastids, and one nuclear sequence for phylogenetic analysis. The result showed that *Parthenocissus* generally have a diploid number of chromosomes and has genome size (mean 1C-value) varying from 0.41 pg – 0.93 pg. They revealed the exciting fact that *Parthenocissus* species with simple or trifoliate leaves have smaller genome size than the others with five leaflets. Lu *et al*., (2018) critically studied recent advances in systematics and the evolution of the family Vitaceae. He stated that Parthenocisseae was one of the five major clades based on Phylogenetic studies. He also revealed that most species have comparatively small genomes.

Chapter-3

Materials and Methods

3.1. Literature survey

The relevant literature and information regarding the taxa under investigation were collected from various resources, including institution libraries and electronic information retrieving systems like JSTOR, Elsevier, Science Direct, Wiley, Springer Link, Shodhganga, etc. Literature from institutional libraries was accessed directly or by personal communication. Some crucial old literature was accessed from online literature retrieval systems of the New York Botanical Garden (http://www.biodiversity heritage library.org), Missouri Botanical Garden Libraries (http://www.botanicus.org and http://www.tropicos.org), and Wallich catalogue details (http://Wallich.rbge.info) of Royal Botanic Garden, Edinburgh, Fairchild Tropical Botanical Garden Virtual herbarium, etc. were also utilised.

3.2. Specimen collection

Extensive field explorations were conducted throughout the forest and non forest areas of Kerala, India, to collect *Parthenocissus* members and the fertile specimens were collected from these areas during 2017–2022. Both inflorescence and vegetative parts of the members were collected. Took photographs of the plant using a Canon Eos R digital camera. Noted the field observations, such as habit, habitat, nature of leaves, colour, the shape of the flowers, etc., in the field book. Different parts of the collected specimens were preserved in a Formalin-Acetic-Alcohol (FAA) mixture for further laboratory studies and for preparing illustrations.

3.3. Herbarium preparation

Plant materials with vegetative and reproductive parts were dried using a herbarium drying cabinet and pressed in a herbarium press. The dried specimens were mounted on standard herbarium sheets (28 x 42 cm) and labelled using standard herbarium labels (14.5 × 11 cm), with information such as scientific name, family, altitude, date of collection, field notes, and name of the collector. All specimens collected were fumigated and deposited in the St. Thomas College herbarium (STC).

3.4. Descriptions and photo plates

The collected specimens have been studied in the laboratory using a Leica stereo microscope. Floral characters of the genus are microscopic and prepare a detailed taxonomic description of each species. Microscopic photographs of dissected plant materials were taken using a camera attached to a Leica S8PO Stereo microscope. Photo plates of each species were prepared, including photographs of Habit, Inflorescence, Tendril, Flower, Petal, Stamen, and Fruit. Micro-tip pens (Rotring Variant) equipped with 0.1 and 0.2 points were used to prepare illustrations.

3.5. Identification, nomenclature, and citations

Identifications of each species were made with the help of relevant literature, including regional floras, revisions, etc. Specimens housed at Botanical Survey of India, Southern Regional Centre, Coimbatore (MH), Calicut University Herbarium, Malappuram (CALI), Kerala Forest Research Institute Herbarium, Peechi (KFRI), Jawaharlal Nehru Tropical Botanical Garden and Research Institute herbarium, Trivandrum (TBGT), St. Thomas College Herbarium (STC) were studied. The digital images of types obtained from A, BM, K, L and virtual herbaria were also consulted. Acronyms of herbaria are cited in accordance with the Index Herbariorum (Thiers, 2018). The plant names were corrected by consultation with authentic websites like IPNI (http://www.ipni.org), The Plant List (http://www.theplantlist.org), Tropicos (http://www.tropicos.org), etc. The nomenclature of each species was updated as per the Shenzhen Code (Turland *et al*., 2018). Author citations followed Brummitt and Powell (1992). For the description of taxa, the terminology followed Simpson (2010).

3.6. Presentation of data

The systematic part begins with the systematic position of the genera, followed by genera characters, the key to the species, present name of the species, citation, type, synonym, detailed taxonomic characters, flowering and fruiting, habitat and distribution. The species are presented in alphabetic sequence. All specimens studied were cited under specimens examined. The details of specimens examined are given in the following sequence: state, district, and collection locality, date of collection, collector/collector name and collection number, and an acronym of the depository.

3.7. Species distribution map

The localities of occurrence of each species were obtained from field trips and specimens housed at various herbariums. Live specimens' data were recorded using GPS navigators (Garmin GPS etrex10). Other data were geo referenced from herbarium vouchers. Distribution records were imported into QGIS Desktop 3.22.12 (QGIS development team 2022) to create species distribution maps of each species.

3.8. Micromorphology

Light microscopic views of the pollen structure and stomata were observed under a Binocular BIOMED Research Microscope using 40 X. Photographs of the sections were taken using a digital camera, and measurements were taken using image j software (Rasband, 2018).

3.8.1. Palynology and Seed coat morphology

Scanning Electron Micrographs of *Parthenocissus* has been done to document the micromorphology of Pollen grains and seeds. Dried seeds and alcohol soaked pollen grains were taken to study the surface ornamentation. A small quantity of the sample was smeared over the multisided adhesive carbon tape fixed on specimen stubs and was over coated with gold using JFC 1600. This ion sputtering device performs rapid and efficient gold coating on the microscopic specimen, allowing surface visualisation using JEOL, JSM—6390LV, Tokyo, Japan. The SEM measurements were performed at 15 kV accelerating voltage, and digital electrophotomicrographs were obtained. SEM of both pollen and seeds was taken at STIC, Cochin University, Kerala. The terminology of Erdtman (1952) was used to describe the pollen grains. Descriptive terminology of seeds followed the Tiffney & Barghoorn (1976), Tiffney (1979) and Chen and Manchester (2007).

3.9. Molecular phylogenetic analysis

3.9.1. Genomic DNA extraction

The Genomic DNA was extracted from silica dried leaf samples of the specimen using the QIAGEN DNeasy Plant Mini Kit following the manufacturer's protocol

(Qiagen, Germany) as well as the CTAB (Cetyl Trimethyl Ammonium Bromide) method of Doyle and Doyle (1987) with slight modifications.

3.9.2. Modified CTAB method

For preparing 2.5 ml of CTAB solution, 0.05 gm of CTAB powder was weighed using an electric weighing balance and added to a 250 ml beaker. Calibrated micropipettes were used to pipette the required chemical solutions and added to the beaker containing CTAB. 350 µl of 0.7 M (molar) Sodium chloride (NaCl) solution, 250 µl of 0.05 M Ethylene Diamine Tetra Acetic acid (EDTA) and 250 µl of Tris hydrochloric acid.

For the DNA isolation, we preheat the CTAB buffer at 65°C prior to the grinding. We weighed 200 mg of silica dried leaf samples, and the leaf tissue was weighed with liquid nitrogen in chilled mortar and pestle to a fine powder. The 1ml of preheated (65°C) CTAB mix was added and mixed to get a homogenate. The homogenate was then transferred into a sterile centrifuge tube, and 10 µl of RNase A was added, mixed by inverted shaking and incubated at 37°C for 30 minutes with inverted shaking every minute. The tube was then allowed to cool at room temperature for 4 – 5 minutes. The aqueous layer was collected, and an equal amount of Chloroform: Isoamyl alcohol (24:1) was mixed by inversion and centrifuged at 5000 rpm for 10 minutes. The aqueous layer was collected, and again added an equal amount of Chloroform: Isoamyl alcohol was mixed by inversion. After successive centrifugation, the supernatant was collected and doubled the volume of ice cold ethanol. After some centrifugation steps at 5000 rpm for 10 minutes, the Ethanol was decanted, and the tube was air dried for about 10 minutes. After the tube was wholly dried, the DNA was dissolved in 50 µl of autoclaved water and then stored in a deep freezer.

3.9.3. Agarose gel electrophoresis

The extracted DNA was qualitatively analysed using 1% agarose electrophoresis and quantified using a Nanodrop spectrophotometer (Thermo Fisher Scientific, USA) at 260 nm. For preparing 1% agarose gel, 1.5 g of agarose was weighed and added to a clean conical flask. 80 ml of 5x Tris Borate EDTA (TBE) buffer was added to it and mixed well. The solution was then heated in a microwave oven to dissolve all the particles to get a clear solution completely. The conical flask was then allowed to cool

at room temperature until it reached a bearable heat. 1µl of Ethidium Bromide (EtBr) solution was added to the agarose solution contained in the beaker using a micropipette and mixed thoroughly. The above solution was added to a previously cleaned gel casting tray with a comb placed on one side along one side of the tray without forming bubbles. It was kept undisturbed to solidify the gel, and the comb was removed to form wells. 5 µl of isolated DNA was then loaded into the wells. The gel box was adjusted to 80V, 400-ampere current and ran for 15 minutes.

3.9.4. Polymerase chain reaction

Polymerase chain reaction (PCR) was performed to amplify the plastid genome's *rbcL* (coding region). Amplifications were done using the CBOL plant working group (2009) recommended universal primer for the rbcL region. A BIO-RAD T20 thermal cycler was used to amplify the target fragments consistently. The annealing temperatures of each primer were at 50°C. The PCR products were resolved on 2 % agarose gel and documented using the gel documentation system (BIO-RAD). Then, the products were purified with a Nucleosieve gel extraction and PCR purification kit (Primordia Lifesciences Pvt. Ltd.). Cycle Big Dye Terminator cycle sequencing chemistry (Scigenom, Cochin) was used to carry out the cycle sequencing reactions.

3.9.5. Phylogenetic analysis

The chromatogram of the barcode regions *rbcL* gave quality reads. The sequence alignment was done using Clustal w with default parameters (Larkin *et al*., 2007). For getting the sequence identity, BLAST analysis was carried out, and the sequences were submitted to NCBI GenBank (http://www. ncbi.nlm.nih.gov/genbank). The evolutionary history was inferred using the Maximum Likelihood method using MEGA 6, (Tamura *et al.*, 2013). Kimura 2 parameter model (Kimura, 1980) was the best fit model for the *rbcL* gene.

Chapter-4

Results

4.1. SYSTEMATIC TREATMENT

Bentham and Hooker System of Classification

Kingdom	: Plantae
Division	: Magnoliophyta
Class	: Magnoliopsida
Order	: Rhamnales
Family	: Vitaceae
Genus	: *Parthenocissus*

APG IV System of Classification

Kingdom	: Plantae
Clade	: Tracheophytes
Clade	: Angiosperms
Clade	: Eudicots
Clade	: Rosids
Order	: Vitales
Family	: Vitaceae
Genus	: *Parthenocissus*

Parthenocissus Planchon.

Planch, in A. DC. Monogr. Phaner. V, 2 (1887) 446. Psedera Necker. Elem. Bot. I (1790) 158. Ampelopsis L. C. Rich, in Michx. Fl. bor. amer. I (1803) 159, p. p. Quinaria Raf. Amer. Man. of Grap. Vin. (1830) 6, non Lour.

Woody vines are climbing or trailing by tendrils and rootlets, deciduous, rarely evergreen. Young stems are villous to glabrous, and old ones contain rough and furrowed lenticellate. The branchlets have white pith. Tendrils intermittent monochasial 4 – 12 branched, leaf opposed, never associated with the inflorescence, each branch ending with an adhesive disc. Leaves simple, alternate, or palmately compound, long petioled, leaflets medium sized to large, coarsely toothed, subsessile to long petiolulate. Inflorescence usually involves many flowered, cymose panicles with prolonged monochasial branched rachises or crowded into a terminal panicle.

Flowers in tendril free inflorescences in axils or opposite leaves. Flowers bisexual, or the outer bisexual, then actually some of them functionally staminate, tetra or pentamerous, small. Calyx small, cupular, pedicelled, shallowly irregularly 5 lobed. Petals 4 or 5, concave, thickish, spreading in flowering, very rarely connate at the summit, falling after flowering like a cap, cucullate with bifid appendage. Stamens 4 or 5 were inserted under the disk. The nectariferous disc is usually obscure, fused with the ovary base, not definite at the margin, but readily distinguishable from the ovary by darker colour, secretion of nectar, and anatomical structure. Style narrowly conical, short, Stigma simple, short, sub capitate to inconspicuous. Ovary 2 locular, the septa meeting in the centre and not or weakly connate. Ovary gradually tapering to a short, thick style. Berries subglobular, 5 – 10 mm in diameter, dark blue to black, often glaucous, 1 – 4 seeded, globose. Seed obovate to obovate suborbicular in outline, convex on the abaxial, angular, keeled on the adaxial side, chalazal note round to short spatulate, situated in or above the centre of the abaxial surface, extended to the seed apex into a linear salient raphe inconspicuous and thread like on the adaxial side, two adaxial grooves narrow, crack like, slightly curved, extending nearly from apex to base of the seed.

Key to the Species

1a. Leaves simple ……....2

1b. Leaves compound…….…….5

2a. Leaf margins entire to slightly serrate ……..…….……...3

2b. Leaf margins angled or lobed……....4

3a Petals with T shaped hairs……...……*P. renukae*

3b. Petals glabrescent …….……*P. sasii*

4a. Tendril with ball shaped adhesive pad……..*P. tricuspidata*

4b. Tendril with ring shaped adhesive pad…….…*P. subferruginea*

5a. Flowers pentamerous…….…6

5b. Flowers tetramerous ……...*P. wallichianus*

6a. Tendrils with monochasial branching……...*P. quinquefolia*

6b. Tendrils with dichasial branching……7

7a. Young branches, petioles, hispid…….... .*P. semicordata* var. *semicordata*

7b. Young branches, petioles glabrous.....*P.semicordata* var.*roylei*

1. *Parthenocissus renukae* Anto & Pradeep. in Taiwania 63(2):139 –142. 2018.

Type: India, Kerala, Thrissur district, Mangad, 1 April 2016, *P.V. Anto 125* (Holotype-CALI! Isotype-MH! CAL! STC!). **Plate 01; Fig. 01 & 02**

Woody climber, 50 m height, stems and branches nodose, lenticellate, young branches and tendrils, brownish rose, soft hairy. Tendrils leaf opposed, 8 branched, tips of tendrils modified to fist like attaching pads. Leaf blades deeply cordate bristle serrate, leathery, and ferruginous when young, 5 ribbed, acuminate, 9 –18 × 9 –18 cm, lateral veins 3 – 5 pairs. Petiole up to 8 cm long, reddish brown at tips. Stipules oblong, hairy, two at the base, internodes 11 cm long. Inflorescence leaf opposed, short, branched, hairy, umbellate. Flowers drooping, regular, tetra or pentamerous, disc yellow, prominent, pedicellate; pedicels 0.5 cm long; calyx cupulate; 4 or 5 sub lobed below the disc, 0.12 cm. Petals 4 or 5, 2.5 × 2 mm, hairy, caducous, reddish, tip yellowish red, hooded tip 0.25 cm long, soft yellowish red inside. Hairs drooping tomentose, T shaped, one side flat. Stamens 4 or 5, 2.5 mm long, antipetalous; anthers 0.8 × 0.8 mm, dithecous, yellowish, attached to the base of the disc; filaments subulate, 2 mm long Disc yellowish, 4 or 5 lobed, densely pubescent with soft white hairs. Ovary ovoid, sunk in the disc; style short, 0.8 mm long, thick, stigma, capitate. Fruit obovate, berry, and seeds 2.

Flowering and fruiting: April–May.

Habitat: Moist deciduous forest.

Distribution: Thrissur, Palakkad.

Specimens examined: **Kerala**, Palakkad district, Mundur, 19.10.2018, *Nimmi & Anto 135* (STC); Kulappully, 10.03.2020, *Nimmi & Anto 150* (STC). Thrissur district, Mangad, 1.04.2018, *Nimmi & Anto 02859* (STC);Vellarakkad, 22.10.2018, *Nimmi & Anto 136* (STC); Peruvanmala, 15.02.2019, *Nimmi & Anto 142* (STC).

2. *Parthenocissus semicordata* (Wallich) Planchon in DC., Monogr. Phan. 5:451. 1887. *V. semicordata* Wallich in Roxb., Fl. Ind. 2: 481. 1824. *A. himalayana* Royle, Illustr. Himal. Bot. 149. 1839. *V. neilgherriensis* Wight, Ic. Pl. Ind. Orient. 3: t. 965. 1845. *V. anamalayana* Beddome in Trans. Linn. Soc. 25: 213. 1865; M. Lawson in Fl. Brit. India 1: 656. 1875. *V. himalayana* (Royle) Brandis, For. Fl. 100. 1874; M. Lawson in Fl. Brit. India 1: 655. 1875. *P. himalayana* (Royle) Planchon in DC., Monogr. Phan. 5:450. 1887. *P. cuspidifera* Planchon in DC., Monogr. Phan. 5:451.

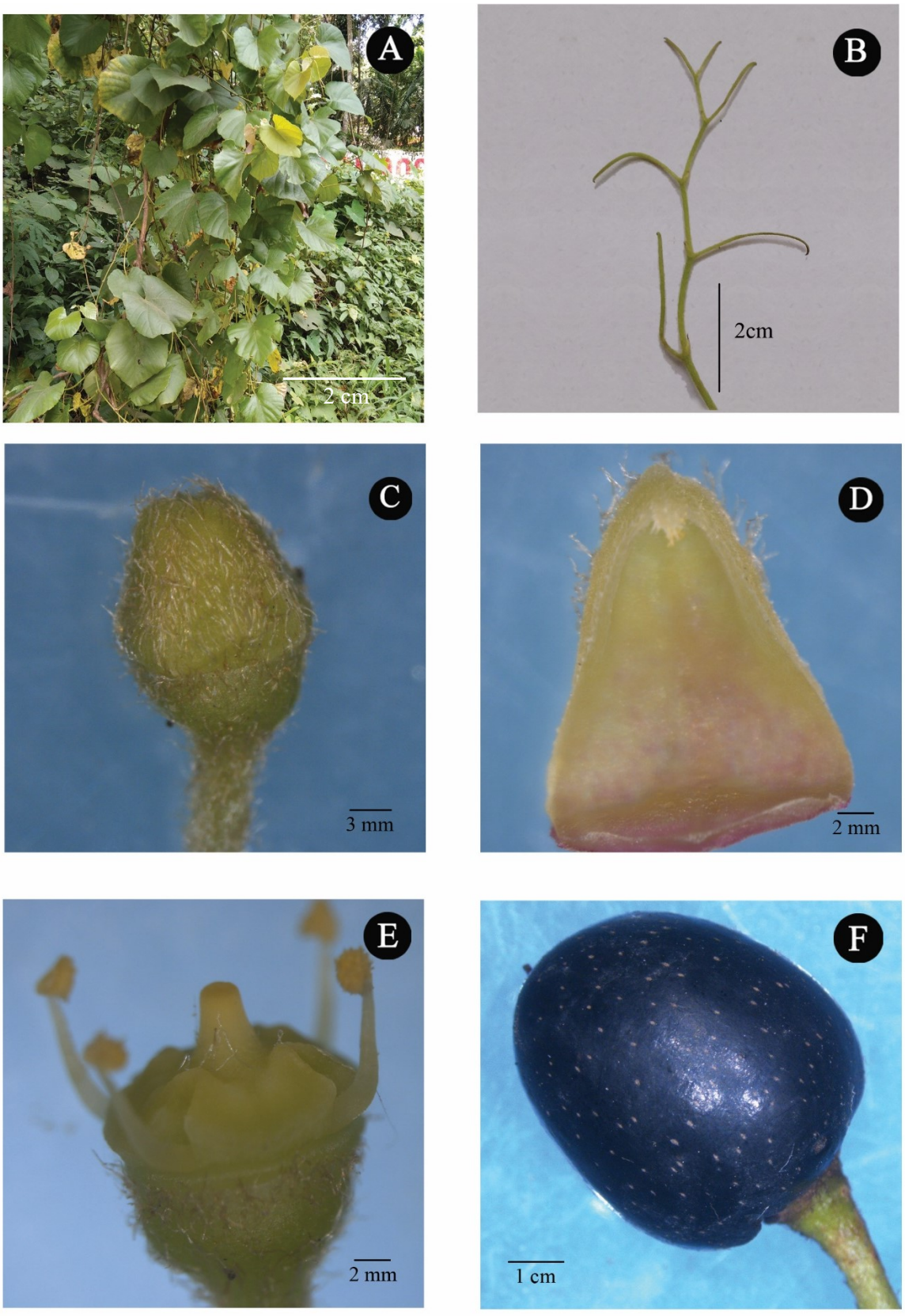

Plate 01. *Parthenocissus renukae*. **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Flower bud dissected; **F.** Fruit.

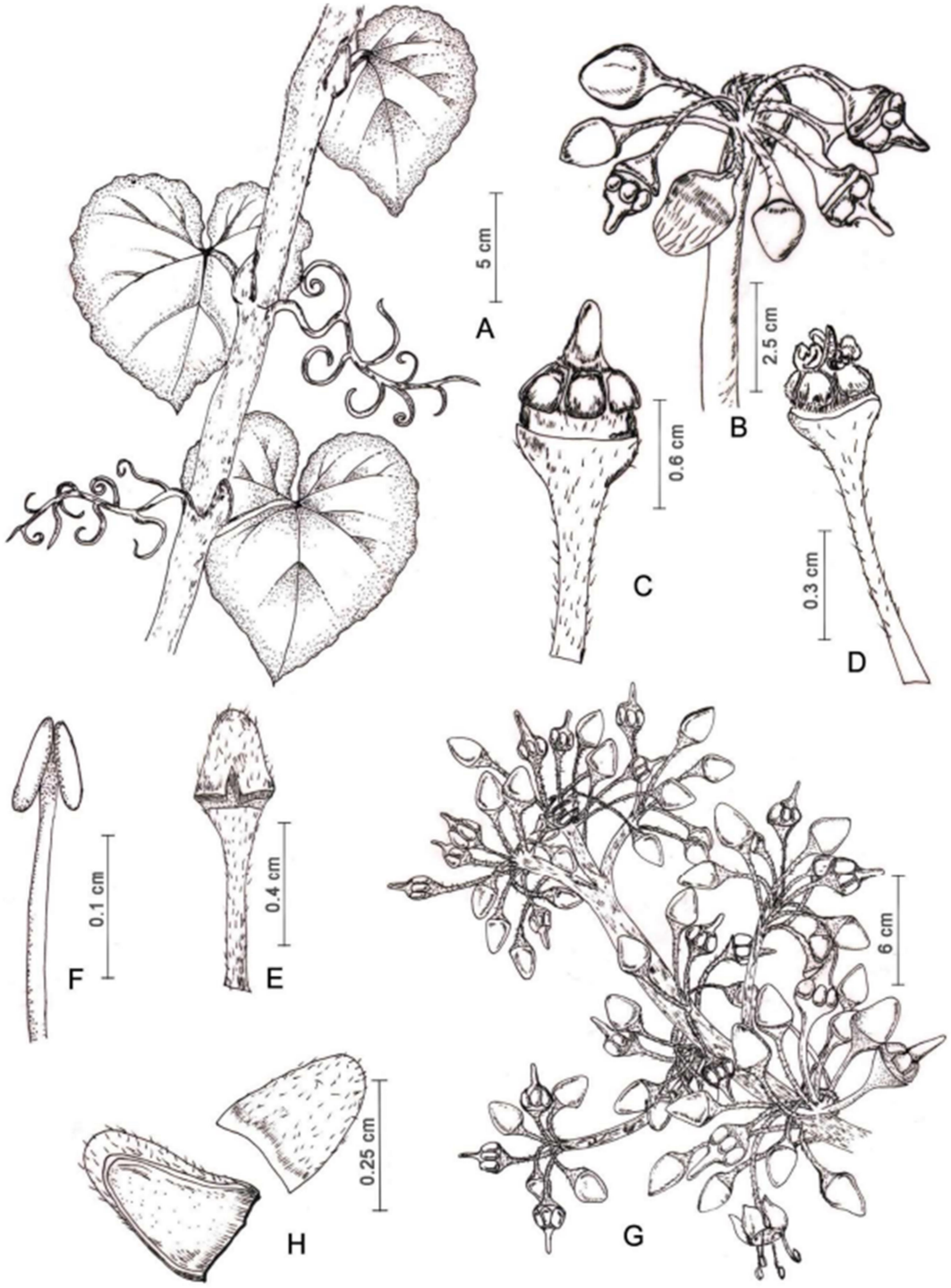

Figure 01. Illustration of *Parthenocissus renukae*. **A.** Habit; **B.** Inflorescence; **C.** Gynoecium; **D.** Bud dissected; **E.** Flower Bud; **F.** Stamen; **G**. Flowering twig; **H.** Petal.

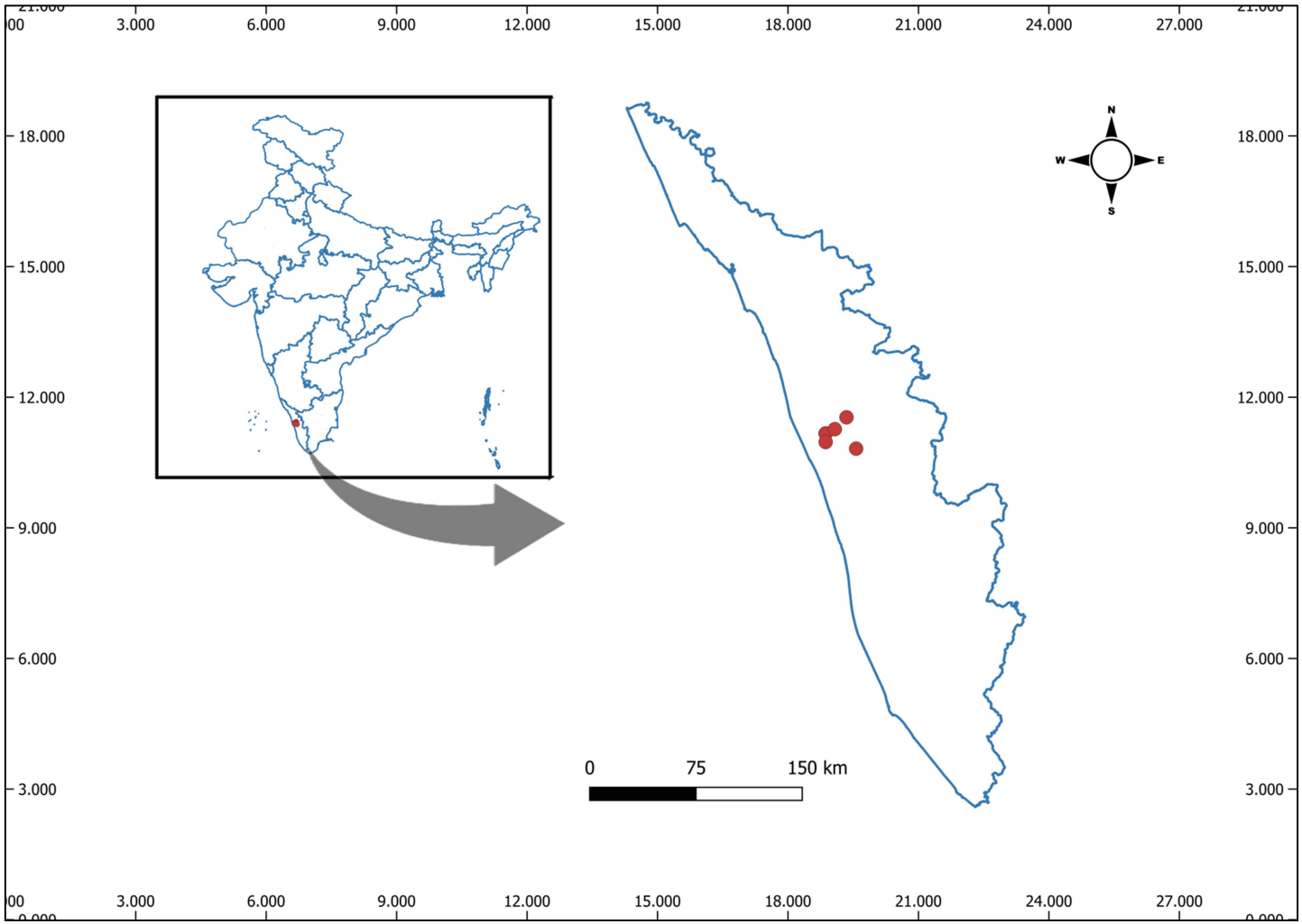

Figure 02. Distribution map of *Parthenocissus renukae.*

1887. *V. himalayana* (Royle) Brandis var. *semicordata* (Wallich) M. Lawson in Fl. Brit. India 1: 656. 1875

2a. *Parthenocissus semicordata* var. *semicordata* (Wall. ex Roxb.) Planchon. in A. Candolle & C. Candolle, Monogr. Phan. 5: 451. 1887. *V. semicordata* Wallich in Roxburgh, Fl. Ind. 2: 481. 1824; *V. himalayana* Brandis var. *semicordata* (Wall. ex. Roxb.) Lawson in Fl. Brit. India 1:655, 1875. **Fig. 03 & 04**

Branchlets terete, sparsely pilose when young, becoming nearly glabrescent; tendrils with 4 – 6 branches, young apex of tendril curving and slender. Leaves 3 foliolate; petiole 3.5 – 15 cm, sparsely pubescent; leaflets usually nearly sessile, abaxially pubescent on veins, lateral veins 4 –7 pairs, veinlets inconspicuous or slightly raised; central leaflet obovate elliptic or obovate, 5 – 13 × 3 – 6.5 cm, base cuneate, margin 6 – 11 toothed, apex cuspidate; lateral leaflets ovate elliptic or oblong, 5 – 10 × 3 – 5 cm, base asymmetric, nearly rounded, margin toward outside 7 – 15 toothed, margin toward inside 4 – 6 toothed, apex mucronate. Polychasium with inconspicuous main axis; peduncles 1.5 – 3.5 cm, glabrous or slightly pilose. Pedicel 2 – 3 mm, glabrous. Buds elliptic, 2 – 3 mm, apex rounded. Calyx entire. Petals ovate elliptic, 1.8 – 2 × ca. 8 mm, glabrous. Filaments 0.6 – 0.9 mm; anthers ovoid elliptic, 0.4 – 0.6 mm. Disk inconspicuous. Ovary nearly spherical; style short; stigma not expanded. Berry 6 – 8 mm in diameter, 1or 2 seeded. Seeds obovoid, base rostrate, apex rounded.

Flowering and Fruiting: May-October.

Habitat: Evergreen Forest, Shrub jungles, Hillsides.

Distribution: Northeast India, Nepal, Central China.

2 b. *Parthenocissus semicordata* var. *roylei*. (King ex R. Parker) Nazim. & Qaiser, in Fl. Pakistan 147: 10. 1982; var. *roylei* (King) Raiz. & Saxena, Indian For. 92: 319. 1966; Shetty & P. Singh in N.P. Singh et al., Fl. India 5: 303. 2000; B.V. Shetty & P. Singh in P. Daniel, Fl. Kerala 1: 759. 2005. *V. semicordata* Wall. var. *roylei* King, J. Asiat. Soc. Bengal 65: 113. 1896. *V. neilgherriensis* Wight, Ic. t. 965. 1845. *V. himalayana* Brandis, For. Fl. 100. 1874; Hook. f., Fl. Brit. India 1: 655. 1875. p. p. *V. anamalayana* Bedd., Trans. Linn. Soc. London 25:213.1865-1866; Hook. f., Fl. Brit. India 1:656.1875. *P. neilgherriensis* (Wight) Planch. in A. & C. DC., Monogr. Phan. 5: 2. 1887; Gamble, Fl. Pres. Madras 231(166). 1918; Mohanan, Fl. Quilon Dist. 120.

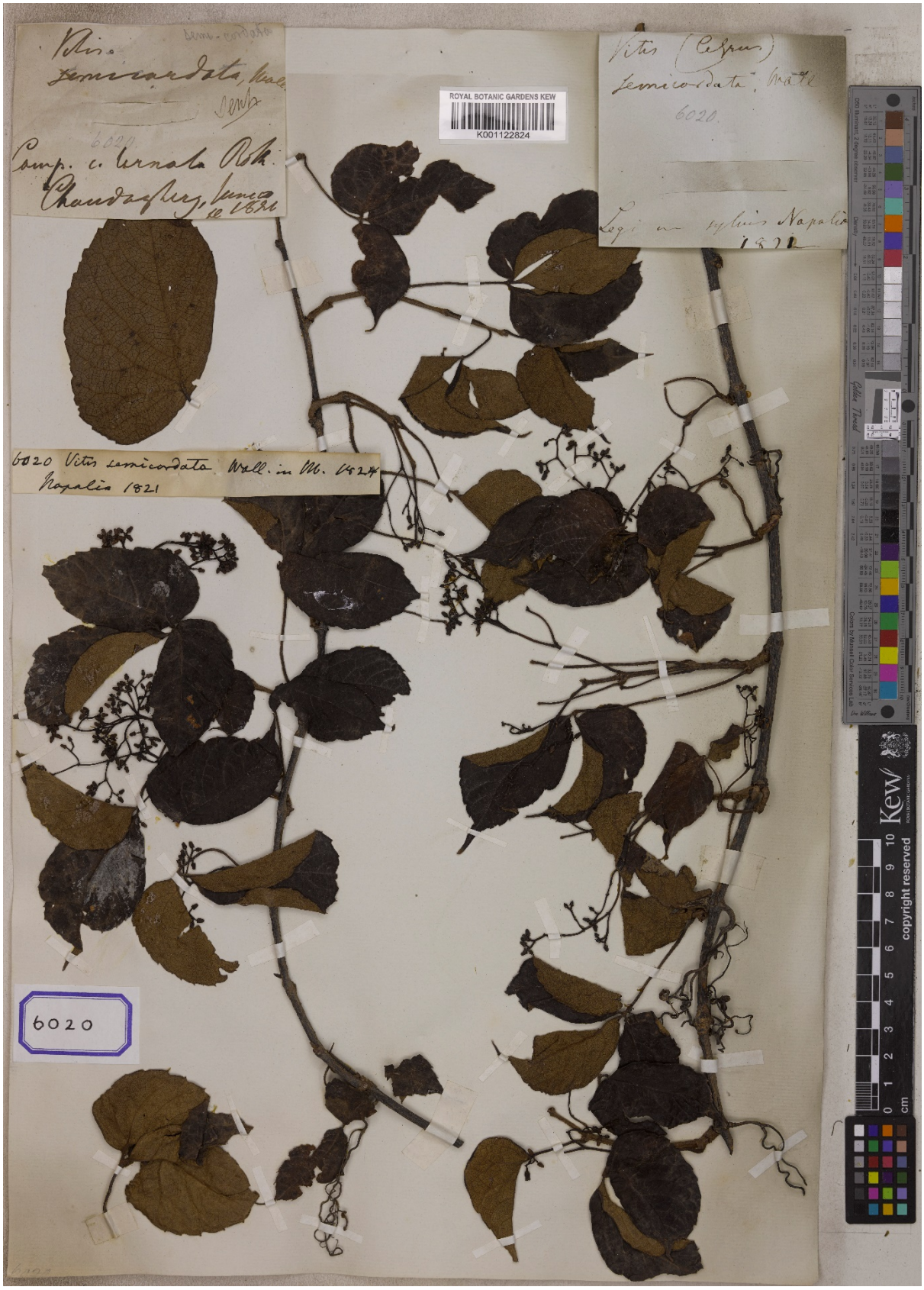

Figure 03. Lectotype of *Parthenocissus semicordata* var. *semicordata*. © The Board of Trustees of the RBG, Kew (K).

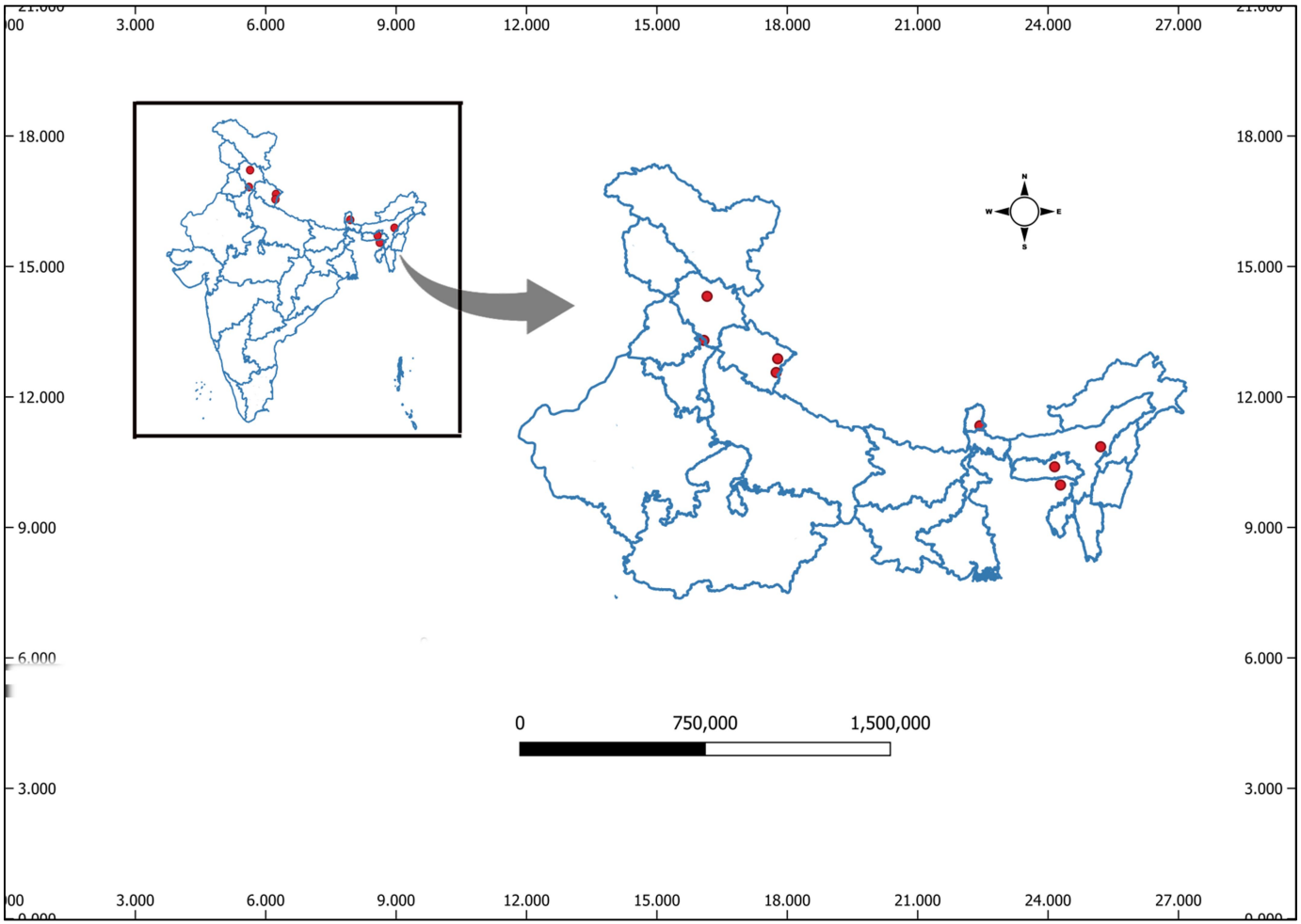

Figure 04. Distribution map of *Parthenocissus semicordata* var. *semicordata.*

1984; Manilal, Fl. Silent Valley 60. 1988; Swarup. et al., Shola For. Kerala 76. 1998; Sasidh., Fl. Periyar Tiger Reserve 74. 1998; Anil Kumar et al., Fl. Pathanamthitta 136. 2005. **Plate 02; Fig. 05, 06 & 07**

Vitis semicordata var. *roylei* King ex R. Parker in Forest Fl. Punjab, ed. 2: 97 (1924) Large climber; stem lenticellate. Leaves 3 foliolate; leaflets to 17 x 10 cm, ovate, acuminate, rounded at base, coriaceous, spinous serrate, 9 nerved; lateral leaflets oblique at base; petiolule 0.5 – 1 cm long; rachis to 11 cm long. Cymes 9 cm across, terminal, peduncled. Flowers bisexual, pedicellate, densely packed; calyx cupular, 5 teethed; petals 4 mm long, oblong; stamens 5, filaments straight; disc obscure; ovary obovoid, truncate, 2 celled; stigma capitate on short style. Fruit a berry; seed 1.

Flowering and fruiting: April -January.
Habitat: Evergreen forests and Sholas.
Distribution: Kerala, Tamil Nadu.
Specimens examined: **Kerala**, Palakkad district, Western bank of Kunthipuzha near suspension bridge silent valley, 22.06.1984, *B. V Shetty 1285* (MH); R.F in front of the proposed dam site, 18.01.1980, *P. Bhargavan 65559* (MH); Dam site, 01.01.1983, *K.S. Prasannakumar 11059* (CALI); Near Silent valley hanging bridge, 29.12.2021, *Nimmi* & *Anto 02817* (STC). Idukki district, In way to Muduvankudi Dhanas Valley, 13.10.1984, *P. Bhargavan 90903* (MH); Cardamom hills, 0.25 km from Munnar on Munnar-Periyar Road, 20.06.1976, *C.E. Ridsdale 187* (MH); Pachakkanam, 08.08.1993, *Jomy Augustine 12311* (KFRI); Anamudi shola National Park, 23.08.2022, *Nimmi* & *Anto 197* (STC). Kottayam district, Pamba, 25.06.1968, *D.B.Deb 30379* (MH). Kollam district, Pamba, 14.11.1975, *K. Vivekananthan 46671* (MH). **Tamil Nadu**, Coimbatore district, Lower Nirar to Italiyar, 6.09.1983, *K. Ramamurthy 78430* (MH). Madurai district, Tiger shola, 17.09.1968, *D.B. Deb 30949* (MH); Way to Vellimalai, 27.05.1989, *V. Lakshmanan 91055* (MH).

3. *Parthenocissus wallichianus* Anto, Nimmi & Pradeep. in Plant Science Today, 10(3):106-110. 2023. **Plate 03; Fig. 08 & 09**

Type: India, Kerala, Thrissur District, Kayambuvum, 31 July 2018, *Anto* & *Nimmi 03074* (Holotype-CALI! Isotype-MH! CAL! STC!).

Rheede & Rumph., Herb. Amboinense, *non* Lam.1783.

*Vitis carnosa auct.*Wight & Arn., Prodr. Fl. Pen. Ind.Orient. 1:127.1834, *pro parte*, *quoad Wallich Num. L.n.,* 6021c, 6021g

non Cissus carnosa Lam., 1783.

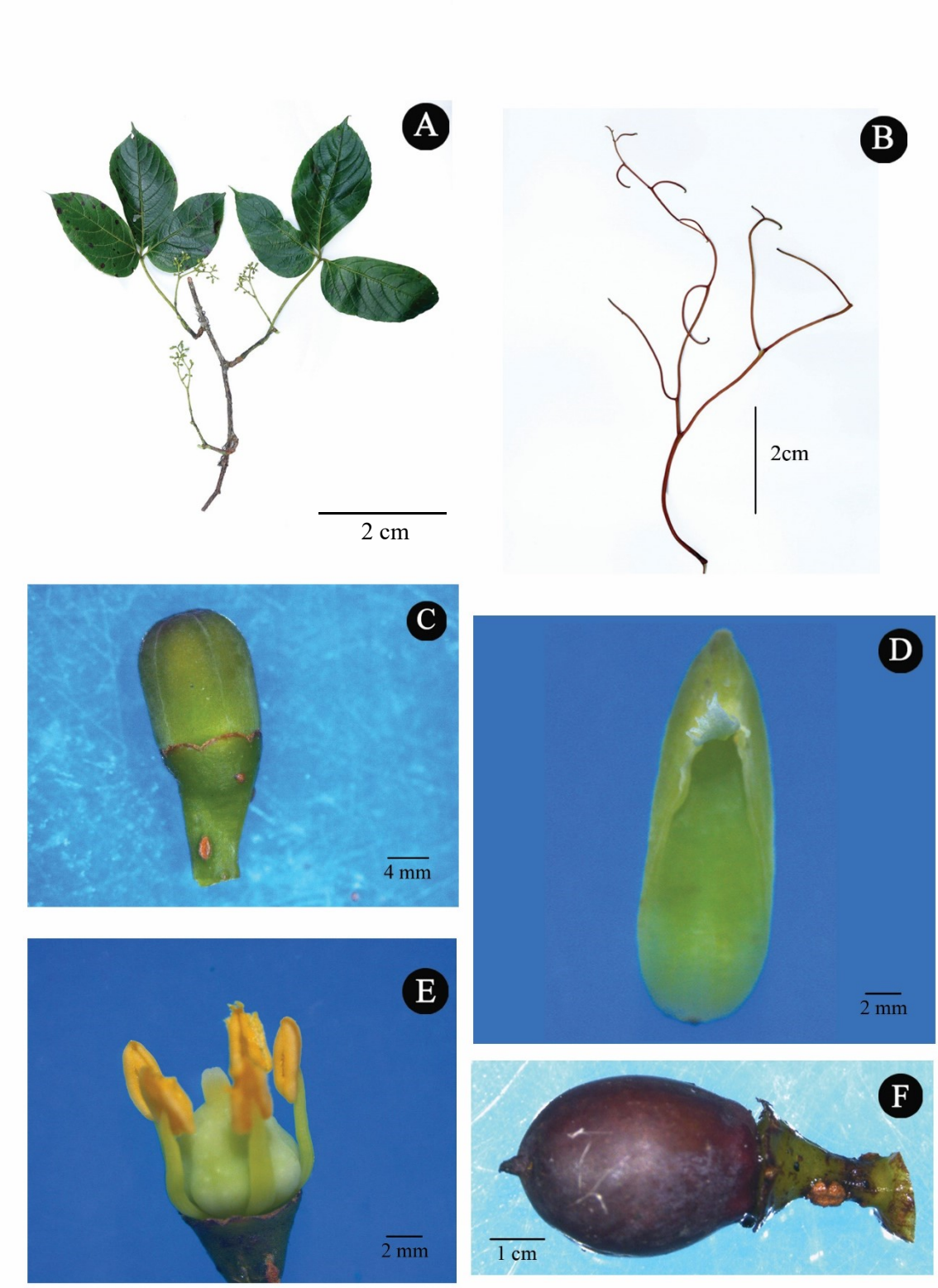

Plate 02. *Parthenocissus semicordata* var. *roylei*. **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Flower bud dissected; **F.** Fruit.

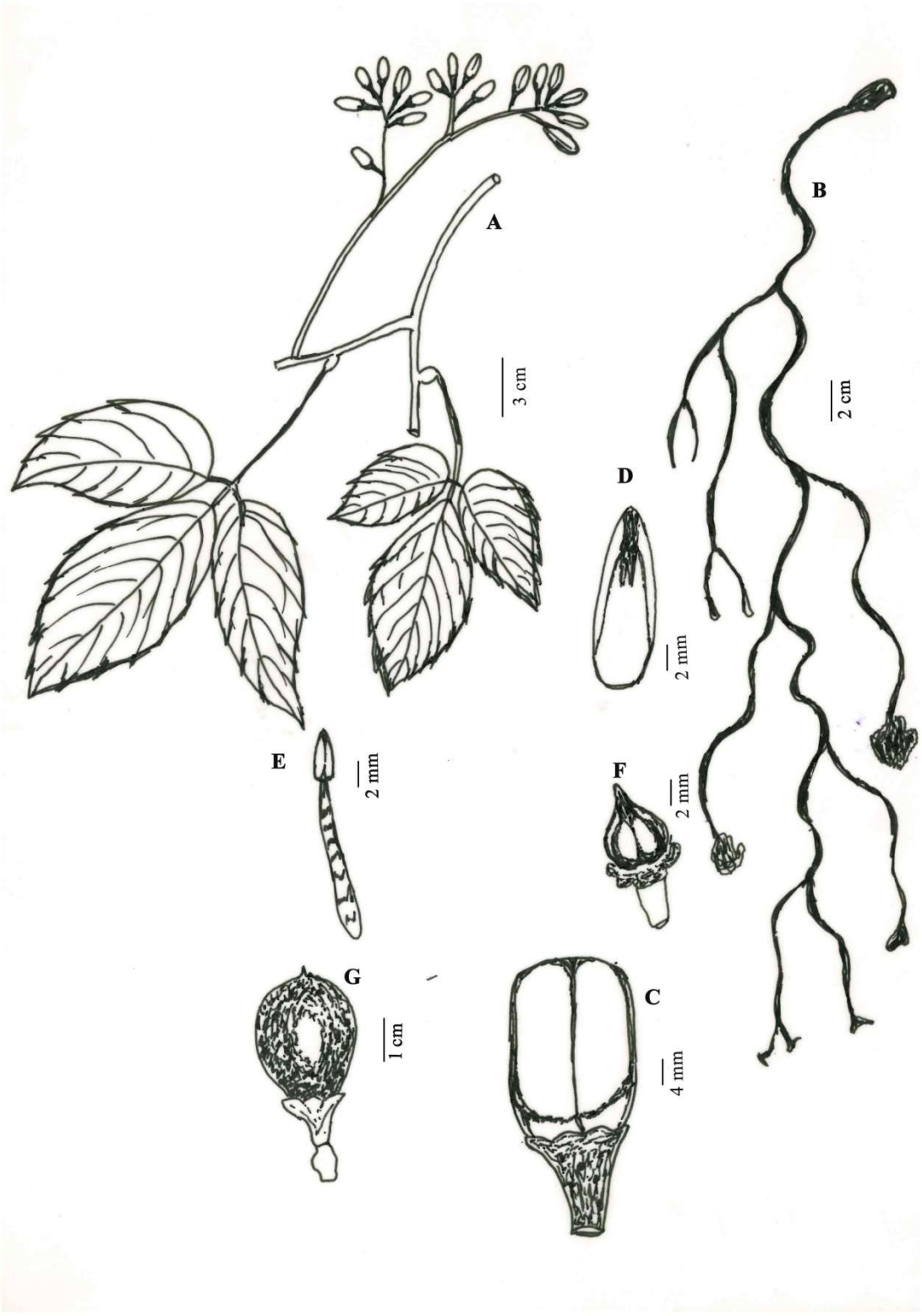

Figure 05. Illustration of *Parthenocissus semicordata* var. *roylei*. **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Stamen; **F.** Gynoecium; **G.** Fruit.

Figure 06. Lectotype of *Parthenocissus semicordata* var. *roylei*. © The Board of Trustees of the RBG, Kew (K).

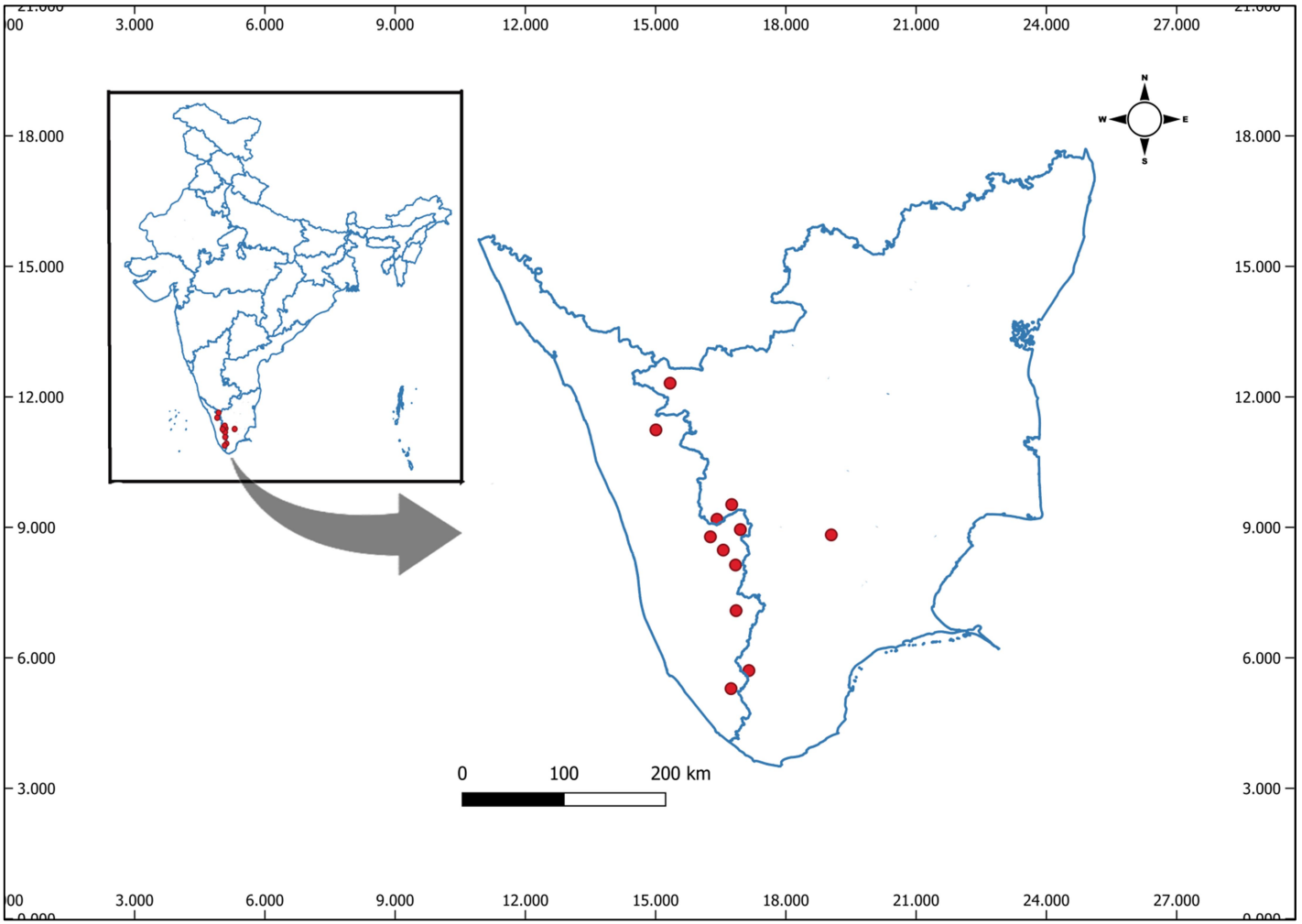

Figure 07. Distribution map of *Parthenocissus semicordata* var. *roylei.*

Robust climber. Stem terete, young stems villous, old stems rough and laterally compressed furrowed, lenticellate. Tendrils, 6 – 7 branched, wiry, glabrous, leaf opposed, bulbous tips modified forming attaching pads. Leaves 3 foliolate; petiole 2.5 – 8 cm., petiolules sub sessile to 2 cm long, terminal leaflet obovate, lateral leaflets oblique, ovate, 5 – 17 × 2.5 – 12 cm, base rounded to oblique, apex mucronate to apiculate; lateral leaflets oblique, ovate to oblong ovate. 5 – 16 × 2.5 – 9 cm, margin serrate, glabrous above, villous below, especially on veins, secondary veins 5 – 6 pairs. Stipules *c.*1.5 mm long, hairy. Inflorescence extra axillary, compound dichasial cyme; peduncle about 6 cm, generally glabrous, pedicels 1 – 3 mm long, glabrous. Calyx cupuliform, entire, margins sinuate, villous. Petals ovate, 2 – 3 × 0.75 – 1.5 mm, coherent to the margins; early caducous. Anthers 4, ovate, 0.35 – 0.75 mm, antipetalous, dorsifixed, dithecous, introse; filaments compressed, broadened at the base, 0.54 mm long. Ovary glabrous, partially fused with nectariferous disc. Style conical 0.4 mm long. Stigma indistinct, hairy, violet coloured. Fruit oblate, dark purplish black berries, 2 seeded, 4 –7 mm in diameter.

Flowering and Fruiting: June-October.

Habitat: Moist deciduous forest.

Distribution: Kerala, Tamil Nadu.

Specimens examined: **Kerala**, Palakkad district, Kollengode, 15.08.2019, *Nimmi* & *Anto 146* (STC); Govindapuram, 05.11.2021, *Nimmi* & *Anto 172* (STC); Karippod, 20.12.2021, *Nimmi* & *Anto 176* (STC); Kanjikode, 02.09.2022, *Nimmi* & *Anto 202* (STC); Walayar, 29.08.2022, *Nimmi* & *Anto 199* (STC). Thrissur district, Kayampoovam, 2.08.2022, *Nimmi* & *Anto 194* (STC). **Tamil Nadu,** Marchinaickenpalayam, 22.08.2022, *Nimmi* & *Anto 196* (STC); Ganapathipalayam, 13.10.2022, *Nimmi* & *Anto 215* (STC).

4. *Parthenocissus sasii* Anto & Nimmi (in press)

Type: India, Kerala, Thrissur district, Asurankundu Dam, 8 March 2021, *Anto* & *Nimmi 02740* (Holotype-CALI! Isotype-MH! CAL! STC!). **Plate 04; Fig. 10 & 11**

Large woody climber. Stilt root 2 to 3 present. Stem round, gland dotted, hairs absent. Leaf simple, stipulate, deeply cordate to shallowly cordate, acuminate, margins distantly serrate, seasonally heteromorphic, adaxial side smooth, abaxial side glabrescent. Leaf length ranges from 5.4 – 17 cm long to 4.9 –17.2 cm broad.

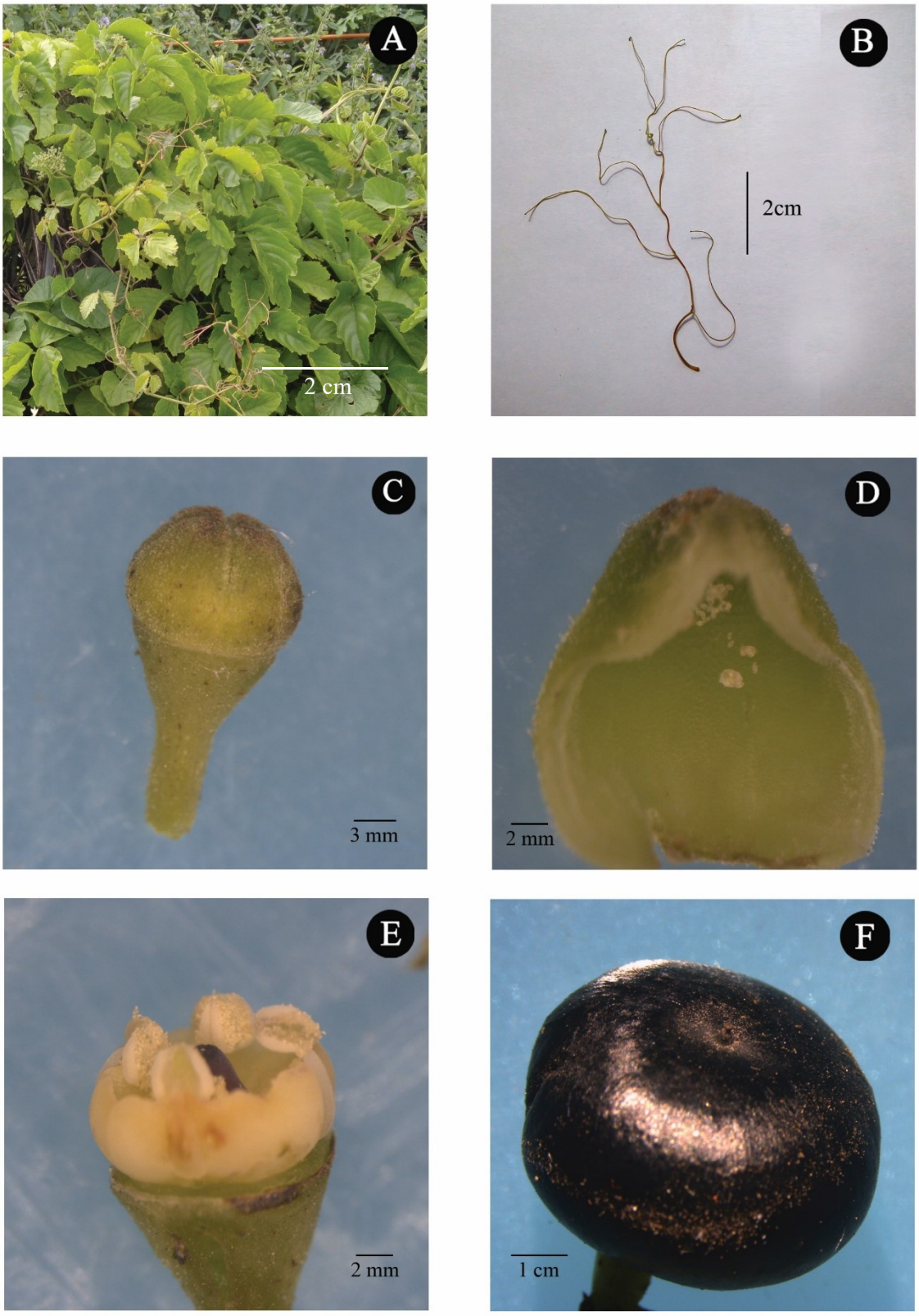

Plate 03. *Parthenocissus wallichianus*. **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Flower bud dissected; **F.** Fruit.

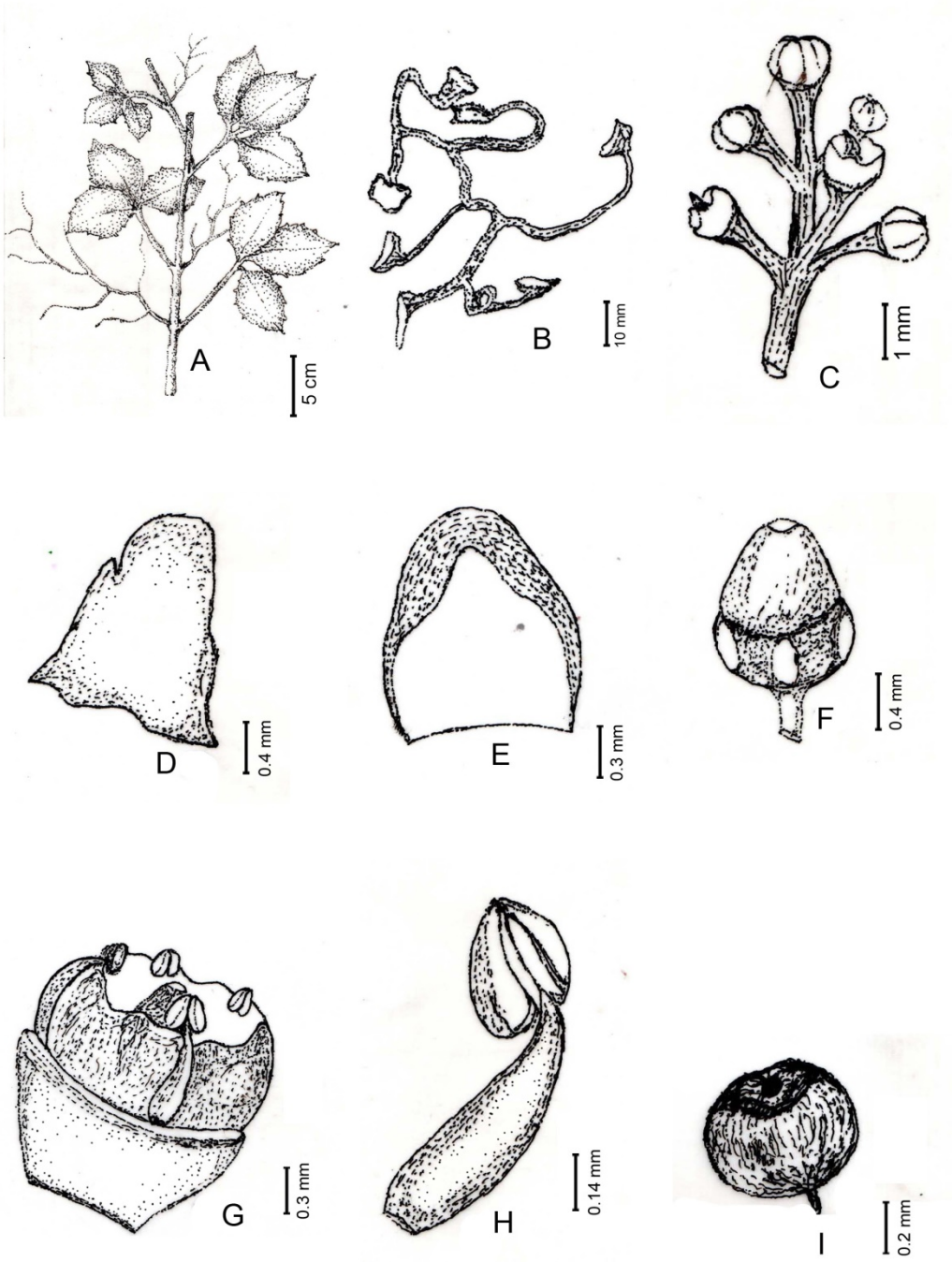

Figure 08. Illustration of *Parthenocissus wallichianus.* **A.** Habit; **B.** Tendril; **C.** Inflorescence; **D.** Stipule; **E.** Petal; **F.** Gynoecium; **G.** Flower bud dissected; **H.** Stamen; **I.** Fruit.

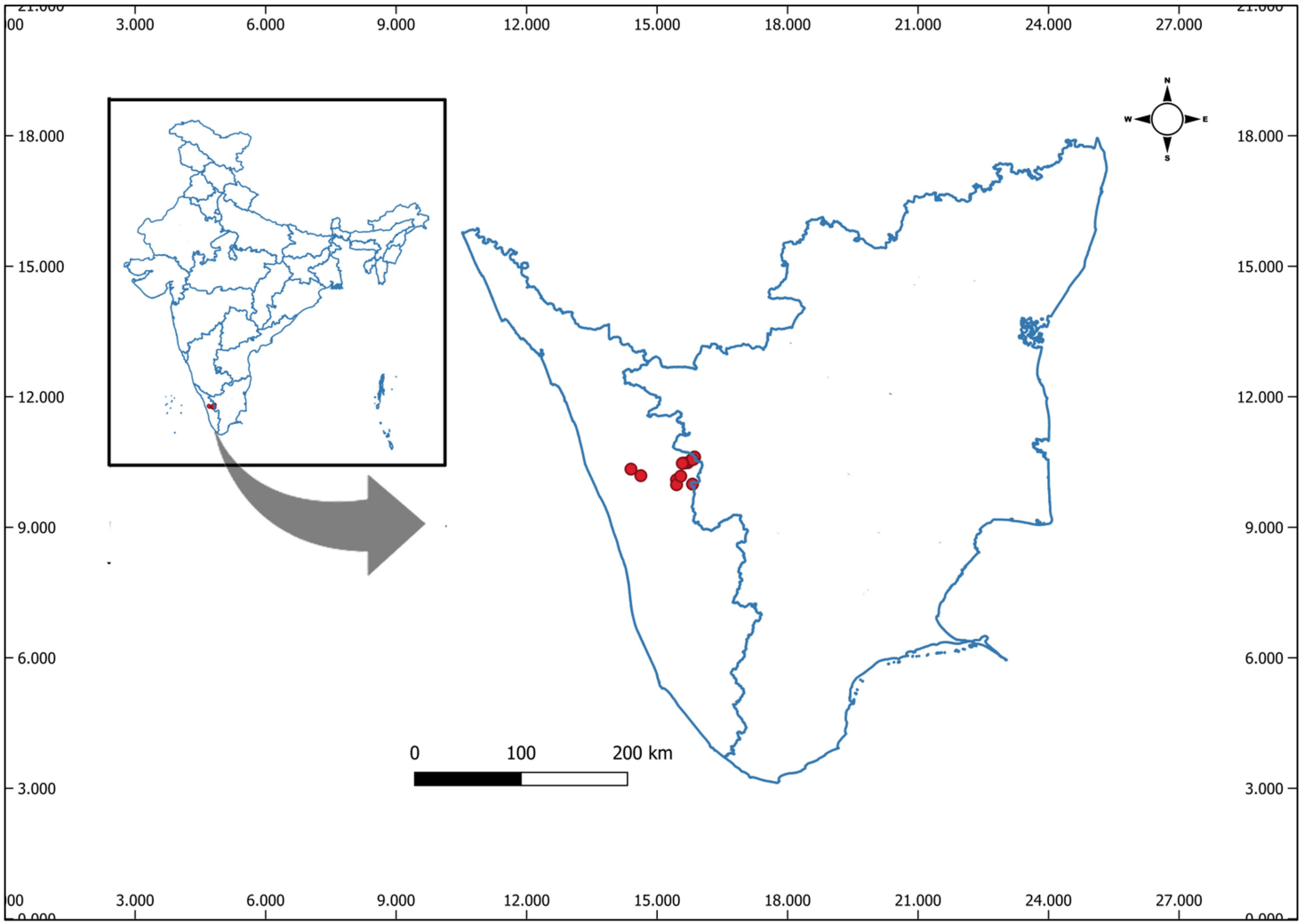

Figure 09. Distribution map of *Parthenocissus wallichianus*.

Petiole 2.6 to 17 cm long, five nerved, lateral veins four pairs. Tendril green, leaf opposed, wiry, > 20 cm, swollen at bass even, seven branched, tip with 1.5 cm diameter adhesive pad. Inflorescence terminal, axillary, directly from mature stem, umbels, and forked short monochasial cyme. Flowers pink, drooping, tetramerous, hairy. Petal 4, 2.2 x 1.5 mm, outer surface clothed with papillate outgrowth, inner surface hooded with papillary hanging a pair of appendages. Anthers 4, dorsifixed, 1.5 mm, filament base broad, shallowly "L" shaped. Disc swollen, ridged in middle, hairy. Ovary fused with the disc; style short, 1.1 mm; stigma short, pink tinged. Fruit obovate, narrowly ridged with numerous minute gland dots.

Flowering and Fruiting: January-May.

Habitat: Moist deciduous forest.

Distribution: Thrissur.

Specimens examined: **Kerala**, Thrissur district, Thumboormuzhy, 21.01.2019, *Nimmi* & *Anto 138* (STC); Asurankundu Dam, 22.02.2022, *Nimmi* & *Anto 185* (STC); Kandassankadavu, 28.02.2022, *Nimmi* & *Anto 188* (STC).

5. *Parthenocissus subferruginea* Merr. & Chun. (in press)

Type: China, Hainan, Lingshui, Chim Shan, Fan Maan Ts'uen (Isotype-A barcode-00051594 **Plate 05; Fig. 12, 13 & 14**

Scandent shrub; branches subterete, woody; young parts appressed wooly, reddish; tendrils, leaf opposed, 30 cm long, 6 –7 branched, subterminal tendril pad form Ring Pad. Leaves suborbicular, sometimes five angled deeply cordate at base, dentate serrate at the margin, short acuminate at apex, 10 – 20 x 7 – 15 cm, densely reddish appressed wooly when young, glabrescent at maturity; petioles 10 cm long; stipules falcate, ca 5 x 2.5 mm, pubescent. Inflorescences lax sub corymbosely branched umbellate cymes, 5 – 11 cm long; peduncles 3 –7 cm long, hairy. Flowers Pink, hairy; pedicels 3 – 4 mm long. Calyx cupular, red, obscurely 4 lobed. Petals are obovate, papillate margins, ca. 2 x 1 mm. Disc, greenish yellow, 4 lobed. Stamens whitish yellow, filaments adnate to anther, 1.5 mm long. Style short, 0.5mm, capitate. Berries ellipsoid pyriform, glandular, mucronate, 5 – 7 mm across, 1 seeded; Seed obovoid, smooth except for longitudinally encircling ridged raphe.

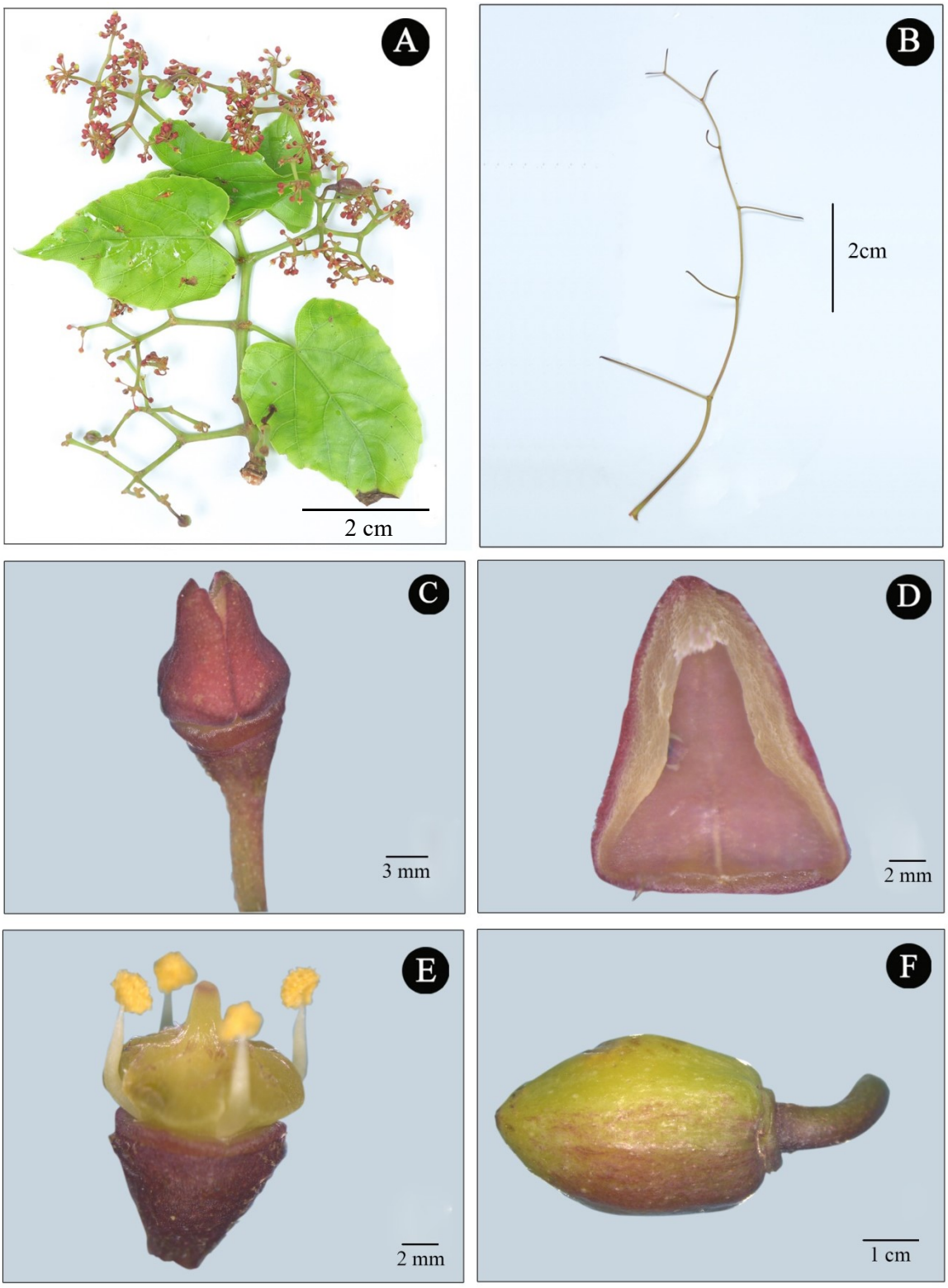

Plate 04. *Parthenocissus sasii.* **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Flower bud dissected; **F.** Fruit.

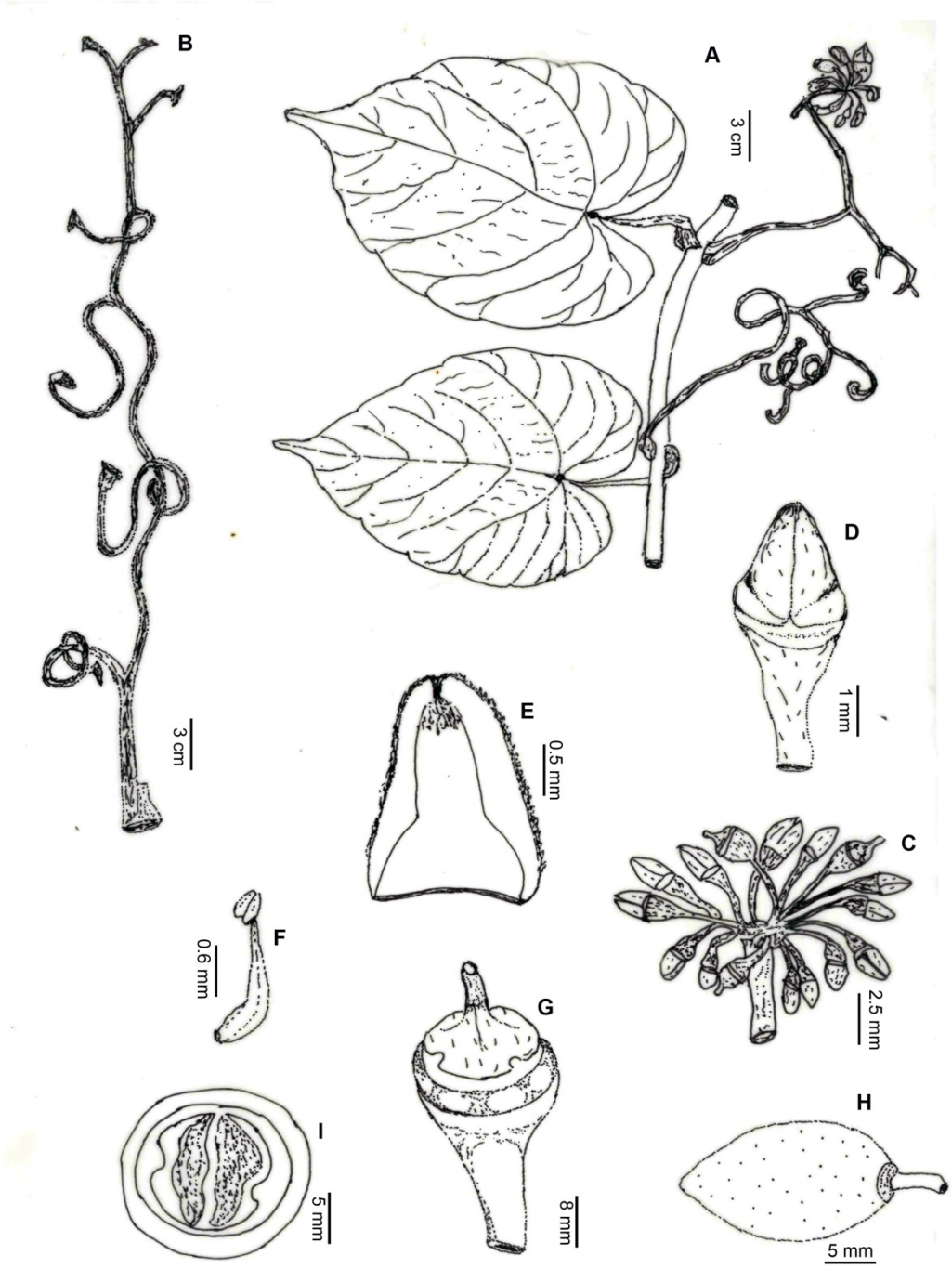

Figure 10. Illustration of *Parthenocissus sasii*. **A.** Flowering twig; **B.** Tendril; **C.** Inflorescence; **D.** Flower bud; **E.** Petal; **F.** Stamen; **G.** Gynoecium; **H.** Fruit; **I.** Fruit C.S.

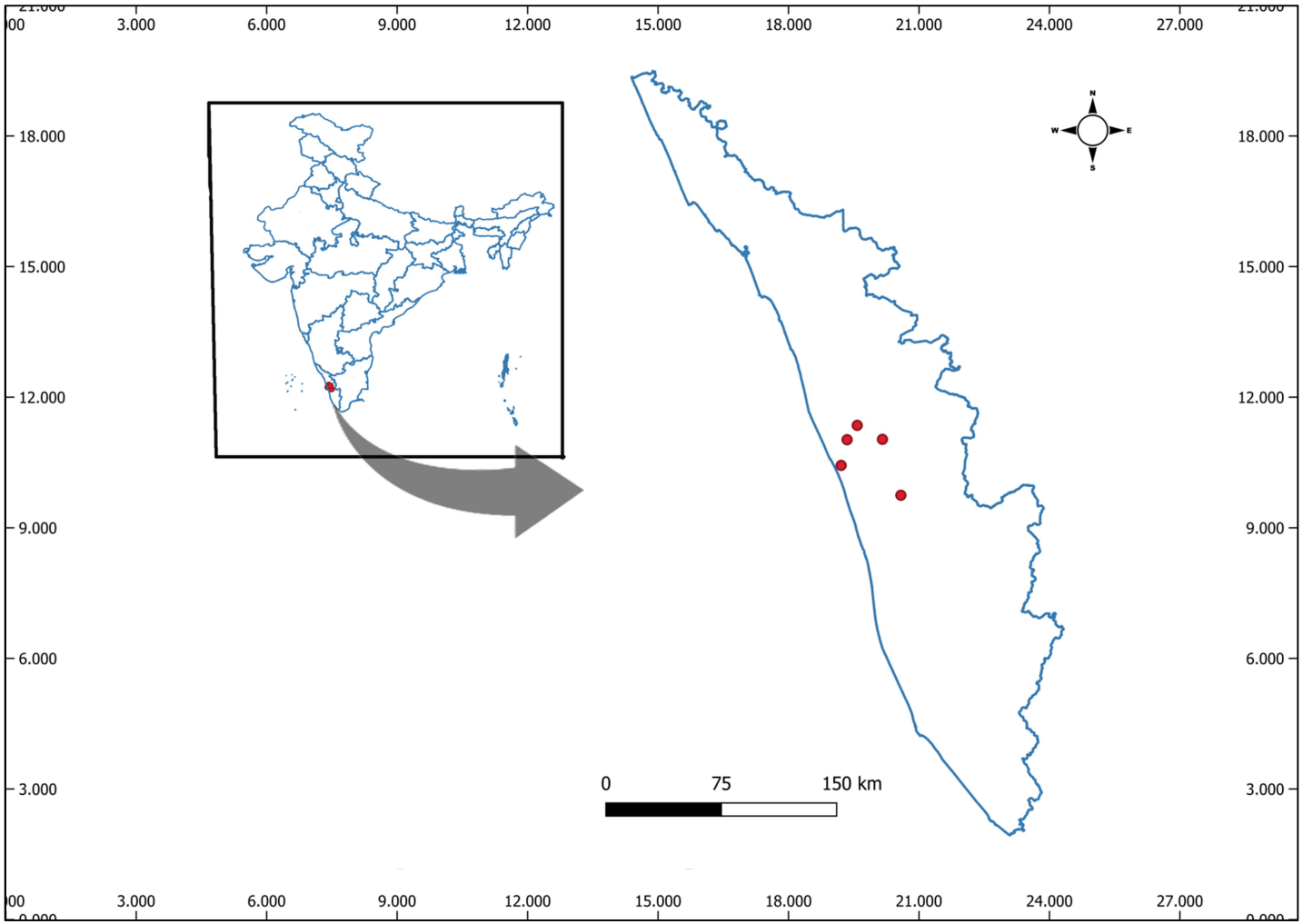

Figure 11. Distribution map of *Parthenocissus sasii.*

Flowering and Fruiting: June-October.

Habitat: Moist deciduous forest.

Distribution: Thrissur, Palakkad, Malappuram, Ernakulam.

Specimens examined: **Kerala**, Ernakulam district, Malayatoor, 10.11.2022, Nimmi & Anto 218 (STC). Malappuram district, Moodal, 27.07.2022, *Nimmi* & *Anto 190* (STC). Palakkad district, Chalissery, 09.09.2022, *Nimmi* & *Anto 205* (STC); Malampuzha, 22.09.2022, *Nimmi* & *Anto* 210 (STC). Thrissur district, Chelakode, 2.08.2022, *Nimmi* & Anto *02850* (STC).

6. *Parthenocissus quinquefolia* (L.) Planch in A. Candolle & C. Candolle, Monogr. Phan. 5: 448. 1887. **Fig. 15**

Hedera quinquefolia Linnaeus, Sp. Pl. 1: 202. 1753; *A. quinquefolia* (Linnaeus) Michaux; *P. engelmannii* Koehne & Graebner; *P. quinquefolia* f. *engelmannii* (Koehne & Graebner) Rehder; *Psedera quinquefolia* (Linnaeus) Greene; Quinaria hederacea Rafinesque, nom. illeg. superfl.; *V. quinquefolia* (Linnaeus) Lamarck**.**

Branchlets terete, glabrous; tendrils 5–9 branched, young apex curving, later developing into suckers. Leaves palmately 5 foliolate; petiole 5 – 14.5 cm, petiolule short or nearly absent, glabrous; leaflets obovoid, obovate elliptic, or elliptic, 5.5 – 15 × 3 – 9 cm, glabrous or veins abaxially sparsely pilose, lateral veins 5–7 pairs, veinlets inconspicuously raised, base cuneate or broadly cuneate, margin with rough teeth, apex cuspidate. Paniculate polychasium pseudo terminal, with conspicuous rachis, 8 – 20 cm; peduncles 3 – 5 mm. Pedicel 1.5 – 2.5 mm, glabrous. Buds elliptic, 2 – 3 mm, apex rounded. Calyx entire. Petals elliptic, 1.7– 2.7 mm, glabrous. Filaments 0.6 – 0.8 mm; anthers elliptic, 1.2 – 1.8 mm. Disk inconspicuous. Ovary is coniform; stigma not expanded. Berry 1–1.2 cm in diam., 1– 4 seeded. Seeds obovoid, base with short, acute rostrum, apex rounded

Flowering and Fruiting: June-October.

Habitat: Deciduous woodlands, Thickets, Limestone glades.

Distribution: China, India, USA.

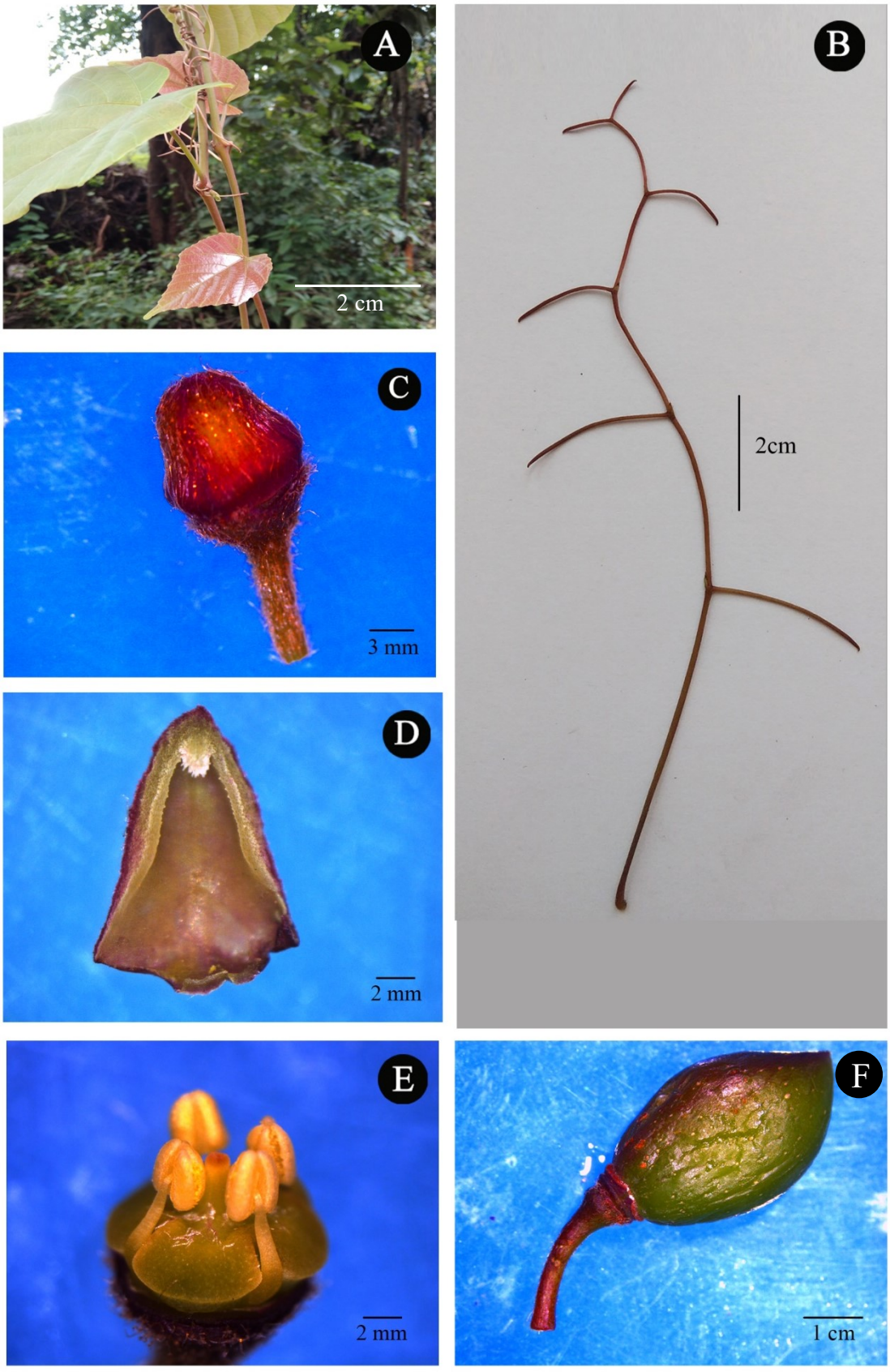

Plate 05. *Parthenocissus subferruginea.* **A.** Habit; **B.** Tendril; **C.** Flower bud; **D.** Petal; **E.** Flower bud dissected; **F.** Fruit.

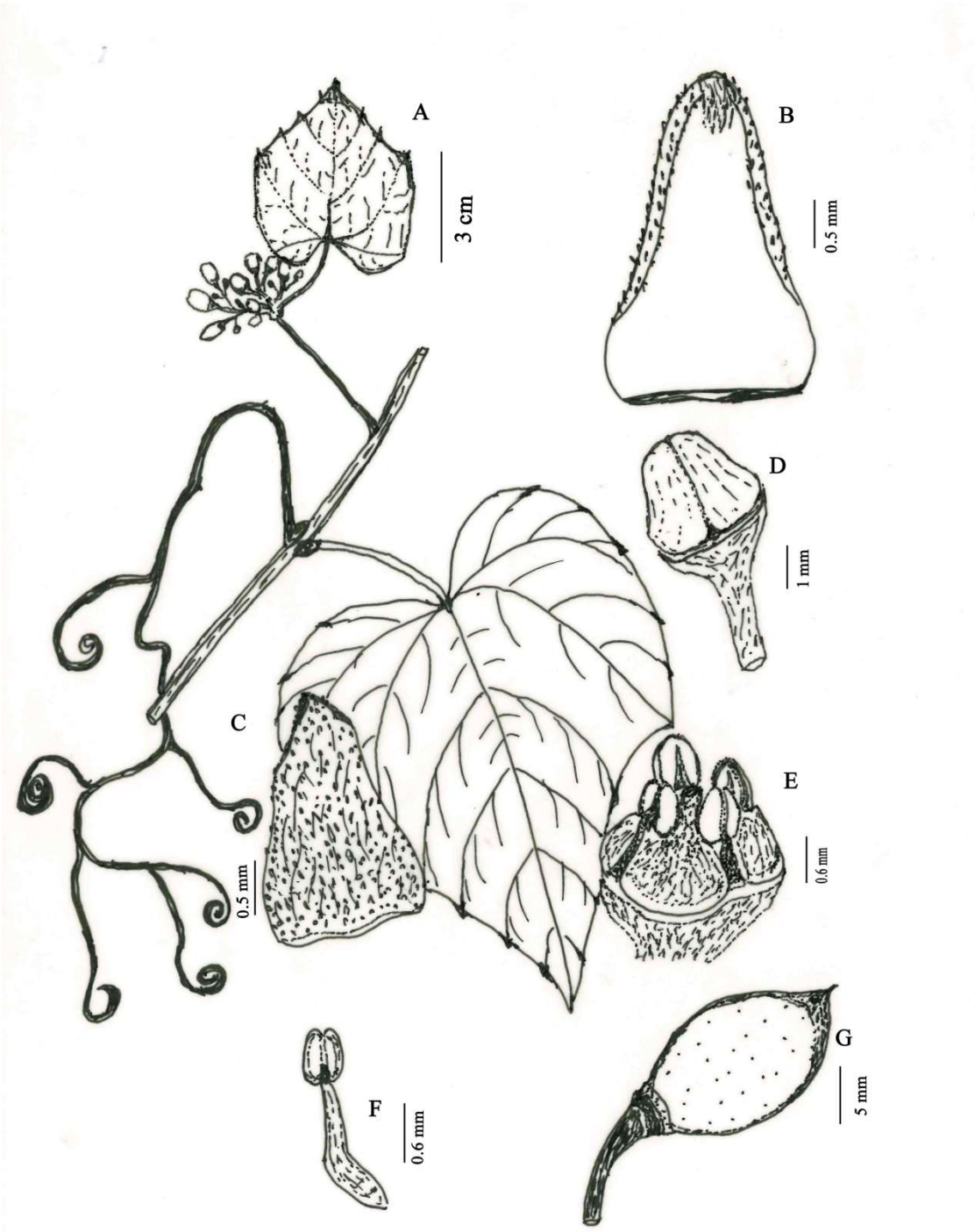

Figure 12. Illustration of *Parthenocissus subferruginea* **A.** Habit with tendril; **B.** Petal with corolla appendage; **C.** Petal with hairs; **D.** Flower bud; **E.** Flower bud dissected; **F.** Anther; **G.** Fruit.

Figure 13. Isotype of *Parthenocissus subferruginea*, © The Herbarium of the Arnold Arboretum of Harvard University (A).

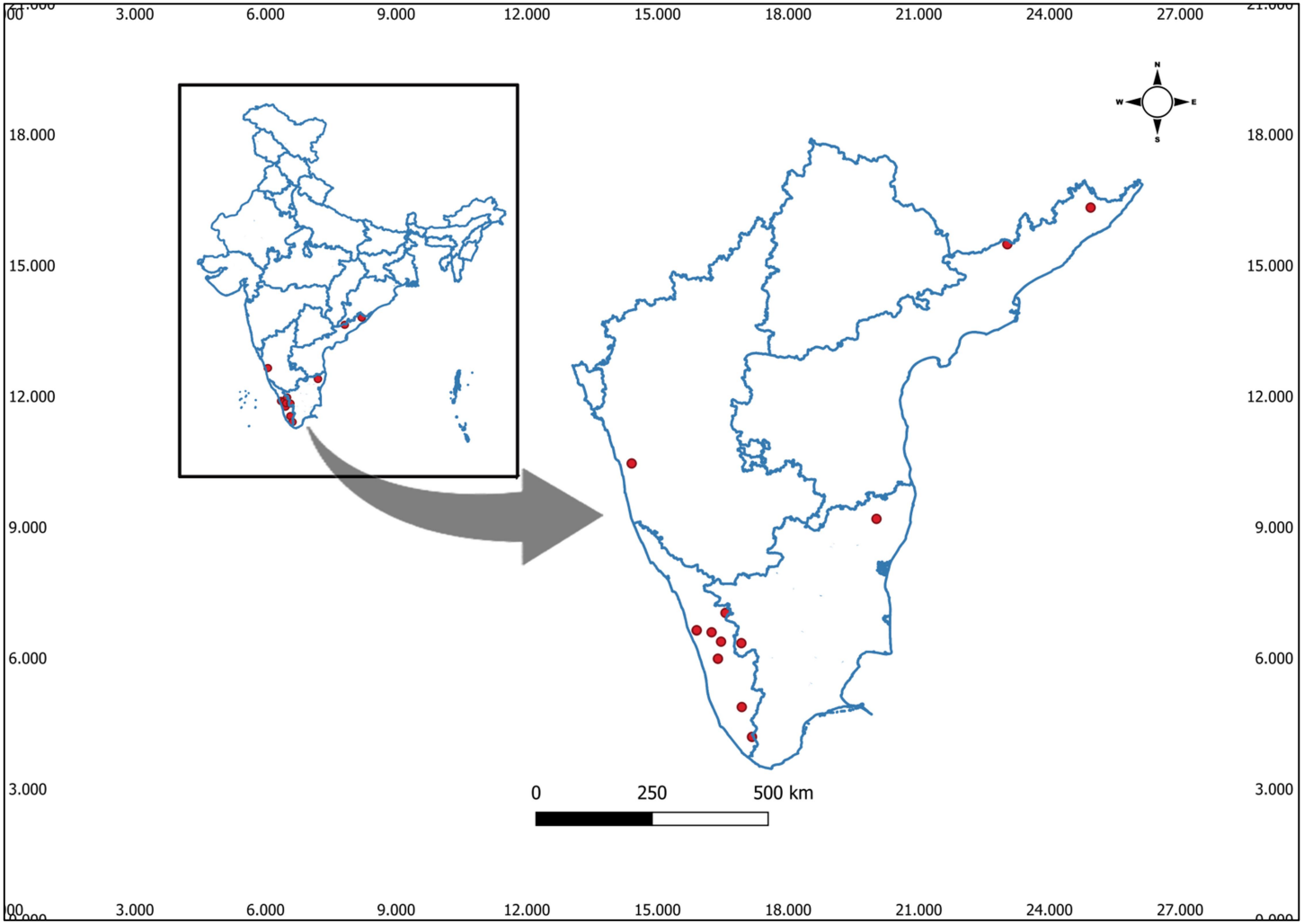

Figure 14. Distribution map of *Parthenocissus subferruginea*.

Figure 15. Lectotype of *Parthenocissus quinquefolia,* ©The Trustees of the Natural History Museum (BM), London.

7. *Parthenocissus tricuspidata* **(**Siebold & Zucc) Planch. in A. Candolle & C. Candolle, Monogr. Phan. 5: 452. 1887. **Fig. 16**

A. tricuspidata Siebold & Zucc. in Abh. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. 4(2): 196 (1845), *Psedera tricuspidata* (Siebold & Zucc.) Rehder in Rhodora 10: 29 (1908), *Quinaria tricuspidata* (Siebold & Zucc.) Koehne in Gartenflora 41: 403 (1892), *V. tricuspidata* (Siebold & Zucc.) T. Moore & Mast. in Gard. Chron. 1871: 1128 (1871), non Heer, fossil name.

Branchlets terete, nearly glabrous or sparsely pilose; tendrils 5 – 9 branched, young apex expanded and ball shaped. Leaves simple, usually 3 lobed on short branches or small and unlobed on long branches; petiole 4 – 12 cm, glabrous or sparsely pubescent; blade obovoid, 4.5 – 17 × 4 – 16 cm, abaxially glabrous or midvein abaxially sparsely pubescent, basal veins 5, lateral veins 3 – 5 pairs on each side, veinlets slightly raised abaxially, inconspicuous adaxially, base cordate, margin with rough teeth on each side, apex acute. Polychasium 2.5 – 12.5 cm; rachis inconspicuous; peduncles 1 – 3.5 cm, nearly glabrous. Pedicel 2 – 3 mm, glabrous. Buds obovoid elliptic, 2 – 3 mm, apex rounded. Calyx entire or undulate. Petals elliptic, 1.8 – 2.7 mm, glabrous. Filaments 1.5 – 2.4 mm; anthers ovoid elliptic, 0.7 – 1.4 mm. Disk inconspicuous. Ovary oval; style conspicuous, base thick; stigma not enlarged. Berry 1 – 1.5 cm in diameter, 1 – 3 seeded. Seeds obovoid, base with a sharp, short rostrum, apex rounded.

Flowering and Fruiting: May-October.

Habitat: Thickets and Woods in hills and mountains.

Distribution: China, India, USA.

4.2. MICROMORPHOLOGY

1. Leaf Stipule

All the taxa in this species contain an interpetiolar scale like stipule.

P. renukae

Stipules are elongated, rectangular, and flat. The tip of the stipule is as broad as the base. The stipule is hairy. The size of the stipule is 1.9 x 1.4 mm.

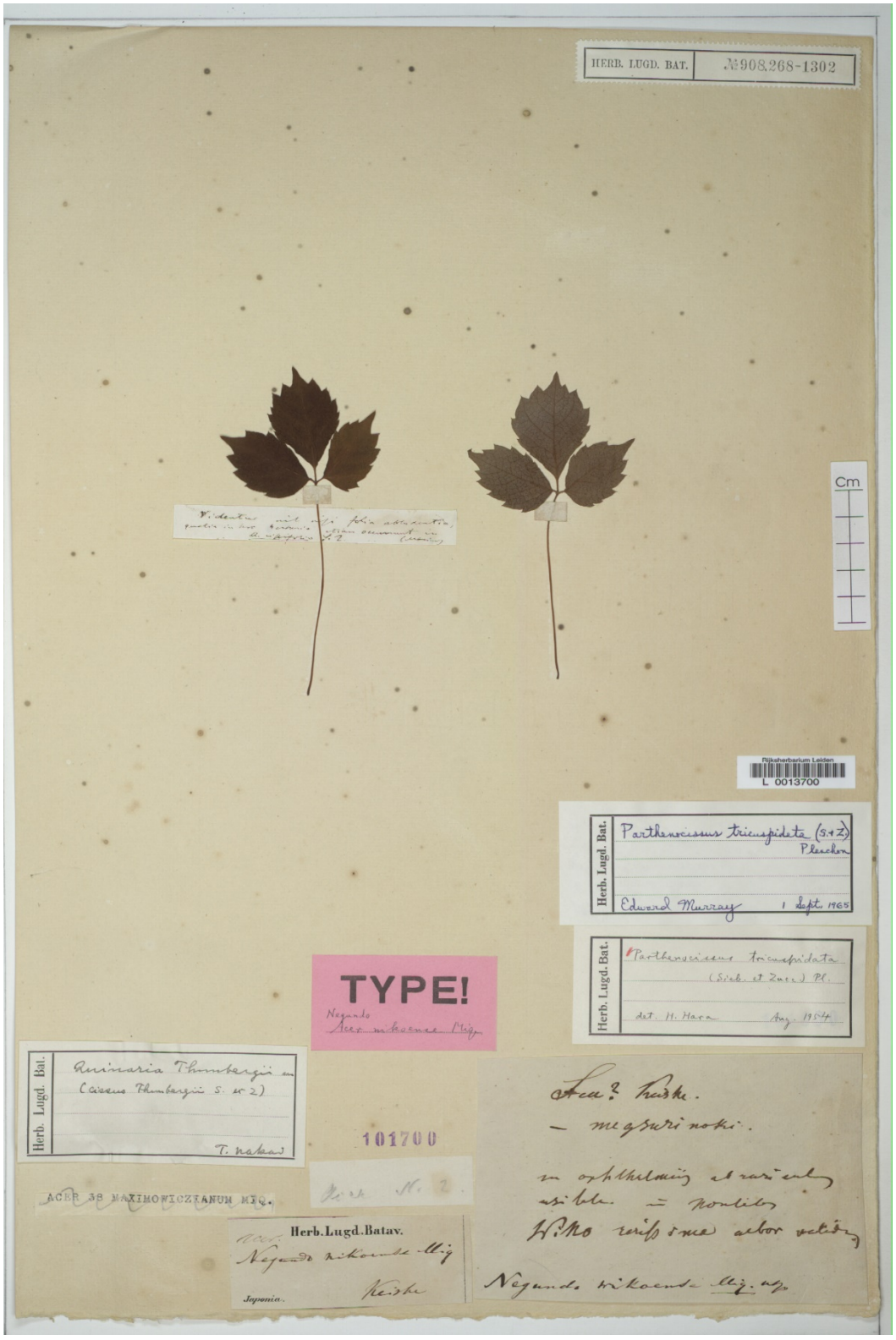

Figure 16. Type of *Parthenocissus tricuspidata,* © The Board Trustees of the Naturalis Biodiversity Center (L), Leiden, Netherland.

P. semicordata

Stipule has a blunt end that is slightly curved, narrowly elongated, one side inflated, and hairless. The size of the stipule is 1.7 x 0.87 mm.

P. wallichianus

Stipules are triangular in shape and elongated, broadly curved tips. The size of the stipule is 1.5 x 0.91 mm.

P. sasii

It has a triangular stipule with a bulged lateral side, pointed tip, and glabrescent. The size of the stipule is 1.4 x 1.02 mm.

P. subferruginea

Stipules are highly pubescent, margins outwardly incurved, elongated and tongue like. The size of the stipule is 1.76 x 1.57 mm.

2. Leaf Stomata (Table 1)

P. renukae

Stomata are anomocytic, abundant abaxially, evenly distributed, and guard cells surrounded by five epidermal cells. Epidermal cells were polygonal. The anticlinal walls are straight and arched. In abaxial stomata, the size of the stomatal pore is ranged from 26.35 x 4.34 µm to 22.4 x 3.84 µm. The size of the guard cells ranges from 26.85 x 8.7 µm to 22.91 x 8.05 µm.

P. semicordata

Stomata are anomocytic, abundant abaxially, evenly distributed, and guard cells surrounded by six ordinary epidermal cells and not differentiated into subsidiary cells. Epidermal cells were irregular. The anticlinal walls are straight and arched. In abaxial stomata, the size of stomatal pore ranges from 14.22 x 3.46 µm to 20.51 x 4.06 µm the size of the guard cells ranges from 20.89 x 8.64 µm to 29.98 x 7.08 µm.

P. wallichianus

Stomata tetracytic, less abaxially, evenly distributed, and guard cells surrounded by four subsidiary cells. Subsidiary cells were polygonal, The anticlinal walls straight,

and sinuolate. In abaxial stomata, the size of the stomatal pois ranged from 27.41 x 8.75 µm to 32.68 x 6.87 µm. The size of the guard cells ranges from 30.77 x 4.19 µm to 37.34 x 7.01 µm.

P. sasii

Stoma is tetracytic, less abaxially, evenly distributed, and guard cells surrounded byfour4 subsidiary cells. Subsidiary cells were polygonal, The anticlinal walls straight, and sinuolate. In abaxial stomata, the size of the stomatal pore ranges from17.36 x 3.91 µm to15.11 x 2.71 µm. The size of the guard cells ranges from 24.41 x 7.22 µm to 21.01 x 6.73 µm.

P. subferruginea

Stomata tetracytic, abundant abaxially, evenly distributed, and guard cells surrounded by four subsidiary cells. Subsidiary cells were polygonal, The anticlinal walls straight, and sinuolate. In abaxial stomata, the size of the stomatal pois ranged from 15.12 x 3.31 µm to 17.66 x 3.01 µm. The size of the guard cells ranges from 20.04 x 6.17 µm to 21.09 x 6.19 µm.

3. Tendril (Plate 06, 07, 08, 09 & 10)

Branched tendrils with adhesive discs at tendril apices are the critical characteristics of the *Parthenocissus* genus. The tendril branches vary from 5 – 10 within the genus.

P. renukae

Tendril has a central axis with 6 – 8 branchlets alternatively attached. The length of the tendril is 7 cm, and the subterminal portion of the tendril forms a fist shaped attaching pad.

P. semicordata

The tendril is 21 cm long, and each tendril comprises the bifurcated central axis and ten branchlets alternatively attached. Here, the subterminal portion of the tendril branchlets forms an elongated fist shaped adhesive pad.

P. wallichianus

This species possesses a wavy tendril 12 cm long. Each tendril comprises the central axis and has six branchlets alternatively attached. The terminal tip becomes swollen and forms a ball like adhesive pad.

Table 1. Measurements of Stomata, Guard cell and Subsidiary cells of *Parthenocissus* spp.

Species	Stomatal pore(µm)		Guard cell (µm)		Subsidiary cells (µm)		Stomatal pore (µm)		Guard cell (µm)		Subsidiary cells (µm)	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
P. renukae	26.35	4.34	26.85	8.7	33.12	18.91	22.6	3.84	22.91	8.05	24.16	15.55
P. semicordata	20.51	4.06	29.98	7.08	30.7	10.11	14.22	3.46	20.89	8.64	22.13	9.45
P. sasii	17.36	3.91	24.41	7.22	38.22	19.11	15.11	2.71	21.01	6.73	27.3	14.97
P. wallichianus	27.41	8.75	30.77	4.19	47.97	17.24	32.68	6.87	37.34	7.01	46.51	19.96
P. subferruginea	15.12	3.31	20.04	6.17	20.46	10.08	17.66	3.01	21.09	6.19	22.55	14.08

P. sasii

The length of the tendril is 30 cm, and each tendril consists of 7 branchlets alternatively attached. In this species, the terminal tip becomes swollen, forming a ball like an adhesive pad.

P. subferruginea

This species has a central axis with six branchlets alternatively attached. The length of each tendril is up to 14 cm. The entire sub terminal portion in this species n develops into a tubercle shaped adhesive pad. A ring shaped pad is also common in this species.

4. Corolla Appendages

Like branched tendrils with adhesive pads, appendages on the inner side of the petals are another diagnostic feature of the genus *Parthenocissus*.

P. renukae

Corolla is a triangular, pale green coloured, slightly pink colour on the base of the corolla, and pointed tips with papillae outgrowth on the inner side of the petal. Highly pubescent.

P. semicordata

Corolla elongated, oval shaped, green colour, glabrescent with multi lobed tongue like membrane outgrowth.

P. wallichianus

Corolla, sub globose, short, green coloured, inconspicuous, with few papillary outgrowths in the inner side of the petal.

P. sasii

Corolla triangular, pink coloured, papillae like projection on the dorsal surface and solid massive papillary outgrowth seen on the inner side of the petal.

P. subferruginea

Corolla triangular, pink coloured with stout glandular multiple outgrowths on the inner side of the petal. T shaped hairs on the outer side of the petal.

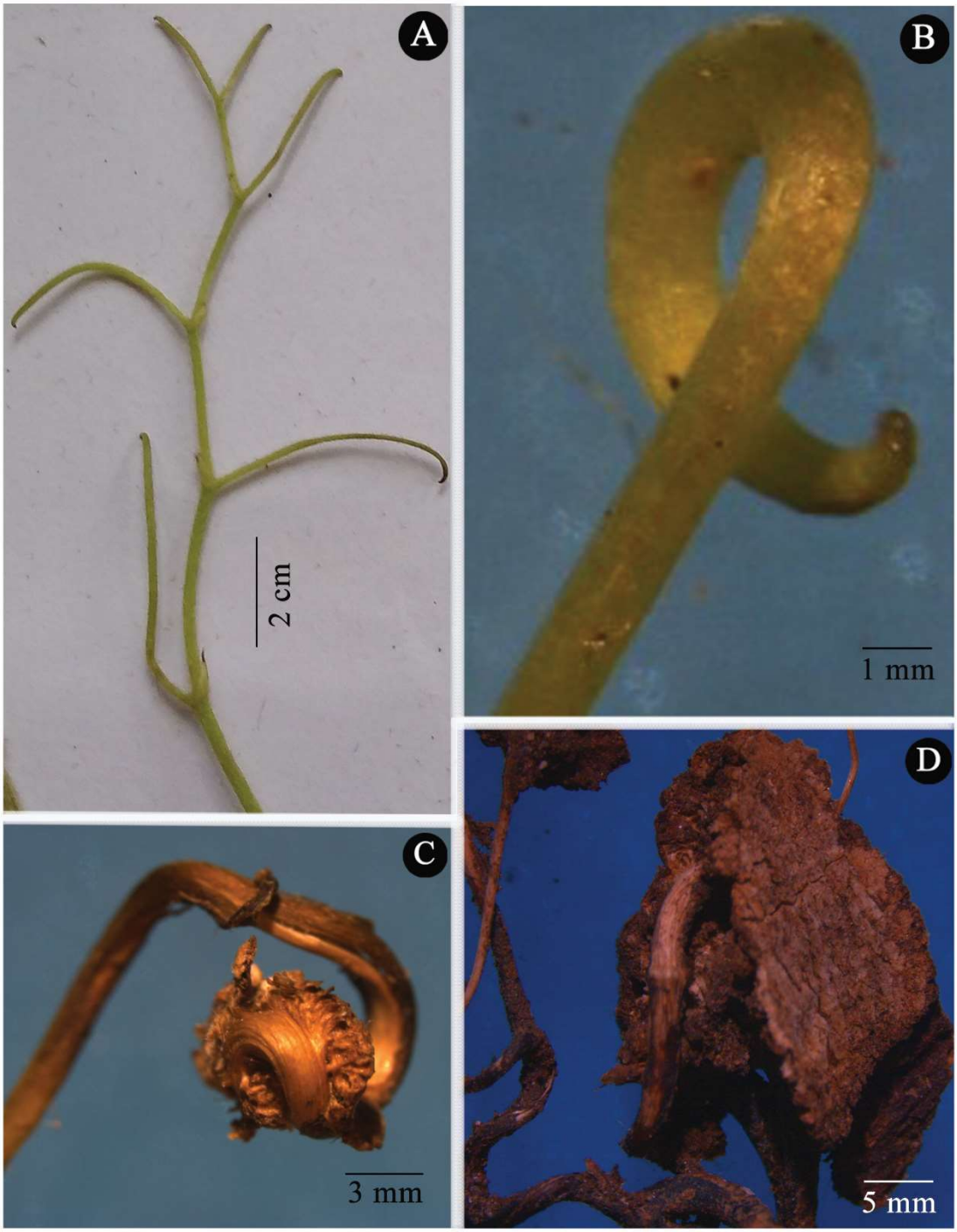

Plate 06. Tendril parts of *Parthenocissus renukae*. **A.** Tendril with branches; **B.** Young tendril tip; **C.** Mature tendril; **D.** Adhesive pad with host plant bark.

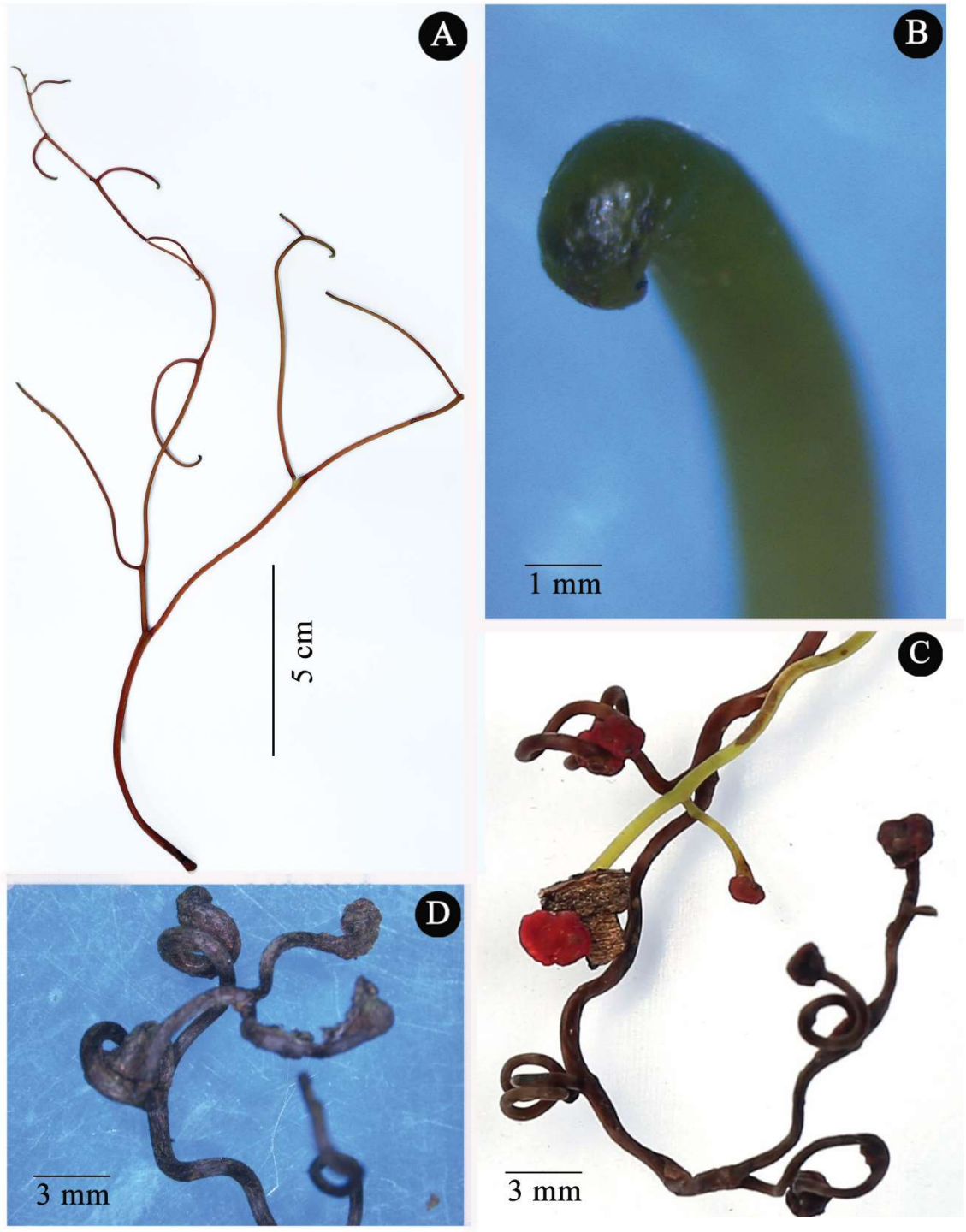

Plate 07. Tendril parts of *Parthenocissus semicordata* var. *roylei*. **A.** Tendril with branches; **B.** Young tendril tip; **C.** Mature tendril; **D.** Adhesive pad with host plant bark.

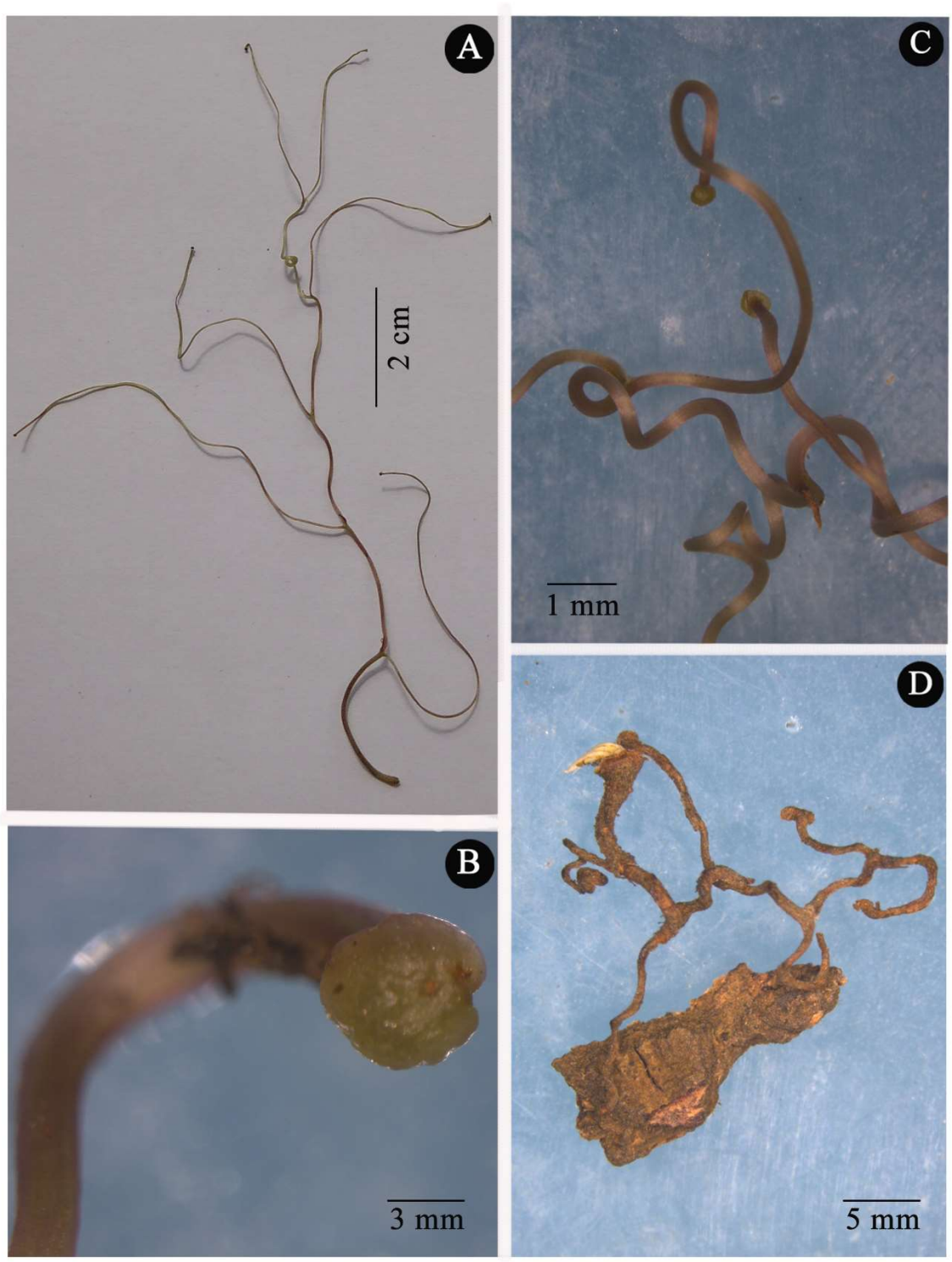

Plate 08. Tendril parts of *Parthenocissus wallichianus*. **A.** Tendril with branches; **B.** Young tendril tip; **C.** Mature tendril; **D.** Adhesive pad with host plant bark.

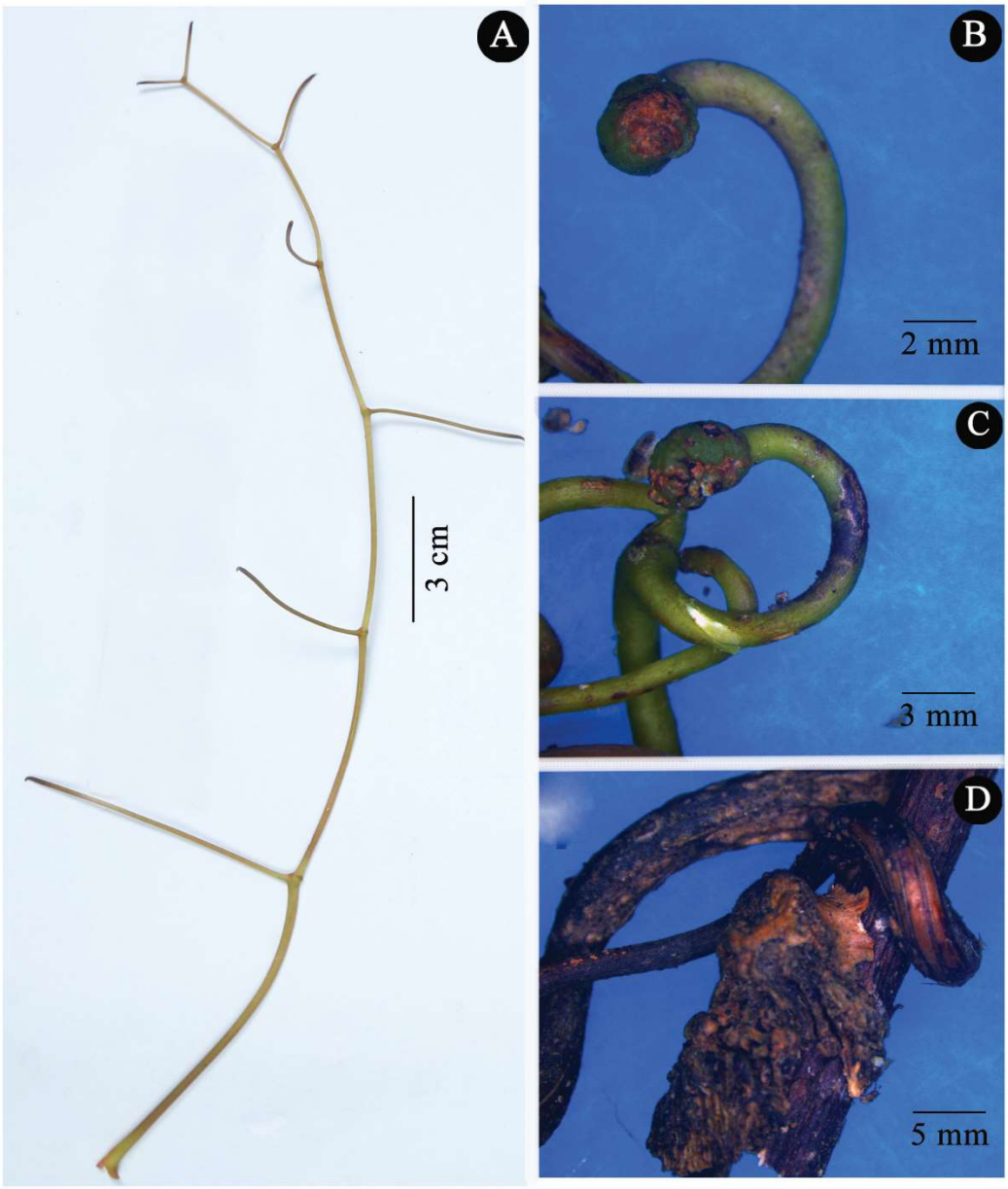

Plate 09. Tendril parts of *Parthenocissus sasii*. **A.** Tendril with branches; **B.** Young tendril tip; **C.** Mature tendril; **D.** Adhesive pad with host plant bark.

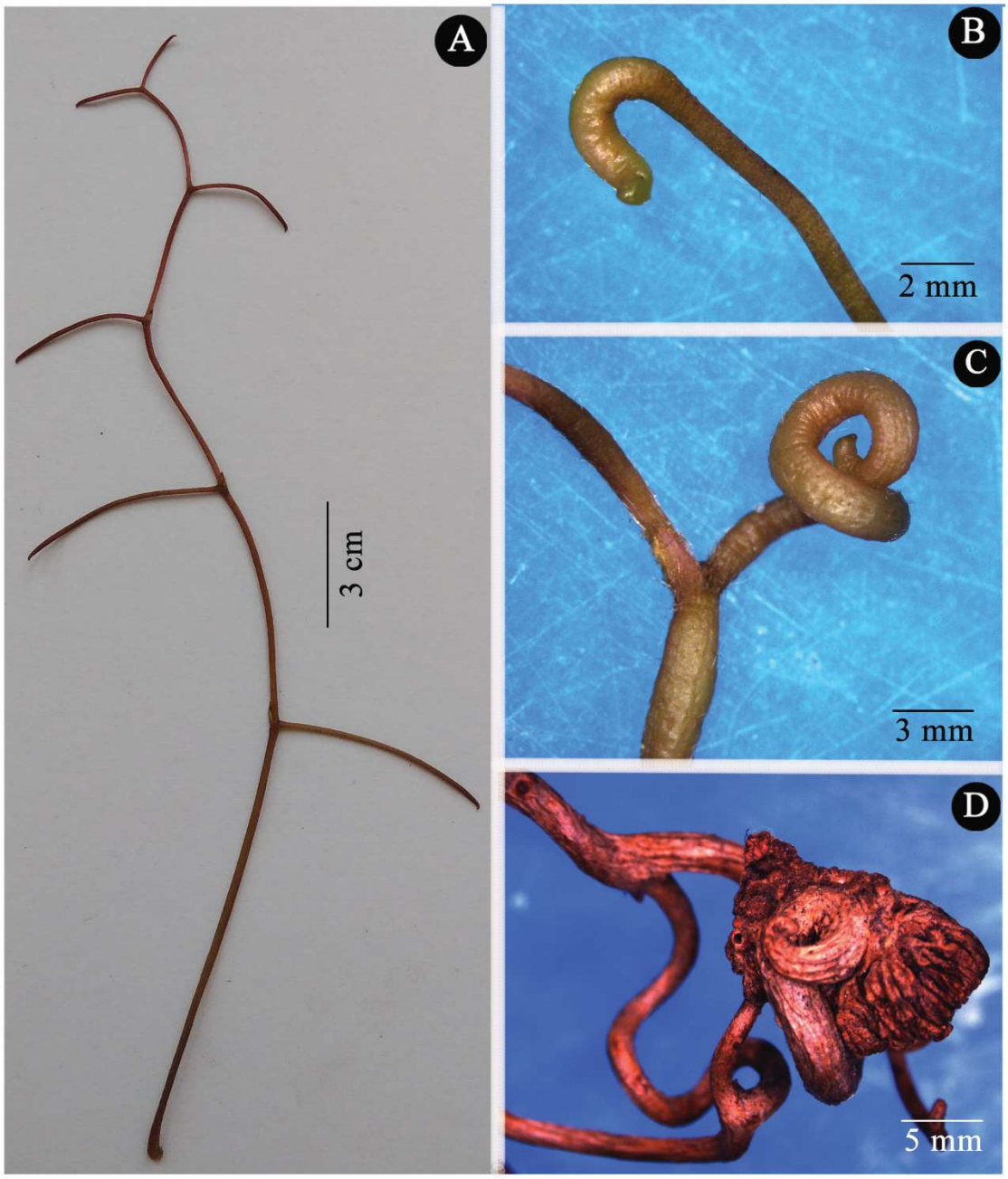

Plate 10. Tendril parts of *Parthenocissus subferruginea.* **A.** Tendril with branches; **B.** Young tendril tip; **C.** Mature tendril; **D.** Adhesive pad with host plant bark.

5. Pollen grain (Table 2) (Plate 11, 12, 13, 14 & 15)

Pollen grains of all the taxa in this genus are monomorphic, radially symmetrical, isopolar, and tricolporate in apertures. The shape of the pollen grain is commonly spheroidal. The outline of pollen grains was elliptical in the equatorial view and was three lobed circular in the polar view. The pollen apertures of all species were sunken and tricolpate, with the colpi extending nearly to the poles. In most cases, the colpi were narrow, smooth, and linear. Then, pollen grains are shed as monads.

P. renukae

Pollen grains are monomorphic, radially symmetrical, isopolar, and tricolpate; the size of the polar axis varies from 44.02 – 57.44 µm, and the size of the equatorial axis varies from 37.31 – 48.47 µm. Colpi length varies from 33.23 – 35.41 µm. The shape of the pollen grain is subprolate. Exine sculpturing shows foveolate ornamentation.

P. semicordata

Pollen grains are monomorphic, radially symmetrical, isopolar, and tricolpate; the size of the polar axis varies from 38.31 – 44.24 µm, and the size of the equatorial axis varies from 25.3 – 28.97 µm. Colpi length ranges from 27.9 – 30.10 µm. The shape of the pollen grain is prolate. Exine sculpturing shows foveolate ornamentation.

P. wallichianus

Pollen grains are monomorphic, radially symmetrical, isopolar, and tricolporate; the size of the polar axis varies from 19.43 – 21.2 µm, and the size of the equatorial axis varies from 24.03 –26.22 µm. Colpi length varies from 19.02 – 20.17 µm. The shape of the pollen grain is suboblate. Exine sculpturing shows reticulate ornamentation.

P. sasii

Pollen grains are monomorphic, radially symmetrical, isopolar, and tricolpate; the size of the polar axis varies from 31.5 – 35.47 µm, and the size of the equatorial axis varies from 16.5 – 18.6 µm. Colpi length varies from 27.47 – 29.17 µm. The shape of the pollen grain is prolate. Exine sculpturing shows foveolate-reticulate ornamentation.

P. subferruginea

Pollen grains are monomorphic, radially symmetrical, isopolar, and tricolpate; the size of the polar axis varies from 29.6 – 39.6 µm, and the size of the equatorial axis varies from 16.02 – 22.09 µm. Colpi length varies from 30.87 – 33.29 µm. The shape of the pollen grain is prolate. Exine sculpturing shows reticulate ornamentation.

6. Seed and Seed coat (Plate 16, 17, 18, 19 & 20)

Parthenocissus seeds show a sharp apical notch, an oval chalaza near the notch, and long, divergent linear ventral infolds. They mostly have very thin endotesta. Seedcoat ornamentation varies significantly in this genus.

P. renukae

The size of the seeds is 5.26 x 3.53 mm. The shape is an elongated water drop; the outline is obovate and sparsely hairy. Testa is slightly rough and shows narrow or inconspicuous lines of reticulation. The beak is prominent. The ventral infold is linear, deep and converging. The raphal ridge is prominent.

P. semicordata

The size of the seeds is 2.74 x 2.01 mm. The shape is plano convex, and the outline is obovate. Testa smooth with inconspicuous membranous reticulation without beaded granules. The beak is somewhat blunt. The ventral infolds are narrow, almost linear, and parallel, extending the complete way of the ventral surface. The raphal ridge is recessed.

P. wallichianus

The size of the seeds is 1.1 x 0.9 mm. The shape is plano convex, and the outline is obovate. Testa ornamentation shows a smooth solid hexagon without projection, having tiny pores. The beak is inconspicuous. The ventral infolds quite deep grooves and converging. The raphal ridge is prominent.

P. sasii

The size of the seeds is 2.2 x 1.19 mm. The shape is a water drop, and the outline is obovate. Testa rough and membranous reticulation with beaded all over the surface, surface filled with granule like particles. The beak is prominent. The ventral infold is linear, deep and converging. The raphal ridge is prominent.

Table 2. Pollen grain P/ E ratio of *Parthenocissus* spp.

Species	Sample 1			Sample 2			Sample 3			Sample 4			Mean (P)	SD	SE	Mean (E)	SD	SE	Mean	SD	Standard error
	P	E	P/E x 100	P	E	P/E x 100	P	E	P/E x 100	P	E	P/E x 100							P/E X 100		
P.renukae	50.69	43.45	117.8	44.0	37.3	117.9	53.8	46.9	114.7	57.4	48.4	118.5	51.5	5.69	2.84	44.04	4.95	2.47	117.2	1.7	0.85
P.semicordata	41.18	27.2	151.3	38.3	25.3	151.4	41.5	27.5	150.9	44.2	28.9	153	41.3	2.42	1.21	27.25	1.51	0.75	151.6	0.925	0.46
P. sasii	31.53	16.5	191	34.9	18.6	187.5	35.4	18.6	190.6	33.7	18.0	187.3	33.9	1.74	0.87	17.9	0.99	0.49	189.1	1.96	0.98
P.wallichianus	21.18	24.94	84.9	19.8	25.4	78.25	20.2	26.2	77.19	19.4	24.0	80.8	20.2	0.74	0.37	25.14	0.91	0.45	80.2	3.42	1.71
P.subferruginea	35.34	19.58	180.4	29.6	16.2	182.7	31.3	17.4	180	39.6	22.0	179.2	33.9	4.45	2.22	18.8	2.59	1.29	180.5	1.5	0.75

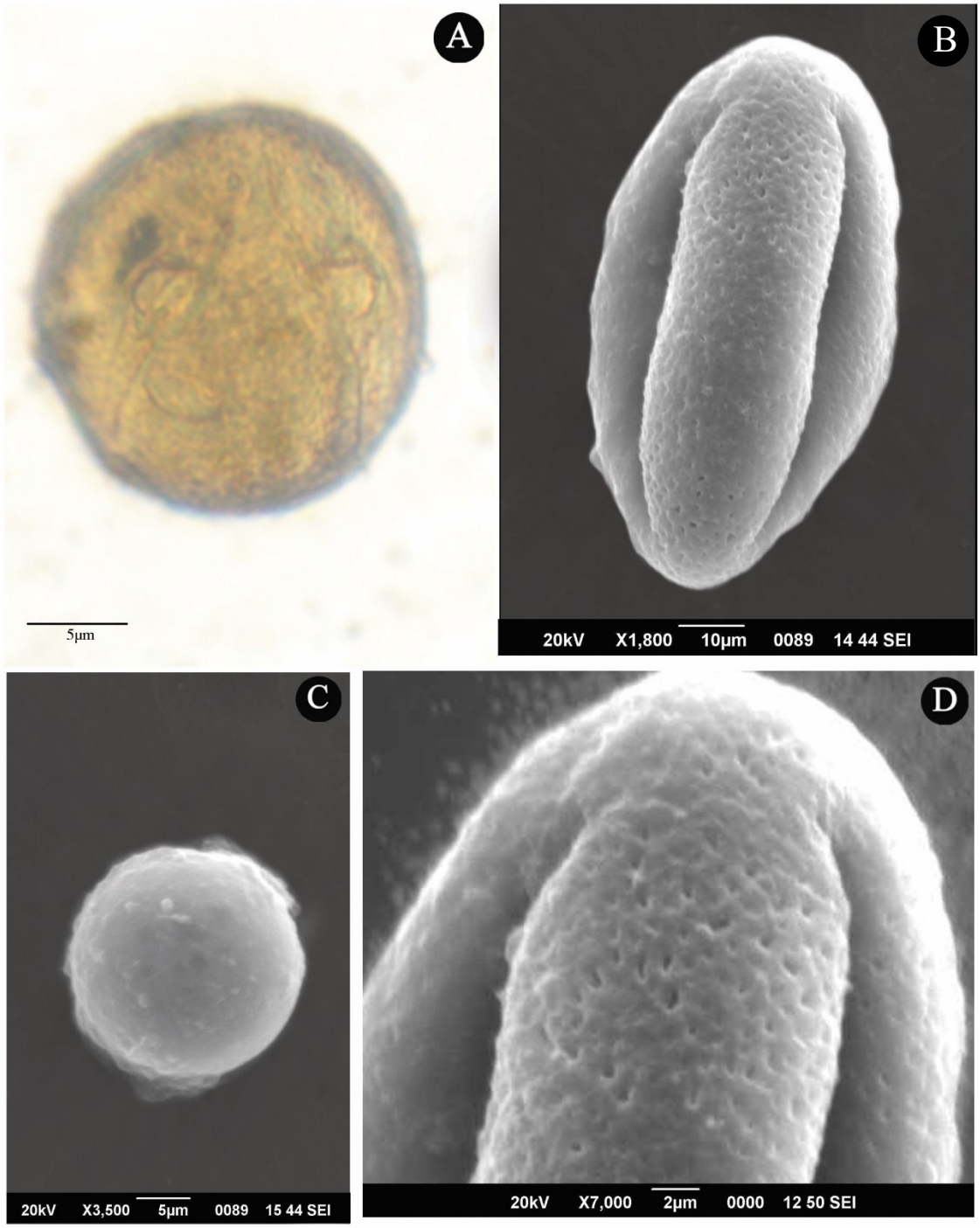

Plate 11. Pollen grain of *Parthenocissus renukae.* **A.** LM view; **B.** Equatorial view; **C.** Polar view; **D.** Exine ornamentation.

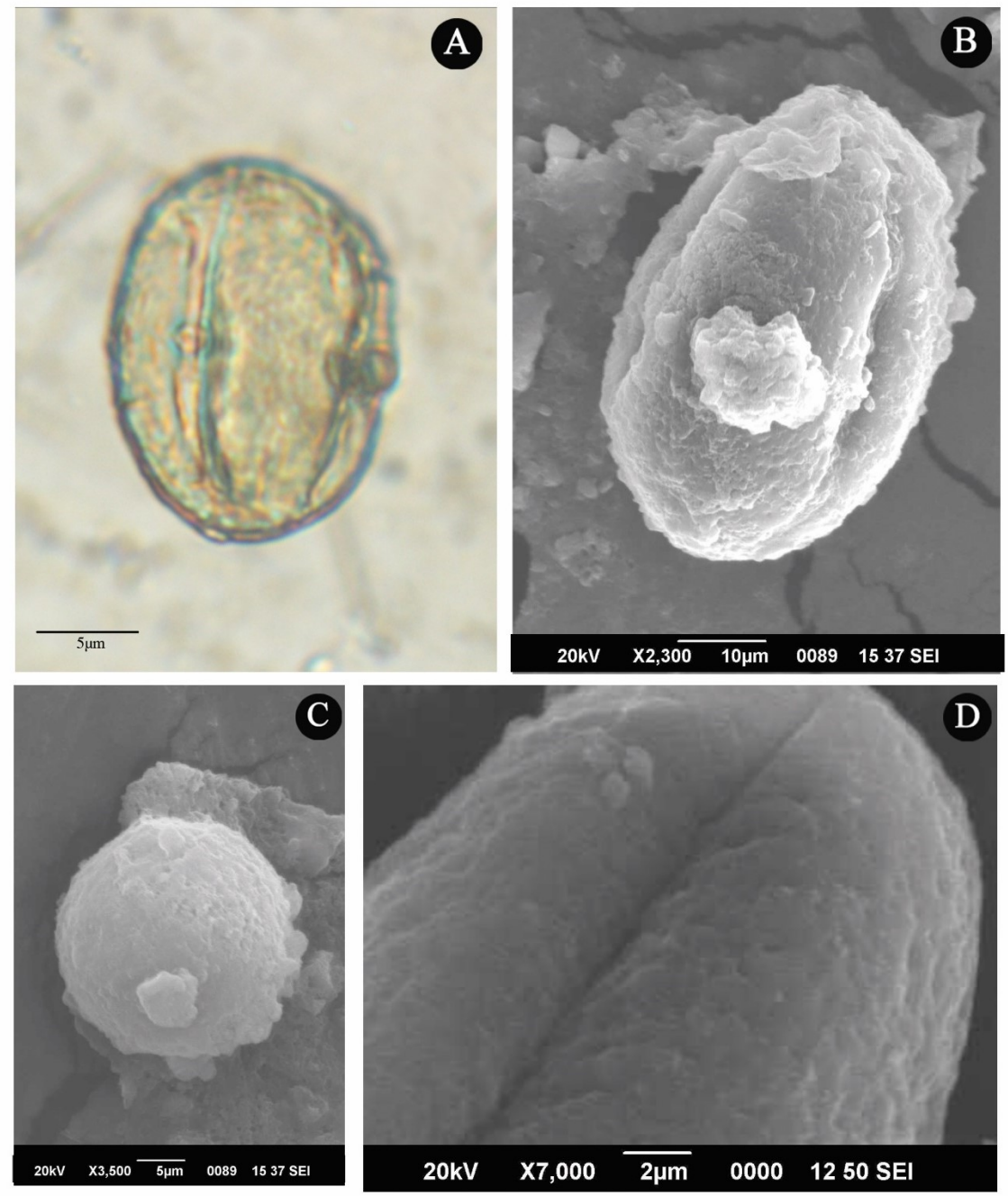

Plate 12. Pollen grain of *Parthenocissus semicordata* var. *roylei.* **A.** LM view; **B.** Equatorial view; **C.** Polar view; **D.** Exine ornamentation.

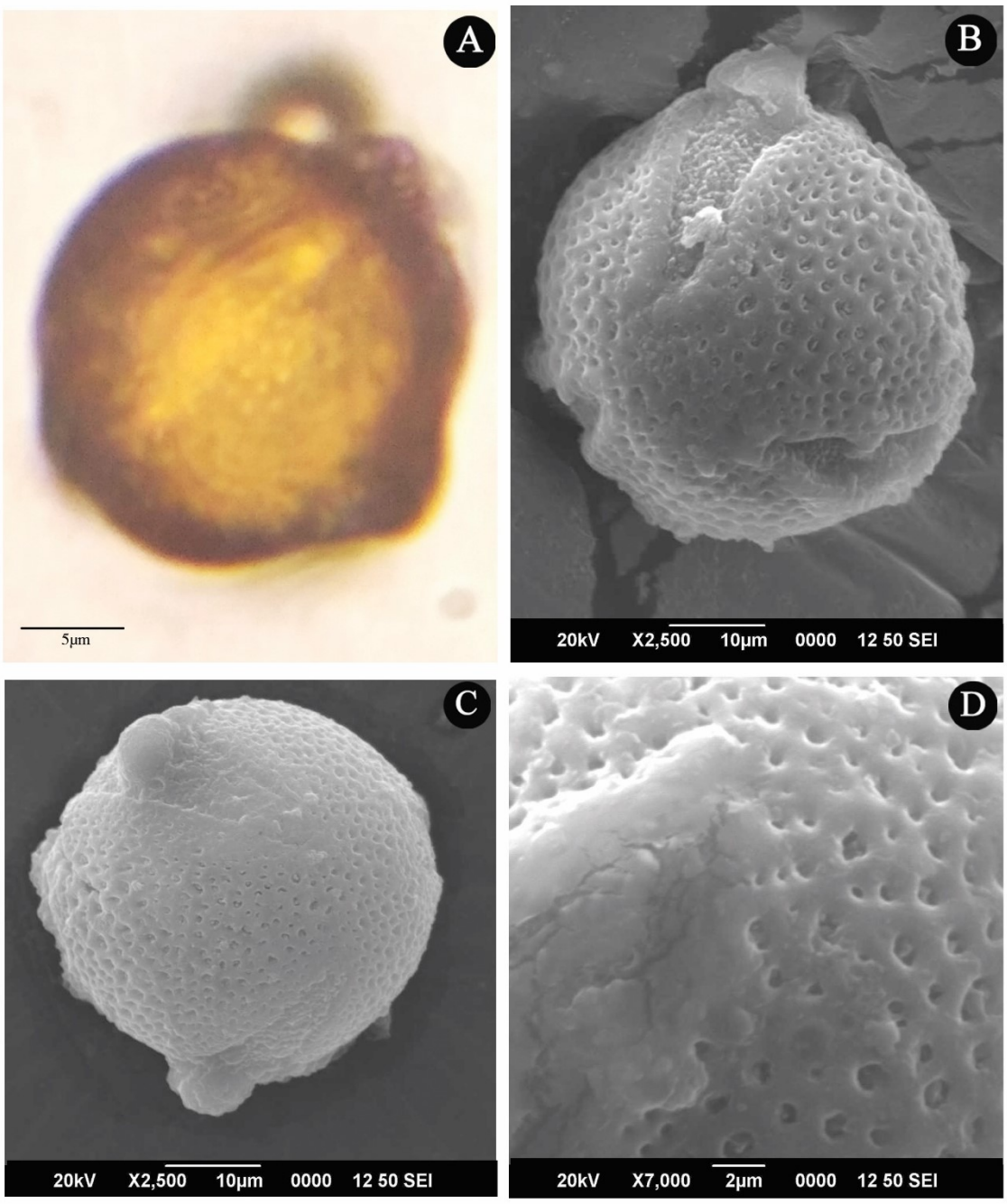

Plate 13. Pollen grain of *Parthenocissus wallichianus.* **A.** LM view; **B.** Equatorial view; **C.** Polar view; **D.** Exine ornamentation.

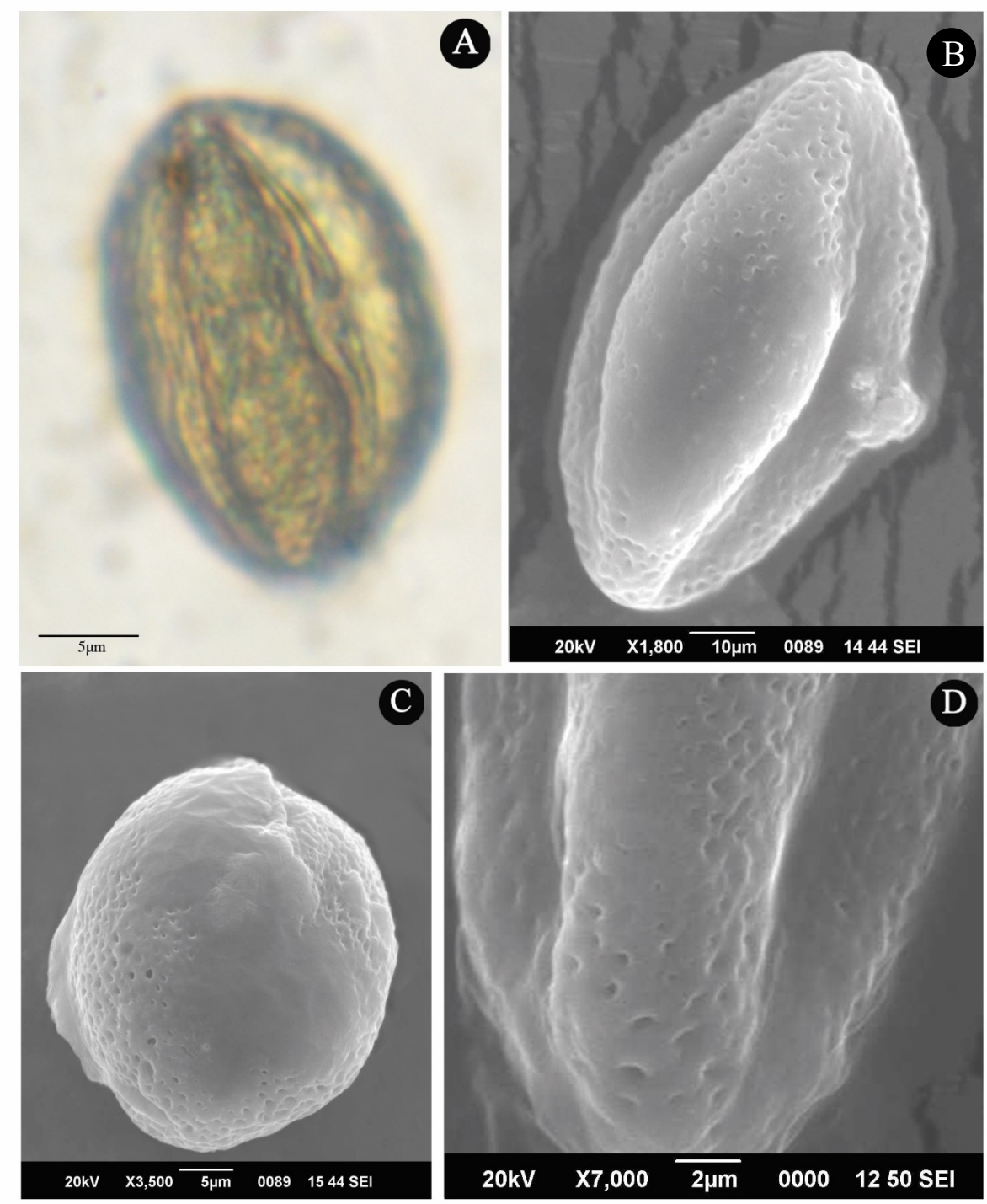

Plate 14. Pollen grain of *Parthenocissus sasii.* **A.** LM view; **B.** Equatorial view; **C.** Polar view; **D.** Exine ornamentation.

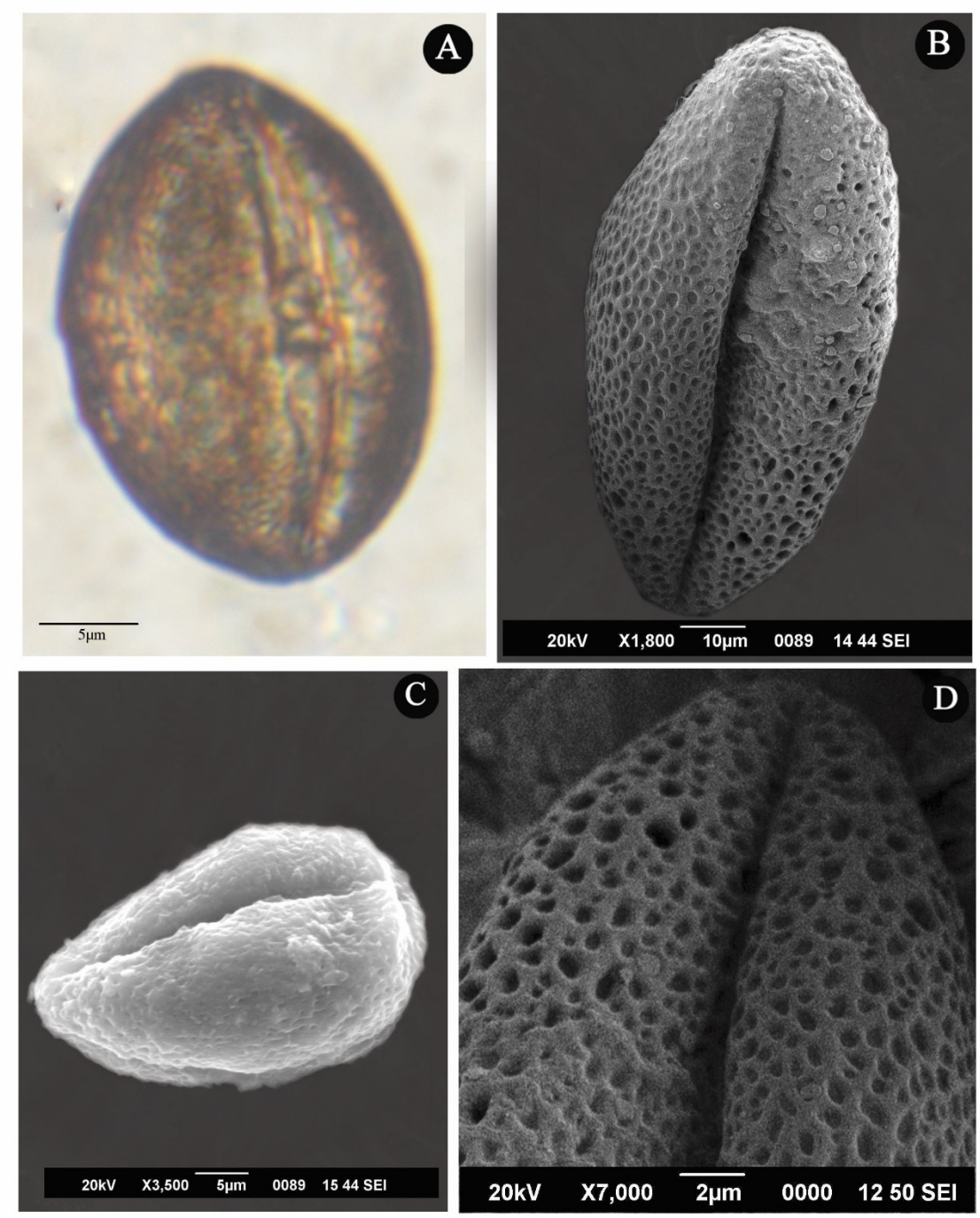

Plate 15. Pollen grain of *Parthenocissus subferruginea.* **A.** LM view; **B.** Equatorial view; **C.** Polar view; **D.** Exine ornamentation.

P. subferruginea

The size of the seeds is 4.01 x 2.2 mm. The shape is an elongated water drop, and the outline is obovate. Testa with membraneous reticulation. The beak is prominent. The ventral infolds are linear, deep and converging. The raphal ridge is prominent.

4.3. Molecular Phylogenetic analysis (Fig. 17, 18, 19, 20, 21 & 22)

In this study, five *rbcL* sequences were newly generated, and an additional 11 *rbcL* sequences of *Parthenocissus* were retrieved from Gen bank. The outgroup was selected from outside the genus. Based on the similarity searches most of the species related to *C. discolor*. So, the sequence of *C. discolor* was downloaded from Genbank as an outgroup. The evolutionary history was inferred by using the Maximum Likelihood method based on the Kimura 2 parameter model. The tree with the highest log likelihood (-2094.9423) is shown. The percentage of trees in which the associated taxa clustered together is shown next to the branches. Initial tree(s) for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood (MCL) approach and then selecting the topology with superior log likelihood value. The analysis involved 17 nucleotide sequences. All positions with less than 95% site coverage were eliminated. That is, fewer than 5% alignment gaps, missing data, and ambiguous bases were allowed at any position. There was a total of 463 positions in the final dataset. Evolutionary analyses were conducted in MEGA 6.

The similarity study conducted among five taxa of *Parthenocissus* using micromorphological characters indicates considerable variation in taxa. The dendrogram reveals that 17 taxa used in phylogenetic analysis fall under three clades.

Clade I: Clade I is represented by seven species. Clade I is further divided into two subclades. The first subclade of clade I consist of 5 species, and the second subclade of clade I consist of two species. Members of the first subclade include *P. semicordata* var. *semicordata, P. suberosa*, *P. feddei*, *P. sichuanensis*, and *P. laetevirens*. Members of the second subclade consist of *P. dalzielii* and *P. henryana.* This clade is supported by a high bootstrap value.

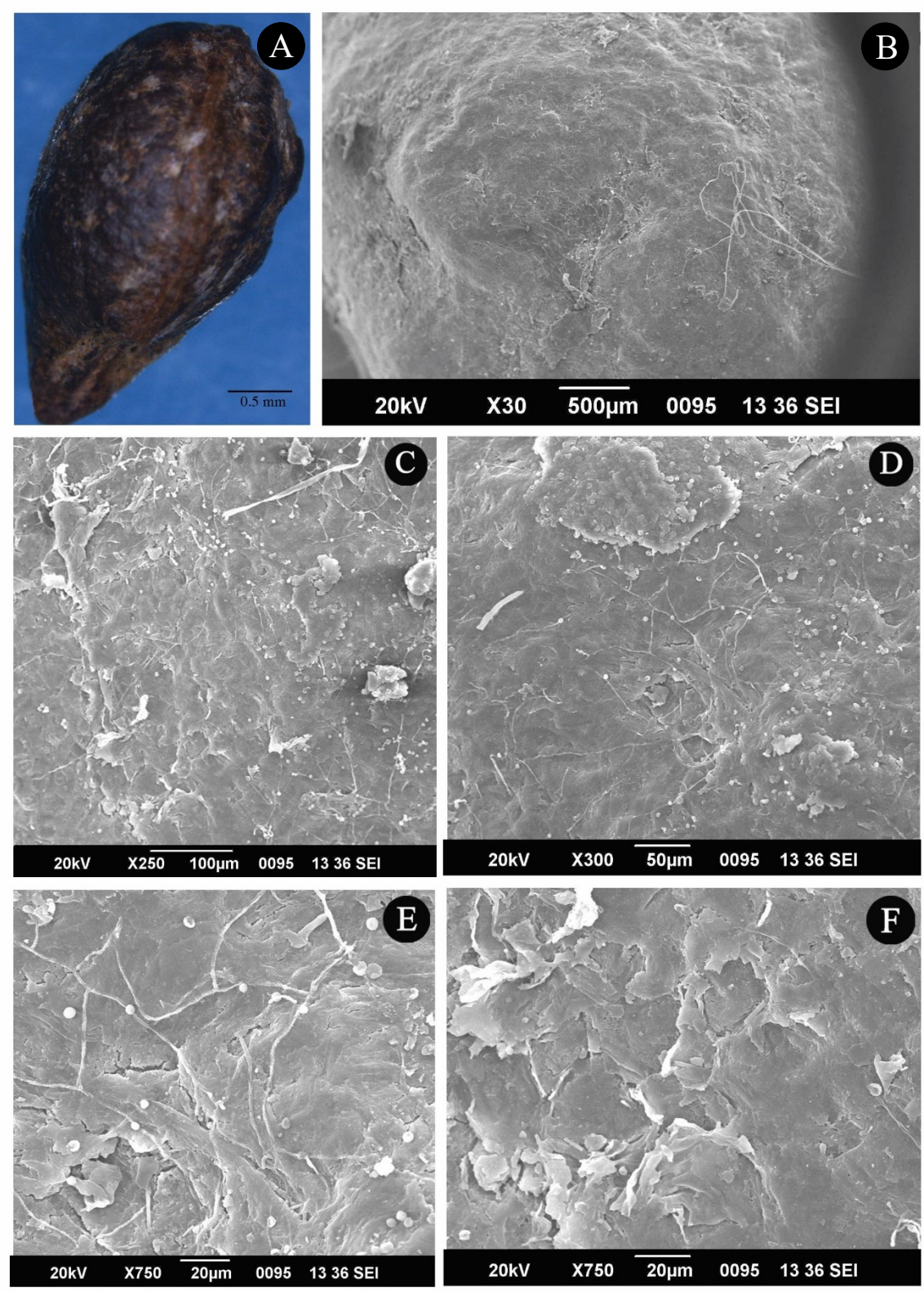

Plate 16. Seed and Seedcoat of *Parthenocissus renukae.* **A.** Seed; **B-F.** Seed coat morphology under scanning electron microscope (SEM).

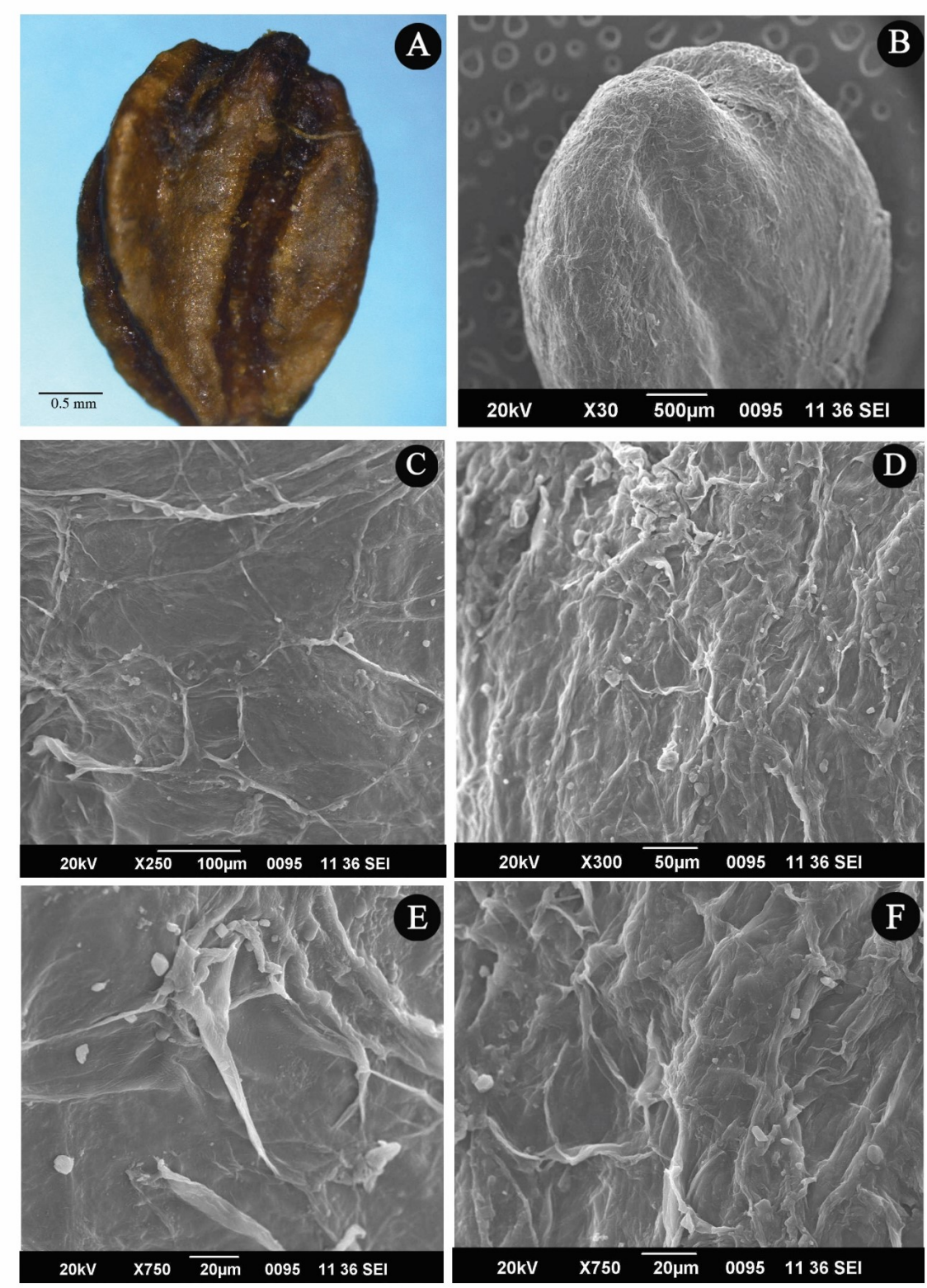

Plate 17. Seed and Seedcoat of *Parthenocissus semicordata* var. *roylei.* **A.** Seed; **B-F.** Seed coat morphology under scanning electron microscope (SEM).

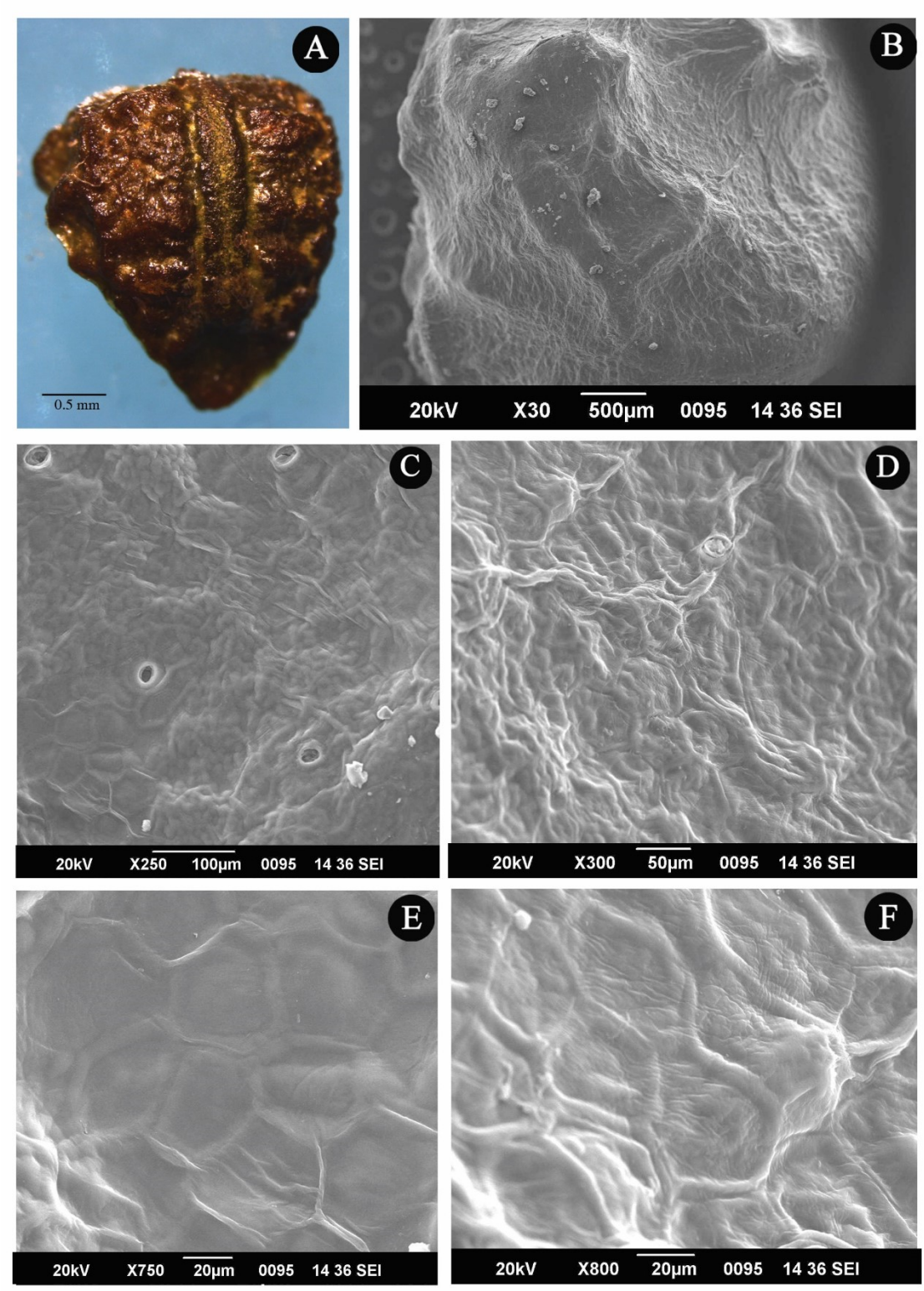

Plate 18. Seed and Seedcoat of *Parthenocissus wallichianus.* **A.** Seed; **B-F.** Seed coat morphology under scanning electron microscope (SEM).

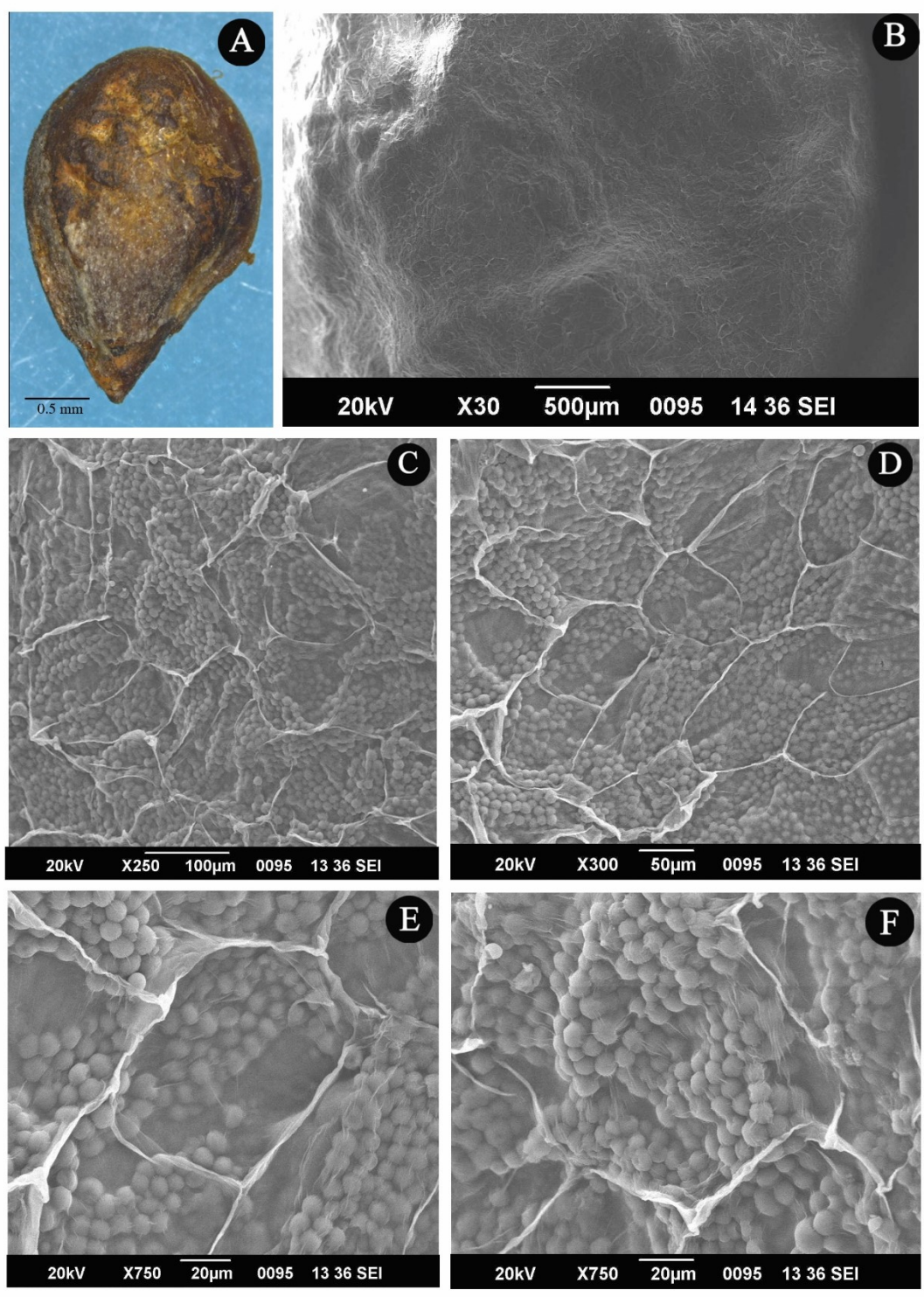

Plate 19. Seed and Seedcoat of *Parthenocissus sasii.* **A.** Seed; **B-F.** Seed coat morphology under scanning electron microscope (SEM).

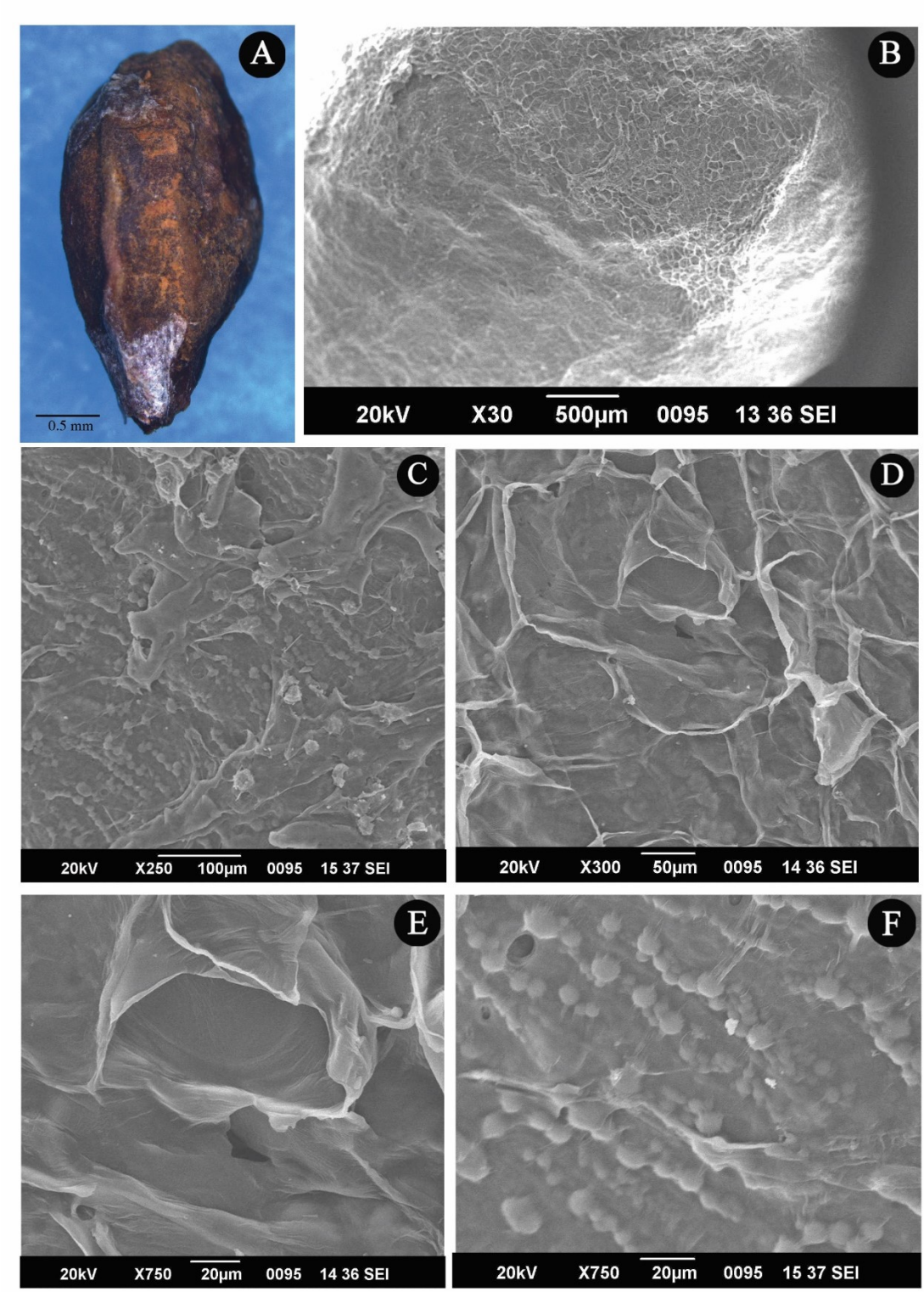

Plate 20. Seed and seedcoat of *Parthenocissus subferruginea* **A.** Seed; **B-F.** Seed coat morphology under scanning electron microscope (SEM).

Clade II: Clade II consist of three species**.** *P. quinquefolia*, *P. heptaphylla* and *P. vitacea*. *P. quinquefolia* strongly support the other two species with high bootstrap values.

Clade III: This clade consists of 5 species and one variety. As per the phylogenetic tree, the clade is divided into two subclades. The first subclade consists of three species: *P. subferruginea*, *P. renukae* and *P. sasii*. The second subclade consists of *P. wallichianus* and *P. semicordata* var. *roylei*. *P. tricuspidata* holds a distinct position. *P. tricuspidata* form a strongly supported clade, with the rest of the species having 100% bootstrap values. *P. wallichianus* and *P. semicordata* var. *roylei* also form a clade with high bootstrap values. *P. subferruginea*, *P. renukae* and *P. sasii* form a clade with moderate bootstrap values.

Table 3. List of *Parthenocissus* spp. with voucher information retrieved from Genbank.

Sl.No	**Taxa**	**Accession number**	**Voucher**
1	*Parthenocissus feddei*	HM223416	ZDG319 (KUN)
2	*Parthenocissus heptaphylla*	HM223366	Wen 9770 (US)
3	*Parthenocissus quinquefolia*	HM223397	Wen 10423 (US)
4	*Parthenocissus dalzielii*	HM223411	DQ024 (PE)
5	*Parthenocissus henryana*	HM223383	Nie & Meng 359 (KUN)
6	*Parthenocissus laetevirens*	HM223378	Wen 9376 (US)
7	*Parthenocissus semicordata* var. *semicordata*	HM223394	Nie & Zhu 564 (KUN)
8	*Parthenocissus sichuanensis*	HM223399	Wen 10635 (US)
9	*Parthenocissus suberosa*	HM223384	Nie & Meng 358 (KUN)
10	*Parthenocissus vitacea*	HM223377	Wen 7312 (US)
11	*Parthenocissus tricuspidata*	KP088704	BOP010173

Table 4. List of newly evolved *Parthenocissus* spp. with Accession number.

Sl.No	**Taxa**	**Accession number**
1	*P. renukae*	OQ994955
2	*P. semicordata* var. *roylei*	OQ985052
3	*P. wallichianus*	OQ971925
4	*P. sasii*	OR532375
5	*P. subferruginea*	OR101255

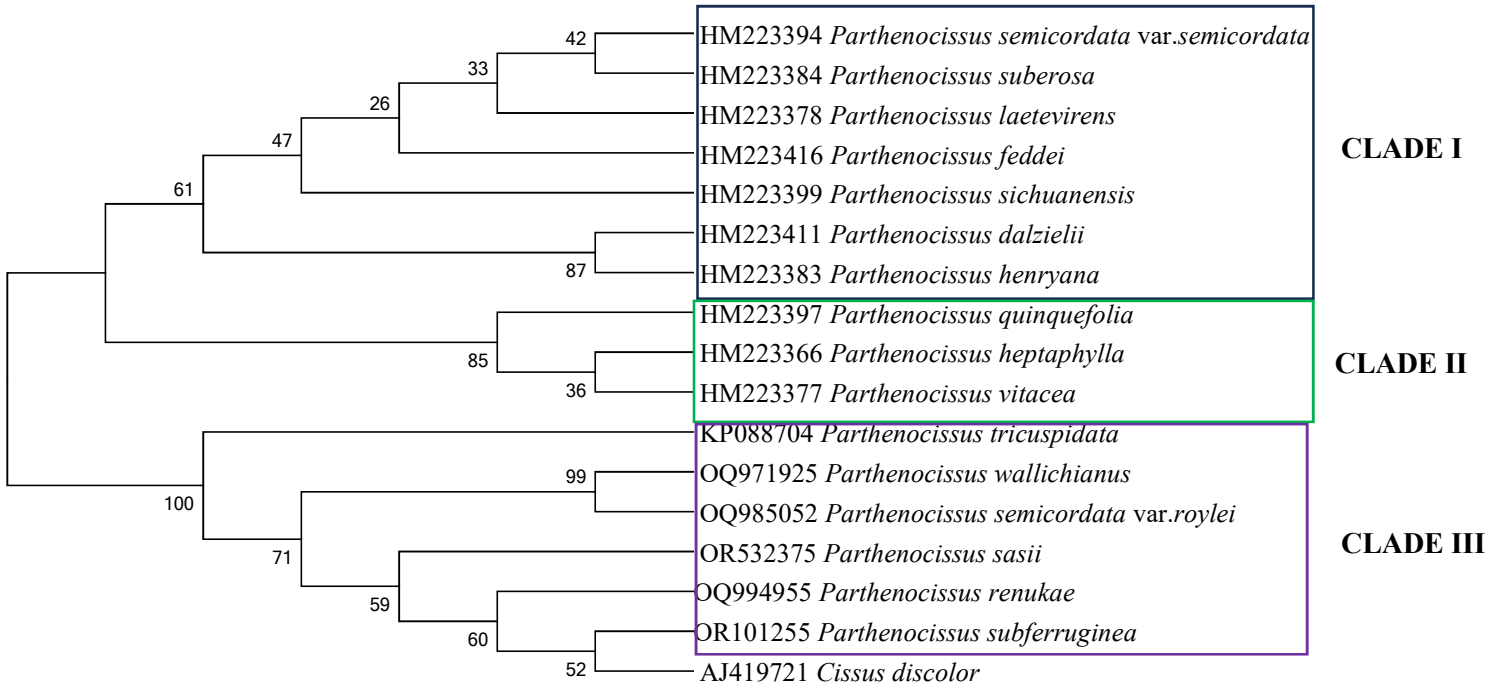

Figure 17. Phylogenetic tree of genus *Parthenocissus*

Chapter-5

Discussion

The main objective of this study is to document the genus *Parthenocissus* using morphological and molecular data. The taxonomic study contains nomenclatural history, systematic treatment, micromorphology, flowering and fruiting, habitat, and species distribution. The present study reports eight taxa in India, including varieties of the genus *Parthenocissus*. Among them, two species were alien and cultivated as ornamentals in the northeast states of India. Two varieties of *P. semicordata* have been reported from India. One from the Northeast states and the other from South India. These two varieties are morphologically similar except for the hispid nature in the young branches, petioles and nerves on the lower leaf surface (Raizada, 1967). The rest of the four species were collected and described from South India.

Most Indian species prefer moist deciduous forests, Such *as P. renukae*, *P. subferruginea* and *P. wallichianus*. *P. sasii* prefers both riparian as well as moist deciduous forests. *P. semicordata* prefer evergreen and sholas with high-altitude ranges. *P. tricuspidata* and *P. quinquefolia* are grown as ornamentals along the roadsides on fences, bricks and walls of buildings.

5.1. Comparative morphology

Habit (Plate 21)

Members of the genus are lianas or woody wines climbing or trailing by tendrils and rootlets. The tendrils attach themselves to the support by twining (coiling) or by adhesive discs developing at the apices of their branches in response to a contact stimulus (Brizicky,1965). *Parthenocissus* species can be easily identified from other climbing species of Vitaceae by its close contact with the main stem of the host plant. These plants flourish and cover the entire canopy of the host plant, which will lead to the destruction of host species. The presence of *Parthenocissus* plants was fragmented and pocketed distribution.

Leaves (Plate 22)

Leaves are mainly two types in the genus *Parthenocissus*: species with simple leaves and compound with trifoliate or multifoliate leaves. *P. renukae*, *P. tricuspidata*, *P. sasii* and *P. subferruginea* show simple leaves with deeply cordate leaf bases and dentate serrate margins. *P. subferruginea* possess simple but five angled leaves. In *P.*

tricuspidata, leaves are simple but trilobed compared to other species. *P. sasii* produces dimorphic leaves during vegetative and reproductive phases. Leaves are small and shallowly cordate in the reproductive phase and large with deep cordate in the vegetative phase. *P. wallichianus and P. semicordata* show trifoliate leaves with one terminal leaflet and two lateral oblique leaflets rounded at the base. *P. quinquefolia* has pentafoliate leaves. In the majority of the species, the leaf apex is acuminate. However, mucronate to the apiculate apex is observed in *P. wallichianus.*

Characteristic T shaped hair was observed on the leaf surface of most species. However, this is absent in *P. sasii* and *P. semicordata*. *P. sasii* has the longest petiole, up to 17cm, and *P. wallichianus* is the smallest one.

Leaf Stipule (Plate 23)

Interpetiolar stipule is prominent in all the species. However, the shape of the stipule has variations in different species; it is elongated in *P. renukae*, *P. semicordata* and *P. subferruginea.* Hence, it is triangular in *P. sasii* and *P. wallichianus*. In some species, the stipule is pubescent as in *P. renukae*, *P. subferruginea and P. wallichianus.* The stipule is broad and falcate in *P. tricuspidata* and *P. quinquefolia* but rarely pointed in *P. sasii*. Stipules are large in *P. renukae* and small in *P. semicordata.* Mature stipules live for two weeks, then come dead and black and remain in the stem.

Leaf Stomata (Plate 24)

Leaf stomata show variation among the genus *Parthenocissus*. Most species, such as *P. wallichianus, P. sasii,* and *P. subferruginea*, show tetracytic stomata surrounded by four subsidiary cells. Species like *P. renukae* and *P. semicordata* found anomocytic stomata with five subsidiary cells. In earlier works, anomocytic stomata were reported in *P. tricuspidata* and *P. quinquefolia* (Lubna *et al*., 2019). The polygonal epidermal cells are the common characteristics of this genus, except irregular epidermal cells present in *P. semicordata.* Based on our observation, we found that the number of subsidiary cells correlated to the merous nature of the flower. The giant stomatal pore and guard cell were found in *P. wallichianus*. The smallest stomatal pore and guard cell was present in *P. subferruginea*.

Tendril (Plate 25)

Parthenocissus can be easily distinguished from the other genera of Vitaceae by its highly branched tendrils and adhesive discs at tendril apices (Lu *et al*., 2012). As a key character, all the species possess leaf-opposed branched tendrils with attaching pads/suckers in the tip. In most species, tendrils are arranged as intermittent, monochasial 3 – 12 branched, and sometimes dichasial. In *P. semicordata,* tendril branching slightly differs from the rest of the species; here, primarily, they show dichasial branching, and then each dichasial branch produces monochasial branchlets. Hence number of branchlets, length of tendril, and shape of the suckers varies among the species. In *P. semicordata,* they observed the highest number of branchlets. At the same time, *P. wallichianus* and *P. subferruginea* observed the least number. The tendril length of each species ranges from 7 – 30 cm. *P. subferruginea* has the longest tendril, and *P. renukae* has the shortest tendril. According to Lu *et al*., (2012), *P. tricuspidata* and *P. quinquefolia* produce 5 – 9 branchlets.

The features of adhesive suckers are essential for identification. It may be fist-shaped, ball-shaped, tubercle, or ring-shaped. Based on our observation, we found that the area of meristematic tissue present in each tendril tip determines the shape of the adhesive pad. Tendril tip with globose meristem promotes ball-shaped adhesive pad as in *P. sasii* and *P. wallichianus*. The short and stout meristem in the subterminal region promotes a shaped adhesive pad like in *P. renukae* and *P. semicordata.* If the meristematic region covers the extended subterminal portion, it will promote the formation of a tubercle or ring-shaped adhesive pad, which presents *P. subferruginea.*

5.2. Floral Morphology

Inflorescence (Plate 26)

In the *Parthenocissus* genus, the inflorescence structure was used as a critical taxonomic character in the classification system of Li (1996, 1998). Inflorescences usually have many-flowered cymose panicles with prolonged monochasial branched rachises or corymb-like bifurcately branched thyrses, lacking tendrils, opposite the leaves, intermittent and sometimes also terminal (Brizicky, 1965). Inflorescence type such as compound dichasial cyme observed in *P. wallichianus.* While in other species, it is umbellate monochasial cymes. In certain species like *P. renukae*, *P. semicordata,*

P. sasii, and *P. subferruginea*, the inflorescence is terminal in position. While extra-axillary in *P. wallichianus.* In *P. renukae,* the inflorescence is extremely short compared to other species. Lu *et al*., (2012) reported that polychasium type of inflorescence was observed in cultivated plants like *P. tricuspidata* and *P. quinquefolia*.

Flower (Plate 27)

Flowers are perfect, minute, pedicellate, bisexual, more or less homogenous in appearance, tetramerous, or pentamerous. In *P. renukae*, both tetramerous and pentamerous conditions occur. *P. semicordata*, *P. tricuspidata* and *P. quinquefolia* have a pentamerous condition, while the rest have a tetramerous condition. The flowers are usually pink in colour. Sometimes, the colour may vary from green to pale green. *P. renukae* flowers are pale green with a pink tinge on the apex. Flowers are green in *P. semicordata* and *P. wallichianus*.

Calyx

The calyx is truncated in most species except for the obscurely 5 lobed calyx observed in *P. semicordata*. In *P. wallichianus,* the calyx is covered by tiny hairs.

Corolla (Plate 28)

Corolla consists of four or five petals, spreading in flowering and falling after blossom but showing a wide range of variation. Petals are mostly pink or pale green with pink in colour. However, in *P. semicordata*, the petals are green. There was an appendage on the inner side of the petals. This is another crucial characteristic of the *Parthenocissus* genus. The inner side of the petals shows papillary outgrowth of certain species, such as *P. renukae* and *P. sasii*. As earlier works reported, inconspicuous corolla appendage in *P. tricuspidata* and *P. quinquefolia* (Lu *et al*., 2012) *P. wallichianus* also shows the inconspicuous corolla appendage. Instead of papillary outgrowth, multiple glandular outgrowths are seen in the *P. subferruginea*. However, in *P. semicordata,* a bi lobed tongue like membrane outgrowth was observed in the inner side of the petal. The dorsal surface of the corolla is papillate and gland dotted in *P. sasii* and *P. subferruginea*. In *P. renukae* and *P. subferruginea*, characteristic T shaped hairs were observed on the outer surface of the petal. Corolla

is triangular in most species. However, sub globose in *P. wallichianus* and an elongated oval shape can be seen in *P. semicordata.*

Androecium (Plate 29)

In the *Parthenocissus* genus, stamens are 4 or 5, antipetalous, anthers dithecous, dorsifixed, and yellow and attached to the base of the disc. The length and shape of the filament vary among the species. Comparing the length of filaments, the most extended filament was observed in *P. semicordata,* while the shortest was in *P. wallichianus.* In most species, the filament is broad at the base, but a shallowly "L" shaped filament base is found in *P. sasii* and *P. subferruginea*.

Gynoecium (Plate 30)

The gynoecium is composed of the ovary, style, and stigma. The genus *Parthenocissus* is characterised by the presence of a glandular disc, which is entirely adnate for the base of the ovary. The nectariferous disc is well developed in *P. wallichianus.* Certain species like *P*. *renukae*, *P*. *sasii*, and *P*. *subferruginea* disc become swollen and form four lobes. T shaped hairs are also found in the disc of the species mentioned above. Disc inconspicuous in *P. semicordata*. The ovary is superior and 2 locular.

The style is short and thick in most species, and the stigma is capitate. However, the *P. wallichianus* style is conical in shape, and the stigma is indistinct. The stigma shows colour variation in certain species, such as violet *P. wallichianus* and white in *P. semicordata.*

Fruits (Plate 31)

In this genus, fruit is a berry, showing variation among the species. Berries are obovate in *P. renukae* and *P. sasii*. Narrowly obovate berries are found in *P. semicordata*. In *P. wallichianus* berries are oblate in shape. Ellipsoid-pyriform berries observed in *P. subferruginea.* Berries of *P. renukae*, *P. sasii* and *P. subferruginea* are gland dotted. In most species, berries are blue-black with 1– 4 seeds.

Seeds (Plate 32)

The seeds between the species showed marked differences in the genus *Parthenocissus*. The shape of the seed is plano convex in *P. semicordata* and *P. wallichianus*. It becomes an elongated water drop in certain species, as in *P. renukae* and *P. subferruginea*. According to Lu *et al*., (2012) seeds are obovate in *P. tricuspidata* and *P. quinquefolia*; this kind of seed is also observed in *P. sasii*. In most species, testa is rough, except for rough *P*. *semicordata*. The beak is prominent in most species, like *P. renukae*, *P. sasii,* and *P. subferruginea*. In *P. semicordata,* the beak is somewhat blunt and inconspicuous in *P. wallichianus.*

The ventral infolds are another key character of the genus *Parthenocissus*. Usually, it is linear, deep, and converging. However, a slight variation is seen in species like *P. semicordata* and *P. wallichianus.* The ventral infolds were found to be narrow, almost linear, and parallel, extending full way of the ventral surface in *P. semicordata,* and ventral infolds become deep grooves and converging in *P. wallichianus*. The raphal ridge is prominent in almost all species but recessed in *P. semicordata.* Latiff (2012) states that the raphal ridge is linear and recessed in *P. tricuspidata*.

5.3. Micromorphology

Pollen (Plate 33)

Pollen grains of all the taxa in this genus are monomorphic, radially symmetrical, isopolar, and tricolporate in apertures. The shape of the pollen grain is commonly prolate. In *P. renukae,* a slight variation is observed here. The pollen grains are subprolate. In *P. wallichianus,* the pollen grains are sub oblate. The outline of pollen grains was elliptical in the equatorial view and was three lobed circular in the polar view. The pollen apertures of all species were sunken and tricolpate, with the colpi extending nearly to the poles. In most cases, the colpi were narrow, smooth, and linear. Then, pollen grains are shed as monads.

In most species, exine sculpturing is foveolate or reticulate ornamentation. However, in *P. sasii,* foveolate-reticulate ornamentation is observed. The largest and elongated pollen grain is found in *P. renukae,* and the smallest and globose in *P. wallichianus*.

Seed coat (Plate 34)

In the *Parthenocissus* genus, the seed coat ornamentation varies among the species. Narrow or inconspicuous lines of reticulation are shared among species like *P. renukae*, *P. semicordata,* and *P. subferruginea*. Highly ornamented seed coat observed in *P. sasii* here membraneous reticulation with small granule like particles all over the seed surface. Lu *et al*., (2012) reported a solid hexagon seed coat in *P. tricuspidata* and *P. quinquefolia*. This type of seed coat is also observed in *P. wallichianus. P. wallichianus* differs from the former species with tiny pores in the seed coat.

5.4. New taxa discovered

The present study identified three new species; they are *P. renukae*, *P. wallichianus,* and *P. sasii*. *P. renukae* collected from Mangad, Thrissur District, Kerala; P. *wallichianus* from Kayampoovam, Thrissur district, Kerala; and *P. sasii* from Asurankundu dam in the Machad forest range from Kerala.

5.5. Reinstatement of *Parthenocissus subferruginea* Merr. & Chun.

In 1794, *C. repanda* was validly published by Vahl in Symbolae botanicae. Later, in 1887, Planchon proposed a new genus in the family of Vitaceae called *Parthenocissus*. Tendrils with more than three branches having an adhesive disc at the end of each tip are the key characteristic features of the genus *Parthenocissus.* Also, this feature separates this genus from its allied genus *Cissus*. Merrill and Chun (1940) jointly publish a new species of *P. subferruginea*. However, in 1996, Li published a unique variety of *C. repanda*: *C. repanda* var. s*ubferruginea*. Later, taxonomists synonymised the *P. subferruginea* with *C. repanda* var. s*ubferruginea*. (Wen, 2007) According to the protologue *C. repanda* is "*foliis cordatis integris fublobatisve repandis utrinque glabris, Ramx teretes, ftexuofi, articulati, tomentofi,tate glabri. Folia petiolata, bi-f. tripollicaria, latiora quam longa, cordata, firmiora quamin congeneribus, integra vel fublobata, nervofa, enofa, adultiora utrinque glabra, juniora villofa, repanda; crenis mucrone minuto terminatis, obtufiffima, interdum acumine brevi obtufo terminata. stipuovales, membranacese, acutaa, oppofitse, femiunguiculares, deciduse peduncuii oppofitifolii; radiiuinbellse tres dichotome ramofi. Pedicelli ultimi umbellati. Squama villofe, breviffimae ad bafin pedicellorum.Bacc/e pyriformes, magnitudine pifi, ftylo perfiftente mucronatae*".

While going through this protologue, it does not match with the original material of *P. subferruginea*.

In the isotype of *P. subferruginea,* Merrill was quoted as *Cissus*, "On tree on open, grassy hillside, woody, climbing, 6 m, flowers cream and collected by F.A. McClure between May 4 – 20, 1932 from Chim Shan, Fan Maan Ts'uen and vicinity as a part of 6th Hainan expedition. Later, in 1940, this specimen was described as the Isotype of *P. subferruginea* Moreover, it was determined by Franklin P. Metcalf on 7th February1941. The specimen was presented to the Arnold Arboretum by the trustees of Lingnan University in October 1954. Now, it is placed in Harvard University Herbaria with the barcode number 00051594. *C. repanda* is mainly located in South East Asia. But *P. subferruginea* shows vast distribution, including the Western ghat region. In the Flora of Khandala, *C. repanda* is described as the "finest vines in Khandala: with the help of sucker-like tendrils, it climbs along thick trunks of trees and covers them with its beautiful foliage". Based on the description above, it is clear that *P. subferruginea* wrongly identified as *C. repanda.* This study also strongly supports the distribution of *P. subferruginea* in the Western ghat region.

5.6. Molecular analysis

Phylogenetic analysis of the chloroplast genome revealed several relationships among the genus *Parthenocissus*. The first clade is represented by Old World species. It shows purely Asian origin, especially from China and Indochina. Here, *P. semicordata* var. *semicordata* is mainly distributed in China, Northern India, Nepal and Southern Tibet. These are neighbouring geographical regions. So, the species in these regions are more closely related and form a clade. This clade covers the morphological heterogeneity of the genus *Parthenocissus*, with the number of leaflets varying from simple to five leaflets.

The three species from the New World form the second clade that is purely American in origin. Here, *P. quinquefolia* holds a distinct position and forms a connecting link between the Asian species and American species. *P. quinquefolia* is widely distributed in these two regions. So, it is a piece of concrete evidence for continental disjunction or continental drift and strongly supports the evolution within the genus. This clade is characterized by their leaves with 5 – 7 leaflets. *P. vitacea* and *P. heptaphylla* a

narrow endemic species restricted to Texas in United States form a clade with broadly distributed *P. quinquefolia*.

Clade III is represented by the mixture of Old World species and newly evolved species. They are of purely Asian origin. Here, *P. tricuspidata* holds a distinct position, like *P. quinquefolia* and connects newly evolved Asian species and American species. Morphologically this clade is characterized by their leaves with simple to three leaflets. The two subclades of Clade III represent the newly evolved Asian species. The first subclade of Clade III consists of three species*: P. subferruginea*, *P. renukae* and *P. sasii*. These three species show simple leaves. The second subclade consists of *P. wallichianus* and *P. semicordata* var. *roylei*; these two show trifoliate leaves in this group. However, *P. tricuspidata* has usually simple leaves with three lobes and rarely three leaflets on short shoots. The first subclade is closely related to the outgroup. These three species evolved from the common ancestor of the genus *Cissus*. Based on our sequence similarity searches, these three species show more similarity to *C. discolor*.

5.7. Evolutionary trend in the genus *Parthenocissus*

Morphological and molecular analysis shows a clear evolutionary trend in the *Parthenocissus* genus. The Old World species in the Clade I inferred a complicated evolutionary pattern. Here, both simple and three-leaflet states were independently derived from the ancestral five leaflet condition. Also, the five leaflet state was inferred to be ancestral for the stem lineages of *Parthenocissus* in the New World clades. So, the evolution of leaves from five leaflets to simple leaves is considered to be the advanced character of the genus *Parthenocissus,* and thus, Clade III represents the newly evolved species.

Based on morphological and molecular phylogenetic analysis found that Indian species mainly shared three ancestors: *Cissus*, *Parthenocissus* and *Causonis*. *P. semicordata* is considered the primitive species which shows trifoliate leaves and pentamerous flowers. Later, the cross pollination among the *Parthenocissus* and *Cissus* species leads to the emergence of new species with simple leaves, tetra and pentamerous flowers. *P. renukae* is the best example of this. Again, the continued evolution leads to the emergence of species with dimorphic leaves and tetramerous

flowers. Here, *P. sasii* is satisfying these entire features. *P. sasii* is a recently evolved advanced species among the Indian species of *Parthenocissus*. *P. renukae* shows the connecting link between *P. semicordata* and *P. sasii*. *P. wallichianus* originated from a combination of *Parthenocissus* and *Causonis*.

5.8. New classification of genus *Parthenocissus*

Three classification systems have been proposed in the genus *Parthenocissus*. Earlier, the genus was classified into two groups, as Asian group and the American group, based on geographic distribution (Suessenguth, 1953). Later, Galet (1967) reported three series in *Parthenocissus* based on the number of leaves and leaflets. Then, in 1996, Li classified the Chinese species of *Parthenocissus* based on tendril morphology. A new classification system proposed in this work and discarded the previous two classifications.

Section 1: Cissoparthe: Simple leaf and tendril with monochasial branching; *P. renukae*, *P. sasii*, *P. subferruginea*, *P. tricuspidata*, *P. dalzielii*, *P. suberosa*.

Section 2: Causoparthe: Trifoliate or multifoliate leaves and tendril with monochasial branching; *P. wallichianus*, *P. feddei*, *P. sichuanensis*, *P. latevirens*, *P. henryana*, *P. quinquefolia*, *P. heptaphylla*, *P. vitacea*.

Section 3: Euparthe: Trifoliate or multifoliate leaves and tendrils with dichasial branching; *P. semicordata*.

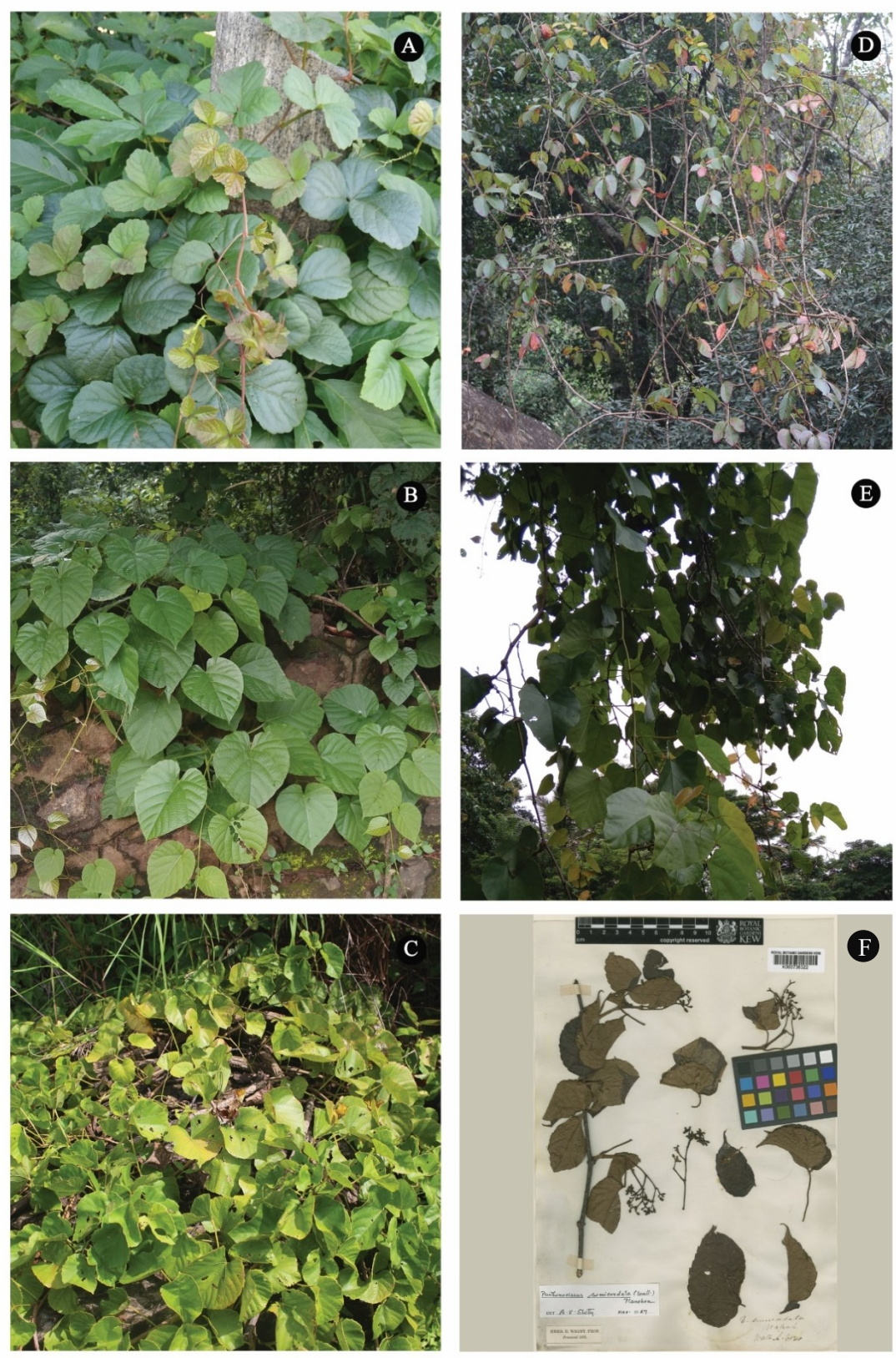

Plate 21. Habits of *Parthenocissus* spp. A. *Parthenocissus wallichianus*; B. *Parthenocissus sasii*; C. *Parthenocissus renukae*; D. *Parthenocissus semicordata* var. *roylei*; E. *Parthenocissus subferruginea* F. *Parthenocissus semicordata* var. *semicordata* (Herbarium specimen © The Board of Trustees of the RBG, Kew (K).

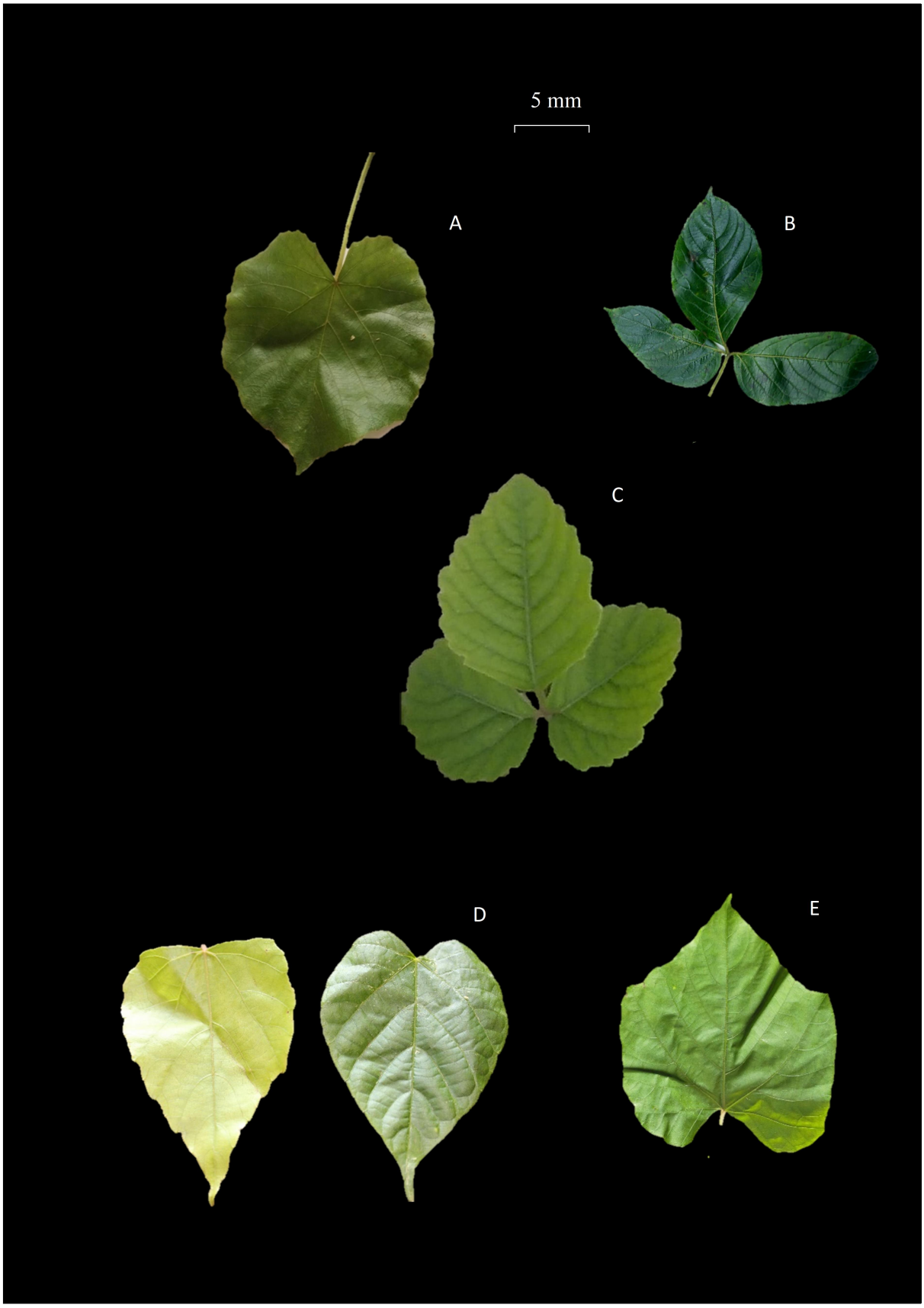

Plate 22. Comparison of Leaves in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

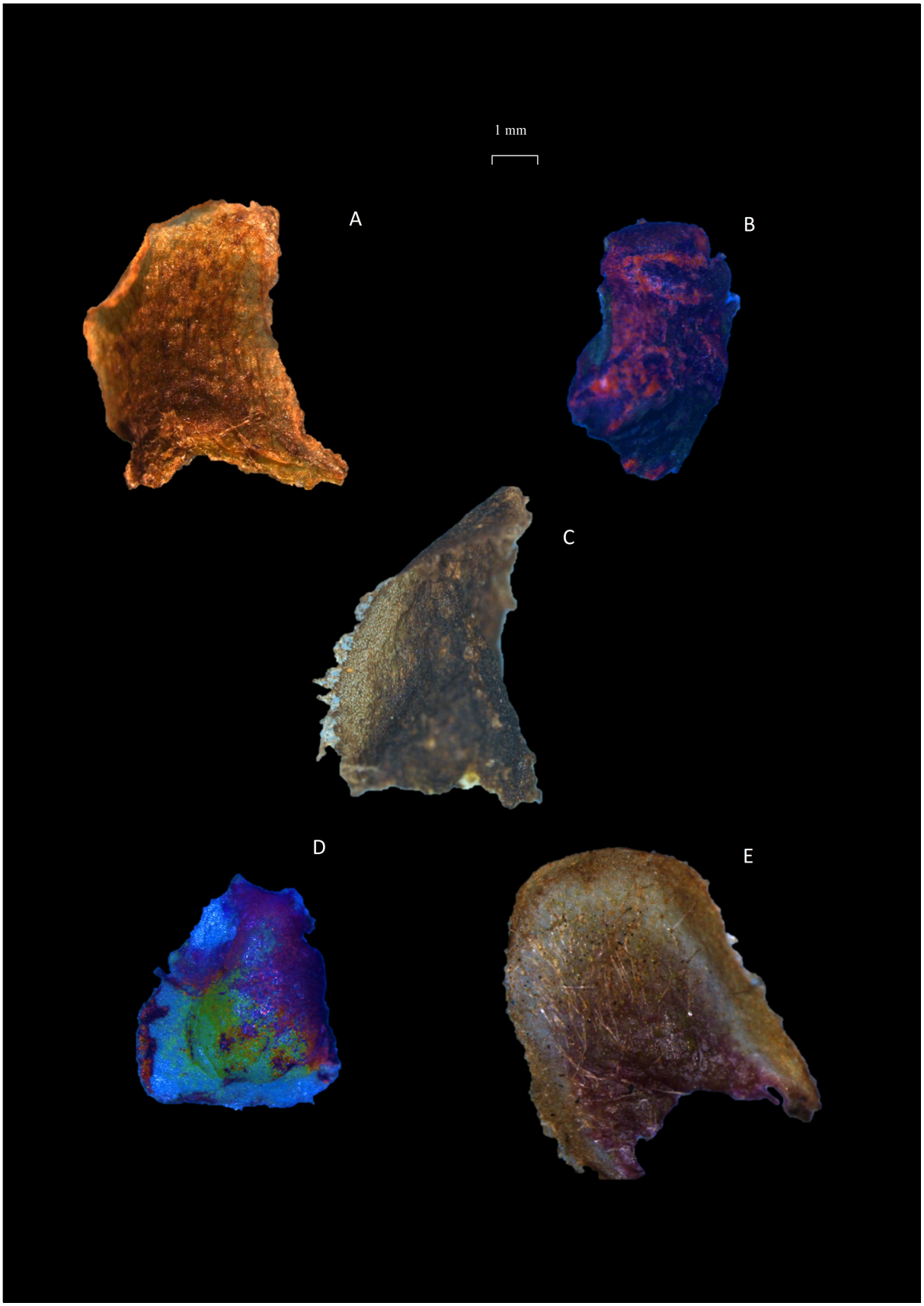

Plate 23. Comparison of Leaf Stipules in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

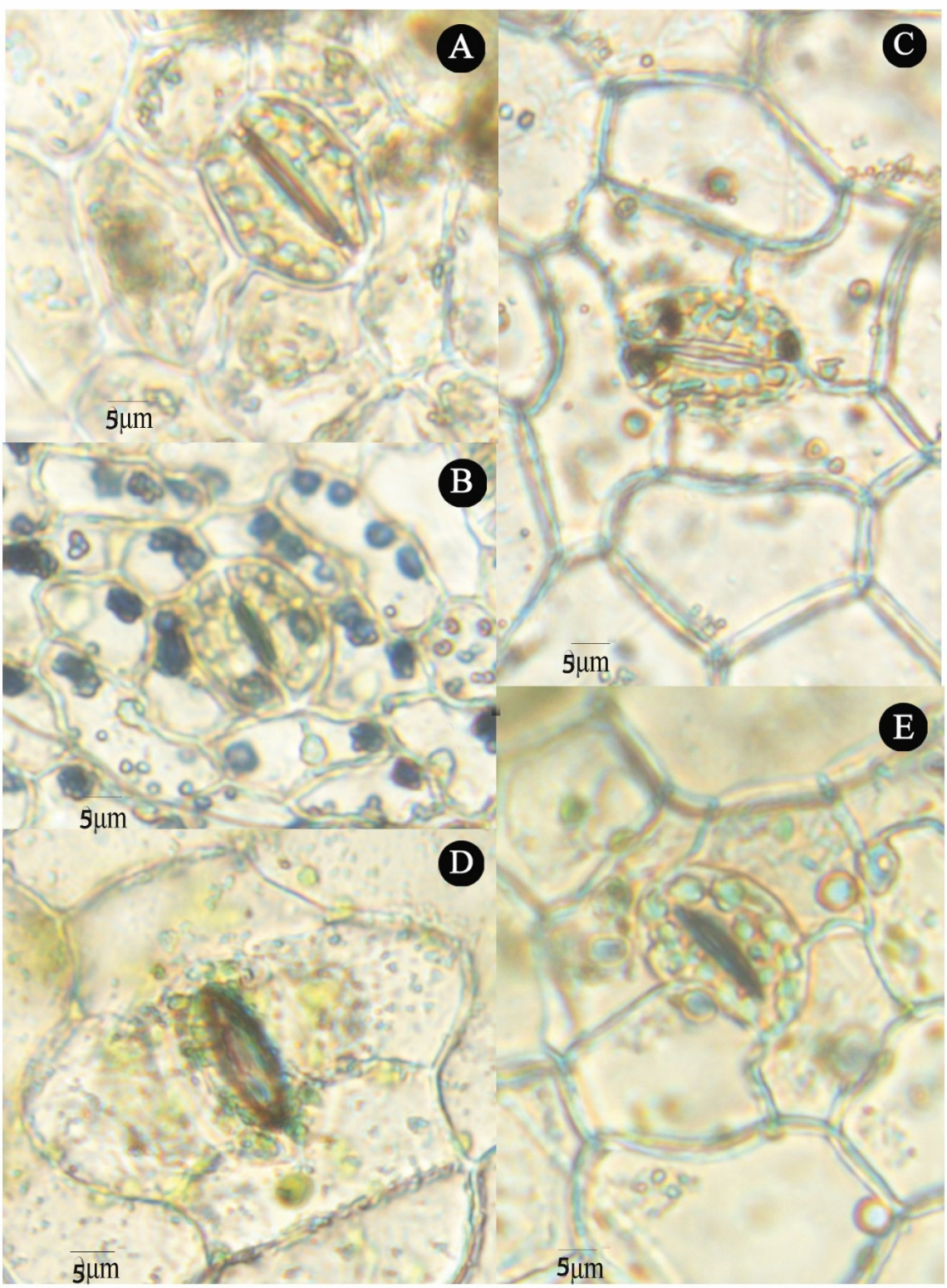

Plate 24. Comparison of Leaf Stomata in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

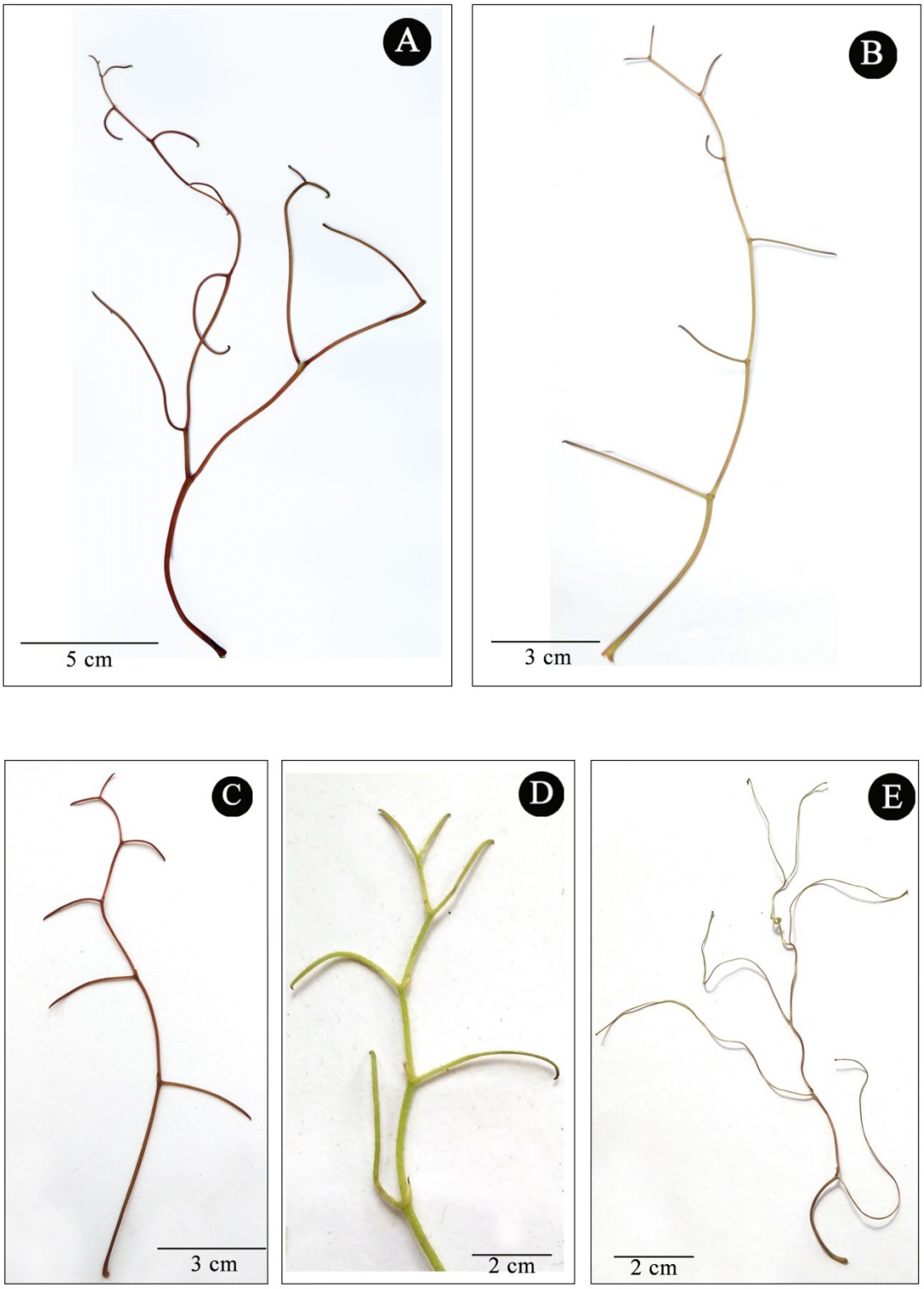

Plate 25. Comparison of Tendrils in *Parthenocissus* spp. **A.** *P. semicordata* var. *roylei;* **B.** *P. sasii*; **C.** *P. subferruginea;* **D.** *P. renukae*; **E.** *P.wallichianus*.

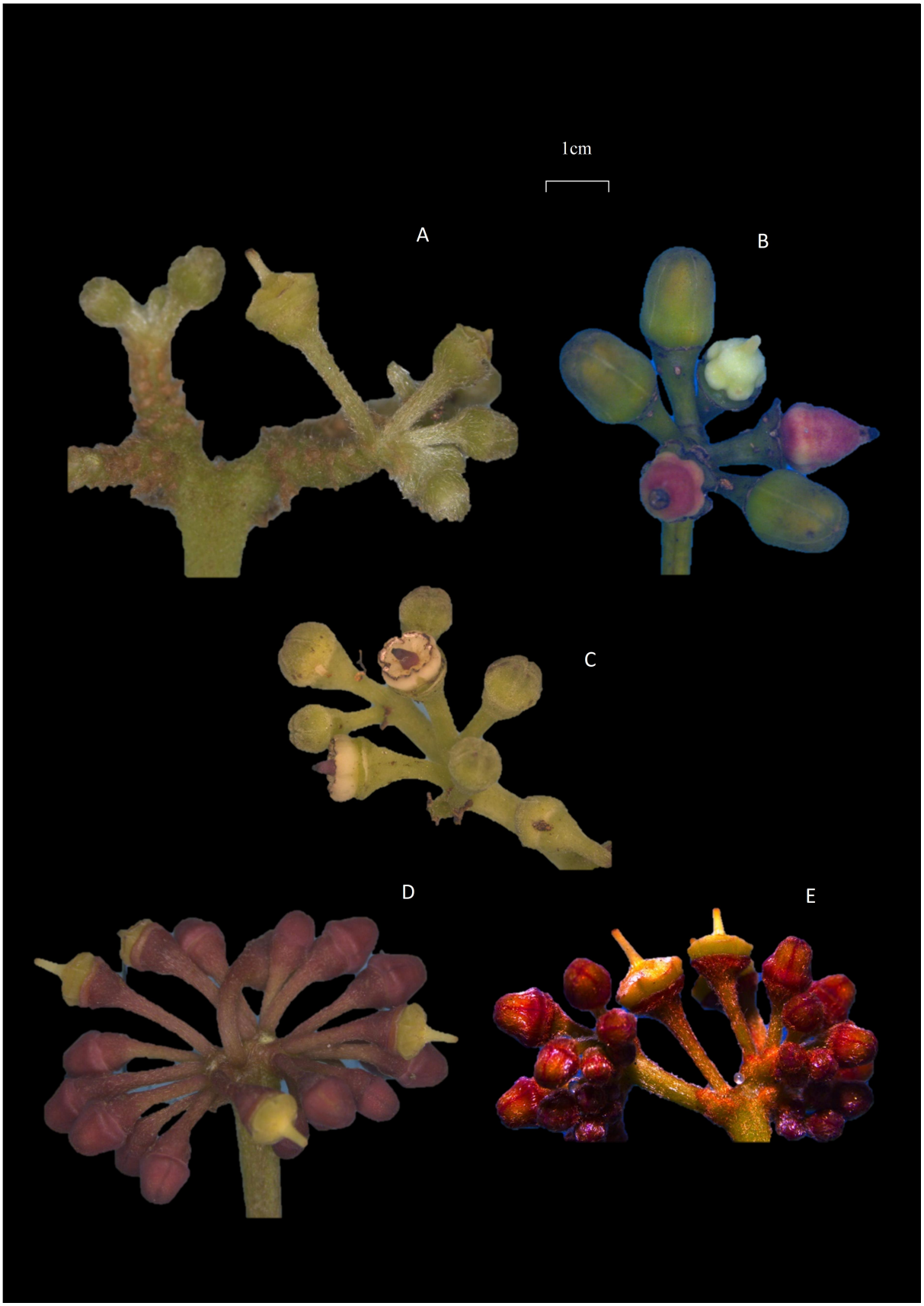

Plate 26. Comparison of Inflorescence in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

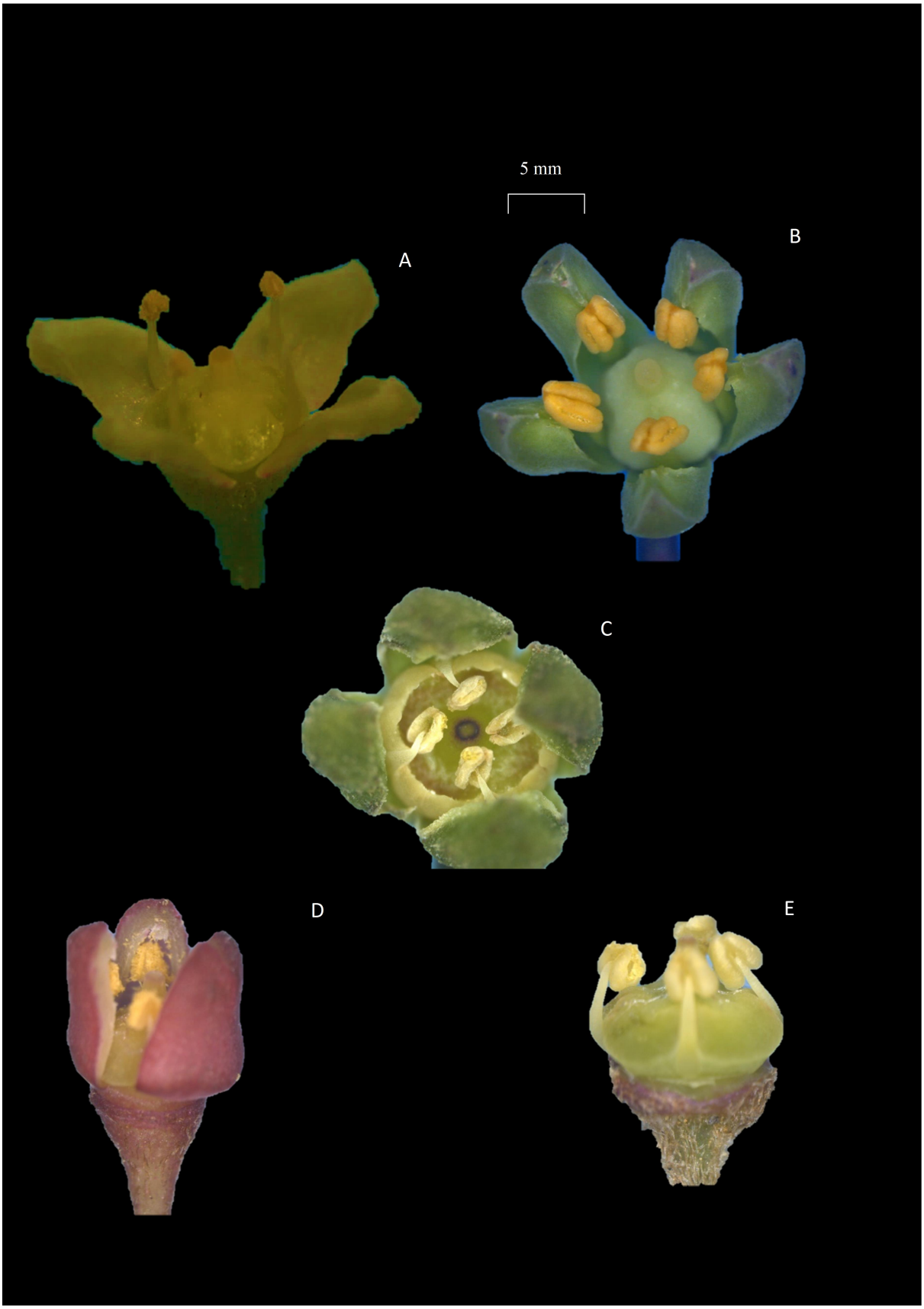

Plate 27. Comparison of Flowers in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

Plate 28. Comparison of Corolla Appendages in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

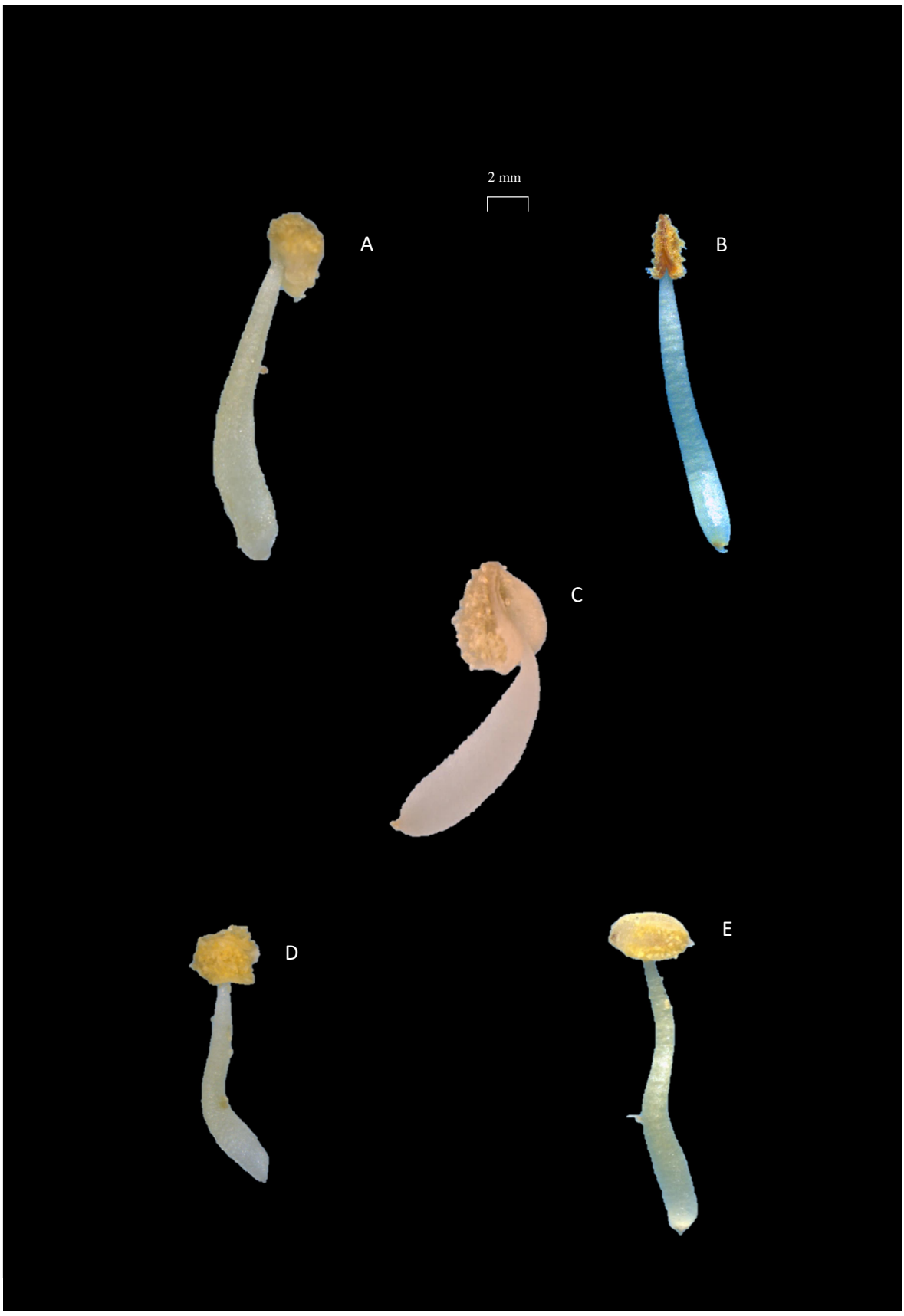

Plate 29. Comparison of Stamens in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

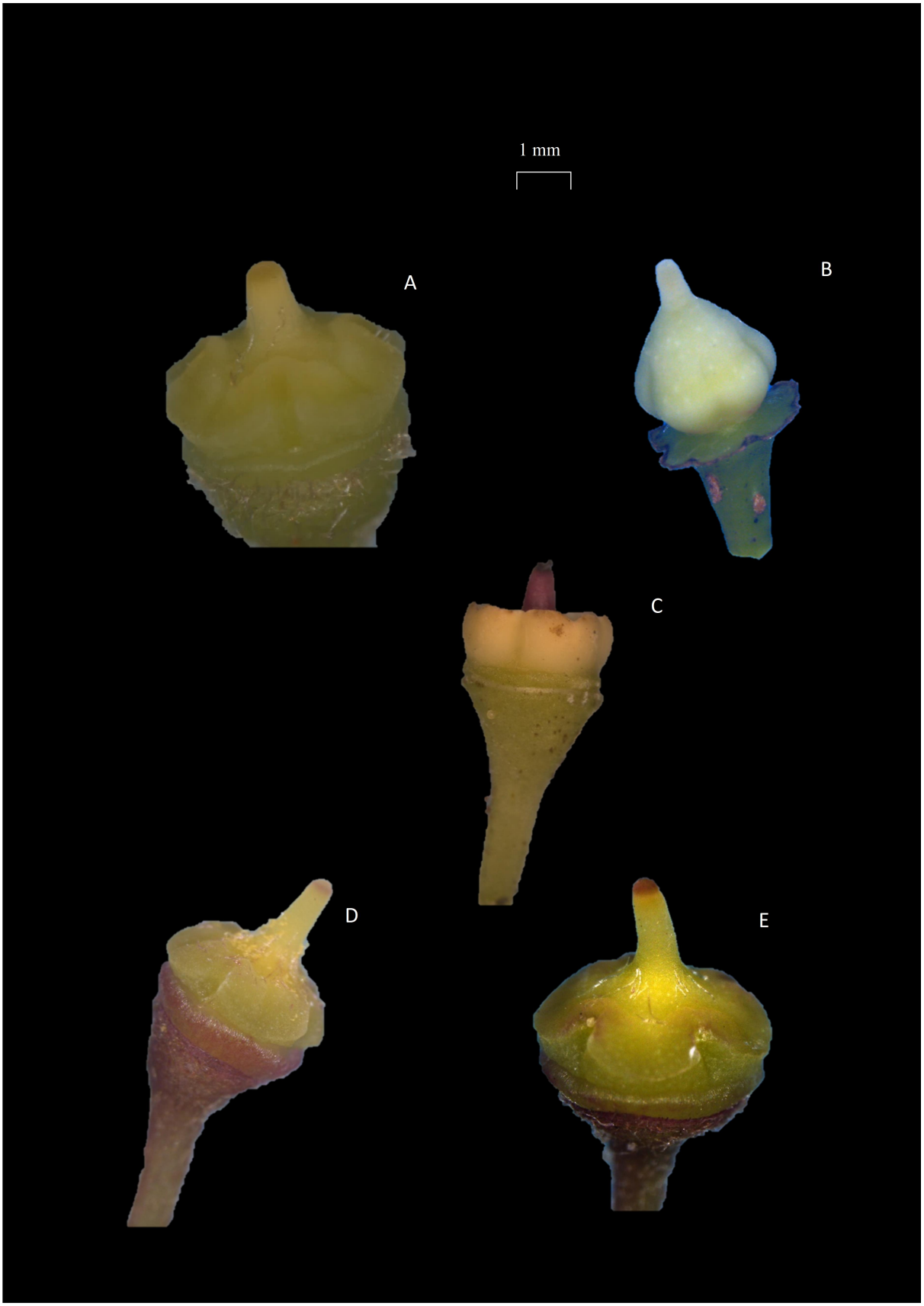

Plate 30. Comparison of Carpels in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

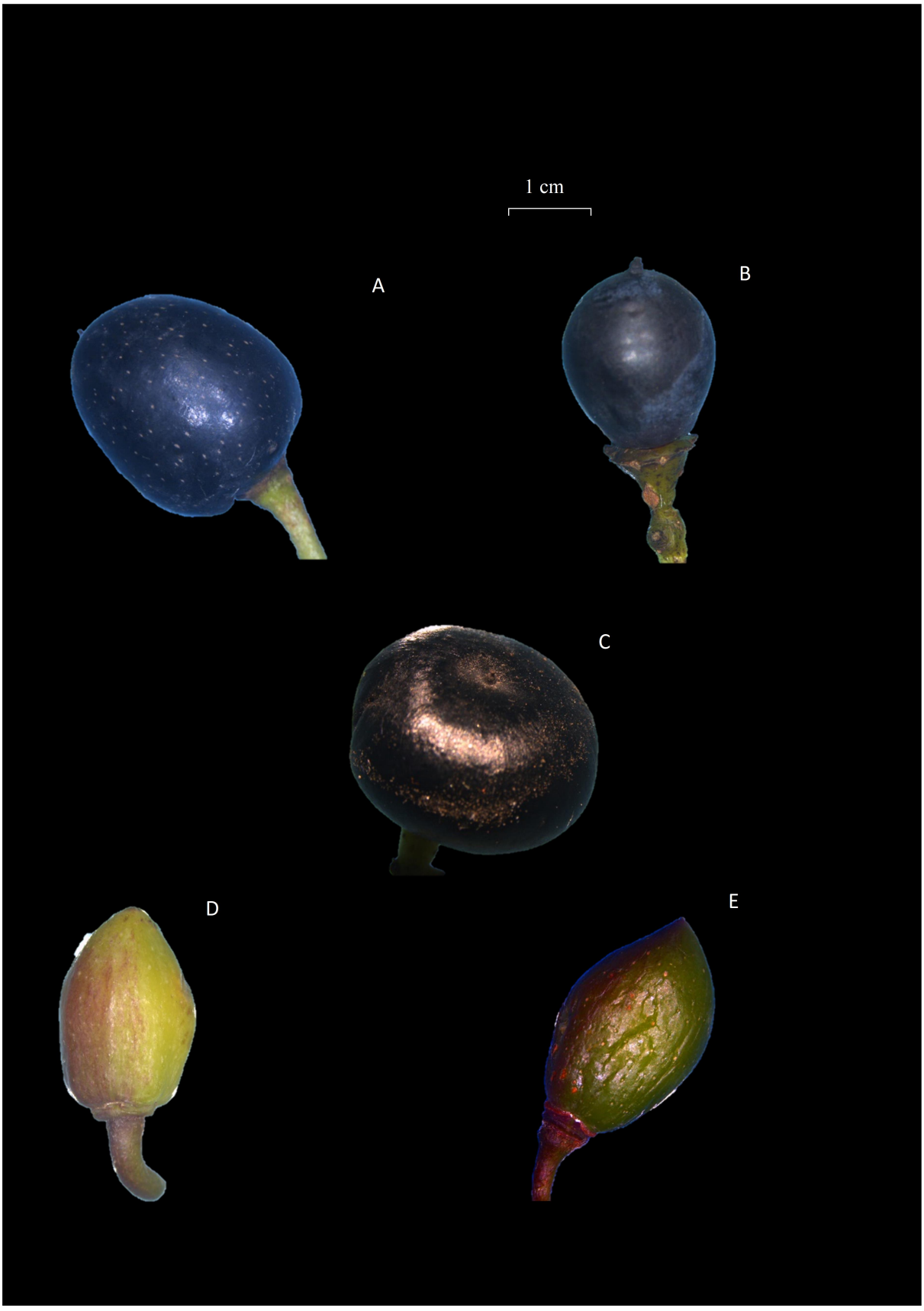

Plate 31. Comparison of Fruits in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

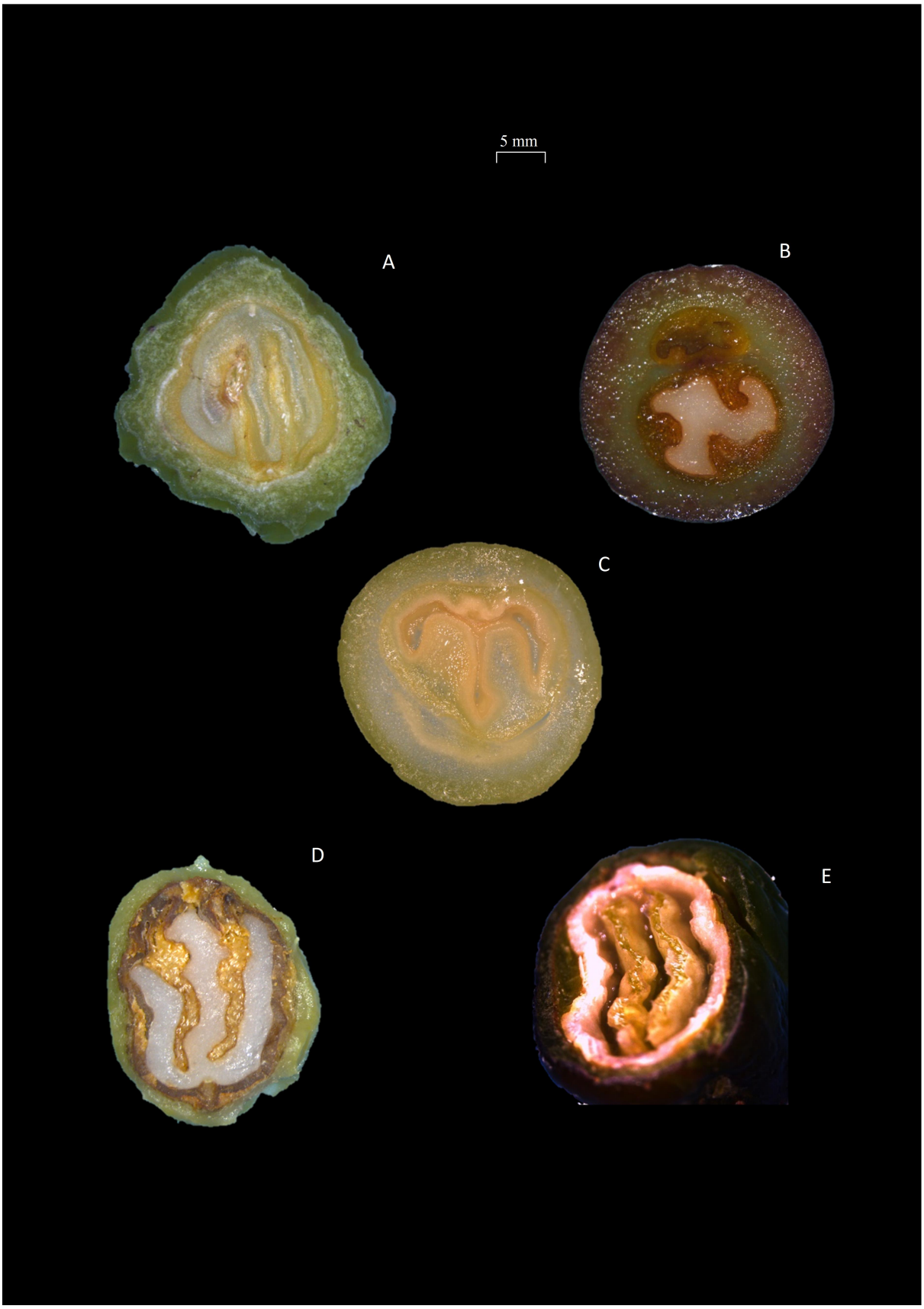

Plate 32. Comparison of Seed cs in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

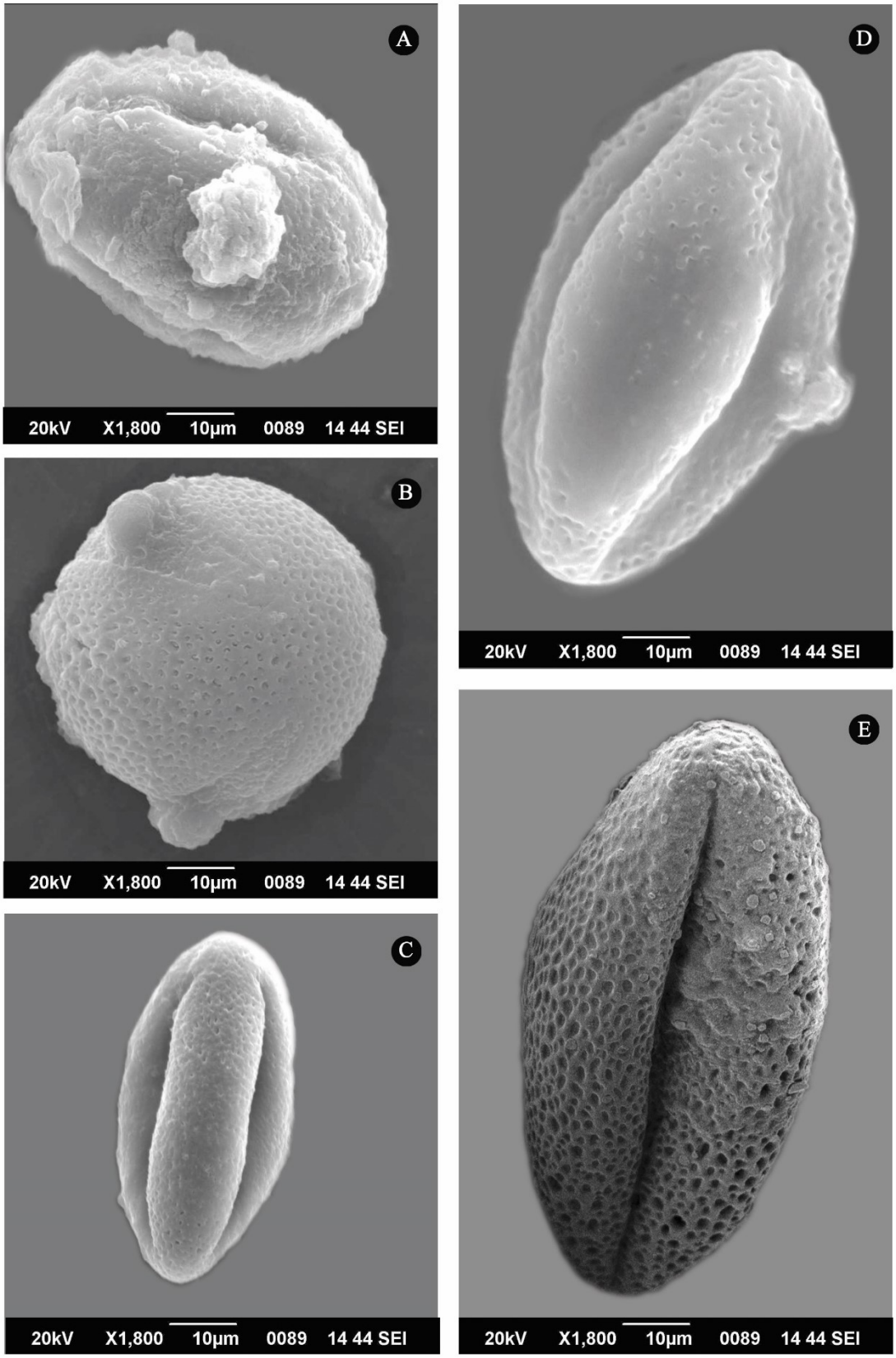

Plate 33. Comparison of Pollen grain in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

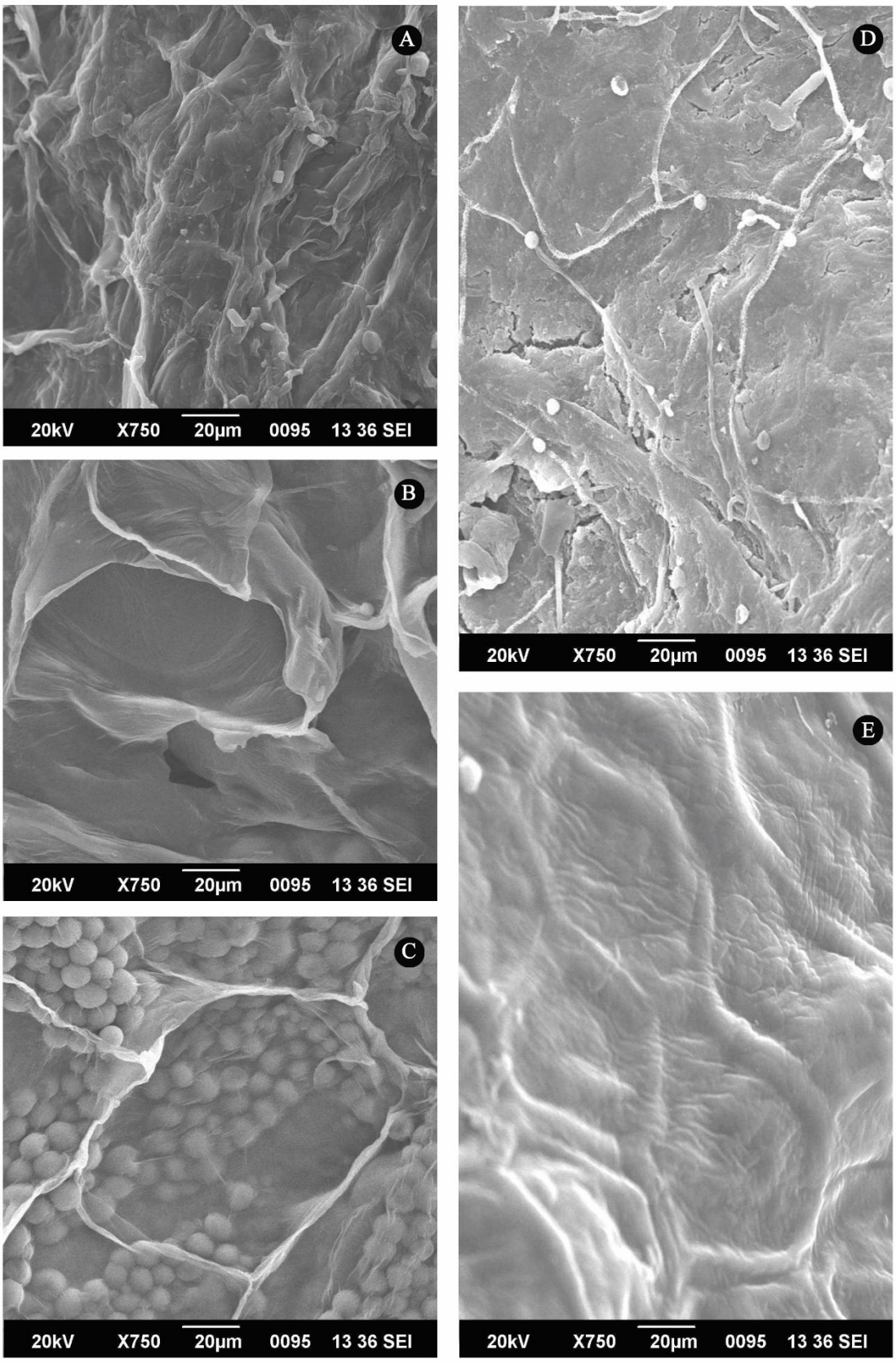

Plate 34. Comparison of Seedcoat morphology in *Parthenocissus* spp. **A.** *P. renukae*; **B.** *P. semicordata* var. *roylei*; **C.** *P. wallichianus*; **D.** *P. sasii*; **E.** *P. subferruginea*.

Chapter-6

Summary

Parthenocissus is one of the two genera within the family Vitaceae, which is disjunctively distributed in the north temperate regions. It shows the intercontinental distribution between Asia and North America. The genus comprises 13 species, with approximately ten species in Asia and three in North America. *Parthenocissus* is an excellent example for elucidating northern hemisphere biogeographic diversification involving temperate and tropical elements. In the present study, the genus *Parthenocissus* in India is revised by extensive field studies and consulting specimens in major Indian herbaria. The molecular phylogeny is also done using sequences from chloroplast.

Extensive field explorations were conducted throughout the forest and non-forest areas of Kerala, India, to collect *Parthenocissus* members and the fertile specimens were collected from these areas during 2017 – 2022. The collected specimens were identified based on authentic literature and type specimens. The collected specimens were preserved, mounted on herbarium sheets, and deposited at STC. The distribution maps were provided based on specimens examined during the present investigation.

As part of the present revision, eight taxa, including two varieties, are recognised from India. Among them, three new species are identified and described. *P. renukae* collected from Mangad, Thrissur District, Kerala; *P. wallichianus* from Kayampoovam, Thrissur district; and *P. sasii* from Asurankundu dam in the Machad forest range from Kerala (one species awaiting publication). *P. subferruginea,* which was synonymised as *C. repanda,* is reinstated (awaiting publication).

Five *rbcL* sequences were newly generated and deposited in the GenBank during this study. The phylogenetic analysis supports the evolutionary trend and the biogeographical diversification of the genus *Parthenocissus*. Though the Infrageneric classification of *Parthenocissus* has been problematic (Nie *et al*., 2010). This study proposed three sections in the genus *Parthenocissus* such as Cissoparthe, Causoparthe and Euparthe.

Recommendations

1. A detailed biochemical characterization of newly described *Parthenocissus* species needs to be undertaken.
2. An extensive chromosomal analysis of the genus *Parthenocissus* is to be useful for Cytogeographic studies.
3. DNA barcoding of *Parthenocissus* members with the help of more genetic markers is needed.
4. A detailed analysis of the Pharmacognostic properties of newly described *Parthenocissus* species is to be done to get the medicinal value of these species.
5. Ecological niche modelling using Qgis technique
6. Find out the Conservation status of species using IUCN strategies.
7. Viability of seeds and their demographic studies.

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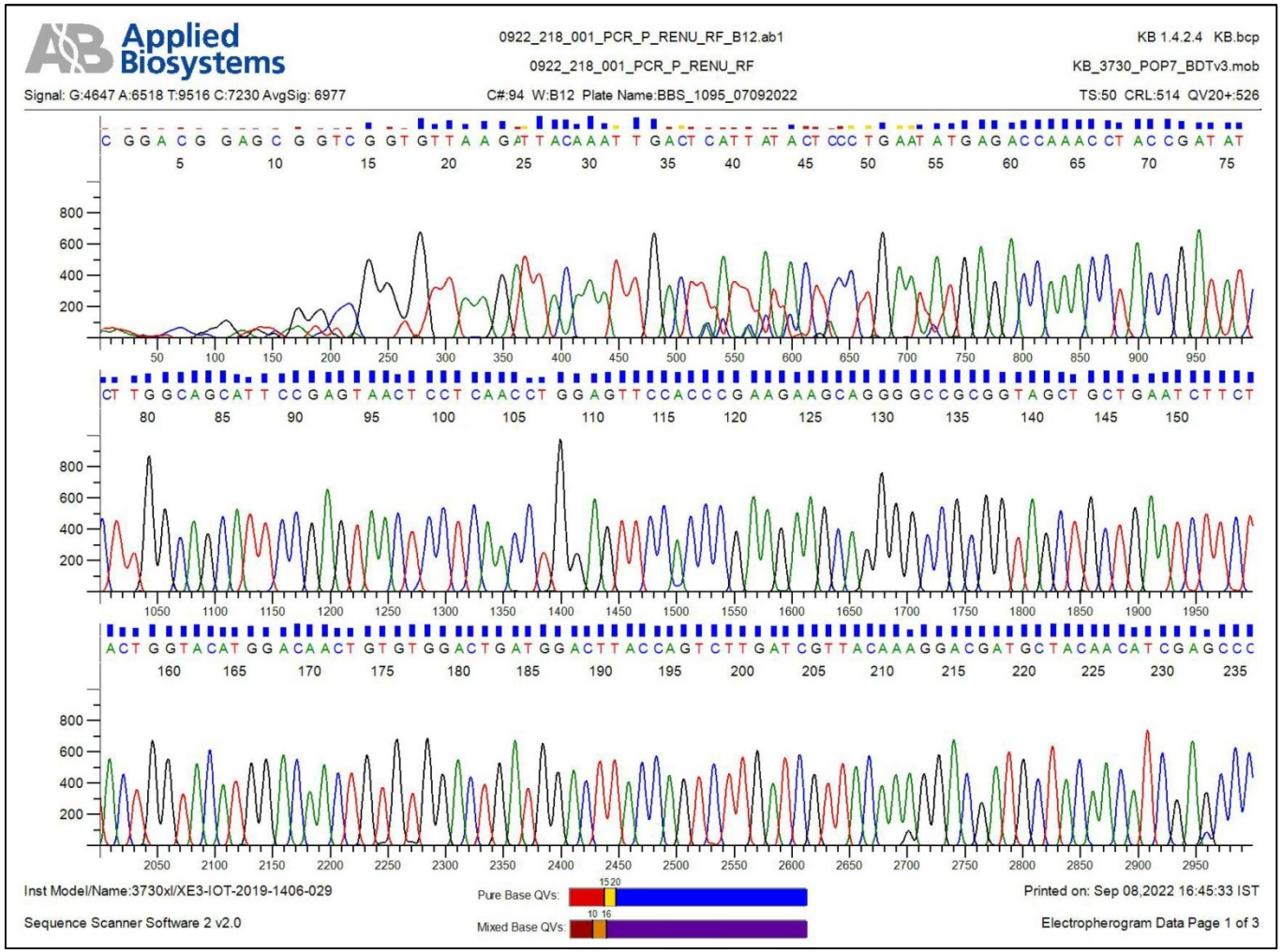
Annexure I	**List of Herbaria Cited**
A	Harvard University
BM	The Natural History Museum, London, England, UK
CDBI	Chengdu Institute of Biology, Chinese Academy of Sciences
CAL	Central National Herbarium, Botanical Survey of India, Howrah, West Bengal, India
CALI	Herbarium of University of Calicut, Malappuram, Kerala, India.
E	Royal Botanical Garden, Edinburgh, Scotland, UK
FTG	Fairchild Tropical Botanical Garden, U.S.A. Florida. Miami.
HN	Vietnam Academy of Science and Technology (VAST)
IBK	Guangxi Institute of Botany, China.
K	Royal Botanical Gardens, Kew, England, UK
KFRI	Kerala Forest Research Institute, Thrissur, Kerala, India
KUN	Kunming Institute of Botany, Chinese Academy of Sciences, People's Republic of China. Yunnan.
L	Naturalis, Leiden, Netherlands
MH	Madras Herbarium, Coimbatore, Tamil Nadu, India
P	Muséum National d'Histoire Naturelle, France. Paris.
PE	Institute of Botany, Chinese Academy of Sciences, China.
STC	St. Thomas College Herbarium, Thrissur, Kerala, India
TBGT	Tropical Botanical Garden and Research Institute (TBGRI), Kerala, India
VNM	Institute of Tropical Biology, Vietnam.

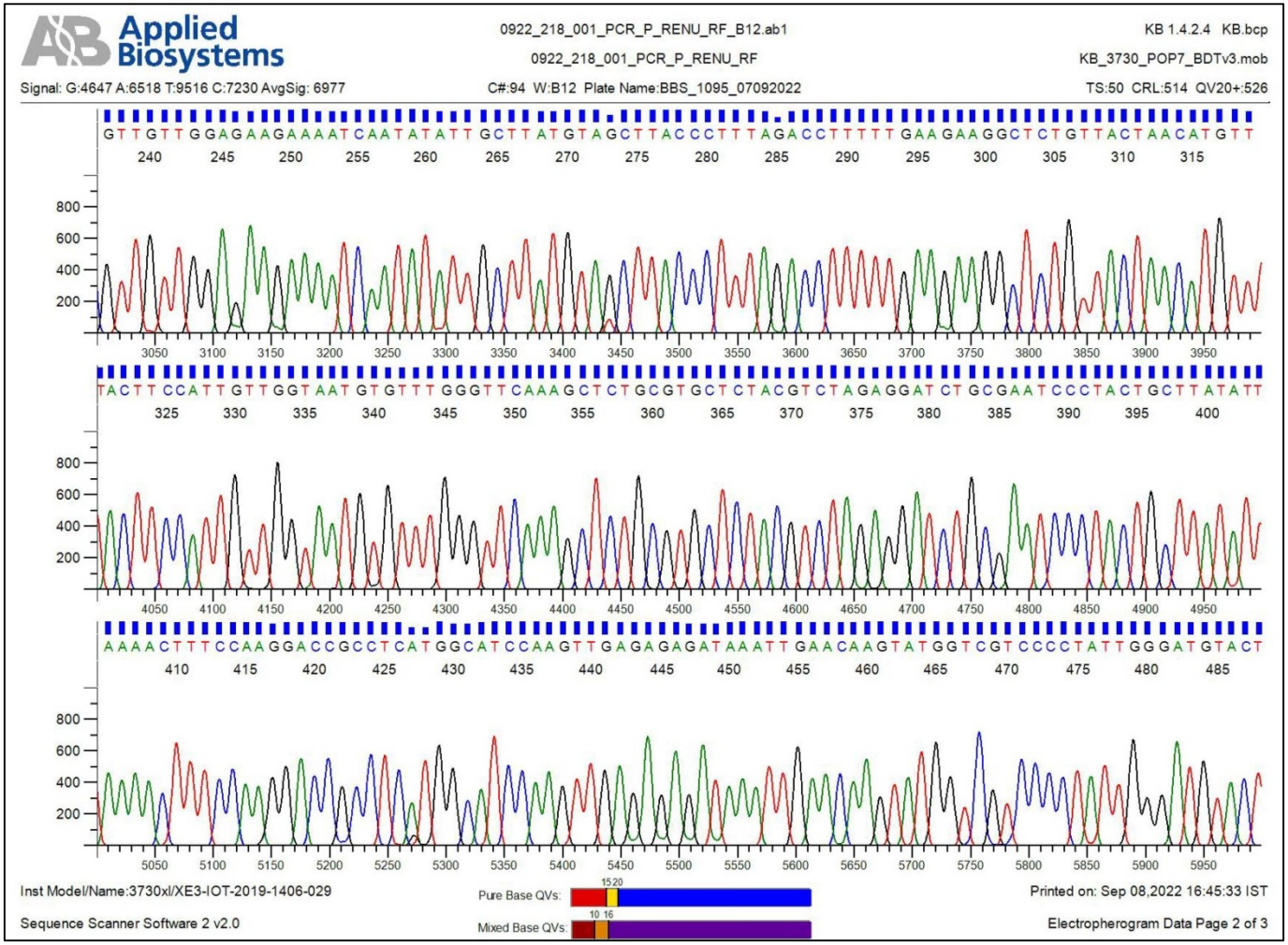
I. Annexure II GPS coordinates of *Parthenocissus* spp.

Sl No	Plant name	Location	Longitude	Latitude
1	*Parthenocissus renukae*	Kulappully	76°16'11.5"E	10°47'02.4"N
		Vellarakkad	76°08'09.0"E	10°40'51.4"N
		Mangad	76°11'43.0"E	10°42'30.0"N
		Peruvanmala	76°08'11.6"E	10°37'33.7"N
		Vellanipacha	76°19'53.8"E	10°35'01.7"N
2	*Parthenocissus semicordata* var.*semicordata*	Morni hills	77°05'15.2"E	30°41'13.8"N
		Khasi hills	91°38'00.0"E	25°35'00.0"N
		Barak valley	91°48'37.4"E	24°53'17.4"N
		Karbi Anglong	93°35'37.8"E	26°10'26.2"N
		East Sikkim	88°40'20.5"E	27°18'30.1"N
		Kumaon gori	80°10'45.6"E	29°31'26.6"N
		Rotang	77°11'09.1"E	32°18'53.3"N
		Munsyari	80°14'42.1"E	30°01'55.1"N
3	*Parthenocissus semicordata* var.*roylei*	Silent Valley	76°26'30.9"E	11°04'01.1"N
		Anamudi shola National Park	77°11'36.0"E	10°10'53.4"N
		Vellimalai	78°00'10.4"E	10°08'03.7"N
		Muthuvankudi	77°02'28.9"E	9°59'57.3"N
		Cardamom Hills	77°09'01.7"E	9°52'00.1"N
		Nirar	76°59'06.7"E	10°16'23.4"N
		Naduvattam	76°34'06.0"E	11°28'54.7"N
		Anamalai	77°06'59.6"E	10°24'13.1"N
		Mankulam	76°55'36.7"E	10°07'02.1"N
		Courtallam	77°16'09.5"E	8°55'44.4"N
		Ponmudi	77°06'37.1"E	8°46'06.3"N
		Periyar Tiger reserve	77°09'19.6"E	9°27'40.6"N
4	*Parthenocissus wallichianus*	Marchinaikenpalayam	76°49'23.7"E	10°37'07.7"N
		Pudussery	76°46'58.5"E	10°48'03.8"N
		Walayar	76°50'24.4"E	10°50'55.1"N
		Pudunagaram	76°41'15.5"E	10°39'22.3"N
		Kollengode	76°41'16.8"E	10°36'49.0"N
		Kayampuwam	76°23'01.9"E	10°41'26.1"N
		Govindapuram	76°49'05.9"E	10°36'56.4"N
		Kanjikode	76°44'29.0"E	10°47'50.7"N
		Ganapathipalayam	76°50'18.6"E	10°37'19.8"N
5	*Parthenocissus sasii*	Kanadassankadavu	76°06'01.7"E	10°28'21.7"N
		Peruvanmala	76°08'07.9"E	10°37'26.2"N
		Thumburmuzhy	76°27'09.3"E	10°17'48.3"N
		Mangad	76°11'43.0"E	10°42'30.0"N
		Peechi	76°20'38.1"E	10°37'34.1"N
6	*Parthenocissus subferruginea*	Malayattoor	76°30'25.7"E	10°11'09.1"N
		Chalissery	76°05'37.7"E	10°43'31.7"N
		Chelakode	76°23'01.9"E	10°41'26.1"N
		Moodal	76° 2' 44"E	10° 52' 5"N

		Malampuzha	76° 40′ 58.4″ E	10° 50′ 1.82″ N
		Chittur	76°39'14.4"E	11°03'37.0"N
		Olippara	76°34'04.3"E	10°30'44.0"N
		Thekkuthode	76°58'13.6"E	9°15'43.7"N
		Chinakottipalae	83°45'07.2"E	18°39'20.9"N
		Andhra Pradesh	82°07'58.0"E	17°58'51.6"N
		Muthavedu TN	79°35'20.1"E	12°50'41.6"N
		Anamalai	76°57'44.8"E	10°29'01.1"N
		Bonacaud	77°10'09.2"E	8°41'24.1"N

Chromatogram of *Parthenocissus renukae*

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Electropherogram Data Page 2 of 3

Applied Biosystems

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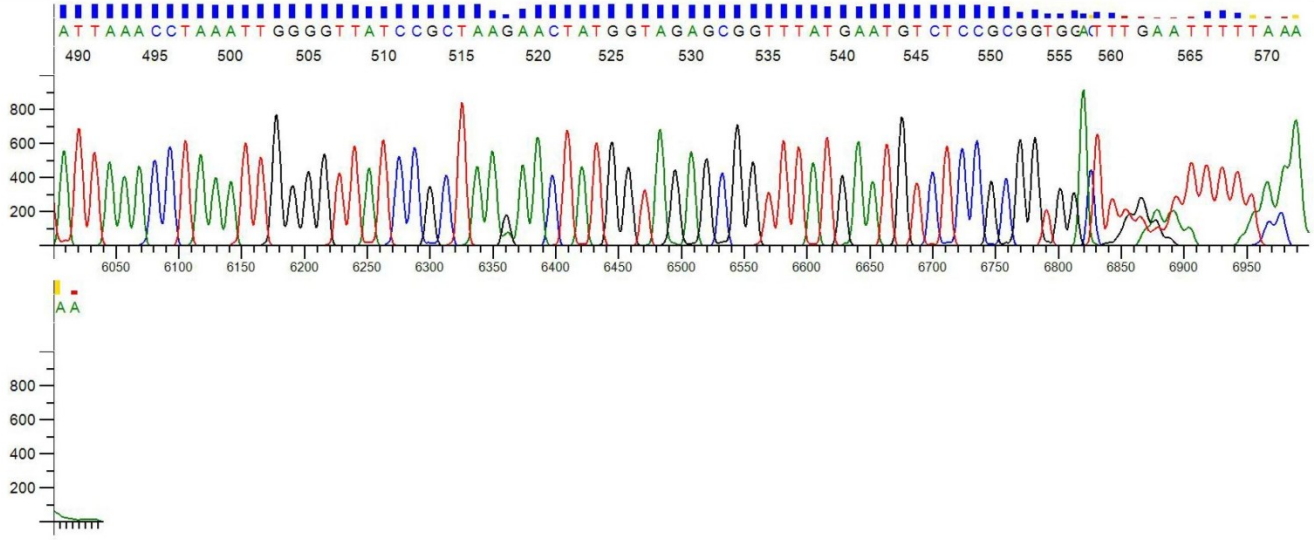

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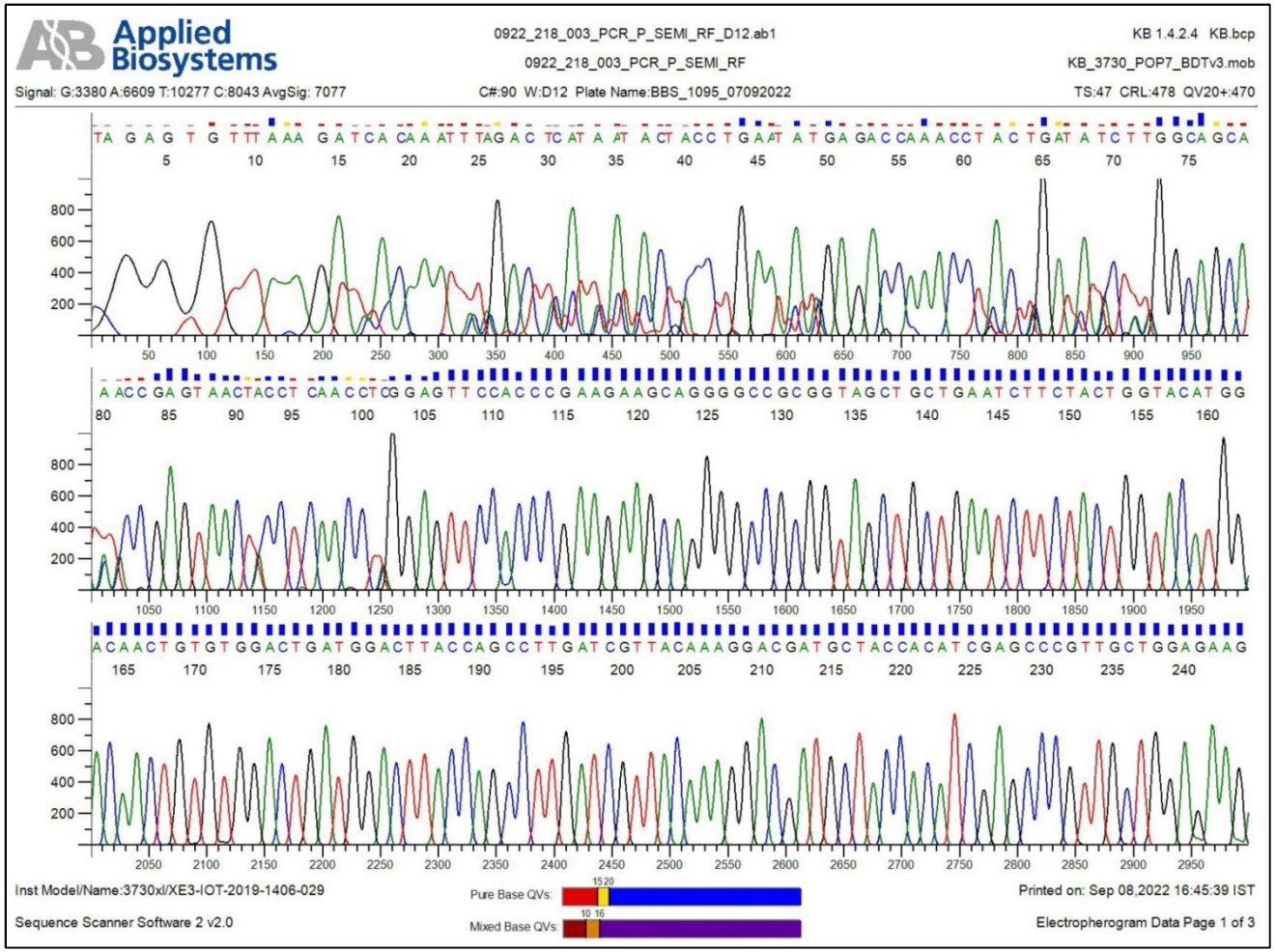
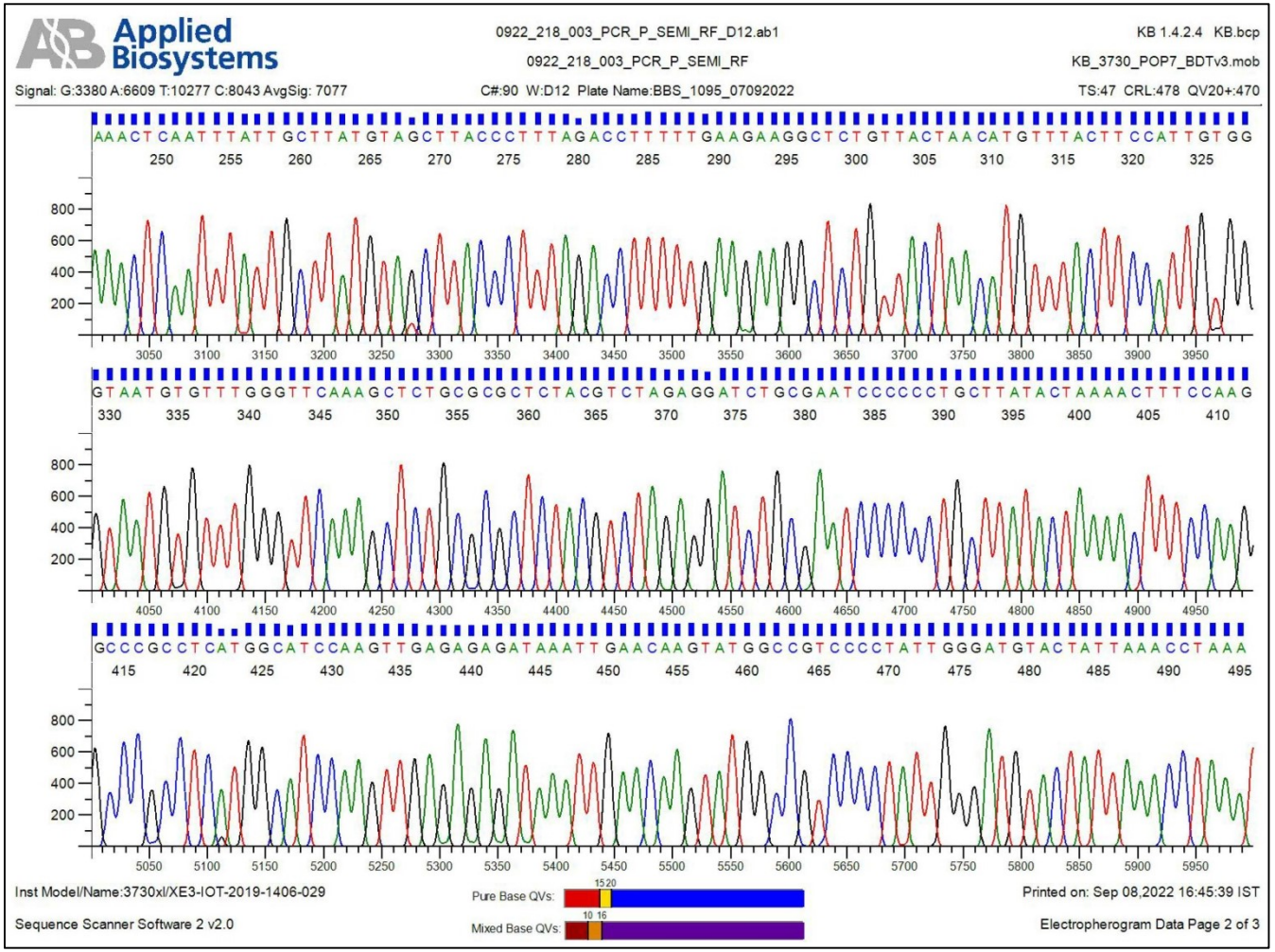
Chromatogram of *Parthenocissus semicordata* var. *roylei*.

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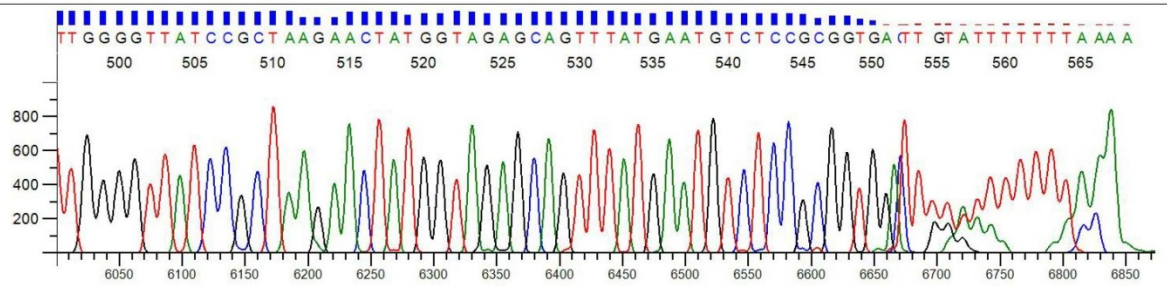

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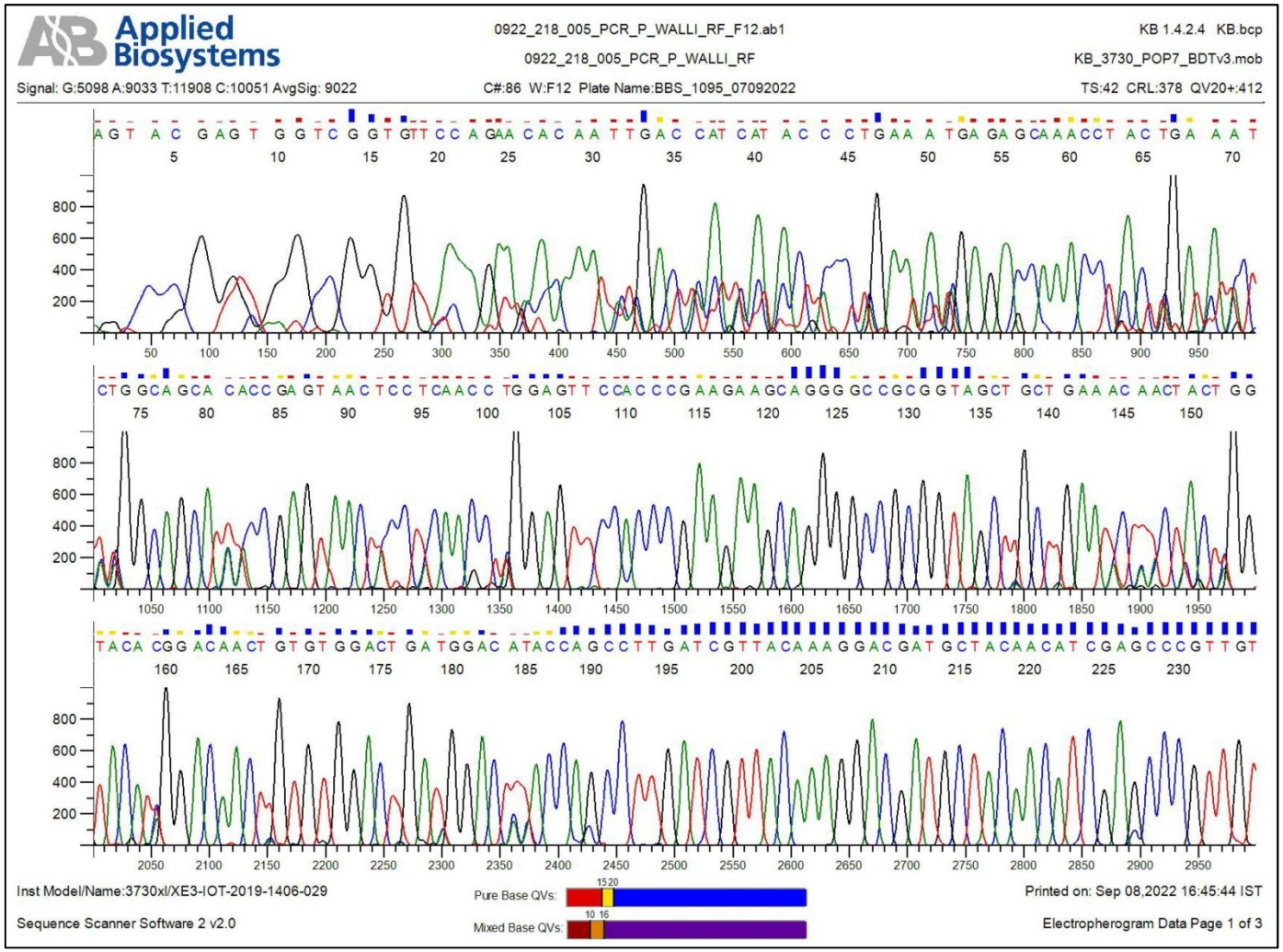
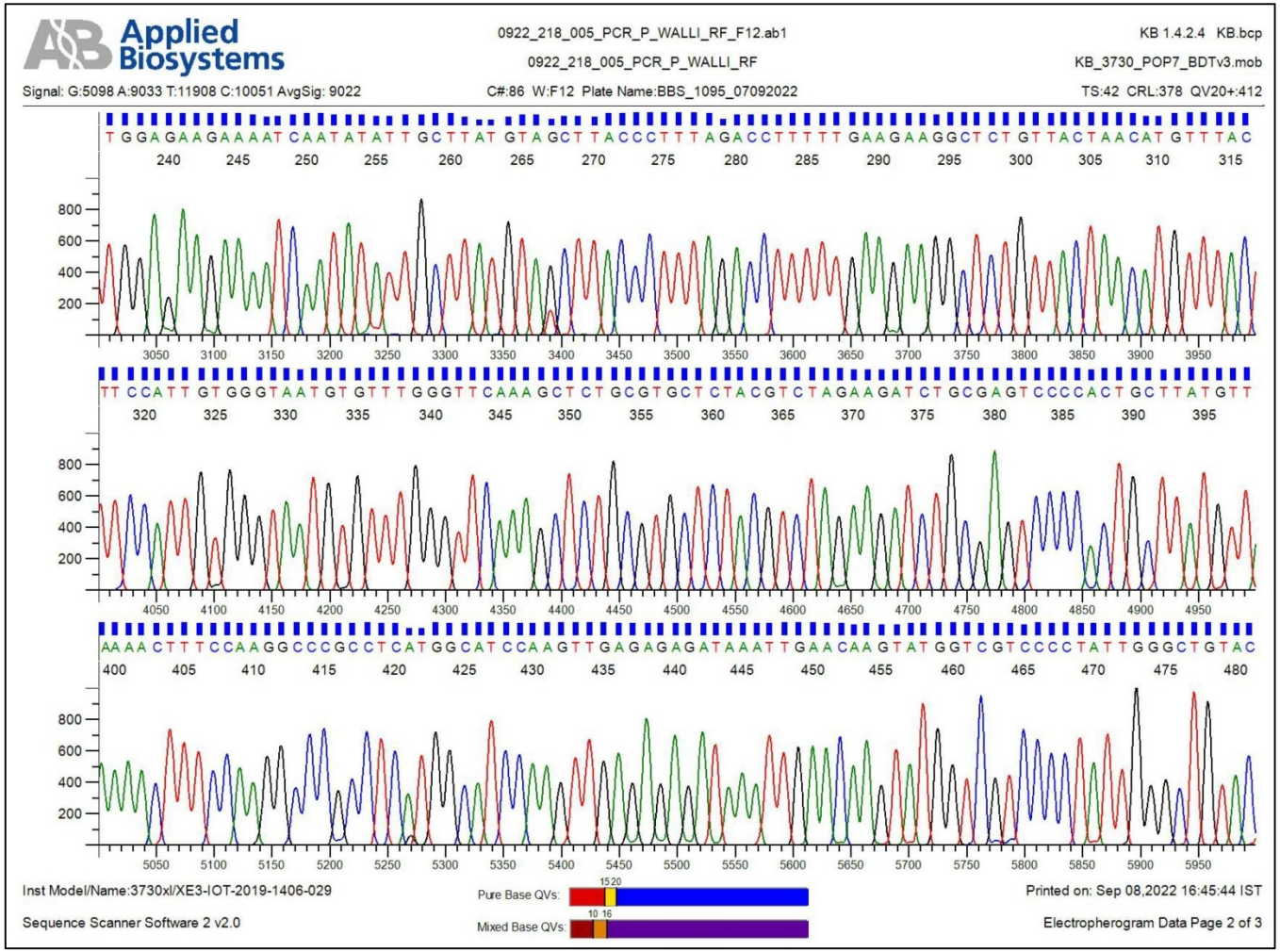
Chromatogram of *Parthenocissus wallichianus*

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Applied Biosystems

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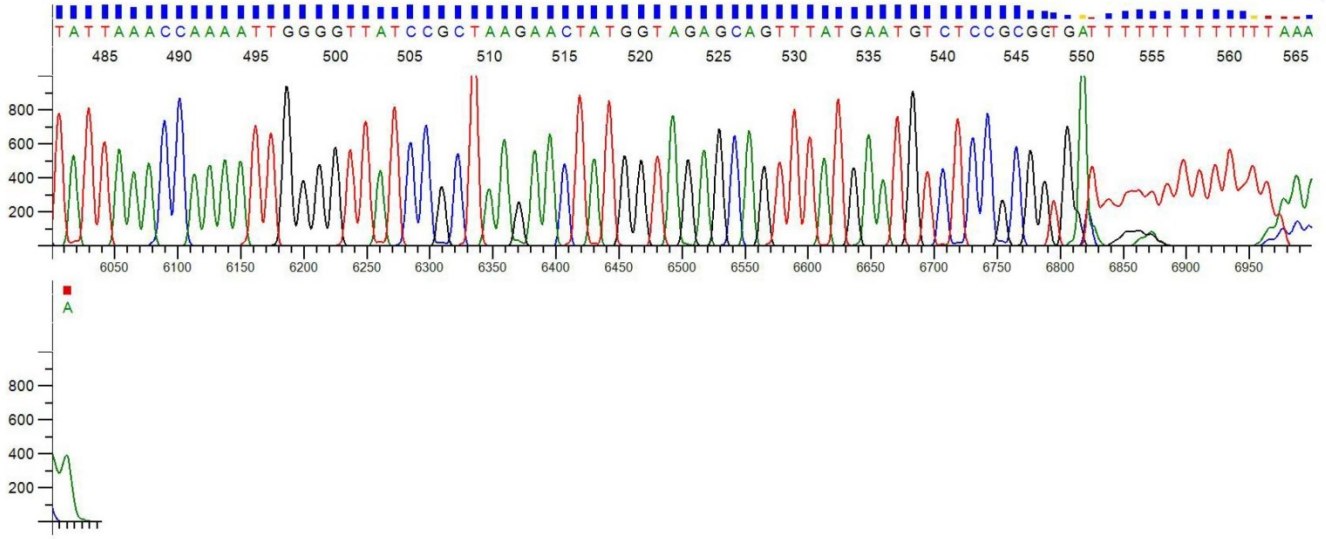

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Electropherogram Data Page 3 of 3

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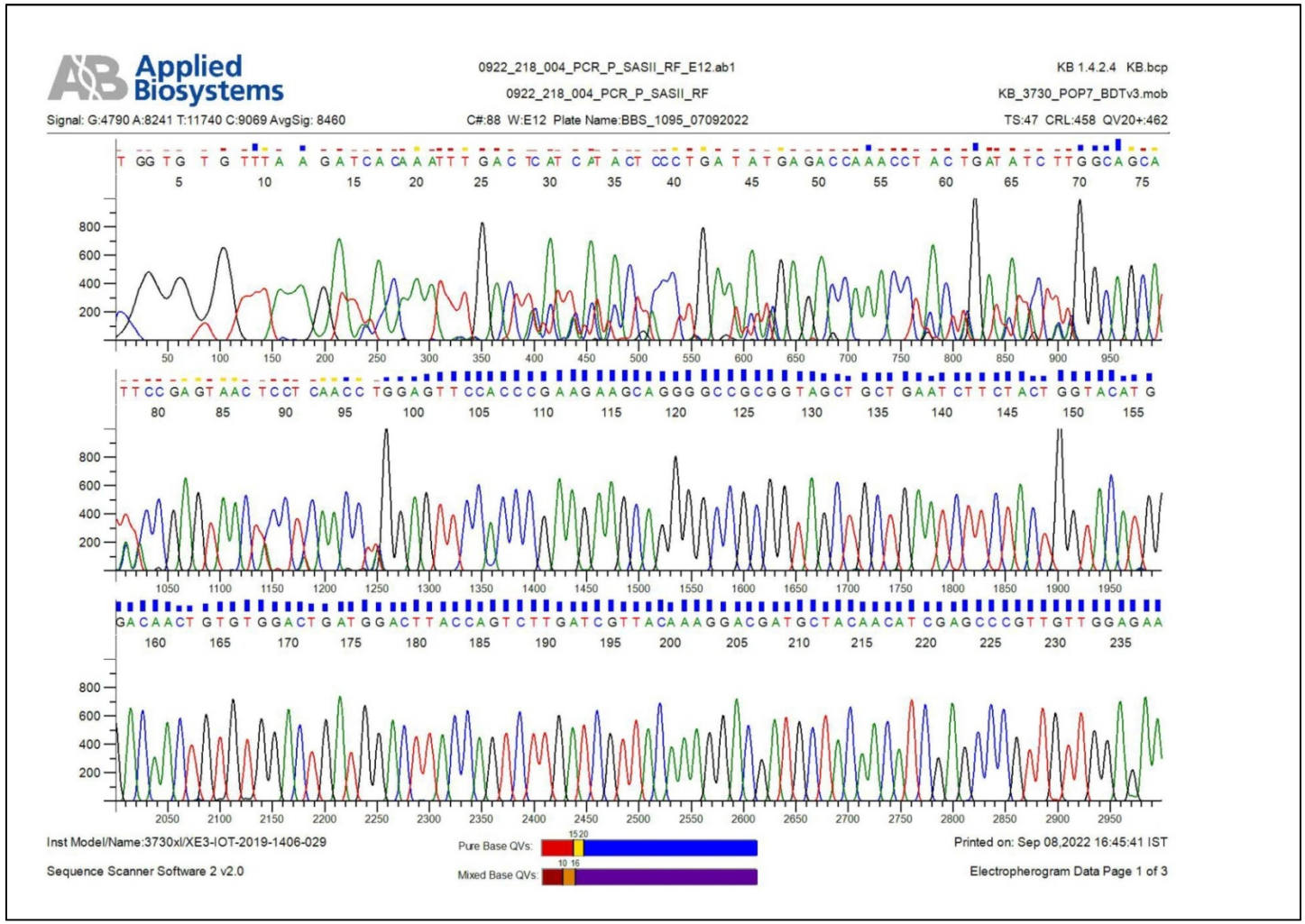

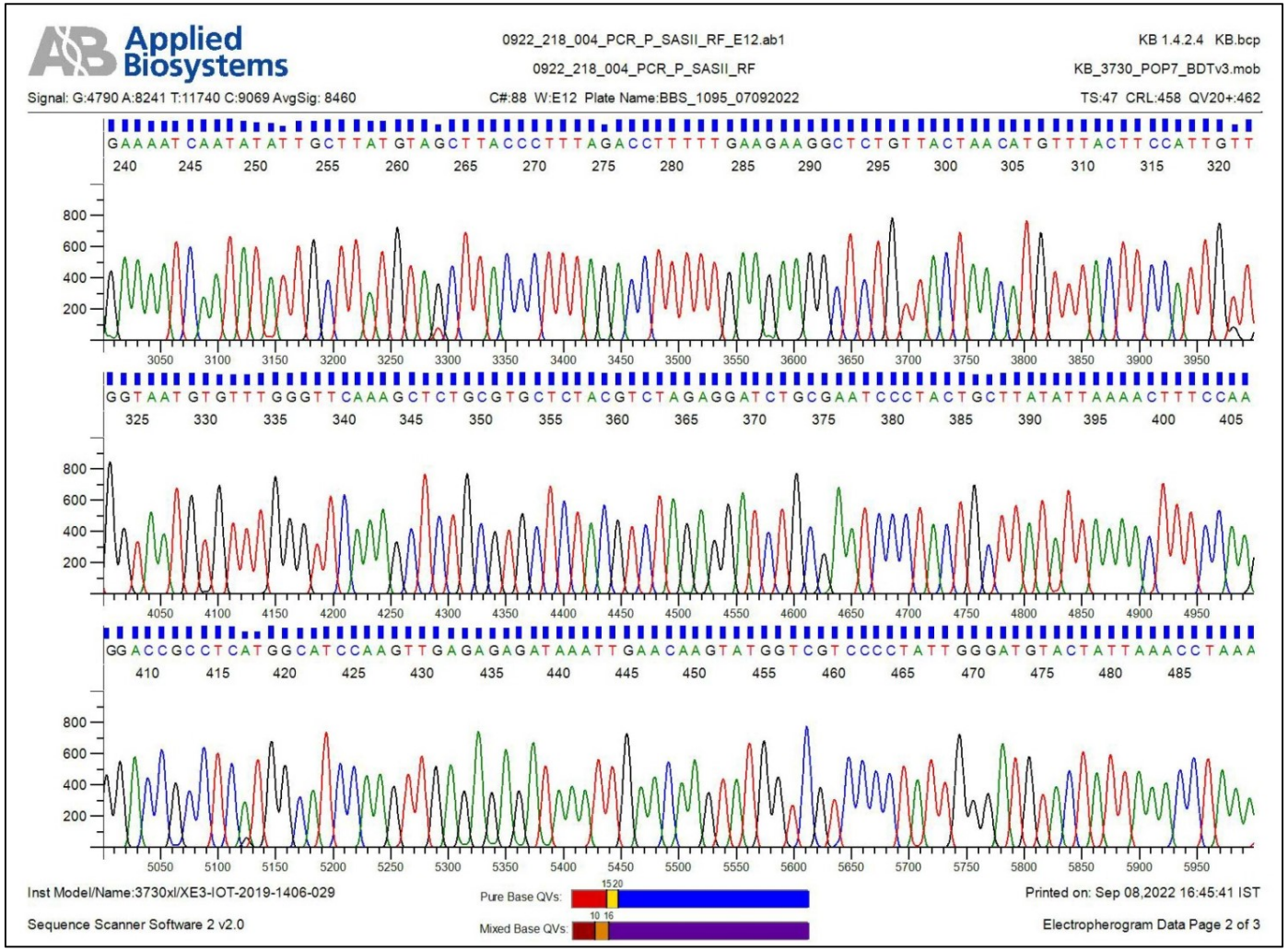
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KB 1.4.2.4 KB.bcp
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C#:88 W:E12 Plate Name:BBS_1095_07092022
TS:47 CRL:458 QV20+:462
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240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320
800 600 400 200
3050 3100 3150 3200 3250 3300 3350 3400 3450 3500 3550 3600 3650 3700 3750 3800 3850 3900 3950
GGTAATGTGTTTGGGTTCAAAGCTCTGCGTGCTCTACGTCTAGAGGATCTGCGAATCCCTACTGCTTATATTAAAACTTTCCAA
325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405
800 600 400 200
4050 4100 4150 4200 4250 4300 4350 4400 4450 4500 4550 4600 4650 4700 4750 4800 4850 4900 4950
GGACCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTATGGTCGTCCCCTATTGGGATGTACTATTAAACCTAAA
410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485
800 600 400 200
5050 5100 5150 5200 5250 5300 5350 5400 5450 5500 5550 5600 5650 5700 5750 5800 5850 5900 5950
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Pure Base QVs:
15 20
Mixed Base QVs:
10 16
Printed on: Sep 08,2022 16:45:41 IST
Sequence Scanner Software 2 v2.0
Electropherogram Data Page 2 of 3

Applied Biosystems

0922_218_004_PCR_P_SASII_RF_E12.ab1

0922_218_004_PCR_P_SASII_RF

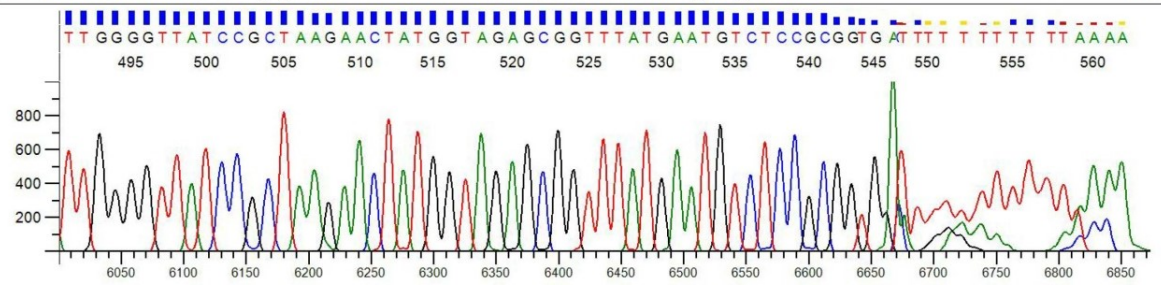
KB 1.4.2.4 KB.bcp

KB_3730_POP7_BDTv3.mob

Signal: G:4790 A:8241 T:11740 C:9069 AvgSig: 8460

C#:88 W:E12 Plate Name:BBS_1095_07092022

TS:47 CRL:458 QV20+:462



Inst Model/Name:3730xl/XE3-IOT-2019-1406-029

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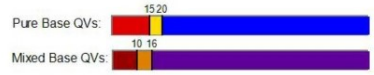
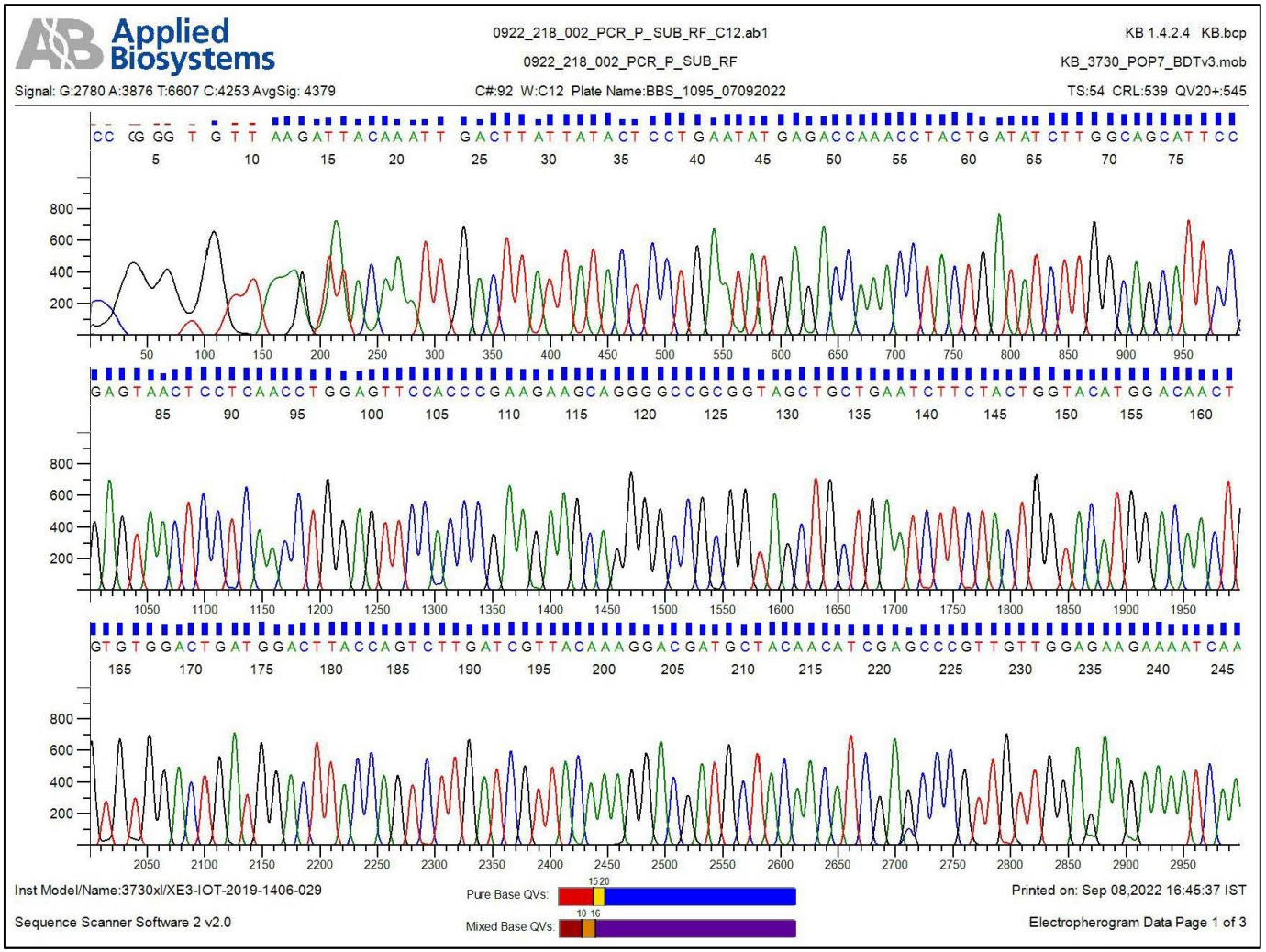
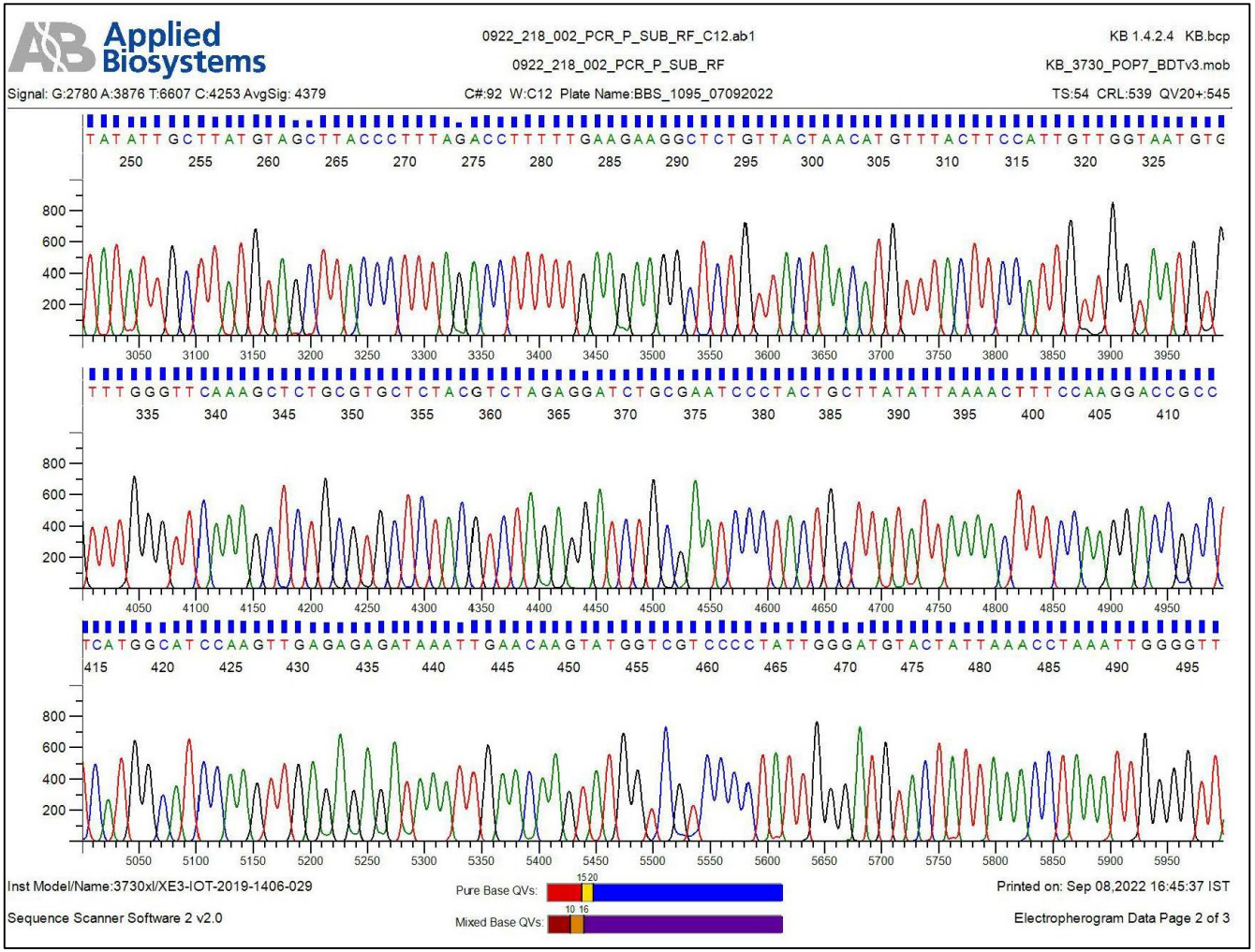


Printed on: Sep 08,2022 16:45:41 IST

Electropherogram Data Page 3 of 3

Chromatogram of *Parthenocissus subferruginea*




Applied Biosystems
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KB_3730_POP7_BDTv3.mob
Signal: G:2780 A:3876 T:6607 C:4253 AvgSig: 4379
C#:92 W:C12 Plate Name:BBS_1095_07092022
TS:54 CRL:539 QV20+:545
TATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTTGAAGAAGGCTCTGTTACTAACATGTTTACTTCCATTGTTGGTAATGTG
TTTGGGTTCAAAGCTCTGCGTGCTCTACGTCTAGAGGATCTGCGAATCCCTACTGCTTATATTAAAACTTTCCAAGGACCGCC
TCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTATGGTCGTCCCCTATTGGGATGTACTATTAAACCTAAATTGGGGTT
Pure Base QVs:
Mixed Base QVs:
Inst Model/Name:3730xl/XE3-IOT-2019-1406-029
Printed on: Sep 08,2022 16:45:37 IST
Sequence Scanner Software 2 v2.0
Electropherogram Data Page 2 of 3

Applied Biosystems

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0922_218_002_PCR_P_SUB_RF

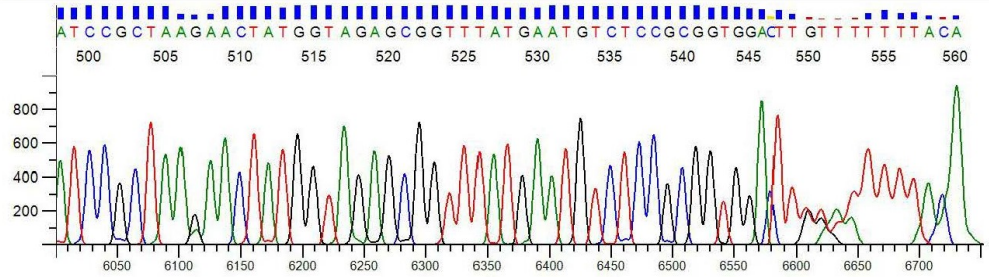
KB 1.4.2.4 KB.bcp

KB_3730_POP7_BDTv3.mob

Signal: G:2780 A:3876 T:6607 C:4253 AvgSig: 4379

C#:92 W:C12 Plate Name:BBS_1095_07092022

TS:54 CRL:539 QV20+:545



Inst Model/Name:3730xl/XE3-IOT-2019-1406-029

Sequence Scanner Software 2 v2.0

Pure Base QVs: 15 20

Mixed Base QVs: 10 16

Printed on: Sep 08,2022 16:45:37 IST

Electropherogram Data Page 3 of 3

***Parthenocissus renukae*, ribulose-1,5-bisphosphate carboxylase, partial cds.**

```
LOCUS       BSeq#1                   487 bp    DNA     linear       16-MAY-2023
DEFINITION  Parthenocissus renukae chloroplast.
ACCESSION   BSeq#1
VERSION
KEYWORDS    .
SOURCE      chloroplast Parthenocissus renukae
  ORGANISM  Parthenocissus renukae
            Unclassified.
REFERENCE   1  (bases 1 to 487)
  AUTHORS   DOMINIGOSE,N.C.
  TITLE     Parthenocissus renukae, a new species of Vitaceae from South India
  JOURNAL   Taiwania 63 (2), 139-142 (2018)
REFERENCE   2  (bases 1 to 487)
  AUTHORS   DOMINIGOSE,N.C.
  TITLE     Direct Submission
  JOURNAL   Submitted (16-MAY-2023) BOTANY, ST.THOMAS COLLEGE THRISSUR,
            CHUNGATH, THRISSUR, KERALA 680503, India
COMMENT     Bankit Comment: TAX: Yes, new species/combinations; SEE ATTACHMENT
            Bankit Comment: ALT EMAIL:nimmidominigose@gmail.com
            Bankit Comment: TOTAL # OF SEQS:1

            ##Assembly-Data-START##
            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
FEATURES             Location/Qualifiers
     source          1..487
                     /organism="Parthenocissus renukae"
                     /organelle="plastid:chloroplast"
                     /mol_type="genomic DNA"
                     /country="India"
                     /collection_date="1/April/2016"
                     /collected_by="Anto,Nimmi"
     gene            <1..>487
                     /gene="rbcL"
     CDS             <1..>487
                     /gene="rbcL"
                     /note="[intronless gene]"
                     /codon_start=1
                     /product="ribulose-1,5-bisphosphate carboxylase"
                     /translation="SLYSLNMRPNLPISWQHSENSSTWSSTRRSRGRGSCESSTGTWT
                     TVWTDGLTSLDRYKGRCYNIEPVVGEENQYIAYVAYPLDLFEEGSVTNMFTSIVGNVF
                     GFKALRALRLEDLRIPTAYIKTFQGPPHGIQVERDKLNKYGRPLLGCTIKPKLGLSAK
                     NY"
BASE COUNT      133 a    108 c    106 g    140 t
ORIGIN
        1 tcattatact ccctgaatat gagaccaaac ctaccgatat cttggcagca ttccgagaac
       61 tcctcaacct ggagttccac ccgaagaagc aggggccgcg gtagctgcga atcttctact
      121 ggtacatgga caactgtgtg gactgatgga cttaccagtc ttgatcgtta caaaggacga
      181 tgctacaaca tcgagcccgt tgttggagaa gaaaatcaat atattgctta tgtagcttac
      241 cctttagacc tttttgaaga aggctctgtt actaacatgt ttacttccat tgttggtaat
      301 gtgtttgggt tcaaagctct gcgtgctcta cgtctagagg atctgcgaat ccctactgct
      361 tatattaaaa ctttccaagg accgcctcat ggcatccaag ttgagagaga taaattgaac
      421 aagtatggtc gtcccctatt gggatgtact attaaaccta aattggggtt atccgctaag
      481 aactatg
//
```

***Parthenocissus semicordata* var. *roylei,* ribulose-1,5-bisphosphate carboxylase, partial cds.**

```
LOCUS       BSeq#1                  435 bp    DNA     linear       12-MAY-2023
DEFINITION  Parthenocissus semicordata var.roylei chloroplast.
ACCESSION   BSeq#1
VERSION
KEYWORDS    .
SOURCE      chloroplast Parthenocissus semicordata var.roylei
  ORGANISM  Parthenocissus semicordata var.roylei
            Unclassified.
REFERENCE   1  (bases 1 to 435)
  AUTHORS   DOMINIGOSE,N.C.
  TITLE     Direct Submission
  JOURNAL   Submitted (12-MAY-2023) BOTANY, ST.THOMAS COLLEGE THRISSUR,
            CHUNGATH, THRISSUR, KERALA 680503, India
COMMENT     Bankit Comment: TAX: No, not new species/combinations; SEE
            ATTACHMENT
            Bankit Comment: ALT EMAIL:nimmidominigose@gmail.com
            Bankit Comment: TOTAL # OF SEQS:1

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            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
FEATURES             Location/Qualifiers
     source          1..435
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                     /organelle="plastid:chloroplast"
                     /mol_type="genomic DNA"
                     /country="India"
                     /collection_date="23/August/2022"
                     /collected_by="Anto,Nimmi"
     gene            <1..>435
                     /gene="rbcL"
     CDS             <1..>435
                     /gene="rbcL"
                     /note="[intronless gene]"
                     /codon_start=1
                     /product="ribulose-1,5-bisphosphate carboxylase"
                     /translation="YLGSKPSNYLNLGVPPEEAGAAVAAESSTGTWTTVWTDGLTSLD
                     RYKGRCYHIEPVAGEETQFIAYVAYPLDLFEEGSVTNMFTSIVGNVFGFKALRALRLE
                     DLRIPPAYTKTFQGPPHGIQVERDKLNKYGRPLLGCTIKPKLG"
BASE COUNT      112 a    104 c    100 g    119 t
ORIGIN
        1 tatcttggca gcaaaccgag taactacctc aacctcggag ttccacccga agaagcaggg
       61 gccgcggtag ctgctgaatc ttctactggt acatggacaa ctgtgtggac tgatggactt
      121 accagccttg atcgttacaa aggacgatgc taccacatcg agcccgttgc tggagaagaa
      181 actcaattta ttgcttatgt agcttaccct ttagaccttt ttgaagaagg ctctgttact
      241 aacatgttta cttccattgt gggtaatgtg tttgggttca aagctctgcg cgctctacgt
      301 ctagaggatc tgcgaatccc ccctgcttat actaaaactt tccaaggccc gcctcatggc
      361 atccaagttg agagagataa attgaacaag tatggccgtc ccctattggg atgtactatt
      421 aaacctaaat tgggg
//
```

***Parthenocissus wallichianus*, ribulose-1,5-bisphosphate carboxylase, partial cds.**

```
LOCUS       BSeq#1                   498 bp    DNA     linear       12-MAY-2023
DEFINITION  Parthenocissus sps chloroplast.
ACCESSION   BSeq#1
VERSION
KEYWORDS    .
SOURCE      chloroplast Parthenocissus sps
  ORGANISM  Parthenocissus sps
            Unclassified.
REFERENCE   1  (bases 1 to 498)
  AUTHORS   DOMINIGOSE,N.C.
  TITLE     Direct Submission
  JOURNAL   Submitted (12-MAY-2023) BOTANY, ST.THOMAS COLLEGE THRISSUR,
            CHUNGATH, THRISSUR, KERALA 680503, India
COMMENT     Bankit Comment: TAX: Yes, new species/combinations; SEE ATTACHMENT
            Bankit Comment: ALT EMAIL:nimmidominigose@gmail.com
            Bankit Comment: TOTAL # OF SEQS:1

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            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
FEATURES             Location/Qualifiers
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                     /organelle="plastid:chloroplast"
                     /mol_type="genomic DNA"
                     /country="India"
                     /collected_by="Anto,Nimmi"
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     CDS             <1..>498
                     /gene="rbcL"
                     /note="[intronless gene]"
                     /codon_start=1
                     /product="ribulose-1,5-bisphosphate carboxylase"
                     /translation="NLAAHRVTPQPGVPPEEAGAAVAAETTTGTRTTVWTDGHTSLDR
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                     LRVPTAYVKTFQGPPHGIQVERDKLNKYGRPLLGCTIKPKLGLSAKNYGRAVYECLRG
                     DFFFFK"
BASE COUNT      134 a    108 c    114 g    142 t
ORIGIN
        1 aatctggcag cacaccgagt aactcctcaa cctggagttc cacccgaaga agcaggggcc
       61 gcggtagctg ctgaaacaac tactggtaca cggacaactg tgtggactga tggacatacc
      121 agccttgatc gttacaaagg acgatgctac aacatcgagc ccgttgttgg agaagaaaat
      181 caatatattg cttatgtagc ttacccttta gacctttttg aagaaggctc tgttactaac
      241 atgtttactt ccattgtggg taatgtgttt gggttcaaag ctctgcgtgc tctacgtcta
      301 gaagatctgc gagtccccac tgcttatgtt aaaactttcc aaggcccgcc tcatggcatc
      361 caagttgaga gagataaatt gaacaagtat ggtcgtcccc tattgggctg tactattaaa
      421 ccaaaattgg ggttatccgc taagaactat ggtagagcag tttatgaatg tctccgcggt
      481 gatttttttt tttttaaa
//
```

***Parthenocissus sasii,* ribulose-1,5-bisphosphate carboxylase, partial cds.**

```
LOCUS       BSeq#1                  520 bp    DNA     linear       07-SEP-2023
DEFINITION  Parthenocissus sasii chloroplast.
ACCESSION   BSeq#1
VERSION
KEYWORDS    .
SOURCE      chloroplast Parthenocissus sasii
  ORGANISM  Parthenocissus sasii
            Unclassified.
REFERENCE   1  (bases 1 to 520)
  AUTHORS   DOMINIGOSE,N.C. and V,A.P.
  TITLE     Direct Submission
  JOURNAL   Submitted (07-SEP-2023) BOTANY, ST.THOMAS COLLEGE THRISSUR,
            CHUNGATH, THRISSUR, KERALA 680503, India
COMMENT     Bankit Comment: TAX: Yes, new species/combinations; SEE ATTACHMENT
            Bankit Comment: ALT EMAIL:nimmidominigose@gmail.com
            Bankit Comment: TOTAL # OF SEQS:1

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            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
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     source          1..520
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                     /organelle="plastid:chloroplast"
                     /mol_type="genomic DNA"
                     /country="India"
                     /collection_date="08/March/2021"
                     /collected_by="Anto,Nimmi"
     gene            <1..>520
                     /gene="rbcL"
     CDS             <1..>520
                     /gene="rbcL"
                     /note="[intronless gene]"
                     /codon_start=2
                     /product="ribulose-1,5-bisphosphate carboxylase"
                     /translation="YETKPTDILAAFRVTPQPGVPPEEAGAAVAAESSTGTWTTVWTD
                     GLTSLDRYKGRCYNIEPVVGEENQYIAYVAYPLDLFEEGSVTNMFTSIVGNVFGFKAL
                     RALRLEDLRIPTAYIKTFQGPPHGIQVERDKLNKYGRPLLGCTIKPKLGLSAKNYGRA
                     VYECLRGDFFFLK"
BASE COUNT      139 a    108 c    116 g    157 t
ORIGIN
        1 atatgagacc aaacctactg atatcttggc agcattccga gtaactcctc aacctggagt
       61 tccacccgaa gaagcagggg ccgcggtagc tgctgaatct tctactggta catggacaac
      121 tgtgtggact gatggactta ccagtcttga tcgttacaaa ggacgatgct acaacatcga
      181 gcccgttgtt ggagaagaaa atcaatatat tgcttatgta gcttaccctt tagacctttt
      241 tgaagaaggc tctgttacta acatgtttac ttccattgtt ggtaatgtgt ttgggttcaa
      301 agctctgcgt gctctacgtc tagaggatct gcgaatccct actgcttata ttaaaacttt
      361 ccaaggaccg cctcatggca tccaagttga gagagataaa ttgaacaagt atggtcgtcc
      421 cctattggga tgtactatta aacctaaatt ggggttatcc gctaagaact atggtagagc
      481 ggtttatgaa tgtctccgcg gtgacttttt ttttttaaaa
//
```

***Parthenocissus subferruginea*, ribulose-1,5-bisphosphate carboxylase, partial cds.**

```
LOCUS       BSeq#1                  533 bp    DNA     linear       05-JUN-2023
DEFINITION  Parthenocissus sps.2 chloroplast.
ACCESSION   BSeq#1
VERSION
KEYWORDS    .
SOURCE      chloroplast Parthenocissus sps.2
  ORGANISM  Parthenocissus sps.2
            Unclassified.
REFERENCE   1  (bases 1 to 533)
  AUTHORS   DOMINIGOSE,N.C.
  TITLE     Direct Submission
  JOURNAL   Submitted (05-JUN-2023) BOTANY, ST.THOMAS COLLEGE THRISSUR,
            CHUNGATH, THRISSUR, KERALA 680503, India
COMMENT     Bankit Comment: TAX: Yes, new species/combinations; SEE ATTACHMENT
            Bankit Comment: ALT EMAIL:nimmidominigose@gmail.com
            Bankit Comment: TOTAL # OF SEQS:1

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            Sequencing Technology :: Sanger dideoxy sequencing
            ##Assembly-Data-END##
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                     /organelle="plastid:chloroplast"
                     /mol_type="genomic DNA"
                     /country="India"
                     /collection_date="02/August/2021"
                     /collected_by="Anto,Nimmi"
     gene            <1..>533
                     /gene="rbcL"
     CDS             <1..>533
                     /gene="rbcL"
                     /note="[intronless gene]"
                     /codon_start=3
                     /product="ribulose-1,5-bisphosphate carboxylase"
                     /translation="YKLTYYTPEYETKPTDILAAFRVTPQPGVPPEEAGAAVAAESST
                     GTWTTVWTDGLTSLDRYKGRCYNIEPVVGEENQYIAYVAYPLDLFEEGSVTNMFTSIV
                     GNVFGFKALRALRLEDLRIPTAYIKTFQGPPHGIQVERDKLNKYGRPLLGCTIKPKLG
                     LSAKNYGRAVYECLRGG"
BASE COUNT      145 a    112 c    119 g    157 t
ORIGIN
        1 attacaaatt gacttattat actcctgaat atgagaccaa acctactgat atcttggcag
       61 cattccgagt aactcctcaa cctggagttc cacccgaaga agcaggggcc gcggtagctg
      121 ctgaatcttc tactggtaca tggacaactg tgtggactga tggacttacc agtcttgatc
      181 gttacaaagg acgatgctac aacatcgagc ccgttgttgg agaagaaaat caatatattg
      241 cttatgtagc ttacccttta gacctttttg aagaaggctc tgttactaac atgtttactt
      301 ccattgttgg taatgtgttt gggttcaaag ctctgcgtgc tctacgtcta gaggatctgc
      361 gaatccctac tgcttatatt aaaactttcc aaggaccgcc tcatggcatc caagttgaga
      421 gagataaatt gaacaagtat ggtcgtcccc tattgggatg tactattaaa cctaaattgg
      481 ggttatccgc taagaactat ggtagagcgg tttatgaatg tctccgcggt gga
//
```

LIST OF PUBLICATIONS

- Nimmi C Dominigose, Anto P.V and A. K Pradeep (2023). A new species of Parthenocissus (Vitaceae) from India with notes on *Causonis trifolia*, *Plant Science Today*. Vol 10(3): 106–110
- Anto P V, A. K. Pradeep, Franklin Francis, Nimmi C. Dominigose and Hari Sasidharan (2018). *Parthenocissus renukae*, a new species of Vitaceae from South India. *Taiwania* 63(2): 139-142
- Nimmi C Dominigose and Anto P.V (2022)- Distribution and morphology of two species of *Parthenocissus* from Kerala Proceedings of the National Seminar "Species The Passion 7", ISBN 978-93-91691-01-1.

LIST OF PAPERS COMMUNICATED

- Nimmi C Dominigose and Anto P.V (2022). A new species of Parthenocissus Planch (Vitaceae) from, Kerala, India. *Indian forester*. (In press)
- Nimmi C Dominigose and Anto P.V (2023). Reinstatement and typification of *Parthenocissus subferruginea* (Vitaceae). *Phytotaxa*. (In press)

LIST OF PRESENTATIONS

- "A revision on genus *Parthenocissus*" in the Two day National seminar "Species the Passion V" at St. Thomas' College (Autonomous), Thrissur from 26/06/2019-27/06/2019.
- A New Species of *Parthenocissus renukae* from South India" in the national seminar "Species the Passion IV" at St. Thomas College (Autonomous), Thrissur on 28/06/2018-29/06/2018

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RESEARCH ARTICLE

A new species of *Parthenocissus* (Vitaceae) from India with notes on *Causonis trifolia*

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Abstract

A new species of *Parthenocissus*, *P. wallichianus* is described and illustrated from Kerala, India. This taxon was found and collected previously from India but misunderstood by earlier Indian botanists for names under various combinations among the such as *Vitis, Cissus, Cayratia,* and *Causonis.* The combinations were based either on the Linnaean *Vitis trifolia* or on Lamarck's *Cissus carnosa*. Both these names are currently accepted as conspecific and validated now as belonging to *Causonis trifolia* (L.) Mabb.et J. Wen. The new taxon has separated from all these genera by a suit of characters and is shown fit best to the genus *Parthenocissus*. A key for the identification of Indian species of *Parthenocissus* is also provided.

Keywords

Cayratia; *Cissus*; Kerala; South India

Introduction

The genus *Parthenocissus* Planch. comprises *c.* 16 species with an intercontinental disjunct distribution between Asia and North America. Thirteen species occur in Asia and three in North America with one extending to the Caribbean (1-4). Among them, three species and two varieties are known to occur in India (5,6). The genus includes deciduous lianas, with leaves usually palmately 3–5 (-7) foliolate, tendrils monochasialy 3-12 branched and usually tipped with adhesive discs. The inflorescence is generally a loose dichasium, corymbose cyme, or an umbel, without a tendril at its base. The floral discs are inconspicuous and fused with the base of the ovary (4). During their taxonomic studies on Vitaceae in South India the authors came across an interesting taxon which initially thought it belong to *Causonis trifolia* (L.) Mabb. & J. Wen [= *Cayratia trifolia* (L.) Domin.], a species fairly common in the plains of South India, and usually associated with mangroves. A close examination of the specimens in consultation with protologue and type of *C. trifolia* (*Samuel Brown* 67, BM-SL [Petiver, 165f.84] digital image!) and the names cited under its synonymy (7) revealed *C. trifolia* was rather misunderstood, and this name was used by some authors (8-11) for a mixture of elements and partly not belonging to *Causonis*. Linnaeus (1753) originally described it as *Vitis trifolia,* "VITIS foliis ternatis; foliolis subrotundis serratis. Vitis pearme doorica, foliis ternis subrotundis serratis, Raj.dendr. 68. Habitat in India" However, he did not mention any specimen except for a reference to "Raj dendr. 68" which was evidently based on Petiver (1702), consequently Shetty and Singh (1988) designated "*Petiver* 67" (BM-SL) as the neotype. Trias–Blasi *et al.* (12) have rightly pointed out that the neotype should

more accurately be referred to as "*Samuel Brown* 67" as he was the collector, and Petiver was the source of the bound volume at Sloane Herbarium. *Cissus carnosa* Lam. and combinations based on this name in *Cayratia* and *Vitis* were also treated as belonging to *Causonis trifolia*. The lectotype of Lamarck's name, *Cissus carnosa* was Rheede's illustration of "Tsjori-Valli" in *Hortus Malabaricus* (7: t.9.1688) which was a perfect match for what is currently treated as *Causonis trifolia.* However, Robert Wight and Walker Arnott (1834, 1840 probably misunderstood *C. trifolia* (= *Vitis carnosa*) as their illustration (1840. t.171) in *Icones Plantarum Indiae Orientalis* is apparently not pertaining to *C. trifolia*, instead, it belongs to the genus *Parthenocissus.* An examination of Wallich's specimens (14) at Kew, and those cited by Wight and Arnott (9) also shows a mixture of elements partly belonging to *Causonis trifolia* and *Parthenocissus*. Lawson (13) also followed a similar broader concept by placing different elements, some of which have since been segregated (14). The present collection of *Parthenocissus* specimens by the authors from the Trichur district of Kerala perfectly agrees with the illustration by Wight and Arnott (9) and Roxburgh's *Flora Indica* drawing (No. 541.) Moreover, some of Wallich's collections (Barcodes K001122820, & K001122827, *Wall. Cat.* 6018, digital image! *Wall. Cat.* 6021C, digital image!) (15) and Rottler's specimens (Barcodes K001089947, K001089948 digital images!) at K cited by Wight and Arnott (l.c.) are strikingly different from *Causonis trifolia* in having many branched tendrils tipped with adhesive discs, a character diagnostic to the genus *Parthenocissus*. However, Roxburgh's *Flora Indica* (16) description, citation of Rheede's plate ("vii.p.17.t.9"), and Rumphius's (17) *Herbarium Amboinense* (5:540.f.t.166, f.2) are in corroboration with the present circumscription of *Causonis trifolia*, while the figures in Roxburgh's Icone (t. 541), and Wight's Icone (t.171) belongs to a hitherto undescribed *Parthenocissus* which is described here as a new species.

According to Lu *et al*. (18), "*Parthenocissus* can be easily distinguished from the other genera of Vitaceae by its highly branched tendrils, adhesive discs at tendril apices, inconspicuous floral discs and two long ventral infolds extending from the apex to the base of the seed" (4,19,20,21). Our new species satisfy above mentioned key characters of *Parthenocissus*. But unfortunately, Parmer *et al*. (22) and Trias-Blasi (23) misidentified our species as *Causonis trifolia*. Findings and descriptions of *C. trifolia* by Parmar *et al*. (22) and Trias-Blasi (23) make a puzzle among *Causonis* and *Parthenocissus* species. This paper intends to solve the puzzle of the above two genera of Vitaceae. According to Parmar *et al* (22), *C. trifolia* shows 2-8 furcate tendrils with adhesive pads and he also suggest that the adhesive disc at the tip of the tendrils is more prominent in populations from the limestone areas. From these words, we can understand that highly branched tendrils and adhesive pads cannot be taken as the key characteristics of the *C. trifolia*. Another fact is that none of the other species of the *Causonis* genus shows these characteristics. If the genus *Causonis* shows the key character of *Parthenocissus* it will be a big question to the existence of the *Parthenocissus* genus.

Materials and Methods

The description of the species is based on live specimens collected from different parts of Kerala. A detailed comparative morphological study was carried out with specimens of closely resembling species and by referring to herbarium specimens housed at various herbaria (BM, CALI, K, and online databases (http://www.ipni.org, http://www.*tropicos*.org)). Field photograph was taken with a DSLR Camera and morphological observations were made using a Leica S8AP0 stereo microscope attached to the digital camera. The acronyms of herbaria are as per Thiers (continuously updated).

Results and discussion

Taxonomic Treatment

Parthenocissus wallichianus Anto, Nimmi & Pradeep, *sp. nov.* (Fig:1, Fig:2)

New species have terete stem, tendrils with 6–7 branches and the tip of the tendril modified as adhesive pads, extra axillary inflorescence, inflorescence length is larger than the length of the leaf, and ovary partially fused with disc. It is separated from *Parthenocissus semicordata* having tetramerous flowers and a moniliform root.

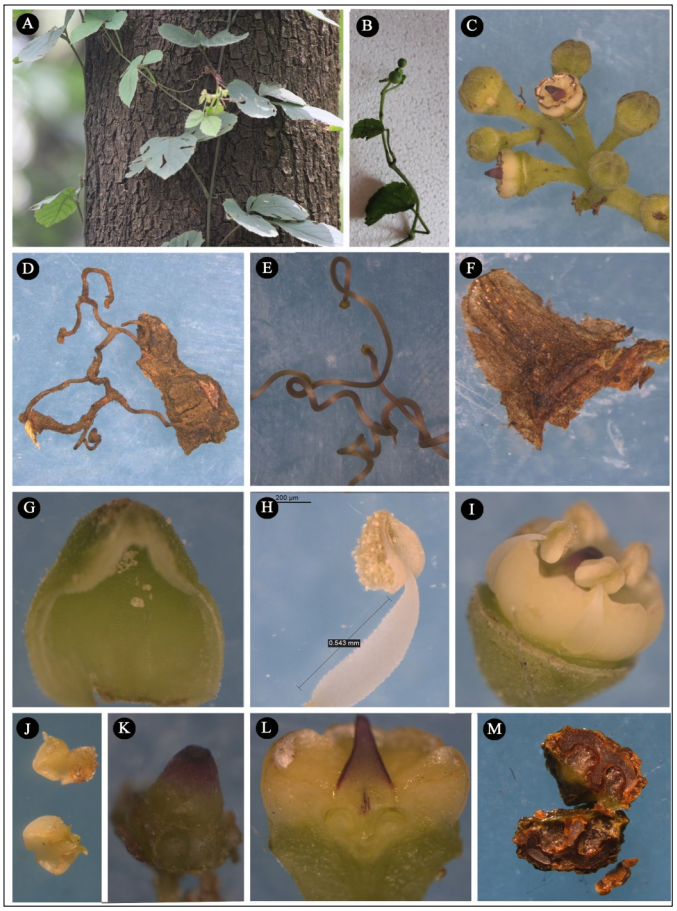

Fig.1. *Parthenocissus wallichianus* Anto, Nimmi & Pradeep. **A**. Habit, **B.** Branch enlarged, **C.** Inclorescence, **D**. Tendril with twig, **E**. Tendril with pad,**F**.Stipule, **G**. Petal, **H**. Stamen, **I**. Flower bud dissected, **J**. Nectariferous disc, **K**. gynoecium, **L**. Flower LS, **M**. Seed CS

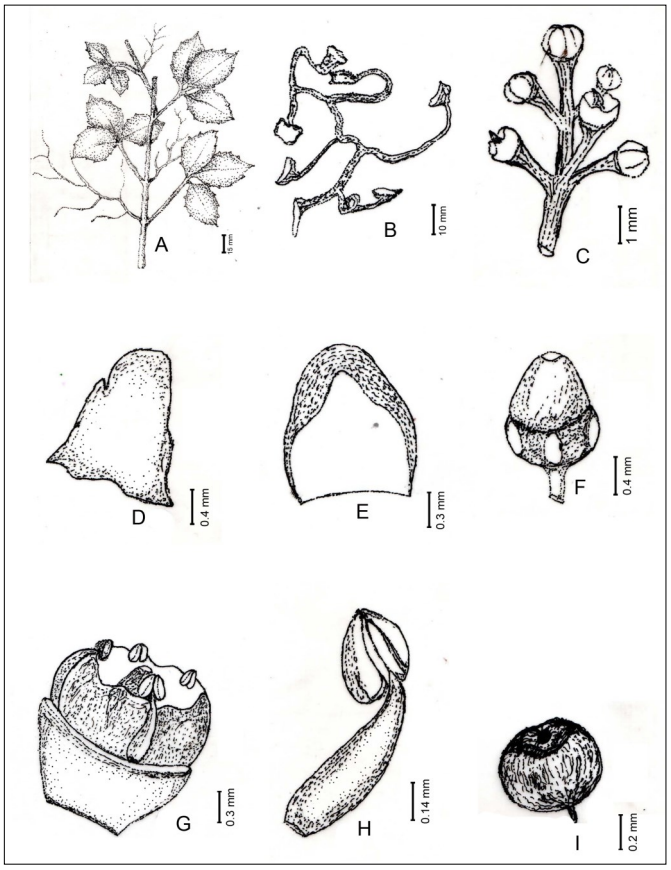

Fig.2. *Parthenocissus wallichianus* Anto, Nimmi & Pradeep. **A**. Habit, **B**. Tendril, **C**. Inflorescence, **D**. Stipule, **E**. Petal, **F**. Gynoecium, **G**. Flower bud dissected, **H**. Stamen, **I**. Fruit

Type

INDIA, Kerala, Thrissur District, Kayambuvum, N10°41′1″, E76°23′1″, 200 m, 31.07. 2018, Anto & Nimmi 102 (holo CALI! iso MH! CAL! STC!).

Cissus carnosa auct. Roxb., Fl. Ind.1:427.1820, ed.2, 1:409.1832, excl. cit. *Tsjori-Valli*, Rheede & Rumph., Herb. Amboinense, *non* Lam.1783.

Vitis carnosaauct. Wight & Arn., Prodr. Fl. Pen. Ind. Orient. 1:127.1834, *pro parte*, *quoad Wallich Num. L.n.,* 6021c.

Robust climber. Stem terete, young stems villous, old stems rough and laterally compressed furrowed, lenticellate. Tendrils, 6–7 branched, wiry, glabrous, leaf-opposed, tips bulbous into forming attaching pads. Leaves 3-foliolate; petiole 2.5–8 cm., petiolules sub sessile to 2 cm long., terminal leaflet obovate, 5–17 × 2.5–12 cm, base rounded to oblique, apex mucronate to apiculate; lateral leaflets oblique, ovate to oblong-ovate. 5–16 × 2.5–9 cm, margin serrate, glabrous above, villous below, especially on veins, secondary veins 5–6 pairs. Stipules *c.*1.5 mm long, hairy. Inflorescence extra axillary, compound dichasial cyme; peduncle 6 – 8 cm, generally glabrous, pedicels 1–3 mm long, glabrous. Sepals 4, cup shaped, entire, margins sinuate, villous. Petals 4, ovate, 2–3 × 0.75–1.5 mm, coherent to the margins; early caducous. Anthers 4, ovate, 0.35 – 0.75 mm, antipetalous, dorsifixed, dithecous, introse, filaments compressed, broadened at the base, 0.54 mm long. Ovary glabrous, partially fused with a nectariferous disc. Style conical 0.4 mm long. Stigma indistinct, hairy, violet coloured. Fruit oblate, dark purplish-black berries, 2–4seeded, 4–7 mm in diameter.

Key to the species of Parthenocissus in India

1a. Leaves simple or 3 –lobed

2a. Leaves 3 –lobed……*P. tricuspidata*

2b. Leaves simple, unlobed..... *P. renukae*

1b. Leaves palmately compound, 3 or 5 –foliolate

3a. Leaves 5-foliolate ……..…….. *P. quinquefolia*

3b. Leaves 3-foliolate……...…….…….... 4

4a. Tendrils 8– branched, flowers pentamerous.....
……..*P. semicordata*

4b. Tendrils 6–7 branched, flowers tetramerous.....
……...*P. wallichianus*

Flowering & fruiting

Flowering starts from June to September and fruiting from September to October.

Etymology

The specific epithet is in honor of the great Danish-born botanist, Nathaniel Wallich (1786-1854), who collected this taxon from Peninsular India.

Habitat

Occurs in the moist deciduous forest along with trees such as *Acacia auriculiformis* A. Cunn. ex Benth., *Mangifera indica* L., *Getonia floribunda Roxb*. and *Borassus flabellifer* L. subshrubs such as *Ageratum conyzoides* L *and Mesosphaerum suaveolans* (L.) Kuntze.

Conservation status

Data deficient

Conclusion

This new taxon was previously confused with *Causonis trifolia* (L.) Mabb. & J. Wen (also with names in combinations with genera such as *Cayratia* and *Cissus* based *Vitis trifolia* L.) although it possesses extra axillary inflorescences and a 6–7branched tendril with adhesive pads at its tip, are the diagnostic characters of the genus *Parthenocissus.* We have studied *Parthenocissus wallichianus* for the past 5 years. According to us our species morphologically (Table 1, Fig 3) and palynologically (Fig 4) differs from *C. trifolia*. The SEM study of pollen grains re-

Table 1. Difference between *Parthenocissus wallichianus* and *Causonis trifolia*

	P. wallichianus	***C. trifolia***
Altitude	Above 100 m	Below mean sea level
Habitat	Moist deciduous forest	Mangroves and sea shore areas
Tendril	Tendril branches 6 or 7 with adhesive pad at tip and ≤10 cm long	Tendril branches 3 without adhesive pad and ≥10 cm long
Climbing pattern	Climbing on host with coiled tendril and sticking pads	Climbing on host with coiled tendrils.

Inflorescence length	Shorter than petiole	Longer than petiole
Nectariferous disc	Present, four distinct lobed	Absent
Fruit shape	Oblate	Globose
Seed	Rough	Smooth
Ruminate endosperm	m-shaped	T-shaped

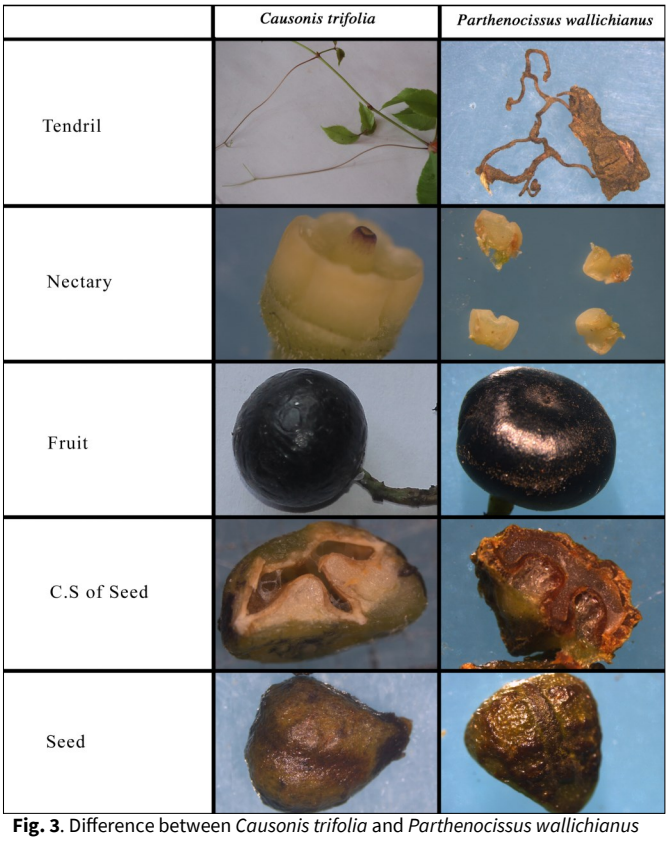

Fig. 3. Difference between *Causonis trifolia* and *Parthenocissus wallichianus*

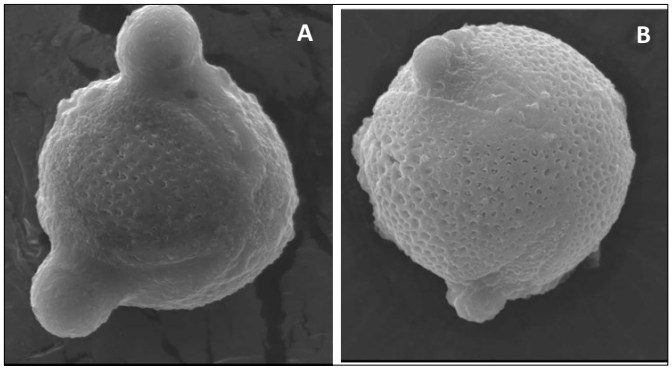

Fig. 4. Pollen grains of **A**. *Causonis trifolia,* **B**. *Parthenocissus wallichianus*

veals that both are tricolporate. But they differ from each other in lateral lobes > 8-micrometer length, colpi width > 6micrometer and heteropolar in *C. trifolia* and lateral lobes < 5-micrometer length, colpi width 10 micrometer and isopolar in *P. wallichianus*.

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The authors are thankful to scientists of the herbarium database division of the Royal Botanic Garden, Kew, and BM. The authors are thankful to DST-FIST funded SIFC Department of Botany and Zoology St. Thomas College (Autonomous), Thrissur, STIC CUSAT, for their assistance.

Authors contributions

NCD contributed in plant collection, workout and drafting, APV in plant collection and identification and AKP as Taxonomy expert

Compliance with ethical standards

Conflict of interest: We declare that there is no financial/ commercial conflict of interest

Ethical issues: None.

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DOI: 10.6165/tai.2018.63.139

Parthenocissus renukae, a new species of Vitaceae from South India

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ABSTRACT: A new species of Vitaceae from Kerala, India, *Parthenocissus renukae* Anto & Pradeep is described and illustrated. The species resembles *P. semicordata* Planch. and *Cissus aristata* Blume in certain morphological characters. It differs from *P. semicordata* in having simple leaves clothed with T-shaped hairs on its abaxial surface, shorter (upto 8cm) petioles, 8-branched tendrils, umbellate inflorescences and tomentose petals. It also differs from *C. aristata* in having pads at tendril tips, 8-branched tendrils and T-shaped hairs on the abaxial leaf surface. The species is known from the type locality, Mangad and Peruvanmala in Thrissur district of Kerala.

KEY WORDS: *Cissus,* India, Kerala, New species, *Parthenocissus*, Vitaceae.

INTRODUCTION

The genus *Parthenocissus* Planch. Currently includes 15 species, occurring in tropical and temperate regions of eastern Asia and North America. It shows disjunct distribution with majority of species occurring in Asia and a few in North and Central America (Trias-Blasi *et al.*, 2017) In India, the genus is represented by two species, *P. semicordata* (Wall.) Planch. and *P. thomsonii* (M. Lawson) P. Singh & B.V. Shetty of which a variety [var. *roylei* (King ex R. Parker) Nazim. & Qaiser] of the former is known to occur in Kerala (Singh & Shetty, 2000). Gamble (1918) treated only one species, *P. neilgherriensis* (Wight) Planch. in his *Flora of the Presidency of Madras* which is later found to be conspecific with *P. semicordata* (Wall.) Planch. var. *roylei* (King ex R. Parker) Nazim. & Qaiser (Shetty & Singh, 2005).

While conducting floristic exploration in Thrissur district of Kerala in South India, the authors collected an interesting specimen of *Parthenocissus* from the rocky slope near Mangad. After critical studies it is revealed to be a hitherto undescribed taxon and hence it is described and illustrated here.

TAXONOMIC TREATMENT

Parthenocissus renukae Anto & Pradeep, ***sp. nov.***
Figs. 1 & 2

***Type*: INDIA**. Kerala: Thrissur, Mangad, 10˚42′30″ N, 76°11′43″E, 150 m, 1 April 2016, *Anto P.V.* 125 (holotype: CALI!, isotype, MH!, CAL!, BLAT!).

The new species differs from *P. semicordata* in having simple leaves clothed with T-shaped hairs on its abaxial surface, shorter (upto 8cm) petioles, 8-branched tendrils, umbellate inflorescences, and tomentose petals. It also differs from *C. aristata* in having pads at tendril tips, 8-branched tendrils and T-shaped hairs on the abaxial leaf surface.

Woody climber, 50 m height, stems and branches nodose, lenticelled. Young branches and tendrils, brownish -rose, soft hairy. Tendrils leaf-opposed, 8-branched, tips of tendrils modified to attaching pads. Leaf blades deeply cordate bristle serrate, leathery, and ferruginous when young, 5- ribbed, acuminate, 9–18 × 9–18 cm, lateral veins 3–5 pairs. Petiole up to 8 cm long, reddish brown at tips-; stipules oblong hairy, 2 at base, internodes 11 cm long. Inflorescence leaf-opposed, short, branched, hairy, umbellate. Flowers drooping, regular, 4-5-merous, disc yellow, prominent, pedicellate-; pedicels 0.5 cm long; calyx cupulate; 4 or 5 sublobed below the disc, 0.12 cm. Petals 4 or 5, 2.5 × 2mm, hairy, cauducous, reddish, tip yellowish red, hooded tip 0.25 cm long, soft yellowish red inside. Hairs drooping tomentous, T-shaped, one side flat. Stamens 4 or 5, 2.5mm long, antipetalous; anthers 0.8 × 0.8 mm, dithecous, yellowish, attached to the base of the disc; filaments subulate, 2mm long Disc yellowish, 4 or 5 lobed, densely pubescent with soft white hairs. Ovary ovoid, sunk in the disc; style short, 0.8 mm long, thick, stigma, capitate. Fruits and seeds not seen.

***Phenology*:** April–May.

***Habitat and distribution*:** *Parthenocissus renukae* is found growing alongwith *Cissus heynana* Steud. and *C. repanda* Vahl. It is known from the type locality, Mangad and Peruvanmala in Thrissur District of Kerala (Fig.3). It usually spread on rocks, grasslands and climb on large trees. It may badly affect the supporting tree by completely covering its canopy finally leading to the death of host tree. The area of occupancy of this taxon is limited to 50 m^2 in moist deciduous forest and at low elevation (150 m) grass lands. The number of individuals

Fig. 1. ***Parthenocissus renukae*** **A**. Habit, **B**. Branch enlarged, **C**. Flowering twig, **D**. Tendril with pad, **E**. Young tendril, **F**. Mature tendril pad, **G**. Inflorescence with 5&4 merous flowers, **H**. Tendril pad enlarged, **I**. Flower bud, **J**. Flower dissected, **K**. Gynoecium, **L**. Aristate nature, **M**. Mature stem.

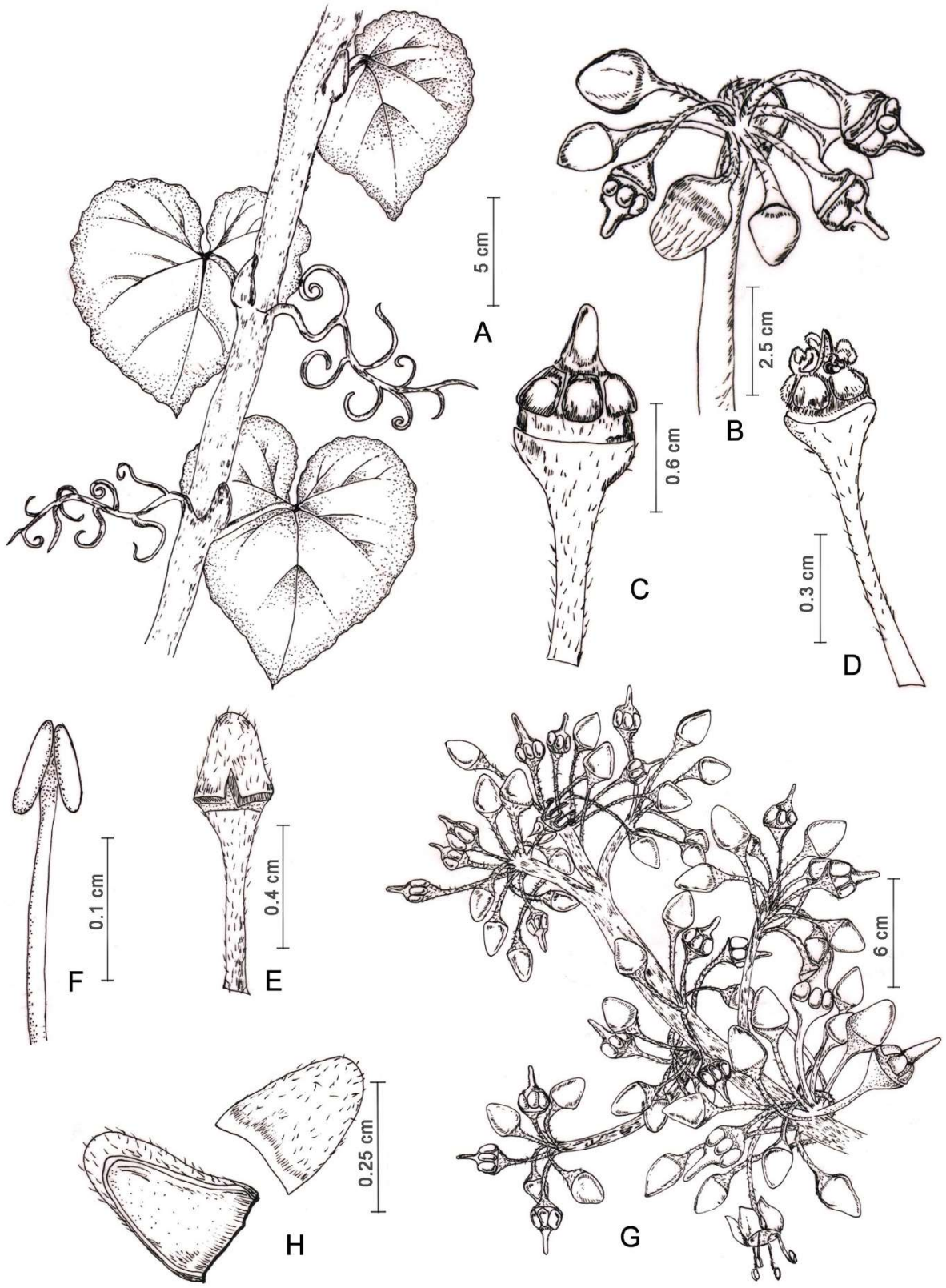

Fig 2. ***Parthenocissus renukae*** **A**. Habit, **B**. Drumping Umbel, **C**. Gynoecium, **D**. Androecium with Gynoecium, **E**. Flower Bud, **F**. Stamen, **G**. Inflorescence, **H**. Petal.

of this taxon in these areas is determined to be less than 15.

***Etymology*:** The specific epithet is in honour of Dr. C. Renuka, Scientist (Rtd.), Kerala Forest Research Institute, Peechi, Thrissur, in appreciation to her contributions to taxonomy and for her support and encouragement to the first author to take up a career in taxonomic research.

Notes: This is the only species having simple leaves and 4-5-merous flowers in the genus *Parthenocissus.* The floral morphology of this species shows an intermediary position between *Cissus* and *Parthenocissus*.

Fig. 3. Distribution of ***Parthenocissus renukae*** sp. nov.

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Distribution and morphology of two species of *Parthenocissus* from Kerala

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Abstract

Distribution and morphology of two major species of *Parthenocissus* are studied and described here

Keywords: *Parthenocissus semicordata var. roylei*, *Parthenocissus renukae*, Kerala

Introduction

Parthenocissus is one of the genus belongs to the family Vitaceae. Members of the family are mainly located in tropical and temperate regions of eastern Asia and North America but are mainly centred in Asia (Trias Blasi *et al.*, 2017). Around 15 species identified worldwide among them five species reported from India.

Members of the genus are mainly lianas, woody and hermaphroditic. The key characteristics of the genus include branched tendril and tendril with attaching pads. *Parthenocissus semicordata var.roylei* and *Parthenocissus renukae* are the two major members of *Parthenocissus* from Kerala. Their distribution and morphology is described here.

Materials and methods

Parthenocissus semicordata var.roylei and *Parthenocissus renukae* are collected from various parts of Kerala. Field photograph was taken with a DSLR Camera and morphological observations were made using a Leica stereo microscope attached to a digital camera.

Results and discussion

Parthenocissus semicordata var. *roylei* (King ex R.Parker) Nazim. & Qaiser

Large climber; stem lenticellate. Leaves 3-foliolate; leaflets to 17 x 10 cm, ovate, acuminate, rounded at base, coriaceous, spinous serrate, 9-nerved; lateral leaflets

oblique at base; petiolule 0.5-1 cm long; rachis to 11 cm long. Cymes 9 cm across, terminal, peduncled. Flowers bisexual, pedicellate, densely packed; calyx cupular, 5-teethed; petals 4 mm long, oblong; stamens 5, filaments straight; disc obscure; ovary obovoid, truncate, 2-celled; stigma capitate on short style. Fruit a berry; seed 1.
Phenology: September-January
Distribution: Idukki, Palakkad, Kollam, Pathanamthitta

***Parthenocissus renukae* Anto & Pradeep**

Woody climber, 50 m height, stems and branches nodose, lenticelled. Young branches and tendrils, brownish -rose, soft hairy. Tendrils leaf-opposed, 8- branched, tips of tendrils modified to attaching pads. Leaf blades deeply cordate bristle serrate, leathery, and ferruginous when young, 5- ribbed, acuminate, 9–18 × 9–18 cm, lateral veins 3–5 pairs. Petiole up to 8 cm long, reddish-brown at tips-; stipules oblong hairy, 2 at base, internodes 11 cm long. Inflorescence leaf-opposed, short, branched, hairy, umbellate. Flowers drooping, regular, 4-5-merous, disc yellow, prominent, pedicellate-; pedicels 0.5 cm long; calyx cupulate; 4 or 5 sublobed below the disc, 0.12 cm. Petals 4 or 5, 2.5 × 2mm, hairy, cauducous, reddish, tip yellowish red, hooded tip 0.25 cm long, soft yellowish-red inside. Hairs drooping tomentous, T-shaped, one side flat. Stamens 4 or 5, 2.5mm long, antipetalous; anthers 0.8 × 0.8 mm, dithecous, yellowish, attached to the base of the disc; filaments subulate, 2mm long Disc yellowish, 4 or 5 lobed, densely pubescent with soft white hairs. Ovary ovoid, sunk in the disc; style short, 0.8 mm long, thick, stigma, capitate.
Phenology: April–May
Distribution: Thrissur, Palakkad

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