

Balsaminaceae
in Madagascar and the Comoro Islands:
Systematics, Evolution, and Biogeography



by

Marie Elisette Rahelivololona

Cover: *Impatiens nomenyae* Eb.Fisch. & Raheliv. (© E. Fischer)

Balsaminaceae
in Madagascar and the Comoro Islands:
Systematics, Evolution, and Biogeography

by

Marie Elisette Rahelivololona

from Mahajanga

Submitted Dissertation thesis for the partial fulfillment of the
requirements for a

Doctor of Natural Sciences

Fachbereich 3: Mathematik/Naturwissenschaften

Universität Koblenz-Landau

December 2018

1. referee: Prof. Dr. Eberhard Fischer

2. referee: Prof. Dr. Wilhelm Barthlott

Date of defence: 06.02.2019

Head of the comission: Prof. Dr. Rainer Graafen

Additional Referees: Prof. Dr. Sylvain Razafimandimbison

Dr. Steven Janssens

Table of Contents

Chapter 1. Introduction	1
Chapter 2. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar I	13
Chapter 3. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar II. A collection from Masoala Peninsula	42
Chapter 4. Balsaminaceae. In: The Natural History of Madagascar	60
Chapter 5. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar III	69
Chapter 6. A new epiphytic species of <i>Impatiens</i> (Balsaminaceae) from the Comoro Islands	90
Chapter 7. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar IV	94
Chapter 8. New taxa of <i>Impatiens</i> from Madagascar V. New species of <i>Impatiens</i> from Masoala Peninsula	152
Chapter 9. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar VI. <i>Impatiens otto-eleonora</i>, a new species from Masoala Peninsula, and notes on the taxonomic relationships of <i>Impatiens firmula</i> and <i>I. hildebrandtii</i>	171
Chapter 10. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar VII. Two new species of <i>Impatiens</i> from Mt. Marojejy, Madagascar	181
Chapter 11. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar VIII. <i>Impatiens max-huberi</i>, a new species from Marojejy and Anjanaharibe-Sud	192
Chapter 12. New taxa of <i>Impatiens</i> (Balsaminaceae) from Madagascar IX. <i>Impatiens lutzii</i>, a new species from Montagne d'Ambre National Park	198

Table of Contents

Chapter 13. <i>Impatiens galactica</i> (Balsaminaceae), a new spurless species of section <i>Trimorphopetalum</i> from Madagascar	207
Chapter 14. <i>Impatiens sielmannii</i> (Balsaminaceae), a new epiphytic species from Madagascar	216
Chapter 15. <i>Impatiens stefan-vogeli</i> (Balsaminaceae), a new species from Madagascar	226
Chapter 16. Phylogeny and biogeography of Balsaminaceae inferred from ITS sequences	236
Chapter 17. Phylogeny, infrageneric classification and species delimitation in the Malagasy <i>Impatiens</i> (Balsaminaceae)	266
Chapter 18. Conclusions	288
Chapter 19. Zusammenfassung	292
Acknowledgements	296
References	298
Declaration on the own contributions on the submitted papers	311
Curriculum Vitae	314
Declaration	

Chapter 1

Introduction

General introduction

The family Balsaminaceae includes only two genera, the monospecific *Hydrocera* Blume ex Wight & Arn. and its species-rich sister *Impatiens*. The latter genus contains more than 1000 species. Plants are more or less succulent, annual, or perennial with a basal aggregation of leaves, or with neither basal nor terminal aggregations of leaves, helophytic or mesophytic, with solitary flowers, or aggregated in cymose inflorescences (Grey-Wilson 1980a, Song 2006). The two genera are easily distinguished from each other: *Hydrocera* has free petals and an indehiscent 'berry-like' fruit, whereas *Impatiens* has the petals variously united, and a characteristic, explosive, dehiscent capsule. Other generic names such as *Petalonema* Peter, *Semeiocardium* Zoll., *Trimorphopetalum* Baker and *Impatientella* H.Perrier, are synonyms of *Impatiens* (Grey-Wilson 1980a; Rao et al. 1986). *Hydrocera* is restricted to the Indo- Malesian countries, while *Impatiens* occurs in Asia, Africa, Madagascar, India, Europe and North America, and is absent from Australia and South America. Its hotspots of diversification are in tropical and subtropical montane regions of the Old World.

Most traditional classifications based on morphology place Balsaminaceae in Geraniales and suggest that it is closely related to Tropaeolaceae and Geraniaceae (Cronquist 1981, Thorne 2000), while some important taxonomists treated Balsaminaceae as an order of its own: the Balsaminales (Dahlgren 1989, Takhtajan 1997). However, recent molecular analyses indicate that Balsaminaceae belong to the order Ericales (Morton et al. 1996, 1997, Soltis et al. 2000, Albach et al. 2001, Anderberg et al. 2002, Bremer et al. 2002, Geuten et al. 2004). Both plastid (rbcL) and nuclear (18S rDNA) or combined sequence data suggest a close relationship between Balsaminaceae and Tetrameristaceae, Marcgraviaceae, and Fouquieriaceae (Song

2006). This knowledge is helpful to choose suitable outgroups for the phylogenetic analyses of Balsaminaceae.

General Ecology and Distribution

Impatiens is nearly always associated with wet and humid places, frequently growing along the sides of rivers and streams, in grassy marshlands, or in the spray zones of waterfalls and cascades. It is rare to find *Impatiens* growing by stagnant waters. Most species are terrestrial and a few are epiphytic. It is a large genus with over 1000 species scattered throughout in the highlands and mountains of the tropical and subtropical regions of the Old World. It has five conspicuous diversity hotspots: tropical Africa (ca. 120 spp. Grey-Wilson 1980a); Madagascar (ca. 260 spp. Fischer & Rahelivololona, 2002, 2003, 2004, 2007, Fischer et al. 2003, 2015a, 2015b, 2015c, 2016, 2017, 2018 submitted); southern India and Sri Lanka (ca. 220 spp., Bhaskar & Razi, 1981); the eastern Himalayas (ca. 120 spp.), and Southeast Asia in its broad sense (including Myanmar, Thailand, southwest China, the Indochina peninsula, and the Malesian archipelago, ca. 250 spp.). There are 7 native species in North America with two species reaching Central America (Mexico: *Impatiens mexicana* Rydb., Costa Rica: *Impatiens turrialbana* J.D.Sm.) 1 native species in Europe (*Impatiens noli-tangere* L.) and 1 native species in boreal Eurasia (*Impatiens parviflora* DC.). Numerous invasive species have been introduced to Europe, including *Impatiens capensis* Meerb. from North America, *Impatiens parviflora* L. from Boreal Eurasia, and *Impatiens glandulifera* Royle from the Himalayas. There are no native species in South America or Australia. However, *Impatiens walleriana* Hook.f. from East Africa is now a neophytic invasive weed in tropical America.

Morphology and Character Evolution of *Impatiens*

Members of *Impatiens* are primarily annual or perennial herbs. The stems are typically rather thick and fleshy and often semi-translucent, only rarely becoming thickened and woody. Some species are rhizomatous or tuberous. While most species in Africa and Madagascar are perennials (Grey Wilson 1980, Perrier de la Bâthie 1934), most Asian species are annuals (Ruchisansakun et al. in press). Tubers occur in African taxa (*Impatiens etindensis* Cheek & Eb.Fisch. 1999) and in Madagascar (e.g. *Impatiens*

Chapter 1 — Introduction

tuberosa H.Perrier, *I. barthlottii* Eb.Fisch. & Raheliv., *I. loki-schmidtiae* Eb.Fisch. & Raheliv.).

While the majority of *Impatiens* species have spirally arranged leaves, only few taxa dispose of opposite or verticillate leaves. The leaves, which are generally simple with a dentate margin often have short hair-like appendages at the leaf base that are functional extrafloral nectaries. Whereas the teeth become less distinct when reaching the leaf base, the appendages become slightly larger often changing into glandular structures on the leaf petiole (Janssens 2008). Most of the *Impatiens* species possess a long leaf petiole, yet this can sometimes be absent. Leaf shape varies from linear-lanceolate to elliptic and sometimes peltate. The leaves are generally becoming membranaceous, often almost transparent when dried.

The genus *Impatiens* has remarkable flowers that show a fascinating diversity in shape and colours. They are monosymmetric and usually resupinate through twisting of the pedicel. In most species each flower has three sepals, two of which are usually small-sized lateral sepals and one petaloid lower sepal that is modified into a nectary-tipped spur. In most *Impatiens*, there are only 2 lateral sepals (one pair) which are narrow-lanceolate as in *I. rubrostriata* Hook.f. or broadly ovate as in *I. purpurea* Hand.-Mazz. Some species have 4 lateral sepals (2 pairs), and usually the inner pair is linear, smaller and more narrow than the out pair. The occurrence of 4 lateral sepals is not common in *Impatiens* but exists in different regions: 7 African *Impatiens* species out of c. 120 (Grey-Wilson 1980b), and 2 species in Madagascar (Fischer & Rahelivololona, 2003, i.e. *I. kuepferi* Eb.Fisch. & Raheliv. and *I. wohlhauseri* Eb.Fisch. & Raheliv.). The number and the form of lateral sepals is a key character for the classification in *Impatiens*.

The lower sepals of *Impatiens* exhibits an extraordinary wide range of variation in form and size: they typically present a shallow naviculate lower sepal constricted into a slender filiform or short cylindrical obtuse spur, and on the other hand the bird-pollinated taxa assigned by Perrier de la Bâthie (1934) to the *Humblotianae*-group have a deeply navicular, large bucciniform or saccate lower sepal, much longer and gradually merging into, or rather abruptly extending into the spur. These bird-pollinated taxa are represented in Africa (e.g. *Impatiens niamniamensis* Gilg, Grey-Wilson 1980a), Madagascar (e.g. *Impatiens humblotiana* Baill., Perrier de la Bâthie 1934) and India (*Impatiens parasitica* Bedd., Bhaskar & Razi, 1981). Usually the spur has nectar

inside. Obviously, these variations are related to different pollinators (Lozada-Gobilard et al. 2018).

In Madagascar we can observe an endemic group of *Impatiens* where the flowers lack a spur: the members of section *Trimorphopetalum* (Baker 1886). The flowers of this group are highly variable morphologically: from small green hyaline flowers to bigger and greenish-yellowish to brownish coloured, e.g. *I. malcomberi* Eb.Fisch. & Raheliv., *I. furcata* H. Perrier.

All species of *Impatiens* have five petals. One upper dorsal petal is usually hood-like. The dorsal petals of *Impatiens* can be divided into two types: the dorsal petal is basically flat, rounded with a crest behind, somewhat concave, or the dorsal petal may be distinctly cucullate, forming a characteristic hood over the top of the androecium and projecting obliquely forward. Grey-Wilson (1980b) mentioned that this kind of dorsal petal is usually associated with a deeply navicular, saccate spur, with the result that there is little room for the upper petal of each lateral united pair, as in *I. auricoma* Baill. The 4 lateral petals of *Impatiens* are connate into 2 pairs, some are joined only near the base as in *I. walleriana* Hook.f. and *I. firmula* Baker.

The gynoecium and androecium are basically very similar to *Hydrocera* placing the species with conspicuous spurs and anthers with apical dehiscence in section *Preimpatiens* (Song 2006). The five stamens have short and flat filaments. The upper parts of the filaments and the anthers are more or less united forming a cap over the superior ovary with a very short style which has 5 fused carpels and contains usually numerous ovules. The fruits are an elongated linear or broadly fusiform explosive capsule.

Taxonomic History and Classification of *Impatiens*

Due to the diverse and complicated floral morphology, no comprehensive infrageneric classification is available for *Impatiens*. Nevertheless, several botanists have proposed classifications based on morphological characters only.

Hooker & Thompson (1859) carried out the first global study on *Impatiens*, in which they illustrated the huge morphological floral variety in the genus. Their classification was mainly based on differences in inflorescence and leaf organisation. They

Chapter 1 — Introduction

recognised only eight African taxa. However, they stated that “numerous species will yet be detected in Madagascar and tropical Africa” (Hooker & Thomson 1859).

Warburg & Reiche (1895) presented the only global infrageneric classification ever made until now. Based on differences in stem structure, leaf arrangement, inflorescence organisation and spur length they divided the genus in two subgenera (*Caulimpatiens* and *Acaulimpatiens*) and fourteen sections. However, their sections and subsections seem to be much too artificial.

The first modern treatment for the genus available is the important revision of African taxa by Grey-Wilson (1980a). While Warburg & Reiche (1895) searched for a comprehensive scheme in which every species is included in an artificial section, Grey-Wilson (1980a) did not intend to make a classification at all. He searched for natural species aggregates in *Impatiens* which could not be divided in discrete lineages (Grey-Wilson, 1980a). His survey provided very useful and testable data for Africa, yet the major relationships in the genus remained obscure.

For Madagascar, Perrier de la Bâthie (1934) divided *Impatiens* first according the presence of spur, then using the type of spur and the way of anther dehiscence. He proposed three sections based on floral morphology: section *Preimpatiens* (=sect. *Impatiens*) (flowers with conspicuous spur), sect. *Trimorphopetalum* (flowers without spur, anthers dehiscent apically), and the monotypic sect. *Impatientella* (flowers without spur, anthers dehiscent laterally), the latter two being endemic to Madagascar. In addition, section *Preimpatiens* was subdivided into two groups: the *Vulgare* group with slender spurs and the *Humboldtianae* group with larger and broader spurs. Fischer & Rahelivololona (2002) used the presence/absence of spurs on lower sepals to subdivide the Malagasy *Impatiens* into two subgenera. They recognized section *Impatiens* with spurs and section *Trimorphopetalum* (including sect. *Impatientella*) without spurs at subgeneric level.

More recently, based on both morphological and molecular evidence; Yu et al. (2015) divided *Impatiens* into two subgenera, subgenus *Clavycarpa* S.X.Yu ex S.X.Yu & Wei Wang and subgenus *Impatiens*. They subdivided subgenus *Impatiens* into seven sections: sect. *Semeiocardium* (Zoll.) S.X. Yu & Wei Wang, sect. *Tuberosae* X.S. Yu & Wei Wang, sect. *Racemosae*, sect. *Impatiens*, sect. *Scorpioidae* S.X. Yu & Wei Wang, sect. *Fasciculatae* X.S. Yu & Wei Wang, and sect. *Uniflorae* Hook. f. &

Thomson. The section *Uniflorae*, characterized by short-fusiform capsules includes all Malagasy *Impatiens* species and also several African and Asian species.

Short taxonomic history of *Impatiens* in Madagascar and the Comoro Islands

The Balsaminaceae of Madagascar and the Comoro islands have been neglected for a long time and only few species were described. At the beginning of the 20th century, only 23 taxa had been described, of which 17 are now considered to represent valid species: *Impatiens auricoma* Baill., *I. baroni* Baker (= *I. emirnensis* Baker), *I. bisaccata* Warb., *I. comorensis* Baker (= *I. Macradenia* Baill.), *I. delicatula* Baill., *I. dorstenioides* (Baker) Warb. (= *Trimorphopetalum dorstenioides* Baker), *I. formula* Baker (= *I. filipes* Baill.), *I. hildebrandtii* Baill., *I. lantziana* Baill., *I. lyallii* Baker, *I. trichoceras* Baker, *I. manaharensis* Baill., *I. rutenbergii* O. Hoffm. (= *I. bakeri* Warb., *I. delphinii* Scott-Elliot ex H. Perrier, *I. salicifolia* Baill.), *I. sacculata* Warb., *I. catati* Drake, *I. humblotiana* Baill., and *I. vilersii* Costantin & Poisson. *Impatiens dorstenioides* was the first and only species of an endemic Malagasy group without a spur and was originally described as *Trimorphopetalum dorstenioides* Baker (1887: 454). However, Warburg & Reiche (1895) did not recognize this special endemic group and they placed *Impatiens dorstenioides* together with *I. auricoma*, *I. comorensis*, *I. sacculata* and *I. humblotiana* in the section *Microcentron* Warburg & Reiche.

The first comprehensive study of *Impatiens* in Madagascar began with Perrier de la Bâthie (1934, 1948) who, in two classical papers, described 83 species, among them 48 taxa of Sect. *Trimorphopetalum* (Baker) H. Perrier. He also established the endemic section *Impatientella* (H. Perrier) H. Perrier with entirely cleistogamous flowers, first considered by him to represent even a new genus (Perrier de la Bâthie 1927). As a result of their numerous expeditions to Madagascar, Humbert & Perrier de la Bâthie (1955) and Humbert (1956) could add 7 new taxa. Thus, 105 species of *Impatiens* have been reported from Madagascar prior to 2002. Humbert also prepared, but never published a manuscript for the Balsaminaceae for “Flore de Madagascar et des Comores”, which remained unfinished at the time of his death in 1967. Since then, numerous new collections have been made, but no systematic treatment has ever

been published and *Impatiens* in Madagascar remained “a terror to botanists” (Grey-Wilson 1980).

Molecular Phylogenetic Studies of Balsaminaceae

Yuan et al. (2004) provided the first molecular phylogenetic study using ITS dataset (Fig. 1, 2). They noticed that the spurless Madagascan endemic taxa (including the cleistogamous *Impatiens inaperta*) were resolved as a highly supported (90%) monophyletic clade (clade 1). Together with a few species from Southeast Asia (clade 2), most of the sampled African, Madagascan, and southern Indian species formed a strongly supported clade (93%).

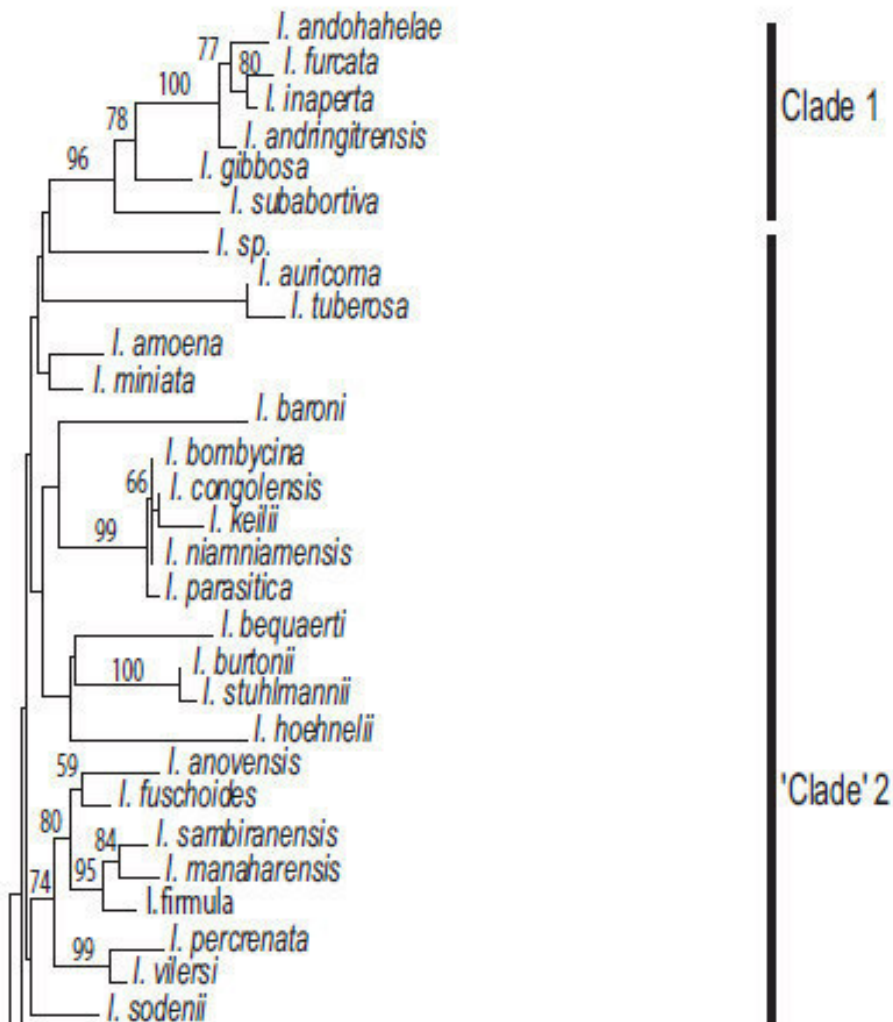


FIGURE 1. Part of the phylogenetic tree from Yuan et al. (2004) based on ITS data set.

Song (2006) provided 3 different Neighbour-joining analyses (Fig. 3-5):

- in ITS dataset it resulted in a NJ tree showing a third Group III (clade H-V) in the terminal position of the tree, that is a heterogeneous collection of Madagascan, African, South Indian and Southeast Asian species. Almost every well-supported lineage in this group is strongly correlated with a specific area of distribution. Madagascan species formed four clades (S T U V). The spurless Madagascan endemic taxa including two strongly supported clades (clade U, 100% & clade V, 97%) are resolved as being monophyletic with a high support (88%). Another Madagascan clade T was strongly supported (100%) and close to the monophyletic spurless clades. The Madagascan clade S was grouped with some African species without significant support and didn't show the direct connection with other Madagascan species. The Madagascan species *I. baroni* Baker and *I. bathiei* Eb.Fisch. & Raheliv. (= *I. manongarivensis* H.Perrier var. *miniata* H.Perrier non *I. miniata* Grey-Wilson) were grouped with African species directly.

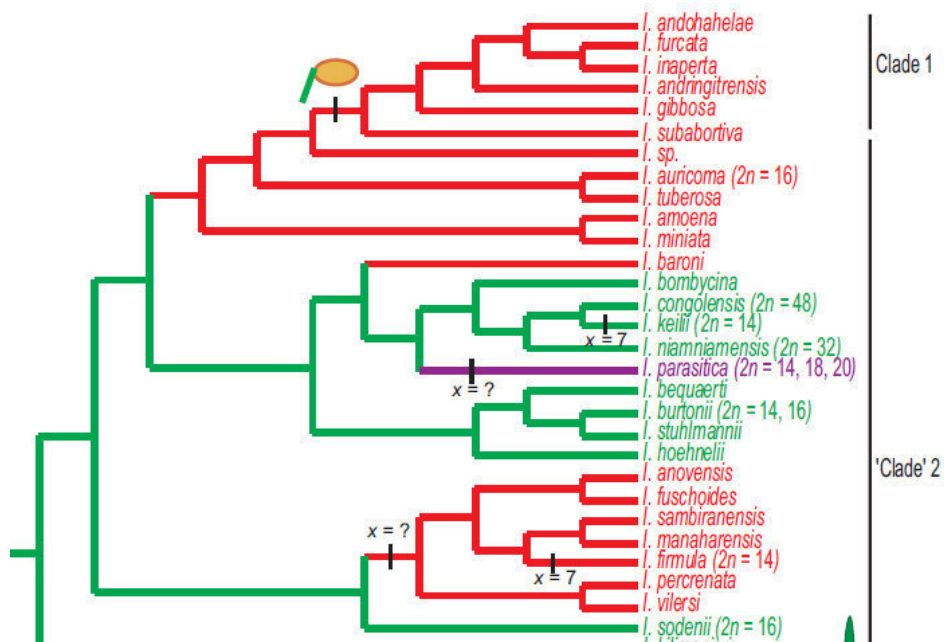


FIGURE 2. Part of the phylogenetic tree from Yuan et al. (2004) based on ITS data set showing position of malagasy taxa.

- in a NJ analysis of ITS dataset and atpB-rbcL it showed Group III (clade H-V) staying in the terminal position of the tree. The Madagascan species were together appearing in the most advanced position of the tree, but the spurless

Chapter 1 — Introduction

species were mixed with spurred species and formed the clade STUV. Several African species (clade R) appeared close to them.

- the phylogram of the Neighbour-joining tree based on Kimura-2-parameter of the combined ITS, trnLF, and atpB-rbcL showed Group III (clade H-V) again staying in the terminal position of the tree that was well supported (BPP:100). The Madagascan species were all grouped together (clade S T U V, BPP:1.0), appearing in the most terminal position of the whole tree. The spurless Madagascan endemic taxa (clade U V) were resolved as being monophyletic with a high support (BPP:1.0); this group is the most derived within *Impatiens*.

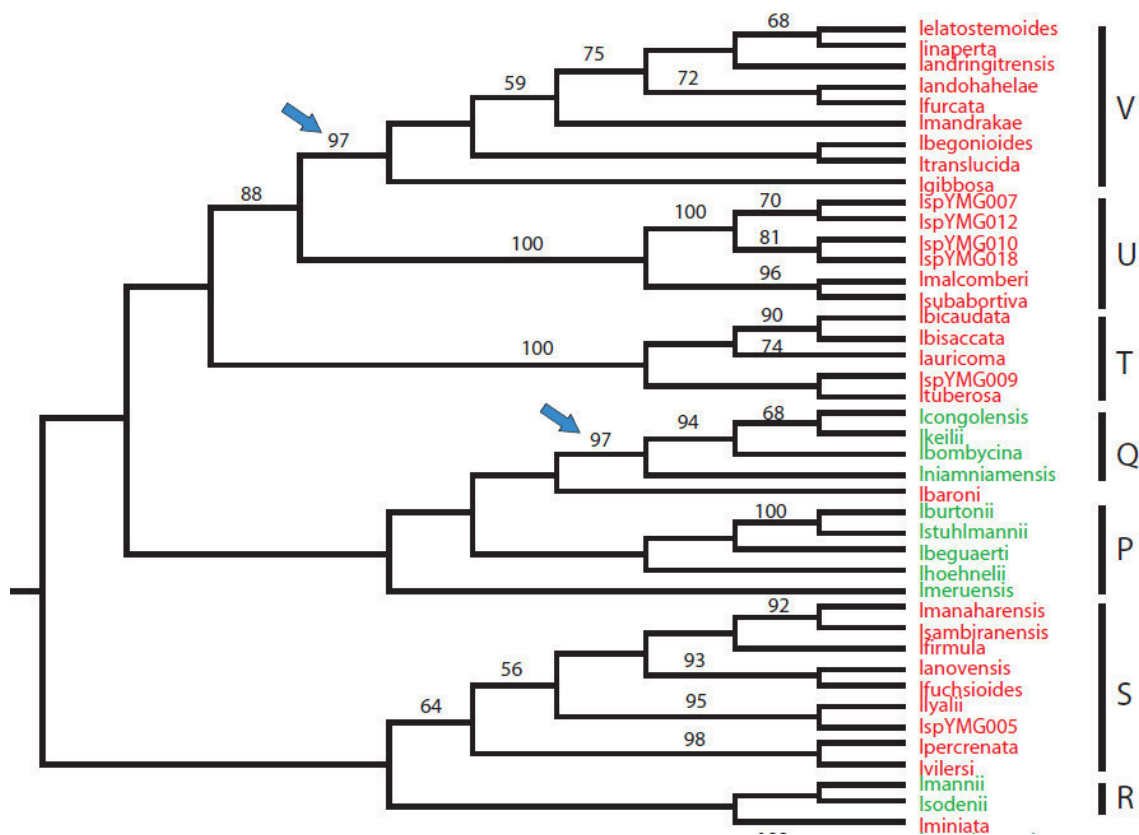


FIGURE 3. NJ analysis based on ITS (Song 2006).

Aims of the thesis

Our study has three main aims that are outlined below:

- to provide additional information on the taxonomic revision of *Impatiens* in Madagascar and the Comoro islands and the identification and description of new species;
- to provide a phylogenetic study focused on the three subdivisions (based on macromorphological characters) proposed by Perrier de la Bâthie (1934) to see if the groups are supported by molecular data
- to study the geographical distribution of *Impatiens* in Madagascar and the Comoro islands and their species richness.

Specifics Aims

The taxonomic part uses vegetative and floral characters such as roots, stems, petioles, leaves, glands, phyllotaxy, inflorescences, floral stems, spur, sepals and petals that are very significant (**chapters 2 – 15**).

The molecular phylogenetic studies were conducted:

- to examine the morphological and karyological evolution, and the historical biogeography of the Balsaminaceae family by using nucleotide sequence data of internal transcribed spacer regions of nuclear ribosomal DNA
- to reconstruct larger phylogeny of the Malagasy *Impatiens*, with a particular emphasis on taxa collected from Marojejy, using two nuclear *AP3/DEF* homologues (*ImpDEF1* and *ImpDEF2*) and the plastid *atpB-rbcL* spacer;
- to reassess the monophyly of the Malagasy *Impatiens* as stated by Janssens et al. (2006, 2007, 2009);
- to assess the monophyly of the sections *Preimpatiens* (*Humblotianae* and *Vulgare* groups) and *Trimorphopetalum* as delimited by Perrier de la Bâthie (1934) as well as that of the subgenera *Impatiens* and *Trimorphopetalum* (including sect. *Impatientella*) as defined by Fischer & Rahelivololona (2002);

Chapter 1 — Introduction

- to assess the current species status of the morphologically variable species *I. elatostemmoides*, *I. "hammarbyoides"*, *I. inaperta* and *I. manaharensis*, using monophyly as the primary criterion;
- to test whether the species of *Impatiens* from the Marojejy National Park form a monophyletic group (**chapters 16 and 17**).

The biogeography of *Impatiens* of Madagascar and the Comoro island was performed

- to investigate the geographical affinities and distribution of the sect. *Preimpatiens* sensu Perrier de la Bâthie (1934) (including former *Humblotianae* and *Vulgare* groups) and the sect. *Trimorphopetalum* sensu Perrier de la Bâthie (1934)
- to establish distribution maps and analyse the relationship between species spatial distribution and environmental parameters
- to highlight the origin and evolution as well as the species richness and endemism

The following main questions are addressed:

- *How many species of Impatiens occur in Madagascar and the Comoro islands?*
- *Are the groups of Impatiens in Madagascar monophyletic and what is the systematic position of Trimorphopetalum?*
- *What are the biogeographical position and the distribution patterns of Impatiens in Madagascar and the Comoro islands?*

Chapter 2

New taxa of *Impatiens* (Balsaminaceae) from Madagascar. I

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2002): New taxa of *Impatiens* (Balsaminaceae) from Madagascar. I. *Adansonia sér.* 3, 24 (2002): 271-291.

¹Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany), efischer@uni-koblenz.de

²Parc botanique et zoologique de Tsimbazaza, BP 4096 Antananarivo (Madagascar), prota.madagascar@dts.mg

Abstract

In a first paper as precursor to a revision of Balsaminaceae in Madagascar and the Comoro Islands, fourteen species of *Impatiens* (Balsaminaceae) are described as new (*I. gautieri*, *I. bemarkensis*, *I. emiliae*, *I. begonioides*, *I. silviana*, *I. andohahelae*, *I. malcomberi*, *I. ranomafanae*, *I. translucida*, *I. albopurpurea*, *I. navicula*, *I. mandrakae*, *I. mananteninae*, and *I. pilosissima*). Two nomina nova (*I. mandrarensis* for *I. acaulis*, and *I. bathiei* for *I. manongarivensis* var. *miniata*) are proposed. A short history of the exploration of *Impatiens* in Madagascar is provided.

Key words *Impatiens*, Balsaminaceae, Madagascar.

Résumé

Nouveaux taxons dans le genre Impatiens (Balsaminaceae) à Madagascar. I.

Dans cette première publication, dans le cadre de la préparation d'une révision des Balsaminaceae de Madagascar et des Comores, quatorze espèces d'*Impatiens* sont

décrites comme nouvelles (*I. gautieri*, *I. bemarahensis*, *I. emiliae*, *I. begonioides*, *I. silviana*, *I. andohahelae*, *I. malcomberi*, *I. ranomafanae*, *I. translucida*, *I. albopurpurea*, *I. navicula*, *I. mandrakae*, *I. mananteninae*, et *I. pilosissima*). Deux nouveaux noms (*I. mandrarensis* pour *I. acaulis*, et *I. bathiei* pour *I. manongarivensis* var. *miniata*) sont proposés. Un bref historique de l'étude des *Impatiens* à Madagascar est présenté.

Mots clés *Impatiens*, Balsaminaceae, Madagascar.

Introduction

The genus *Impatiens* (Balsaminaceae) is considered to be one of the most difficult genera in the angiosperms as species are extremely variable and the preparation of herbarium specimens needs special treatment (Grey-Wilson 1980). Many species have very restricted distributions. Hooker & Thomson (1859) published the first serious study of the genus, in which they recognized only eight African taxa. However, they stated that “numerous species will yet be detected in Madagascar and tropical Africa”. Further important contributions mainly on Indian

species are those of Hooker (1874-1875, 1904, 1905, 1906). The only overview of the genus as a whole is that of Warburg & Reiche (1895), who also proposed the only infrageneric classification. However, their sections and subsections seems to be much too artificial. The only modern treatment for the genus available is the important revision of African taxa by Grey-Wilson (1980).

The Balsaminaceae of Madagascar and the Comores have been neglected for a long time and only few species were described. At the beginning of the 20th century, only 23 taxa had been described, of which 15 are considered to represent valid species: *Impatiens auricoma* Baill., *I. baroni* Baker (= *I. emirnensis* Baker), *I. bisaccata* Warb., *I. comorensis* Baker (= *I. macradenia* Baill.), *I. delicatula* Baill., *I. dorstenioides* (Baker) Warburg (= *Trimorphopetalum dorstenioides* Baker), *I. firmula* Baker (= *I. filipes* Baill., *I. hildebrandtii* Baill.), *I. lantziana* Baill., *I. lyallii* Baker (= *I. trichoceras* Baker), *I. manaharensis* Baill., *I. rutenbergii* O. Hoffm. (= *I. bakeri* Warb., *I. delphinii* Scott-Elliot ex H. Perrier, *I. salicifolia* Baill.), *I. sacculata* Warb., *I. catati* Drake, *I. humblotiana* Baill., *I. vilersii* Costantin & Poisson. *Impatiens dorstenioides* was the first and only species of an endemic Malagasy group without a spur and was originally described as *Trimorphopetalum dorstenioides* Baker 1887, Journ. Linn. Soc. Bot. 22: 454. However,

Warburg & Reiche (1895) did not recognize this special endemic group and they placed *I. dorstenioides* together with *I. auricoma*, *I. comorensis*, *I. sacculata* and *I. humblotiana* in the section *Microcentron* Warburg & Reiche.

The first comprehensive study of *Impatiens* in Madagascar began with Perrier de la Bâthie (1934, 1948), who in two classic papers described 83 species, among them 48 taxa of Sect. *Trimorphopetalum* (Baker) H. Perrier, Arch. Bot., Caen 7, Mém. 1: 64, 1934. He also established the endemic section *Impatientella* (H. Perrier) H. Perrier with entirely cleistogamous flowers, first considered by him to represent even a new genus (Bull. Trimestriel Acad. Malgache, N. S. 10: 22, 1927).

As a result of their numerous expeditions to Madagascar, Humbert & Perrier de la Bâthie (1955) and Humbert (1956) could add seven new taxa. Thus, 105 species of *Impatiens* have been reported from Madagascar. Humbert also prepared, but never published a manuscript for the Balsaminaceae for “Flore de Madagascar et des Comores”, which remained unfinished at the time of Humbert’s death in 1967. Since then, numerous new collections have been made, but no systematic treatment has ever been published and *Impatiens* in Madagascar remained “a terror to botanists” (Grey-Wilson 1980). Three years ago, the first author, who has some field experience with *Impatiens* in Central Africa (Fischer 1997, Cheek & Fischer 1999), became responsible for the Balsaminaceae account in “Flore de Madagascar et des Comores”. It was evident, that such a revision could not be completed by studying only herbarium material and would require additional field work to study the variability of certain species. Kindly, the Muséum National d’Histoire Naturelle, Laboratoire de Phanérogamie gave on loan not only the types of Madagascan *Impatiens* and precious new collections housed at P, but also the draft manuscript left by Humbert. Within this manuscript he proposed several new taxa, which have not been published since and which will be validated in a future paper.

The second author is working in the herbarium of the Parc Botanique Zoologique Tsimbazaza at Antananarivo, preparing a PhD thesis on Malagasy *Impatiens* and she will cooperate with the ongoing revision. The aim of this series of papers is to validate the new species proposed by Humbert, but also to describe the new taxa collected by other botanists during the last years.

Also, some nomenclatural changes became necessary due to later homonyms and subsequently, two nomina nova are proposed. In this first paper on *Impatiens* in

Madagascar, 14 new species are described. Another 36 new species will be described in forthcoming papers. While some species are known only from the holotype or the type locality, we have not hesitated to describe them, as they show clear morphological discontinuities and can be readily distinguished from related taxa. Field studies of other species provided insight on variability of single species.

Material and methods

The study is based on herbarium material from BR, G, NEU, P, TAN (acronyms according to Holmgren et al. 1990) and living plants collected during field trips to Marojejy in March 2000, to Andohahela and Ambohitantely in March 2001. The terminology in the descriptions follows Grey-Wilson (1980) as well as the measurements (Fig. 1). Thus the arrangement of floral parts is described after resupination. The terms used by Perrier de la Bâthie (1934) as labellum (nacelle), vexillum (casque) and alae (ailes) are replaced by lower sepal, dorsal petal and lateral united petals. All specimens have been seen unless otherwise stated.

Impatiens* subg. *Impatiens

Impatiens gautieri* Eb.Fisch. & Rahelivololona, *sp. nov.

Impatiens masoalensi et *I. geniorum affinis*, sed *foliis verticillatis*, *petalo laterale superiore brevior* et *calcar* subcurvato differt.

TYPUS— *Gautier & Chatelain LG 2783*, Madagascar, Réserve spéciale de Manongarivo, Ansatroto, 14°05'S, 48°23'E, entre le campement "Chris" et le sommet, forêt sclérophylle de pente, 1530 m, 25 May 1995 (holo-, G).

Erect herb. Stems 30-40 cm long. Leaves verticillate, each whorl with 3 leaves, dark green, lanceolate, acuminate, petiole 10-15 mm long, lamina 95-115 x 23-26 mm, margin crenate, with broad teeth and short filiform fimbriae. Flowers white, lateral petals with yellow marks, lower sepal and spur with red spots. Pedicels 55-57 mm long. Lateral sepals 2, 4 x 1-1.5 mm. Lower sepal 7-9 x 4 mm, with spur of 8 mm of length.

Dorsal petal 7-8 x 4-5 mm. Lateral united petals 13 mm long, upper petal 5 x 3-4 mm, lower petal 7-8 x 5 mm. Anthers 3-4 mm long. Ovary 3-4 mm long. Fruits unknown.— Fig. 2.

HABITAT— Montane evergreen forest, 1530 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens gautieri is related to the *Impatiens masoalensis*-group with *I. masoalensis* H. Perrier and *I. geniorum* Humbert, but differs in the verticillate leaves, shorter upper lateral petal and the only slightly curved spur. Both species are only known from North-East Madagascar. *Impatiens masoalensis* is known from Masoala Peninsula and the Marojejy Massif while *I. geniorum* is restricted to the Massif de l'Anjanaharibe West of Andapa and the Lokoho valley.

Impatiens bemarahensis Eb.Fisch. & Rahelivololona, **sp. nov.**

Impatiens bemarahensis ab omnibus speciebus madagascariensibus calcari longe, forma cornu-copiae (*Impatienti humblotianae similis*) differt.

TYPUS— *Du Puy, Du Puy, Andrianatina & Carslon MB 766*, Madagascar, Bemaraha massif, escarpment, c. 20 km W of Marerano on the Manambolo River, 19°06'S, 45°03'E, 20 Mar. 1990 (holo-, TAN; iso-, MO, P, not seen).

Annual herb 10-35 cm tall, stems fleshy. Leaves ovate, deep bronze green, with silver veins above, purple beneath, petiole 10-25 mm long, lamina 27-40 x 13-20 mm, margin crenate with short filiform fimbriae. Flowers c. 16 mm tall, spurred to 25 mm long, upper petal lilac pink, lateral united petals strong lilac pink, spur white. Pedicels 20-30 mm long. Lateral sepals 2, 1.8 x 1 mm. Lower sepal 5-6 x 3 mm, spur up to 13 mm long. Dorsal petal 6-7 x 2-2.5 mm.

Lateral united petals 10 mm long, upper petal 3 x 2.5-3 mm, lower petal 6-7 x 5 mm. Anthers 3 mm long. Ovary up to 3 mm long. Fruit 11 x 4-5 mm, with minute white scales.—Fig. 3.

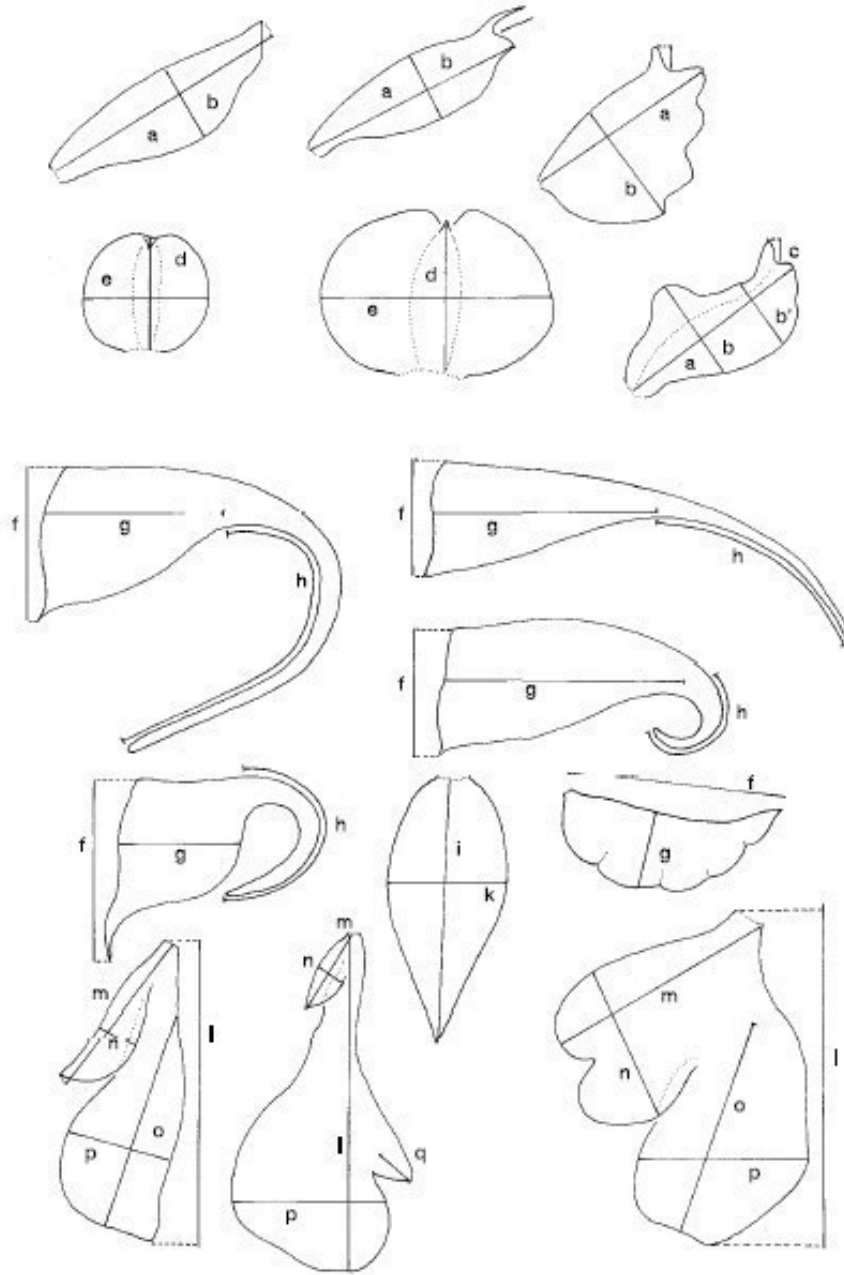


FIGURE 1. Measurements of *Impatiens* flowers: **a**, length of cucullate dorsal petal; **b**, width of cucullate dorsal petal; **c**, length of apicule; **d**, length of flat dorsal petal; **e**, width of flat dorsal petal; **f**, width of lower sepal; **g**, depth of lower sepal; **h**, length of spur; **i**, length of spurless lower petal; **k**, width of spurless lower petal; **l**, overall length of lateral united petals; **m**, length of upper petal; **n**, width of upper petal; **o**, length of lower petal; **p**, width of lower petal; **q**, length of petal lobe.

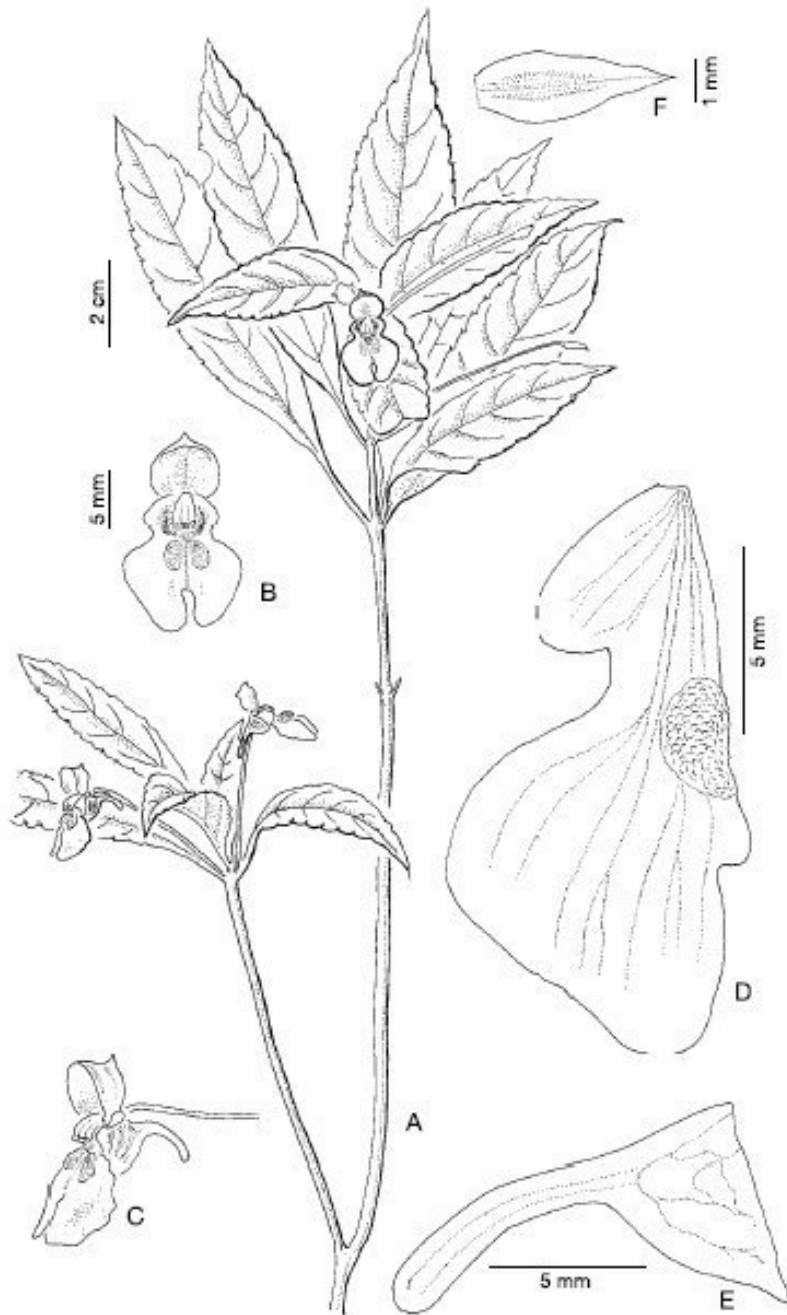


FIGURE 2. *Impatiens gautieri* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, lateral united petals; **E**, lower sepal and spur; **F**, lateral sepal. (*Gautier & Chatelain LG 2783, G*).

HABITAT— Limestone karst, Tsingy, under canopy of *Bussia*, semi-deciduous forest, c.560 m.

DISTRIBUTION— Madagascar, only known from multiple collections at type locality.

Impatiens bemarahensis differs from all Madagascan species in the long, slightly tapering spur which superficially resembles that of the *Impatiens humblotiana*-group (*I. humblotiana* Baill., *I. catati* Drake, etc.). As an annual, *I. bemarahensis*, is adapted to the dry season in the Tsingy and is one of the few taxa outside the eastern rainforests or cloud forests.

***Impatiens emiliae* Eb.Fisch. & Rahelivololona, sp. nov.**

Ab Impatiens manongarivensi et I. bathiei differt forma petalorum lateralium et numero nectariorum extrafloralium.

TYPUS— *Malcomber & Hemingway 2477*, Madagascar, Antsiranana, E of Ambanja, Réserve Naturelle Intégrale 4 Tsaratanana, 14°02'03"S, 48°45'46"E, 1100-1600 m, 8-12 May 1993 (holo-, TAN; iso-, MO, P, not seen).

Herb to 100 cm tall. Leaves verticillate, each whorl with 3 leaves, ovate-lanceolate, with distinct acuminate apex, dark green above, paler beneath, petiole 25-40 mm long, lamina 130-170 x 40-50 mm, margin dentate with short filiform fimbriae. Flowers orange. Pedicels 60-70 mm long. Lateral sepals 2, lanceolate, acuminate, 6 x 1.5 mm. Lower sepal navicular, 14 x 10 mm, with 23-25 mm long filiform and curved spur. Dorsal petal emarginate, dorsal crest with short apicule, 18 x 30 mm. Lateral united petals 35 mm long, upper petal 22 x 18 mm, lower petal 25 x 15-17 mm. Anthers 6-7 mm long. Ovary 5 mm long. Fruit unknown. —Fig. 4.

HABITAT— Montane rainforest, 1100-1600 m, on streamsides.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens emiliae is related to *I. manongarivensis* H. Perrier and *I. bathiei* Eb.Fisch. & Rahelivololona (see below), but differs in the shape of the lateral united petals and the extrafloral nectaries, which are lacking or only present in one pair at base of lamina. While *I. emiliae* is only known from the Tsaratanana-Massif, *I. manongarivensis* is restricted to Manongarivo and *I. bathiei* to the Sambirano area.

Impatiens mandrarensis Eb.Fisch. & Rahelivololona, **nom. nov.**

Impatiens acaulis Humbert, Notul. Syst. (Paris) 15: 114 (1956), non *Impatiens acaulis* Arn., in Hook., Companion Bot. Mag. I: 325 (1835)— Type: *Humbert 20534*, Madagascar, vallée du Mandrare, affluent de la Manampanihy (Sud-Est), montagne au sud de Tanandava, rochers en forêt ombrophile, 700-750 m, 11-16 Mar. 1947 (holo-, P).

DISTRIBUTION— Madagascar, only known from the type collection.

As the epithet *acaulis* had been used yet for an Indian *Impatiens* species by ARNOTT, a new name had to be chosen for the Madagascan taxon. *Impatiens mandrarensis* is related to *I. tuberifera* Humbert, which also lives as a geophyte with subterranean tubers.

Impatiens bathiei Eb.Fisch. & Rahelivololona, **nom. nov.**

Impatiens manongarivensis H. Perrier var. *miniata* H. Perrier, Arch. Bot. Mém. 1: 48 (1934), non *I. miniata* Grey-Wilson, Kew Bull. 33: 645 (1979), type: *A.S. Thomas 510*, Uganda, Mt. Elgon, Bulambuli (holo-, K)— Type: *Perrier de la Bâthie 15118*, Madagascar, dans la haute vallée du Sambirano, rocailles humides, vers 200 m, Dec. 1921 (holo-, P).

The var. *miniata* of *Impatiens manongarivensis* H. Perrier differs in many respects from the typical species and is here considered to represent a species of its own. As the name *I. miniata* is no longer available on specific level, the nomen novum *I. bathiei* is proposed.

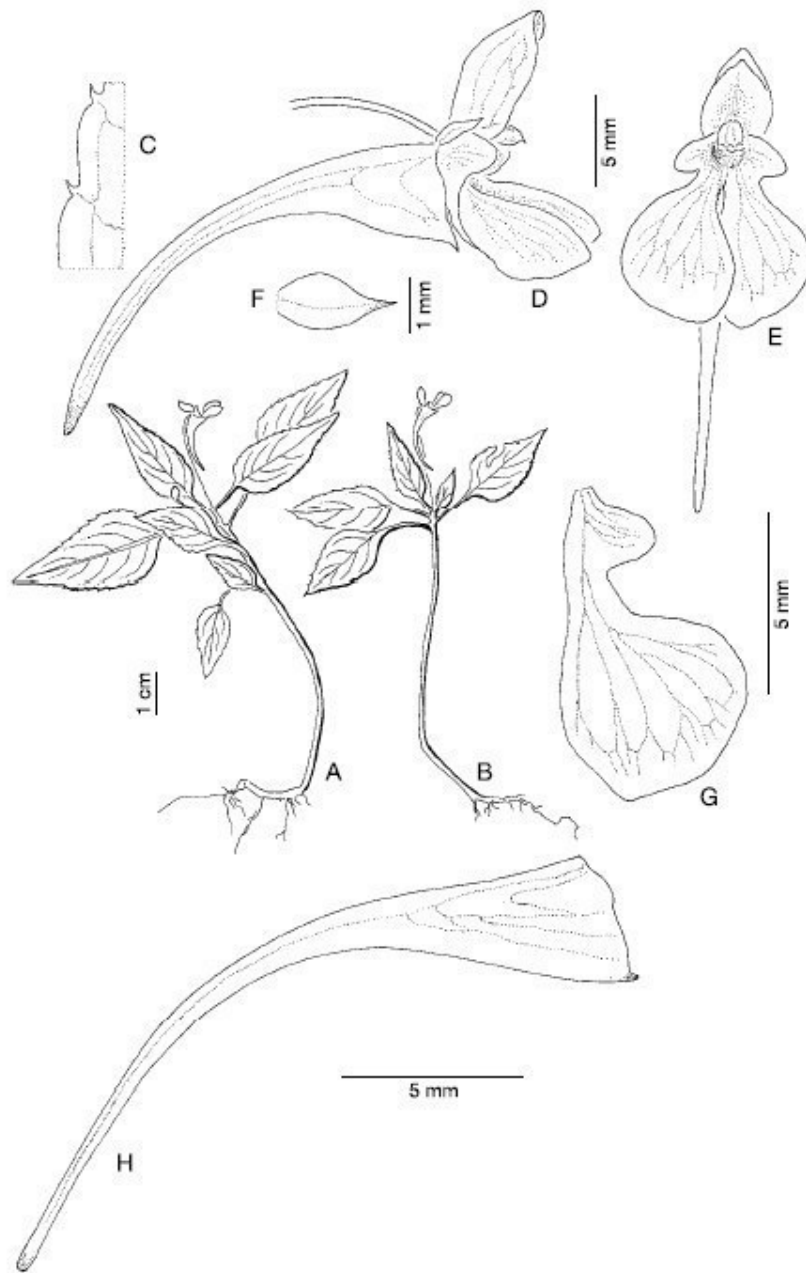


FIGURE 3. *Impatiens bemarahensis* Eb.Fisch. & Rahelivololona: **A**, **B**, habit; **C**, leaf margin; **D**, flower, lateral view; **E**, flower, anterior view; **F**, lateral sepal; **G**, lateral united petals; **H**, lower sepal and spur. (Du Puy, Du Puy, Andrianatina & Carlson MB 766, P).

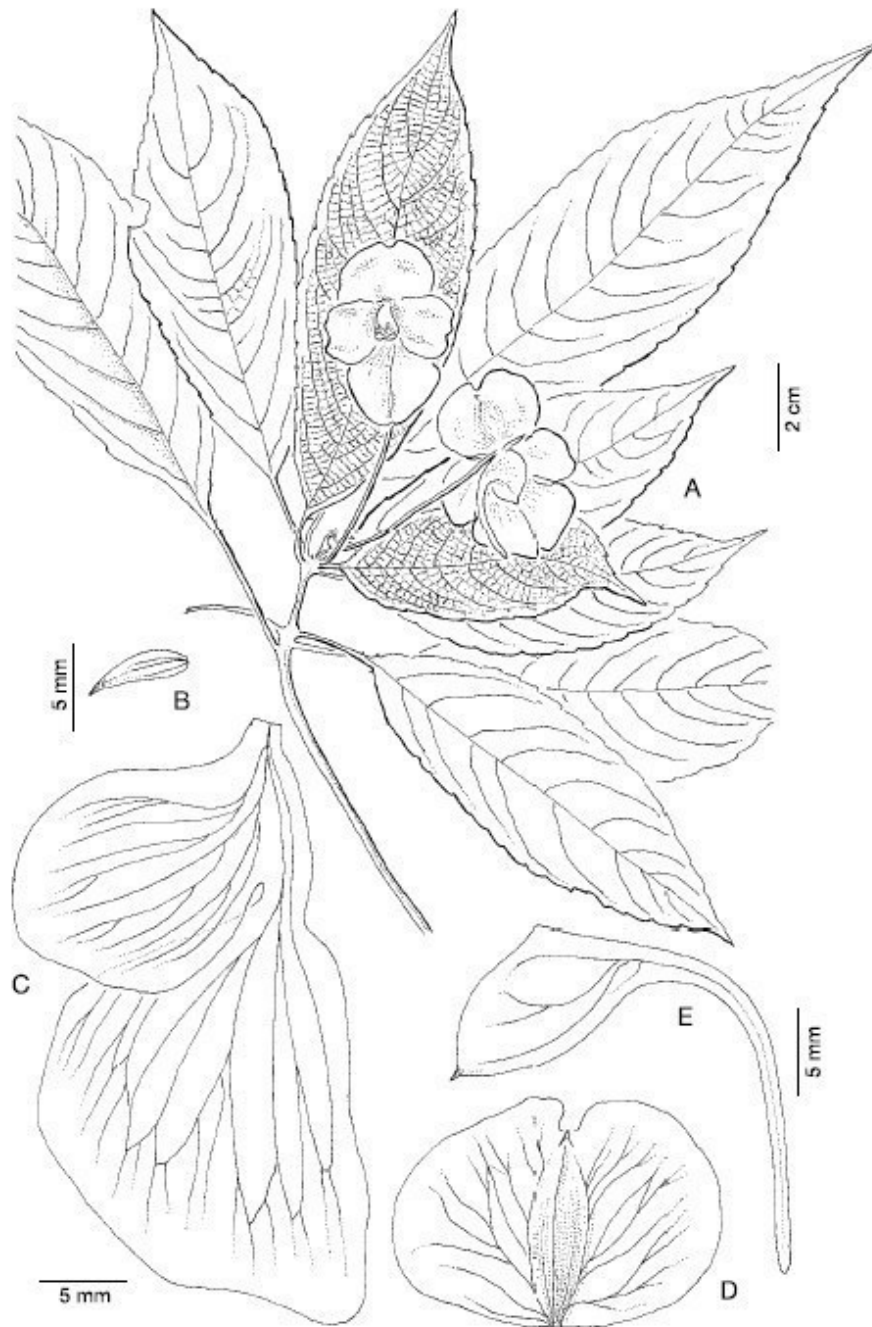


FIGURE 4. *Impatiens emiliae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, lateral sepal; **C**, lateral united petals; **D**, dorsal petal; **E**, lower sepal and spur. (Malcomber & Hemingway 2477, P).

Impatiens subg. *Trimorphopetalum* (Baker) Eb. Fisch., **stat. nov.**

Trimorphopetalum Baker, Journ. Linn. Soc. Bot. 22: 454 (1887).

Impatiens begonioides Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab omnibus speciebus madagascariensibus subg. Trimorphopetali differt foliis peltatis.

TYPUS— *Turk & Randrianasolo 584*, Madagascar, Fianarantsoa, Ranomafana National Park, parcelle 3, S of National Road 25 at 7 km W of Ranomafana, Vatoharanana trail system, 21°17'S, 47°26'E, 18 Nov. 1993 (holo-, MO; iso-, P, TAN).

Procumbent to ascending herb up to 15-30 cm tall, spreading by runners in leaf litter. Leaves peltate, dark green above, pale green below, petiole 19-30 mm long, lamina 35-47 x 20-25 mm, acuminate, margin slightly dentate with minute fimbriae. Flowers pale yellow-green with tuberculous dark purple-brown spots on lateral petals, ovary and staminal tube pale green, anthers pale yellow. Pedicels 20-25 mm long. Lateral sepals 2, 3-5 x 0.5-1 mm. Lower sepal 11-13 x 5-7 mm, with darker relief caused by veins. Dorsal petal helmet-like, crest with short spur at apex and sinus-like protuberance below middle. Lateral united petals 15-19 mm long, upper petal 5-7 x 1.5 mm, lower petal 12 x 10 mm, with darker nerves and tubercles. Anthers 5 mm long. Ovary 5-6 mm long. Fruit unknown. —Fig. 5.

PARATYPE— *Rahelivololona, RMN 10*, Madagascar, Parc National de Ranomafana, piste W20-W15, SW du camp Vatoharanana, 17 May 2000 (TAN).

HABITAT— Moist montane forest characterized by trees of *Weinmannia* sp., Monimiaceae (*Tambourissa*, *Decarydendron*, *Ehippiandra*), Lauraceae (primarily *Ocotea* and *Cryptocarya*); understory with abundant *Psychotria* spp. And *Oncostemum* spp., 1100-1250 m.

DISTRIBUTION— Madagascar, only known from the type locality.

Impatiens begonioides differs from all Madagascan *Impatiens* in the peltate leaves, resembling those of a *Begonia*.

Impatiens silviana Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab Impatiens decaryana differt petalis lateralibus superioribus latis et obtusis.

TYPUS— *Schatz, Dransfield & Du Puy 2783*, Madagascar, Toamasina, Masoala Peninsula, c. 3 km NE of Antalavia, along Antalavia River, 15°47'S, 50°02'E, 200-380 m, 13-16 Nov. 1989 (holo-, TAN; iso-, MO, P, not seen).

Herb with succulent stem growing on rock or epiphyte. Stems up to 50 cm tall. Leaves dark green above, light green below tinged light purple, petiole 17-60 mm long, lamina ovate-lanceolate, distinctly acuminate, 130-180 x 50-67 mm, margin broadly dentate with small fimbriae. Flowers with sepals green, lateral petals olive translucent green with purple striations and dorsal petal clear translucent with purple fenestration. Pedicels up to 20 mm long. Lateral sepals 2, 6 x 2.5 mm. Lower sepal 15 x 6 mm, with relief forming bars. Dorsal petal hood-like, 17 x 6 mm. Lateral united petals 24 mm long, upper petal 7 x 3 mm, lower petal 17 x 10 mm. Anthers 4-5 mm long. Ovary 3.5-4 mm long. Fruit unknown.—Fig. 6.

HABITAT— Rainforest, growing on rock or epiphyte at 380 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens silviana belongs to the *Impatiens decaryana*-group, which represent large plants with rather large flowers. It differs from *I. decaryana* H. Perrier in the lateral united petals, which are narrow with reduced to lacking upper petal in *I. decaryana* and broad, obtuse and curved upper petal in *I. silviana*. Typical *I. decaryana* is restricted to Central Madagascar (Ikongo, Prov. Fianarantsoa), while *I. silviana* is endemic to Masoala Peninsula.

Impatiens andohahelae Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab omnibus speciebus ex grege Impatiens decaryanae petalo dorsali cum apice calcarato et basi laminae foliorum cordato differt.

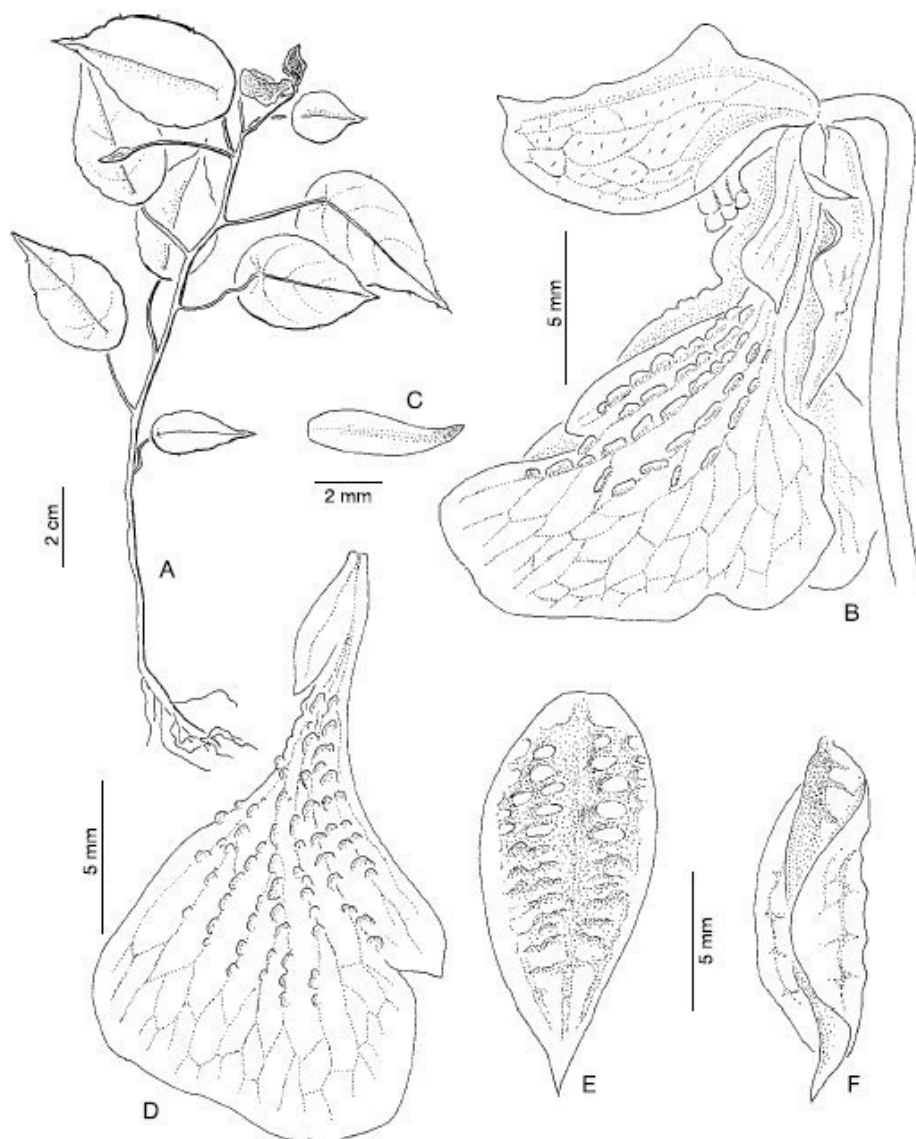


FIGURE 5. *Impatiens begonioides* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, lateral sepal; **D**, lateral united petals; **E**, lower sepal, anterior view; **F**, lower sepal, lateral view. (A, *Turk & Randrianasolo 584*, TAN; B-F, *Rahelivololona, RMN 10*, TAN).

TYPUS— *Dransfield, Cooke, Cheek, Du Puy & Rafamtantsoa JD 6781*, Madagascar, Tolanaro, Réserve Naturelle Andohahela, Parcelle 1, Col Tanatana, Andranomitely, submontane rainforest, vet valley bottom, among boulders, 700 m, 8 Dec. 1989 (holo-, TAN; iso-, MO, P, not seen).

Erect succulent herb to 30 cm tall, pale green throughout. Stems glabrous. Leaves with petiole 20-70 mm long, lamina ovate-lanceolate, distinctly acuminate, broadly cordate at base, 80-145 x 28-50 mm, margin broadly crenate with fimbriae in sinus between two crenations. Flowers translucent pale green, lateral petals olive green with chocolate drawn lines, scented of *Sambucus*. Pedicels up to 19 mm long. Lateral sepals 2, 6 x 0.8-1 mm. Lower sepal 17 x 5-6 mm, green with dark brown relief formed by veins. Dorsal petal hood-like, 22 x 6 mm, with 3-4 mm long spur at apex. Lateral united petals 20 mm long, upper petal 5-6 x 1-1.5 mm, lower petal 15 x 8-10 mm. Anthers 5-6 mm long. Ovary 4-5 mm long. Fruit unknown. —Fig. 7.

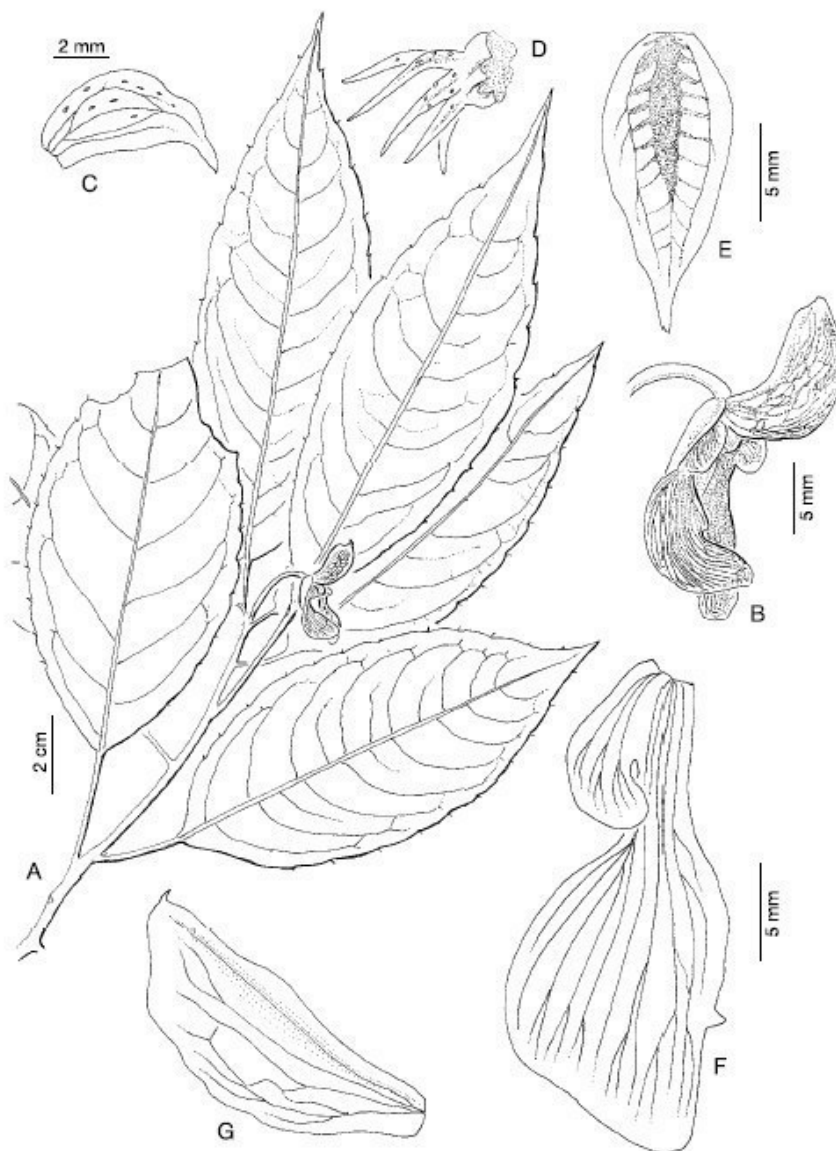


FIGURE 6. *Impatiens silviana* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, lateral sepal; **D**, anthers; **E**, lower sepal, anterior view; **F**, lateral united petals; **G**, dorsal petal. (Schatz, Dransfield & Du Puy 2783, P).

HABITAT— Submontane rainforest, growing on rock at 700 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens andohahelae is also a member of the *Impatiens decaryana*-group, but differs in the long, spur-like projection of the dorsal petal and the lamina, which is cordate at base. It is the only taxon of this group occurring in South-Eastern Madagascar. All the other species are only known from Northern and Central Madagascar.

***Impatiens malcomberi* Eb.Fisch. & Rahelivololona, sp. nov.**

Ab omnibus speciebus ex grege Impatiens parvigaleatae differt forma petalorum lateralium, margine foliorum dentato et habitu epiphytico.

TYPUS— *Malcomber, Andrianantoanina & Rebety 2356*, Madagascar, SW of Antsiranana, near Joffreville, Parc National Montagne d'Ambre, near Sommet d'Ambre, 12°35'S, 49°09'E, 1400-1475 m, 9-13 Apr. 1993 (holo-, TAN; iso-, MO, P, not seen).

Epiphytic herb. Stems fleshy, red, 25-30 cm tall. Leaves ovate-lanceolate, acuminate, petiole 15-22 mm long, lamina 65-100 x 28-35 mm, margin dentate. Flowers bright yellow with darker purplish veins. Bracts filiform, 2 x 0.1 mm. Pedicels 10-18 mm. Lateral sepals 2, lanceolate, acuminate, 5 x 1-1.2 mm. Lower sepal acuminate, 6-8 x 2.5-3 mm. Dorsal petal hood-like, 6-9 x 2-3 mm. Lateral united petals 10 mm long, upper petal 1 x 0.8 mm, lower petal 7 x 5 mm. Anthers 3 mm long. Ovary 3 mm long. Fruit unknown. —Fig. 8.

HABITAT— Epiphyte in montane rainforest, 1400-1475 m.

DISTRIBUTION— Madagascar, known from only the type collection.

Impatiens malcomberi belongs to the *Impatiens parvigaleata*-group, comprising *I. parvigaleata* H. Perrier, *I. pellucidinervia* H. Perrier, *I. rubrolineata* H. Perrier, *I. luteo-viridis* H. Perrier and *I. asperipetala* H. Perrier. It differs in the shape of the lateral united

petals, the dentate leaf margin (crenate with broad sinus in the remaining taxa) and the epiphytic habit, which is not known from any member of *I. parvigaleata*-group.

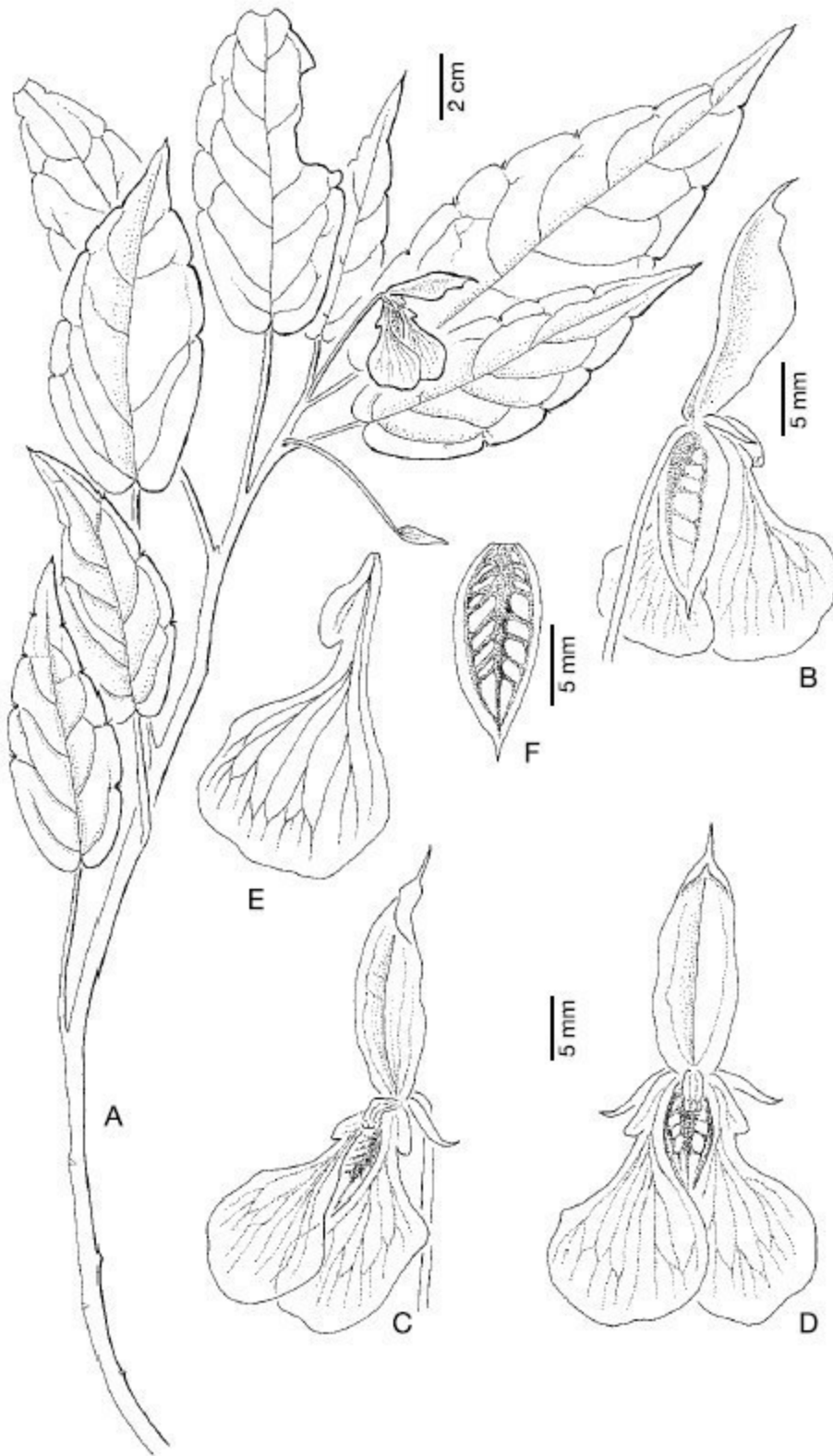


FIGURE 7. *Impatiens andohahelae* Eb.Fisch. & Rahelivololona: **A**, habit; **B-D**, flower; **E**, lateral united petals; **F**, lower sepal. (Dransfield, Cooke, Cheek, Du Puy & Rafamtantsoa JD 6781, TAN).

Impatiens malcomberi is the only taxon of this group occurring in the Montagne d'Ambre. The centre of diversity of *I. parvigaleata*-group is found in the Tsaratanana Massif, where 3 species occur: *Impatiens parvigaleata*, *I. asperipetala* and *I. pellucidinervia*. *Impatiens rubrolineata* is known from the Onivé-bassin and *I. luteo-viridis* from Bemarivo.

***Impatiens ranomafanae* Eb.Fisch. & Rahelivololona, sp. nov.**

Differt ab Impatienti fontinalii et I. dorstenioides caule et foliis dense pilosis et petalis lateralibus angustioribus cum petalo superiore breve.

TYPUS— *Malcomber, Rakoto, Randriamanantena & Rafamantanantsoa 1586*, Madagascar, Fianarantsoa, Parc National Ranomafana, Parcelle I, south of Ambohimiera, valley of Sakavolo River, 21°04'S, 47°29'E, 880-1100 m, 15-17 Sep. 1992 (holo-, P; iso-, MO, not seen).

Erect herb. Stems up to 9-12 cm tall, densely pilose. Leaves dark green, densely pilose, ovate lanceolate, petiole 7-15 mm long, lamina 35-45 x 13-21 mm, margin dentate. Flowers dark olive green with maroon markings. Pedicels 11 mm long. Lateral sepals 2, linear-lanceolate, 2.2 x 0.2 mm. Lower sepal ovate, acuminate, 6-7 x 3 mm. Dorsal petal hood-like, 6 x 3 mm. Lateral united petals 7 mm long, upper petal 0.7 x 0.2 mm, lower petal 3 x 2 mm. Anthers 2.8 mm long. Ovary 3 mm long. Fruit unknown.— Fig. 9.

HABITAT— Riverside herb growing on mossy boulders, 880-1100 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens ranomafanae belongs to the *Impatiens fontinalis*-group and differs from *I. fontinalis* H. Perrier and *I. dorstenioides* (Baker) Warburg in the densely pilose stems and leaves, and the narrow lateral petals with short and narrow upper petal. *Impatiens dorstenioides* is only known from the type specimen (*Baron 4476*, Central Madagascar, holo-, K; iso-, P) and the species has never been recollected. It might probably be extinct. *Impatiens fontinalis* is endemic to Masoala Peninsula.

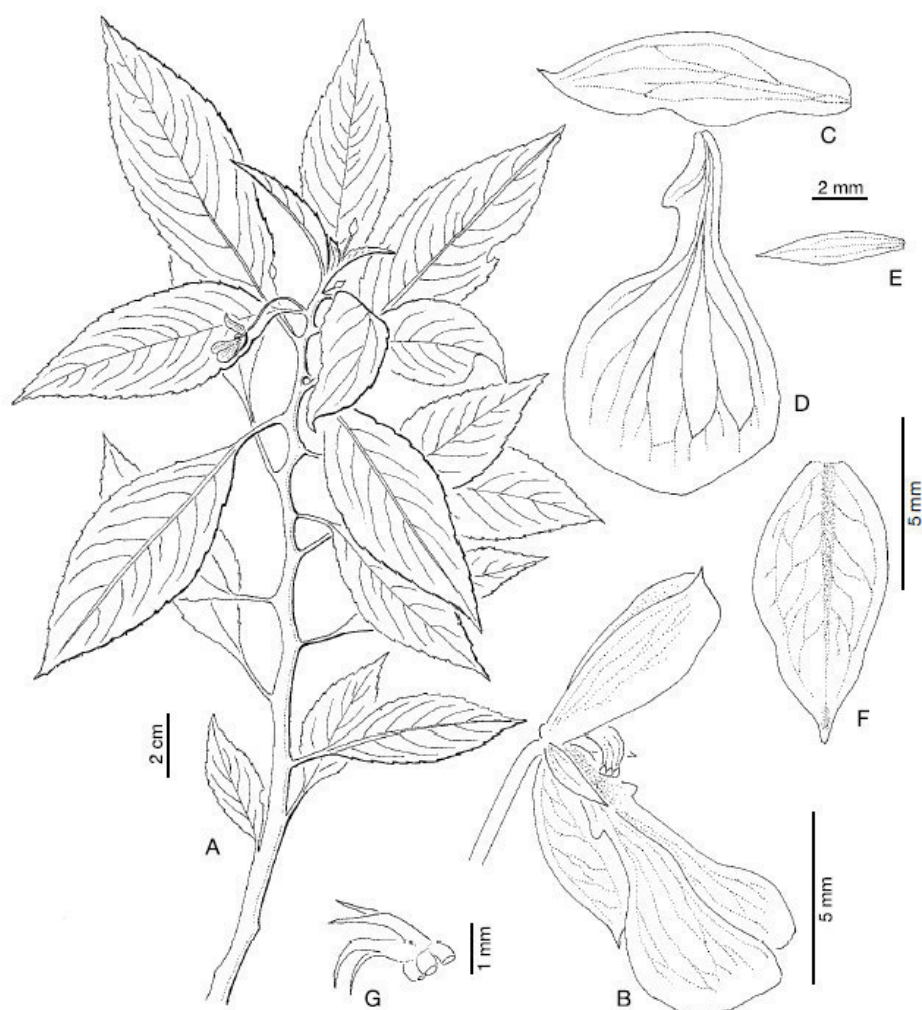


FIGURE 8. *Impatiens malcomberi* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower; **C**, dorsal petal; **D**, lateral united petals; **E**, lateral sepal; **F**, lower sepal; **G**, anthers. (*Malcomber, Andrianantoanina & Rebety 2356, P*).

Impatiens translucida Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab Impatiens fontinali et I. dorstenioides foliis subtus rubro-reticulatis, petalo dorsali cum apice obtuso, petalo laterali superiore latiore et brevioris et sepalis inferioribus ovato-orbicularibus differt.

TYPUS— *Phillipson 2152*, Fianarantsoa, Madagascar, Forest E of Ranomafana between Fianarantsoa and Ifandiana, 21°15'S, 47°24'E, 1200 m, 29 July 1987 (holo-, TAN; iso-, MO, P, not seen).

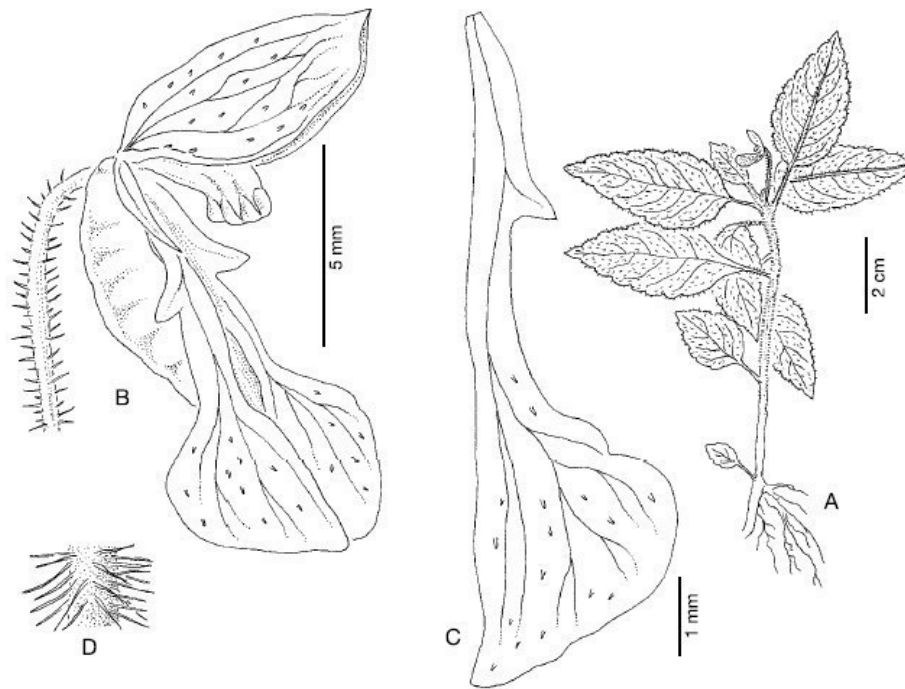


FIGURE 9. *Impatiens ranomafanae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower; **C**, lateral united petals; **D**, stem. Malcomber, Rakoto, Randriamanantena & Rafamantanantsoa 1586, P).

Erect herb with creeping rhizome. Stems succulent, up to 13 cm tall, covered with small white scales. Leaves dark green on upper surface, covered with small white scales, pale green with darker reticulate venation on lower surface, petiole 7-14 mm long, lamina ovate-lanceolate, 50- 55 x 18-19 mm, margin dentate-crenate with small fimbriae. Flowers bright green sepals translucent green shading to dark red. Corolla dark red with translucent bilobed lower lip. Ovary bright green with yellow stigma. Pedicels 7-15 mm long, covered with small white scales. Lateral sepals 2, 1-1.2 x 0.5 mm. Lower sepal 4- 4.5 x 2-2.3 mm, with darker relief. Dorsal petal hood-like, 4-5 x 2 mm. Lateral united petals 7 mm long, upper petal 1.5 x 1 mm, lower petal 5 x 3 mm. Anthers 3 mm long. Ovary 2.5-3 mm long. Fruit unknown. —Fig. 10.

HABITAT— Montane rainforest, growing on wet rocks, 1200 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens translucida belongs to the *Impatiens fontinalis*-group and differs from *I. fontinalis* H. Perrier and *I. dorstenioides* (Baker) Warburg in the leaves, which are finely reddish-reticulate below, the dorsal petal with obtuse apex, the broader and shorter upper lateral petal and the ovate-orbicular lower sepal. Beside *Impatiens ranomafanae* Eb.Fisch. & Rahelivololona (see above) it is the second species of this group from the Ranomafana-National Park near Fianarantsoa.

***Impatiens albopurpurea* Eb.Fisch. & Rahelivololona, sp. nov.**

Impatiens perfecunde affinis, sed petiolo et lamina dense pilosis, petalo dorsale lineari et petalo laterali superiore linearo-lanceolato differt.

TYPUS— *Schatz, Dransfield & Du Puy 2788*, Madagascar, Masoala Peninsula, c. 3 km NE of Antalavia, along Antalavia River, 15°47'S, 50°02'E, 200-380 m, 13-16 Nov. 1989 (holo-, TAN; iso-, MO, P, not seen).

Erect to ascending herbs. Stems up to 5-6 cm tall, densely pilose. Leaves dark green above, light whitish green below, petiole 2-4 mm long, lamina lanceolate, obtuse to subapiculate, 35-55 x 8-9 mm, margin dentate, pilose. Flowers with lateral sepals green, lower petal saccate, somewhat fleshy, magenta, lateral petals white with purple at base, upper petal clear translucent with purple markings (fenestrate). Pedicels 12-13 mm long. Lateral sepals 2, 1.5 x 0.5 mm. Lower sepal deeply navicular, 8 x 5.5 mm, pilose outside. Dorsal petal hood-like, pilose, 8-9 x 2 mm. Lateral united petals 10-11 mm long, upper petal 4 x 1.5 mm, lower petal 6 x 2.5-3 mm. Anthers 2-3 mm long. Ovary 2-3 mm long. Fruit 5-7 mm long, pilose— Fig. 11.

HABITAT— Herb growing on rock in river bed, 200-380 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens albopurpurea belongs to the *Impatiens perfecunda*-group. It differs from *I. perfecunde* H. Perrier in the densely pilose petiole and lamina, the narrow-linear dorsal

petal and the linear-lanceolate upper lateral petal. *Impatiens perfecunde* occurs close to the Masoala Peninsula in the Bay of Antongil.

Impatiens navicula Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab omnibus speciebus madagascariensibus differt petalis lateralibus navicularibus margine recurvato.

TYPUS— *Fischer & Rahelivololona, MJ 10, Madagascar, Marojejy massif, below camp 3, c.1100 m, 23 Mar. 2000 (holo-, TAN; iso-, P).*

Erect herb, stems up to 6 cm tall, simple, densely pubescent. Leaves pubescent above, glabrous below, petiole 8-12 mm long, lamina 18-19 x 18 mm, broadly ovate to orbicular, lower face pale green, upper face darker green, margin with 4-5 teeth and filiform fimbriae. Flowers hidden by leaves, nodding. Pedicels up to 10 mm long. Lateral sepals 2.3 x 1 mm, greenish-brown, hairy outside. Lower sepal 8 x 3 mm, with thickened dark brown longitudinal nerve on inner face and 10 dark brown lateral thickened bars on each side, the parts between these bars pale green and translucent. Dorsal petal 8 x 7 mm, dark green with reddish-brown venation, outside hairy on dorsal crest. Lateral united petals 8-9 mm long, dark chocolate brown, upper petal 4 x 3 mm, lower petal 6 x 5 mm, margin of lower petal folded upwards thus resembling a leguminose navicule. Anthers 3 mm long. Ovary 2-3 mm long. Fruit hairy, 5 x 3 mm— Fig. 12.

HABITAT— Montane rain forest, at 1100 m, growing between moss cushions.

DISTRIBUTION— Madagascar, known from only the type collection from the Marojejy massif.

Impatiens navicula shows superficial resemblance to the insufficiently known *I. meeuseana* H. Perrier from Eastern Madagascar, but differs clearly in the dark chocolate brown flowers and the navicular lateral petals with upwards folded margin. The type specimen of *I. meeuseana* at P unfortunately lacks a flower and only a pencil

sketch of the floral morphology is available. The protologue of this taxon, however, clearly indicates the mentioned differences to *I. navicula*.

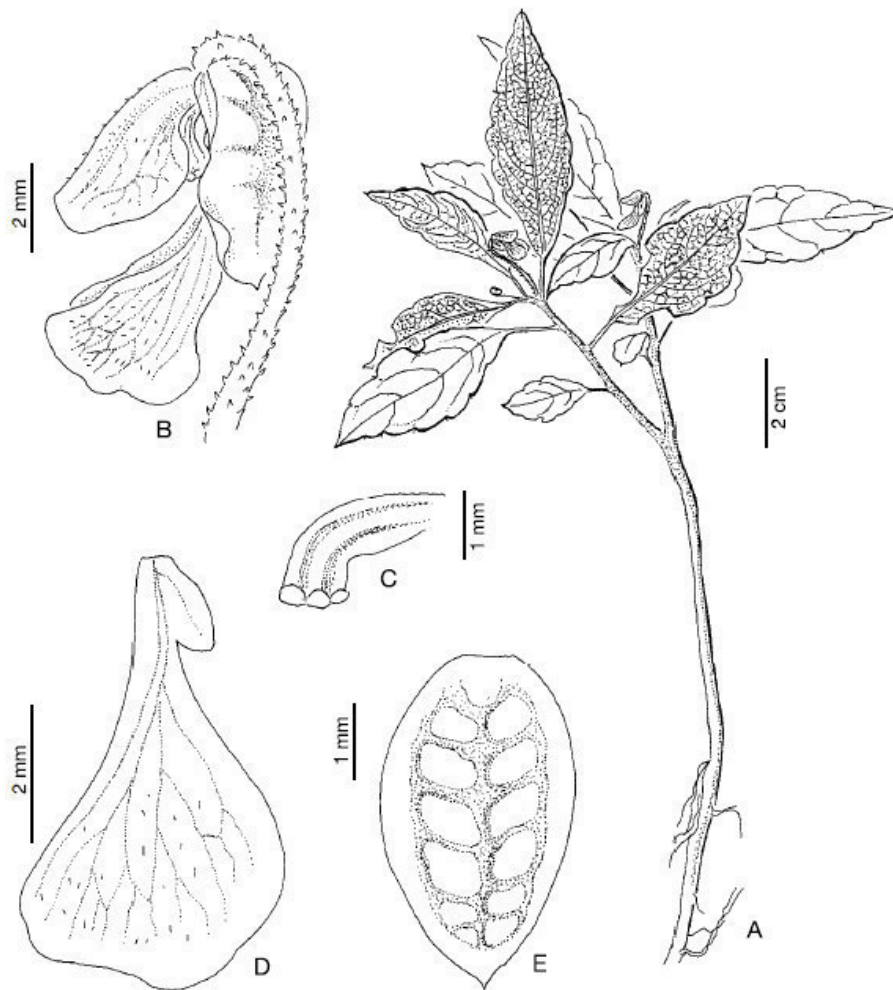


FIGURE 10. *Impatiens translucida* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower; **C**, anthers; **D**, lateral united petals; **E**, lower sepal. (*Phillipson 2152, P*).

Impatiens mandrakae Eb.Fisch. & Rahelivololona, **sp. nov.**

Differt ab Impatienti arachnoide foliis ovalibus, petalis lateralibus loriformibus longioribus cum petalo superiore lato-obtuso, petalo dorsale ovali-orbiculare et sepalis inferioribus lato-ovalibus.

TYPUS— *Rahelivololona, Mk 1, Madagascar, Mandraka village, station, 12 Apr. 2000* (holo-, TAN; iso-, P).

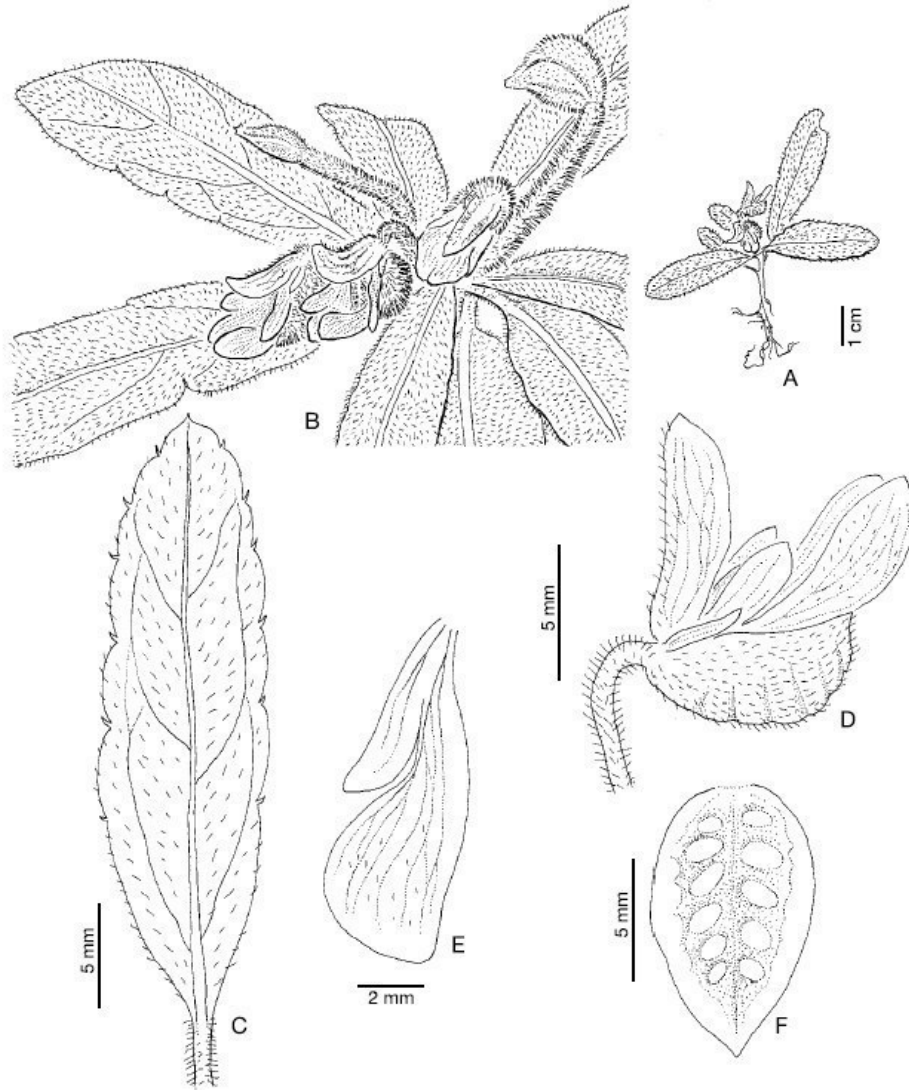


FIGURE 11. *Impatiens albopurpurea* Eb.Fisch. & Rahelivololona: **A, B**, habit; **C**, leaf; **D**, flower, lateral view; **E**, lateral united petals; **F**, lower sepal. (Schatz, Dransfield & Du Puy 2788, P).

Procumbent to ascending herb, glabrous. Stems round, stoloniferous, greyish-green, up to 30 cm long. Leaves dark green with petiole reddish-green, 10-25 mm long, lamina 40-45 x 20-25 mm, margin slightly dentate. Flowers greenish, more or less transparent. Pedicels 8-13 mm long. Lateral sepals 2, 3 x 0.5 mm. Lower sepal ovate to orbicular, 4.5-5 x 3-3.5 mm. Dorsal petal emarginate with short apex, 3.5-4 x 2.5-3 mm. Lateral united petals (7-)9-11 mm long, upper petal 2 x 1.5 mm, lower petal 7-9 x 0.5 mm. Anthers 1.8 mm long. Ovary 1.5-1.8 mm long. Fruit unknown. —Fig. 13.

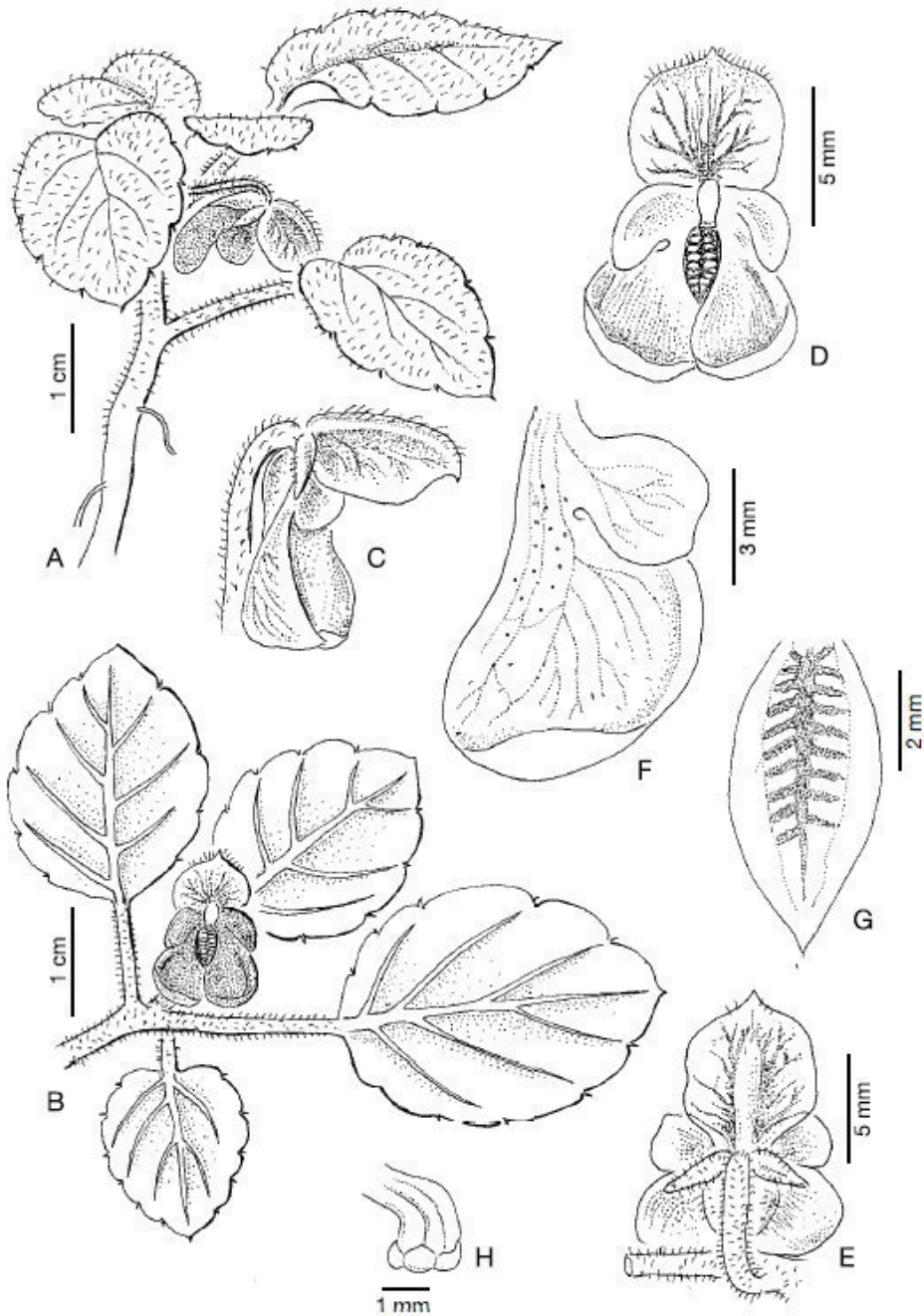


FIGURE 12. *Impatiens navicula* Eb.Fisch. & Rahelivololona: **A, B**, habit; **C**, flower, lateral view; **D**, flower, anterior view; **E**, flower, posterior view; **F**, lateral united petals; **G**, lower sepal; **H**, anthers. (Fischer & Rahelivololona MJ 10, TAN).

HABITAT— Montane rain forest, at a small stream.

DISTRIBUTION— Madagascar, only known from the type collection. *Impatiens mandrakae* belongs to the *Impatiens arachnoides*-group and is closely related to *I. arachnoides* H. Perrier from Mt. Fody in the upper Mangoro basin, but differs in the

ovate leaves, the longer loriform lateral petals with broad obtuse upper petal, the ovate-orbicular dorsal petal and the broadly ovate lower sepal.

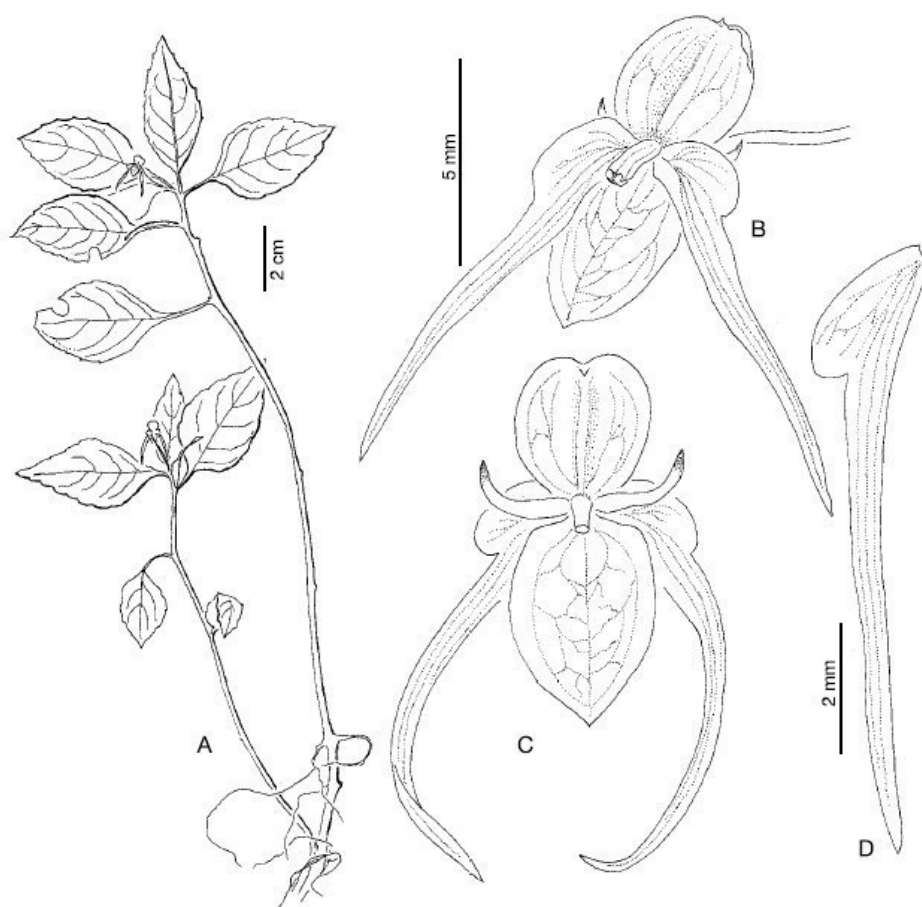


FIGURE 13. *Impatiens mandrakae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, posterior view; **D**, lateral united petals. (Rahelivololona Mk 1, TAN).

Impatiens mananteninae Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab omnibus speciebus ex grege Impatiens arachnoide differt foliis lanceolato-oblongis cum petiolo vaginato et petalo dorsale angustiore.

TYPUS— *Messmer, Rakotomalaza & Ravelonarivo NM 388*, Madagascar, Antsiranana, Marombihy, Mandena, Parc National de Marojejy, 11 km de Manantenina, à la source de la rivière Andranomifotatra, campement 5, 1950 m, 16 Nov. 1996 (holo-, G).

Erect herbs, glabrous. Stems up to 20 cm tall. Leaves oblanceolate, obtuse, petiole very short and indistinct, 1-2 mm long, with basal sheath surrounding the stem, lamina 13-20 x 4 mm, margin dentate. Flowers green-purple. Pedicels 10-11 mm long. Lateral sepals 2, 1 x 0.5 mm. Lower sepal 2.8-3 x 1-1.5 mm. Dorsal petal 3 x 1-1.5 mm. Lateral united petals 4.5 mm long, upper petal 0.8 x 0.3 mm, lower petal 3.5-3.7 x 0.3 mm. Anthers 1 mm long. Ovary up to 1 mm long. Fruit unknown. —Fig. 14.

HABITAT— Ericaceous vegetation, on a crest, 1950 m.

DISTRIBUTION— Madagascar, only known from the type collection at Marojejy massif.

Impatiens mananteninae also belongs to the *Impatiens arachnoides*-group, but can be readily distinguished from the related taxa *I. arachnoides* H. Perrier, *I. albopustulata* H. Perrier and *I. andringitrensis* H. Perrier by the narrow dorsal petal and the lanceolate-oblong leaves with basal sheath and usually two fimbriae per margin. *Impatiens mananteninae* is up to now the only species of this group known from Marojejy massif, while the other taxa are restricted to Eastern-Central Madagascar (Mangoro basin, Andringitra massif)

Impatiens pilosissima Eb.Fisch. & Rahelivololona, **sp. nov.**

Ab omnibus speciebus subg. Trimorphopetali differt habitu grandiore (usque ad 50 cm alto) cum caulibus et foliis dense pilosis et floribus minutis.

TYPUS— *Rahelivololona*, T5, Madagascar, Tsaratanana, fond de ruisseau, vers 1850 m (holo-, TAN; iso-, P).

Erect herb up to 50 cm tall, densely pilose. Leaves dark green with greyish indumentum, petiole 5-13 mm, lamina 32-40 x 12-17 mm, ovate-lanceolate, acuminate, margin dentate. Flowers greenish with dark brown venation. Pedicels up 13 mm long, covered with whitish scales. Lateral sepals 2, 1.5 x 0.5 mm. Lower sepal 4 x 2 mm, with darker relief forming bars and translucent windows. Dorsal petal hood-like, 5 x 2.5

mm, with hairs on dorsal crest. Lateral united petals 6 mm long, upper petal 1.5 x 0.5 mm, lower petal 4 x 2 mm, with tuberculous crest on inner margin. Anthers 2 mm long. Ovary 1.5-2 mm long. Fruit unknown. —Fig. 15.

HABITAT— Montane rain forest, at 1850 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens pilosissima differs from all Madagascan species of subg. *Trimorphopetalum* in the large habit (up to 50 cm tall) with densely pilose stems and leaves and the small flowers, which bear a characteristic crest between upper and lower lateral petal.

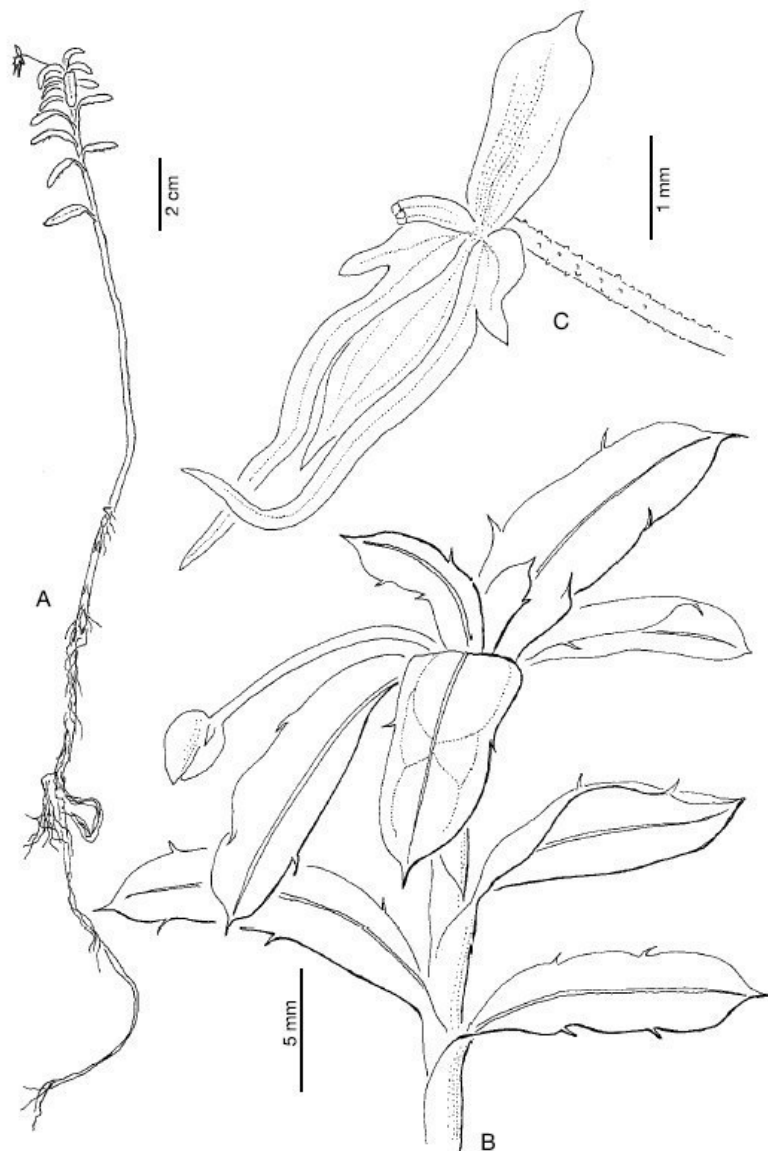


FIGURE 14. *Impatiens mananteninae* Eb.Fisch. & Rahelivololona: **A**, **B**, habit; **C**, flower. (Messmer, Rakotomalaza & Ravelonarivo NM 388, G).

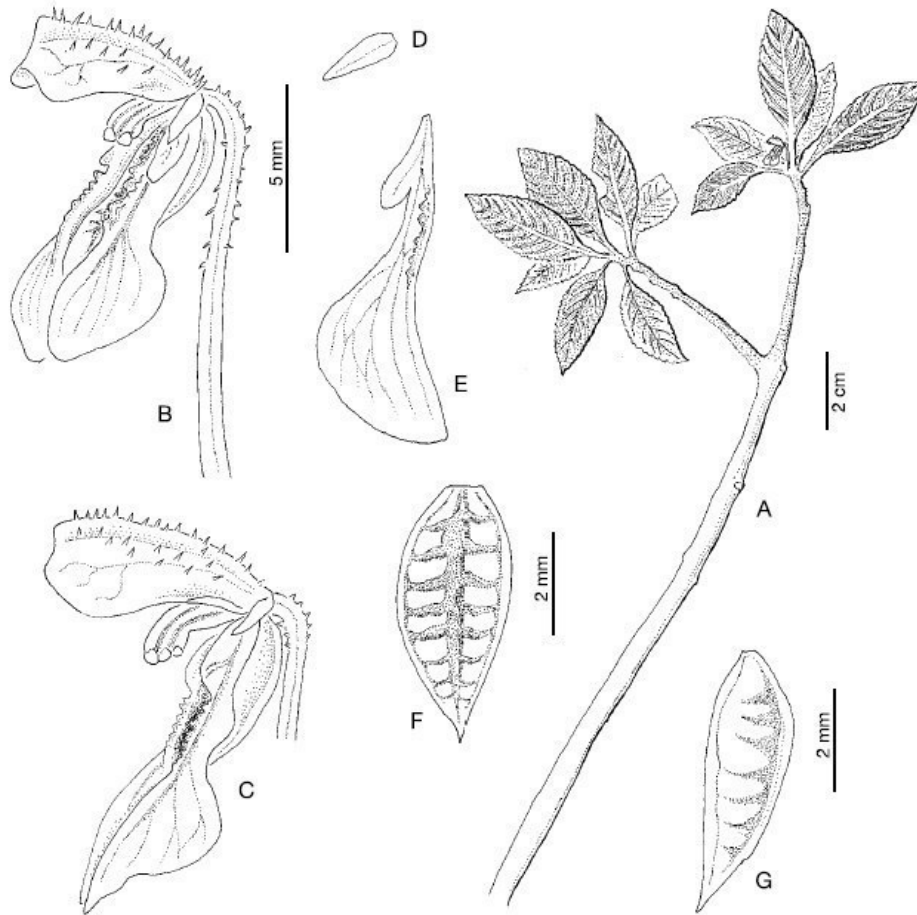


FIGURE 15. *Impatiens pilosissima* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, **C**, flower; **D**, lateral sepal, **E**, lateral united petals; **F**, lower sepal, anterior view; **G**, lower sepal, lateral view. (*Rahelivololona* T5, TAN).

Acknowledgements

First, we would like to thank the staff of the Herbarium, Muséum National d'Histoire Naturelle (P), who kindly sent specimens on loan to the first author and who gave the permission to use the preliminary manuscript of Humbert. We also like to thank the directors of the following herbaria for loan of specimens (acronyms according to Holmgren et al. 1990): BR, G, K, NEU, TAN. Special thanks go to Laurent Gautier (Geneva) for kindly sending *Impatiens* from Manongarivo, Marojejy and Masoala for identification. Finally we would like to thank ANGAP for the permission to collect in Marojejy National Park, to the Direction des Eaux et Forêts for export permission of Balsaminaceae herbarium material and to Ludwig Kientzler for financial support of the field trip.

Chapter 3

New taxa of *Impatiens* (Balsaminaceae) from Madagascar II. A collection from Masoala Peninsula

This chapter has been published as:

Fischer, E.¹, Wohlhauser, S.² & Rahelivololona, E.³ (2003): New taxa of *Impatiens* (Balsaminaceae) from Madagascar II. A collection from Masoala Peninsula. *Adansonia* sér. 3, 25: 17-31.

¹ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany), efischer@uni-koblenz.de

² Institut de Botanique, Université de Neuchâtel, Chantemerle 18, CH-2007 Neuchâtel, Suisse

³ Parc botanique et zoologique de Tsimbazaza, BP 4096 Antananarivo (Madagascar), prota.madagascar@dts.mg

Abstract

In a second paper as precursor to a revision of Balsaminaceae in Madagascar and the Comoro Islands, nine species of *Impatiens* (Balsaminaceae) from the Masoala peninsula are described as new (*I. purroi*, *I. mindiae*, *I. vebrowniae*, *I. benitae*, *I. luisae-echterae*, *I. callmanderi*, *I. kraftii*, *I. purpureolucida* and *I. rivularis*).

Key Words *Impatiens*, Balsaminaceae, Masoala Peninsula, Madagascar.

Résumé

Nouveaux taxons dans le genre Impatiens (Balsaminaceae) à Madagascar. II. Espèces de la presqu'île de Masoala.

Dans cette deuxième publication effectuée dans le cadre de la préparation d'une révision des Balsaminaceae de Madagascar et des Comores, neuf nouvelles espèces d'*Impatiens* de la presqu'île de Masoala sont décrites (*I. purroi*, *I. mindiae*, *I. vebrowniae*, *I. benitae*, *I. luisae-echterae*, *I. callmanderi*, *I. kraftii*, *I. purpureolucida* et *I. rivularis*).

Mots Clés *Impatiens*, Balsaminaceae, presqu'île de Masoala, Madagascar.

Introduction

The Masoala Peninsula is a large area of mostly undisturbed lowland and submontane forest around the Bay of Antongil in North-East Madagascar. Closed-canopy forest remains in some places from sea-level up to 1200 m. The Masoala area is especially famous for its c. 25 endemic species of palms (Dransfield & Beentje 1995). Also several species of *Impatiens* (Balsaminaceae) are known from the area near the Bay of Antongil (e.g. *Impatiens antongiliana* H. Perrier), but systematic surveys of the flora have not yet been taken place. In 1996, the second author, together with M. Callmänder and C. Purro (Neuchâtel) visited the Masoala peninsula and made extensive collections of *Impatiens*. Surprisingly, nine species proved to be new to science and are described in this second paper of a series on *Impatiens* in Madagascar. A short history of exploration of *Impatiens* in Madagascar as well as details on terminology and measurements were provided by Fischer & Rahelivololona (2002).

Impatiens subg. *Impatiens*

Impatiens purroi Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Ab omnibus speciebus madagascariensibus differt calcaribus gibbosis apice obtusis.

TYPUS— Purro & Wohlhauser 1003, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, 500 m above camp 1, 15°24'95"S, 49°56'84"E, 21 Sep. 1996 (holo-NEU; iso-, TAN).

Chapter 3 — New taxa from Madagascar. II

Erect herb. Stems lignous at base, up to 25-30 cm tall, pubescent. Leaves ovate, acuminate, margin crenate-dentate with fimbriae in the sinus between two teeth, petiole 25-30 mm long, lamina 80-115 x 30-48 mm, lower surface pale-green with distinct reticulate venation. Flowers pale pink to purple with greenish venation. Pedicels 18-25 mm long. Lateral sepals 2, 4 x 1.2 mm. Lower sepal 11 x 5 mm, hairy outside, with gibbose, obtuse and \pm straight spur of 7 mm of length. Dorsal petal helmet-like, 9 x 4 mm, with small apicule, hairy on crest. Lateral united petals 16 mm long, upper petal 10 x 4 mm, lower petal 12 x 8 mm. Anthers 3-4 mm long. Ovary 3 mm long. Fruit unknown. —Fig. 1.

HABITAT— Epiphyte in dense evergreen forest, 720 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens purroi does not show close affinities to any known Madagascan *Impatiens*. The gibbose, \pm straight and obtuse spur seems to be a unique feature.

Impatiens mindiae Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatiens manaharensis et *I. tsaratanensis* affinis, sed floribus majoribus, calcari curvato longiore et petalis lateralibus latioribus roseo-violaceis differt.

TYPUS— *Purro & Wohlhauser 1004*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, 15°25'31"S, 49°57'00"E, 21 Sep. 1996 (holo-, NEU; iso-, TAN).

Erect herb. Stems up to 45 cm tall. Leaves ovate, acuminate, petiole 7-13 mm long, lamina 55-70 x 23-27 mm, margin with 6-8 pairs of teeth and filiform fimbriae. Flowers with rose lateral united petals, two yellow spots in the centre, upper dorsal petal white with red dots. Pedicels 50-55 mm long. Lateral sepals 2, 6-7 x 2 mm. Lower sepal navicular, 16 x 5-6 mm, with 5 mm long spur-like apicule at lower base of mouth, spur up to 10 mm long, curved. Dorsal petal hood-like, 15 x 11 mm, with 5 mm long spur at apex. Lateral united petals 25 mm long, upper petal 8-10 x 4-5 mm, lower petal bilobed, 16-17 x 15 mm. Anthers 4-5 mm long. Ovary 4 mm long. Fruit unknown. —Fig. 2.

HABITAT— Montane bamboo evergreen forest, 1073 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens mindiae is related to *I. manaharensis* Baill. and *I. tsaratanensis* H. Perrier, but differs in the longer curved spur and the broader, rose lateral united petals. *Impatiens manaharensis* is known from Eastern Madagascar, while *I. tsaratanensis* is restricted to the Tsaratanana Massif.

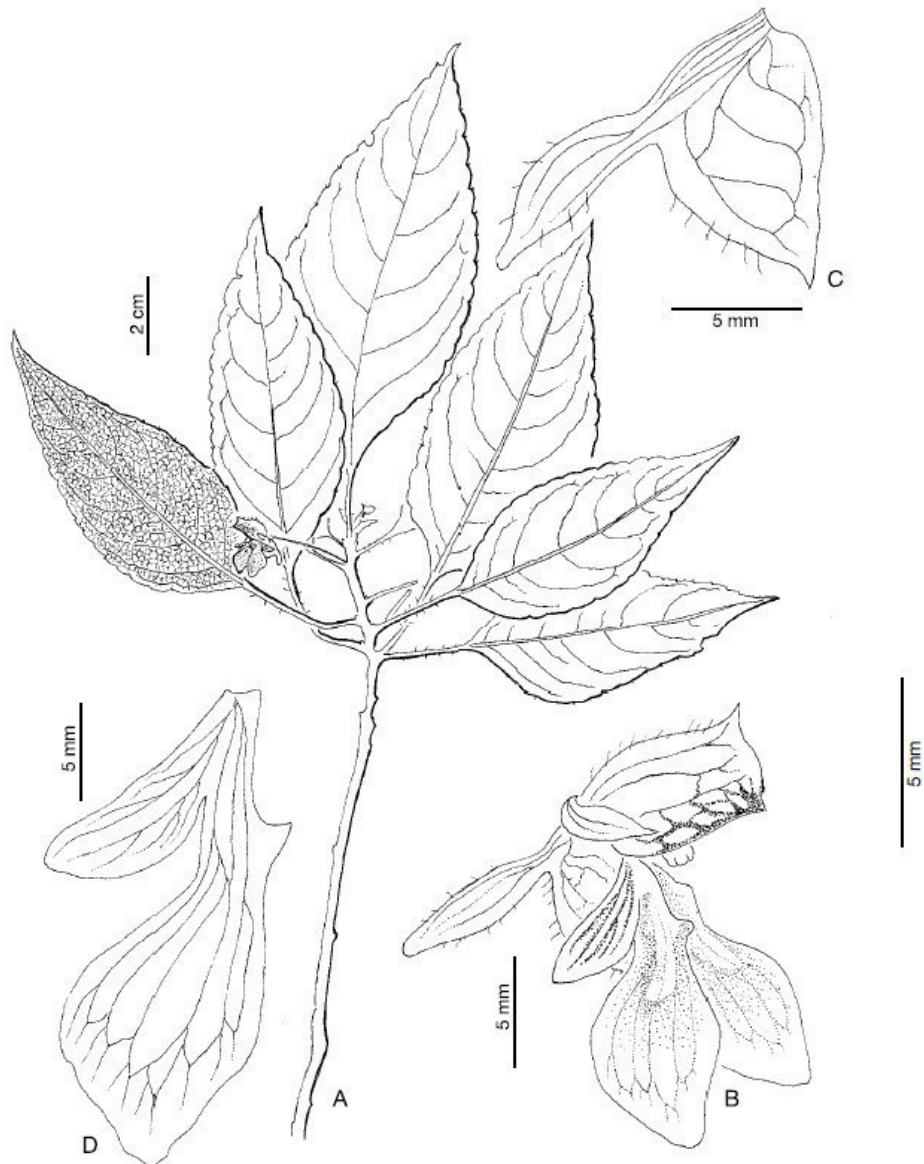


FIGURE 1. *Impatiens purroi* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower; **C**, lower sepal and spur; **D**, lateral united petals. (*Purro & Wohlhauser 1003*, NEU).

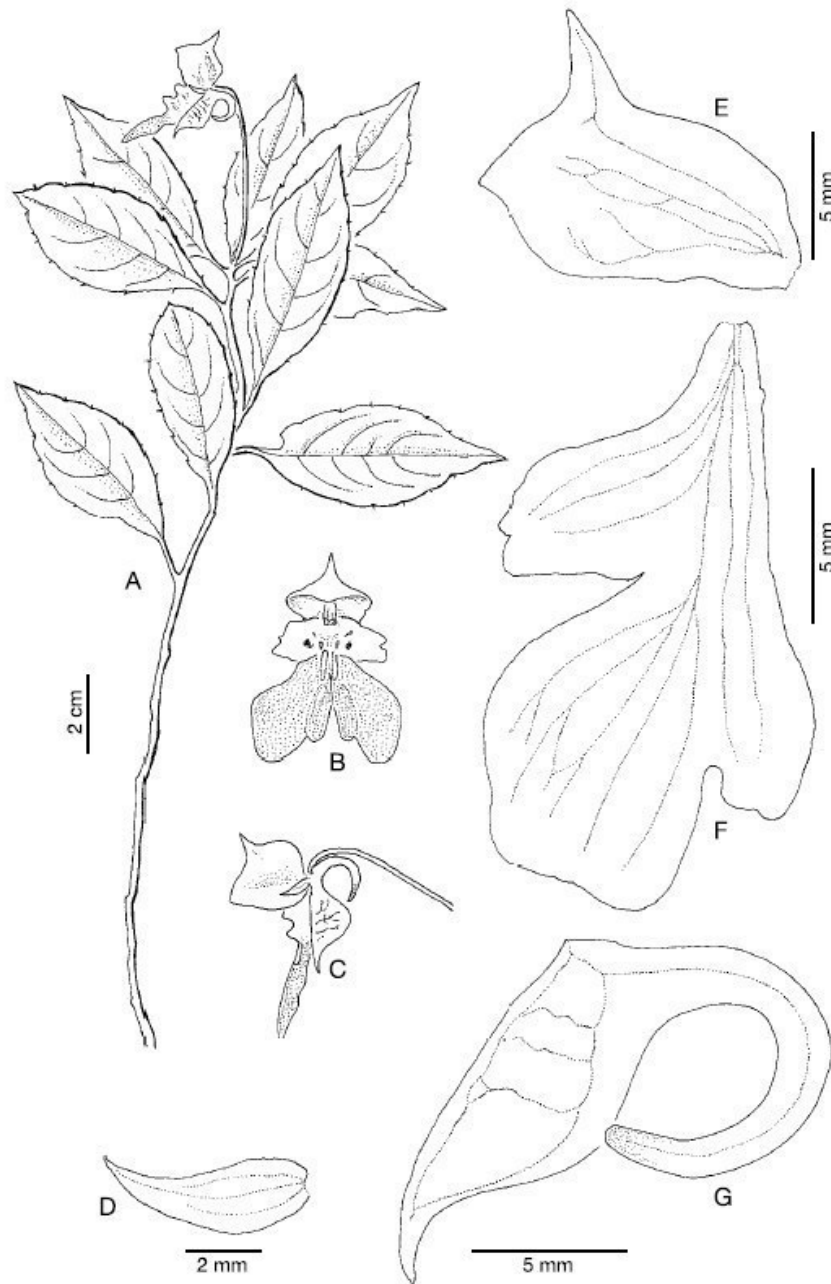


FIGURE 2. *Impatiens mindiae* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, lateral sepal; **E**, dorsal petal; **F**, lateral united petals; **G**, lower sepal and spur. (Purro & Wohlhauser 1004, NEU).

Impatiens vebrowniae Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Ab Impatienti viguieri calcari longiore, petalis lateralibus superioribus longioribus et angustioribus, sepalis lateralibus lanceolatis et foliis succulentis margine late-crenato sine petiolo et nectariis extrafloralibus differt.

TYPUS— *Purro & Wohlhauser 1014*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, SE of camp 2, 15°25'90"S, 49°58'14"E, 950 m, 22 Sep. 1996 (holo-, NEU; iso-, TAN).

Suffrutescent herb. Stems up to 150 cm tall. Leaves linear-lanceolate, medium to dark green above, light green below, the marginal fimbriae red, somewhat succulent, petiole up to 10 mm long, lamina 110-130 x 10 mm, margin crenate. Flowers white or very pale pink, the nectar spur light pinkish white, with nice smell. Pedicels 50-75 mm long. Lateral sepals 2, lanceolate, 3 x 1 mm. Lower sepal navicular, 17 x 7 mm, with 55-65 mm long filiform spur. Dorsal petal emarginate, dorsal crest with short apicule, 17 x 16-17 mm. Lateral united petals 24 mm long, upper petal oblanceolate, slightly bilobed, 20 x 9-10 mm, lower petal rounded, 19 x 14 mm. Anthers 4-5 mm long. Ovary 4-5 mm long. Fruit unknown.—Fig. 3.

HABITAT— Montane evergreen forest, growing on boulder along river bed, 950 m.

DISTRIBUTION— Madagascar, only known from the Masoala peninsula.

Impatiens vebrowniae belongs to the *Impatiens viguieri*-group. It differs from *I. viguieri* H. Perrier in the longer spur, the longer and narrower upper lateral petal, the lanceolate lateral sepals, the ± succulent leaves with broadly crenate margin lacking a distinct petiole and extrafloral nectaries. *Impatiens viguieri* occurs close to the type locality of *I. vebrowniae* in the Anove basin. Recent studies (Fischer & Rahelivololona in prep.) have shown a considerable geographical differentiation and the occurrence of vicarious *Impatiens* species within the Masoala Peninsula.

PARATYPES— MADAGASCAR: *Purro & Wohlhauser 1013*, Antsiranana, Masoala Peninsula Réserve Intégrale, camp 3, 15°25'90"S, 49°58'14"E, 1174 m, 22 Sep. 1996 (NEU); *Schatz, Dransfield & Du Puy 2812*, Toamasina, Masoala Peninsula, c. 3 km NE of Antalavia, along Antalavia River, 15°47'S, 50°02'E, 200-380 m, 13-16 Nov. 1989 (MO, P, TAN); *Zjhra & Hutcheon 379*, Toamasina, Ambanizana, Masoala Peninsula, along Androka river S of MBG house, June 1993 (MO, P).

Impatiens benitae Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatiens baronii affinis, sed calcar longiore, petalis lateralibus superioribus longioribus latioribusque et fructibus non tuberculatis differt.

TYPUS— Purro & Wohlhauser 1002, Madagascar, Antsiranana, above Mahalevona village on the way to Ambohitsitondroina, Masoala Peninsula Réserve Intégrale, 15°24'72"S, 49°56'33"E, 20 Sep. 1996 (holo-, NEU; iso-, TAN).

Annual herbs. Stems 45-50 cm long. Leaves ovate to ovate-lanceolate, petiole 18-30 mm long, with 3-4 pairs of extrafloral nectaries, lamina 62-70 x 20-25 mm, margin dentate. Flowers rose to purple, with yellow marks on lateral petals. Pedicels 40-45 mm long. Lateral sepals 2, 2.5-3 x 1 mm. Lower sepal 9 x 4 mm, with up to 25 mm long filiform spur. Dorsal petal 9 x 6 mm, slightly emarginate at apex, with small apicule. Lateral united petals 15 mm long, upper petal 10 x 6-7 mm, lower petal 10-11 x 6-7 mm. Anthers 4 mm long. Ovary 3-4 mm long. Young fruits smooth, mature fruit unknown. —Fig. 4.

HABITAT— Secondary forest, open areas at path sides, 420 m.

DISTRIBUTION— Madagascar, only known from the type collection.

VERNACULAR NAME— Famakivato.

Impatiens benitae is related to *I. baroni* Baker, but differs in the longer spur, the longer and larger upper lateral petal and the smooth, not tuberculate fruits. While *I. baroni* is distributed over most parts of Madagascar and can be found even outside forests (e.g. on granitic inselbergs), *I. benitae* is restricted to Masoala Peninsula and the Marojejy Massif.

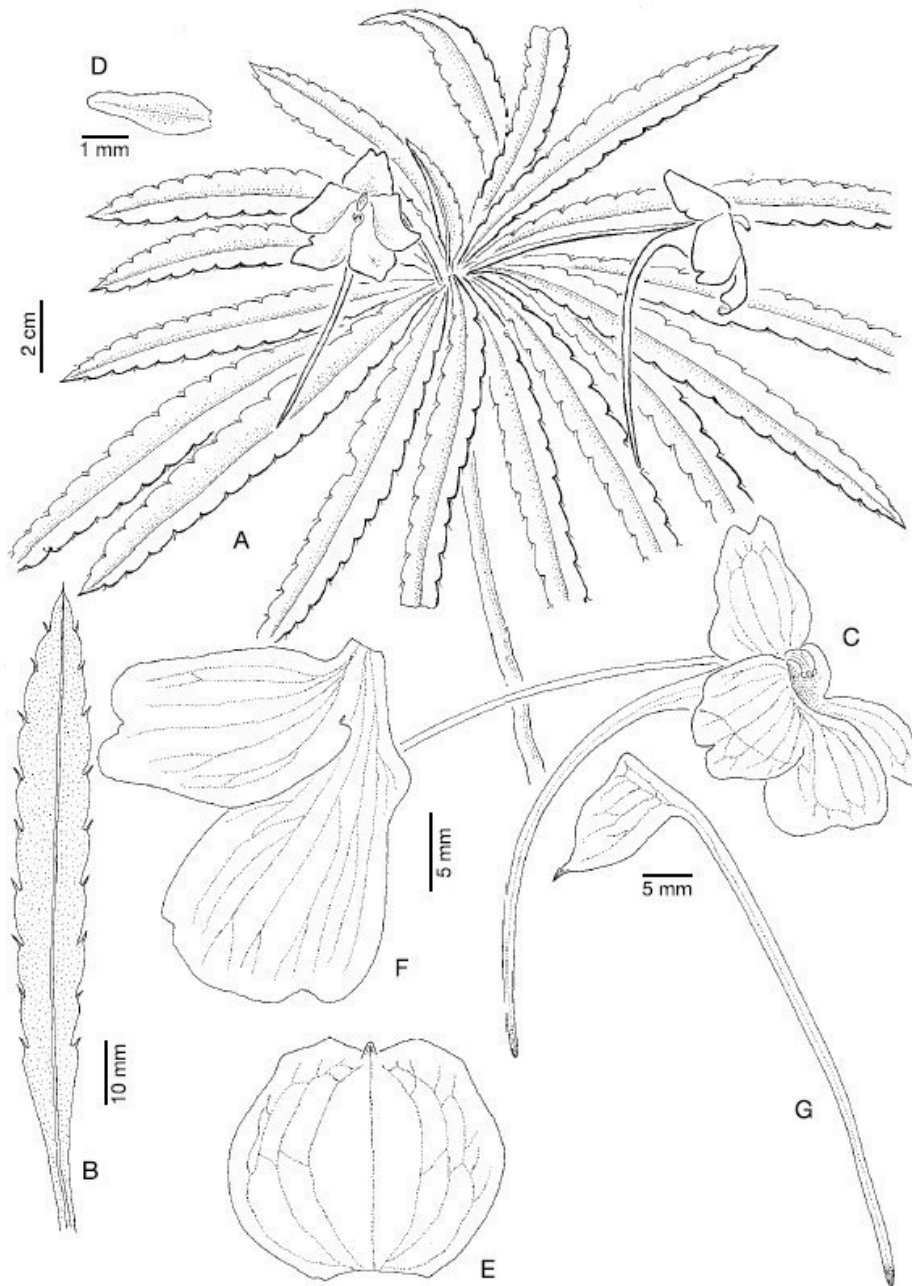


FIGURE 3. *Impatiens vebrowniae* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, leaf; **C**, flower; **D**, lateral sepal; **E**, dorsal petal; **F**, lateral united petals; **G**, lower sepal and spur. (Purro & Wohlhauser 1014, NEU).

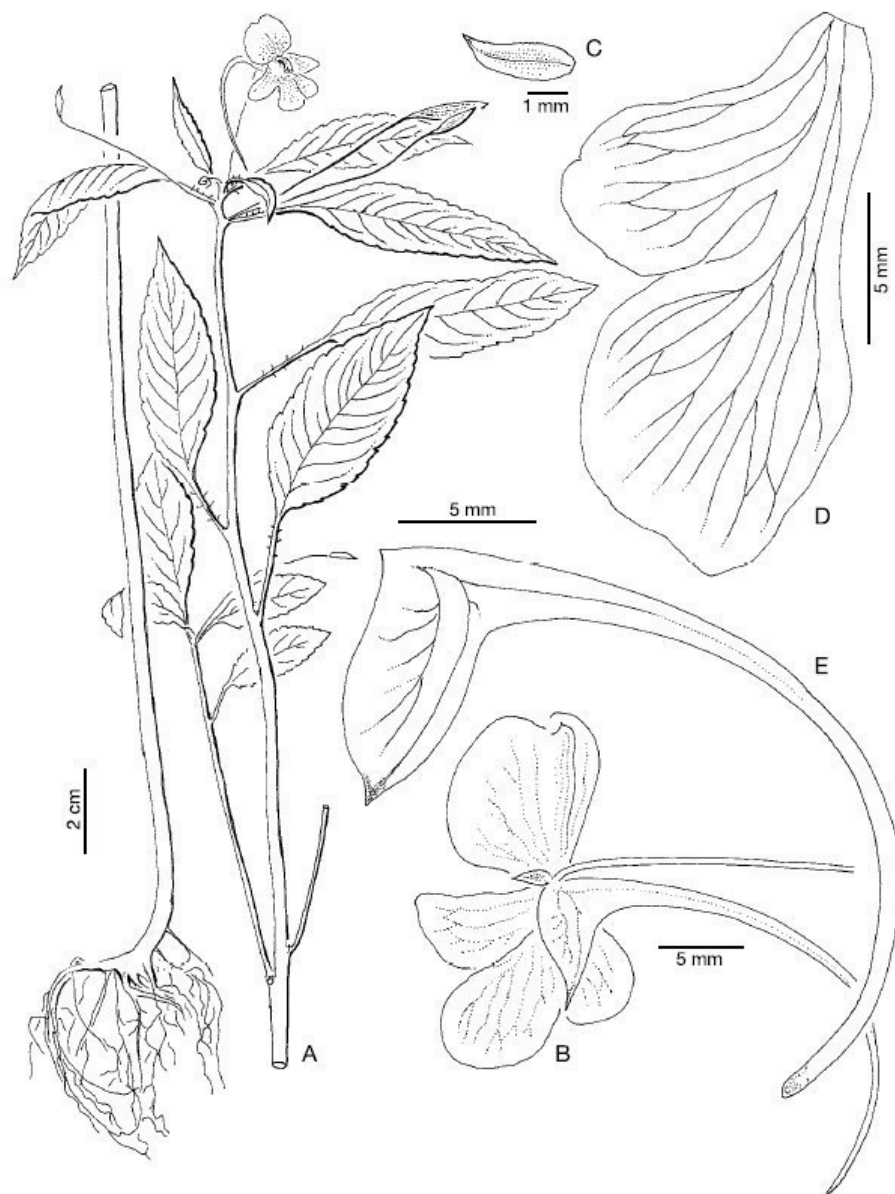


FIGURE 4. *Impatiens benitae* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, posterior view; **C**, lateral sepal; **D**, lateral united petals; **E**, lower sepal and spur. (Purro & Wohlhauser 1002, NEU).

PARATYPES— MADAGASCAR: *Humbert 23240*, contreforts occidentaux du massif de Marojejy, près du col de Doanyala, 500 m, 25 June-25 Feb. 1949 (P); *Purro & Wohlhauser 1016*, Masoala Peninsula Réserve Intégrale, W of Ampokafo, 15°19'30"S, 50°02'30"E, 25 Sep. 1996 (NEU).

Impatiens* subg. *Trimorphopetalum (Baker) Eb. Fisch.

Impatiens luisae-echterae Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatienti gibbose affinis, sed petalo dorsali angustiore-elongato, petalis lateralibus superioribus acuminates et foliis lanceolatis differt.

TYPUS— *Purro & Wohlhauser 1015*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, above camp 3, Andranomaloto basin, 15°25'90"S, 49°58'14"E, 1174 m, 23 Sep. 1996 (holo-, NEU; iso-, TAN).

Erect herb, glabrous. Stems 25-50 cm tall. Leaves with petiole 15-25 mm long, lamina lanceolate to ovate, 75-110 x 28-40 mm, with acute apex, margin with 9-10 crenulations, the sinus each with a filiform fimbria. Flowers purple, yellowish-green purple veined. Pedicels 23-28 mm long, glabrous. Lateral sepals 2, 4 mm long, green. Lower sepal 15 mm long, yellowish with purple veins. Dorsal petal helmet-like, 26 x 7-8 mm, transparent greenish-yellow with purple nervation, dorsal crest in upper third with a geniculation. Lateral united petals 20 mm long, upper petal dark purple, lower petal 12 mm large, transparent greenish-yellowish with purple veination. Anthers 5 mm long. Ovary 4 mm long. Fruit unknown. —Fig. 5.

HABITAT— Shaded slope in montane moss evergreen rainforest, 1174 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens luisae-echterae belongs to the *Impatiens decaryana*-group and is closely related to *I. gibbosa* H. Perrier, from which it differs in the narrower and elongate dorsal petal, the acuminate upper lateral petal and the lanceolate-ovate leaves. *Impatiens gibbosa* is a narrow endemic from Tsaratanana Massif.

Impatiens callmanderi Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatiens gibbosa affinis, sed petalo dorsali latiore, sepalis lateralibus lanceolatis, petalis lateralibus latioribus obtusisque et nervis secundariis a nervo mediano sub angulo 90° abeuntibus differt.

TYPUS— Purro & Wohlhauser 1027, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, massif de Bevontsira, Antsahabefiana, 27 Sep. 1996 (holo-, NEU; iso-, TAN).

Erect herb, glabrous but covered with minute white scales, crest of dorsal petal with some hairs. Stems up to 25-50 cm tall. Leaves with petiole 7-15 mm long, lamina lanceolate-ovate, acute, 110-130 x 40-50 mm, margin crenulated with small filiform fimbriae. Flowers purpleblackish, with reddish-veined yellow lateral united sepals. Pedicels up to 28 mm long. Lateral sepals 2, large, 7 x 2 mm, green. Lower sepal yellowish with blackish spots, 12 mm long. Dorsal petal helmet-like, 15 x 10 mm, in lower third on crest with distinct geniculation at apex with small recurved spur. Lateral united petals 19 mm long, upper petal 2 x 5 mm, obtuse, purple-blackish, lower petal 11-12 mm long, transparent yellowish with purple-blackish veins. Anthers 5 mm long. Ovary 4-5 mm long. Fruit unknown.— Fig. 6.

HABITAT— Montane moss evergreen forest, 900 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens callmanderi also belongs to the *Impatiens decaryana*-group and is related to *I. gibbosa* H. Perrier and *I. luisae-echterae* Eb. Fisch., Wohlhauser & Rahelivololona, from which it differs in the broader dorsal petal, the lanceolate-ovate lateral sepals, the broader and obtuse lateral united petals and the secondary nerves of leaf lamina, arising in an angle of approximately 90° from mid-nerve.

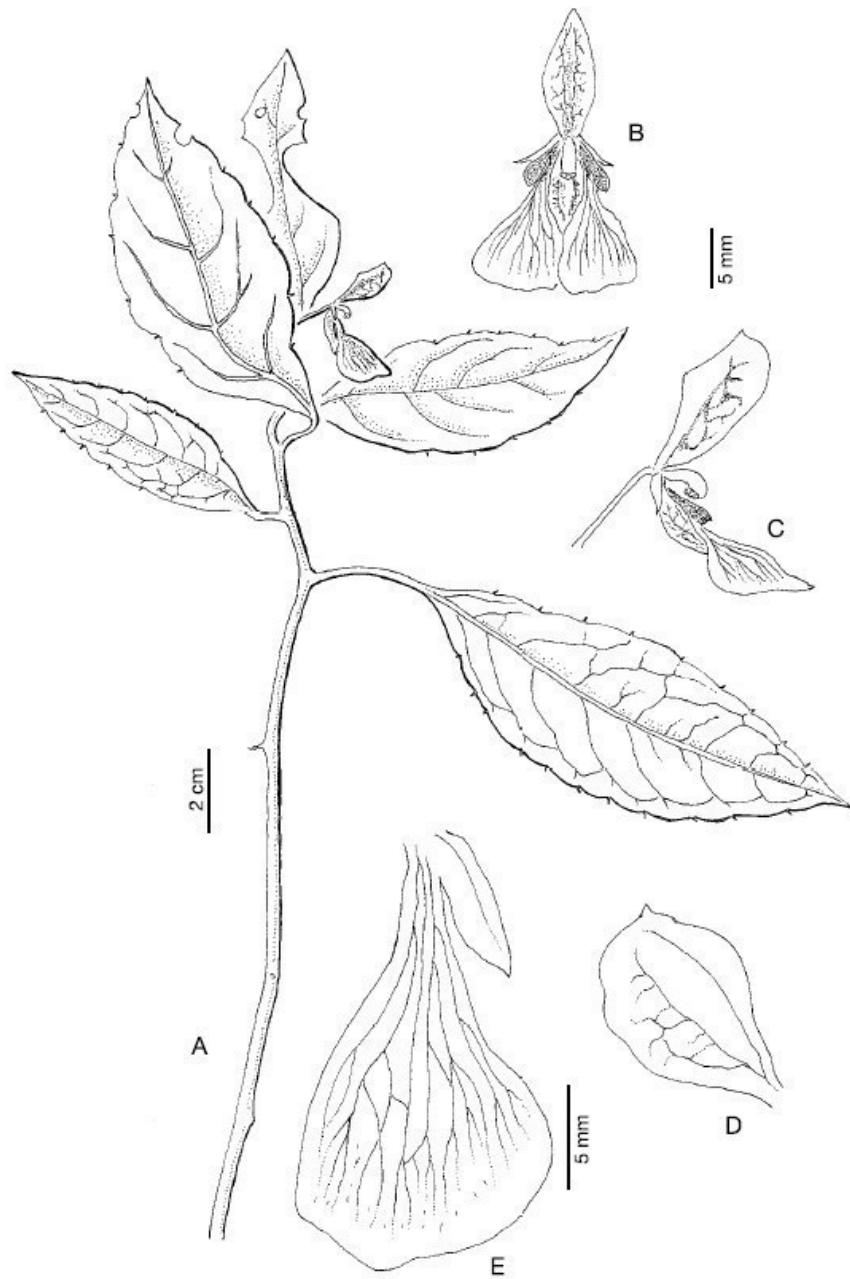


FIGURE 5. *Impatiens luisae-echterae* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, dorsal petal; **E**, lateral united petals. (*Purro & Wohlhauser 1015*, NEU).

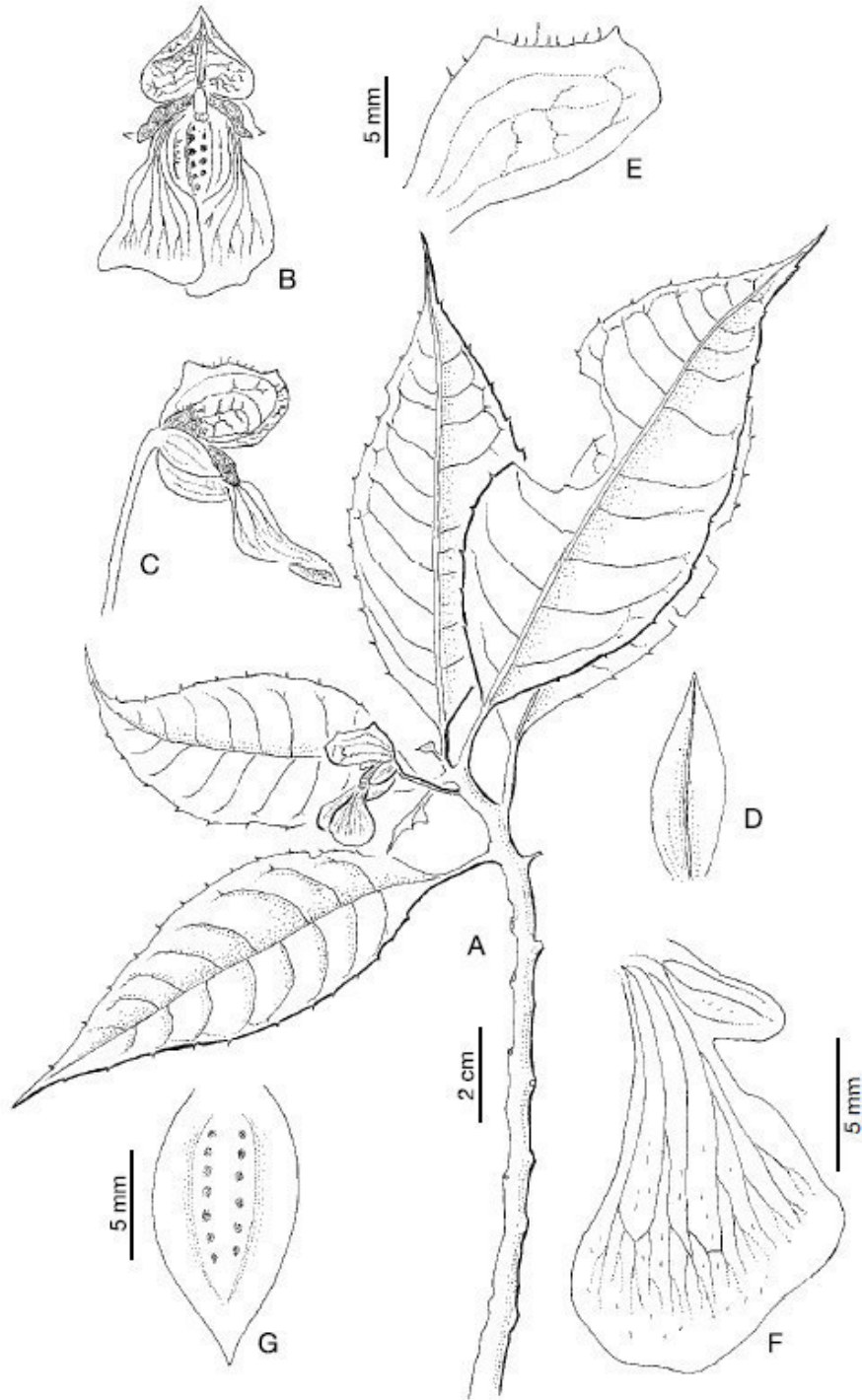


FIGURE 6. *Impatiens callmanderi* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, lateral sepal; **E**, dorsal petal; **F**, lateral united petals; **G**, lower sepal. (Purro & Wohlhauser 1027, NEU).

Impatiens kraftii Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatienti silviane affinis sed petalis lateralibus superioribus acuminatis, sepalis lateralibus linearo-lanceolatis, basi laminae et nervis subtus distincte reticulatis differt.

TYPUS— *Purro & Wohlhauser 1007*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, camp 2, 15°25'95"S, 49°57'56"E, 1100 m, 21 Sep. 1996 (holo-, NEU; iso-, TAN).

Erect robust herb up to 25-30 cm tall. Stems broad green, pubescent. Leaves large, lower face of leaves hairy on nerves, with finely reticulate nerves, petiole 15-25 mm long, lamina ovatelanceolate, (65-)90-110 x 29-48 mm, margin crenate with 14-17 pairs of filiform fimbriae. Flowers greenish-brown, with brown-red venation. Pedicels covered with white scales, up to 30 mm long. Lateral sepals 2, linear-lanceolate, 4 x 0.8 mm. Lower sepal 8 x 3-4 mm, with dark transverse bars formed by the nerves. Dorsal petal cucullate, hairy, 7-8 x 3-4 mm, with short spur at apex. Lateral united petals 12 mm long, upper petal 3 x 1 mm, lower petal 7 x 5 mm. Anthers 3 mm long. Ovary 2-3 mm long. Fruit unknown. —Fig. 7.

HABITAT— Montane evergreen forest, growing on rocks in small streams, 1100 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens kraftii belongs to the *Impatiens decaryana*-group and differs from *I. silviana* Eb.Fisch. & Rahelivololona, which is also known from Masoala Peninsula, in the acuminate upper lateral petal, the linear-lanceolate lateral sepals, the shape of lamina with narrow base gradually tapering into petiole and the distinct reticulate nerves on lower leaf-surface.

Impatiens purpureolucida Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Ab Impatienti translucida differt petalis lateralibus angustioribus et caule petioloque pilosis, ab I. ranomafanae differt lamina glabra vel sparsim pilosa, petalo dorsali obtusi et petalis lateralibus latioribus.

TYPUS— *Purro & Wohlhauser 1025*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, E of Ampokafo, Bevontsira Range, 26 Sep. 1996 (holo-, NEU; iso-, TAN).

Erect herbs. Stems 4-6 cm tall, densely pilose. Leaves lanceolate, acuminate, coarsely dentate, petiole 9-10 mm, densely pilose, lamina 35-50 x 16-20 mm, with reddish veins on the lower side, glabrous or sparsely pubescent. Flowers minute, hidden by the leaves, translucent purple. Pedicels 6 mm long, pilose. Lateral sepals 2, 1 x 0.3 mm. Lower sepal 4 mm long. Dorsal petal 5 x 1.5-2 mm, hairy on crest. Lateral united petals 5-6 mm long, upper petal up to 2 mm, lower petal 3 x 2.5-3 mm. Anthers 1-1.5 mm. Ovary 1 mm long. Fruit unknown.— Fig. 8.

HABITAT— Montane mossy evergreen rain forest, on stones in streams, 950 m.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens purpleolucida belongs to the *Impatiens fontinalis*-group and is closely related to *I. translucida* Eb.Fisch. & Rahelivololona and *I. ranomafanae* Eb.Fisch. & Rahelivololona. It differs from *I. translucida* in the narrower lateral united petals and the pilose stem and petiole. From *I. ranomafanae*, the new species differs in the glabrous or only sparsely hairy lamina, the obtuse dorsal petal and the broader lateral united petals. Both *I. translucida* and *I. ranomafanae* are only known from Ranomafana-National Park near Fianarantsoa.

Impatiens rivularis Eb. Fisch., Wohlhauser & Rahelivololona, **sp. nov.**

Impatiens ivohibensi affinis, sed petalo dorsali angustiore, petalis lateralibus longioribus acuminatisque et caule piloso differt.

TYPUS— *Purro & Wohlhauser 1018*, Madagascar, Antsiranana, Masoala Peninsula Réserve Intégrale, between camp 3 and Ilampy, 23 Sep. 1996 (holo-, NEU; iso-, TAN).

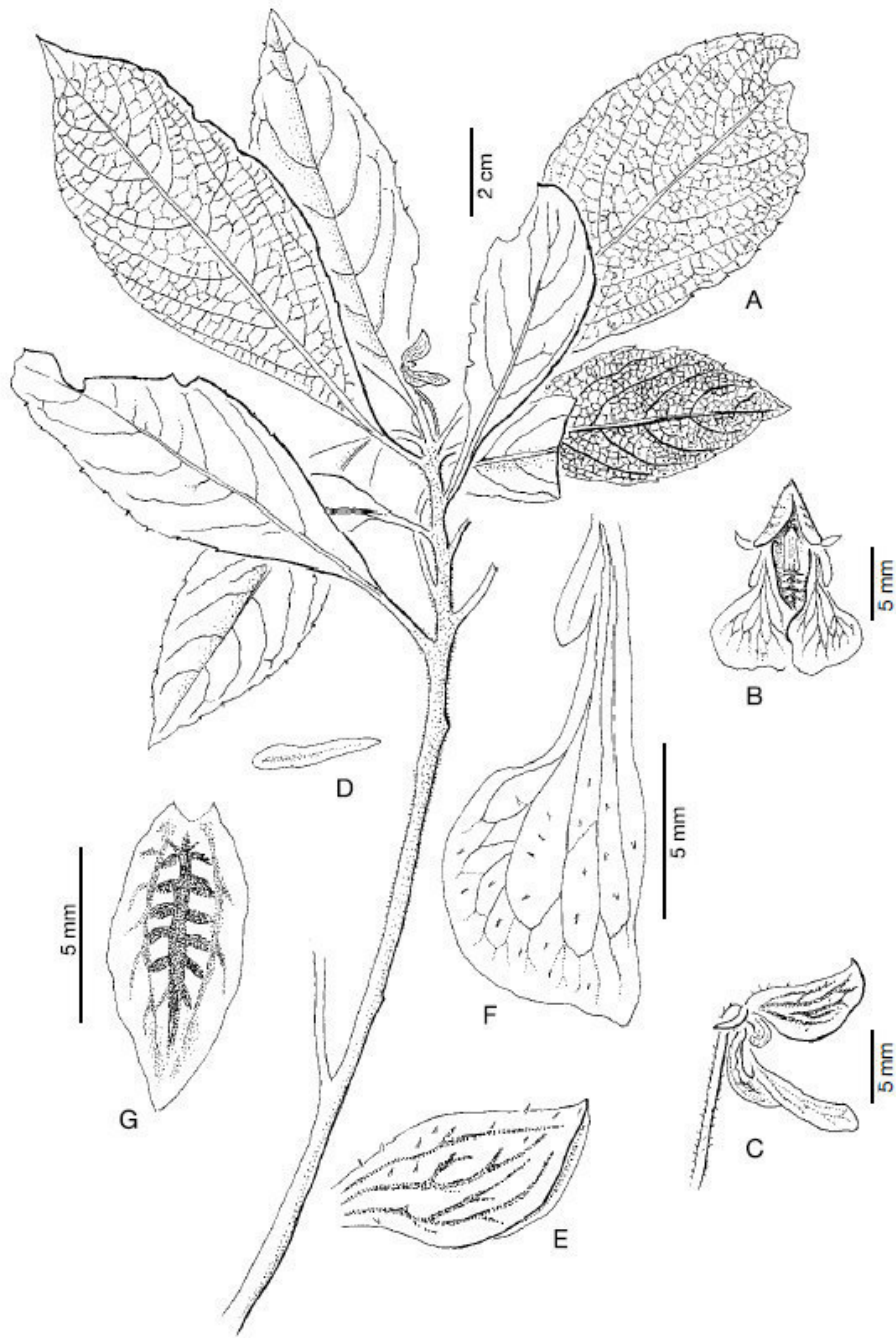


FIGURE 7. *Impatiens kraftii* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, lateral sepal; **E**, dorsal petal; **F**, lateral united petals; **G**, lower sepal. (Purro & Wohlhauser 1007, NEU).

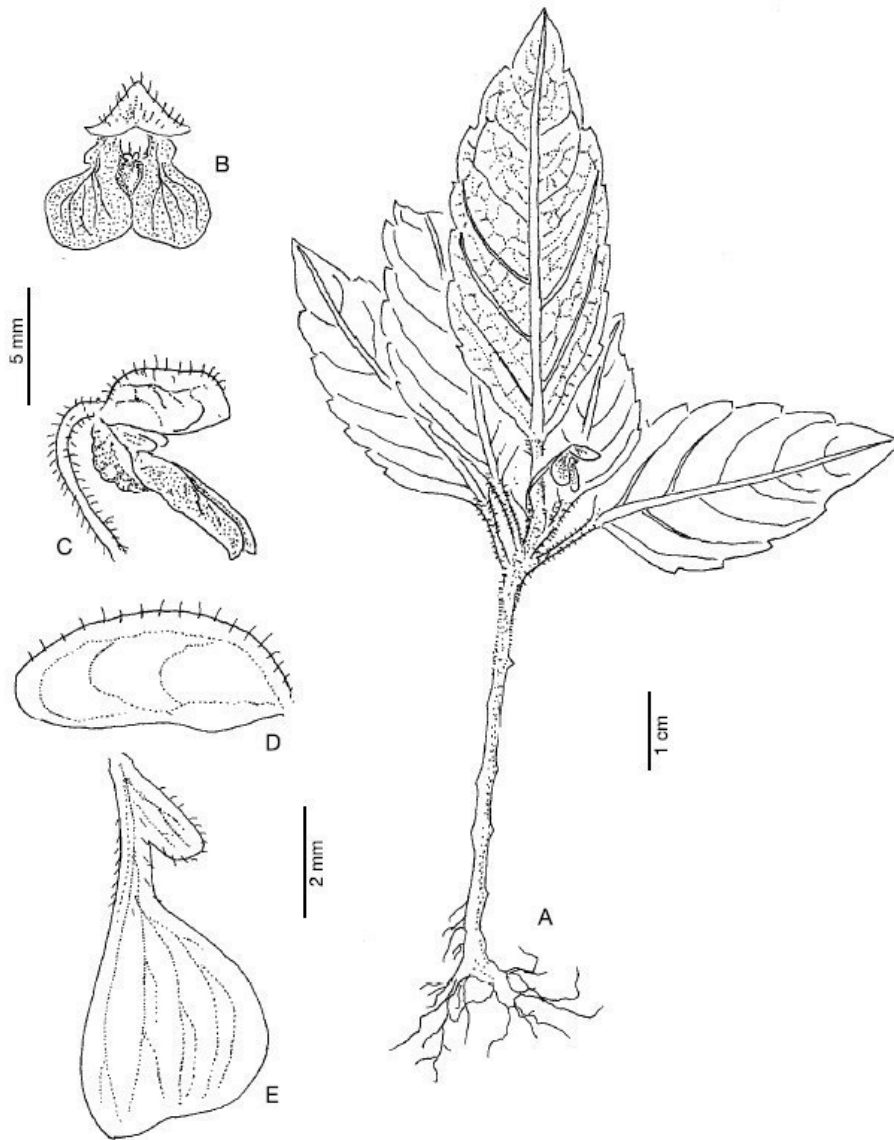


FIGURE 8. *Impatiens purpleolucida* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, dorsal petal; **E**, lateral united petals. (Purro & Wohlhauser 1025, NEU).

Erect herb. Stems up to 14 cm tall, pubescent. Leaves linear-lanceolate, acuminate, margin dentate, with small fimbriae, petiole 5-12 mm long, lamina 57-70 x 16-18 mm, covered with small whitish scales on upper surface. Flowers greenish-yellow, lower sepal with purple-blackish relief. Pedicels up to 15 mm long. Lateral sepals 2, 2 mm long. Lower sepal 7 x 3 mm, with relief formed by veins. Dorsal petal helmet-like, 7 x 2 mm. Lateral united petals 7 mm long, upper petal 1 mm, lower petal 4 x 3 mm. Anthers 3 mm long. Ovary 2-3 mm long. Fruit unknown. —Fig. 9.

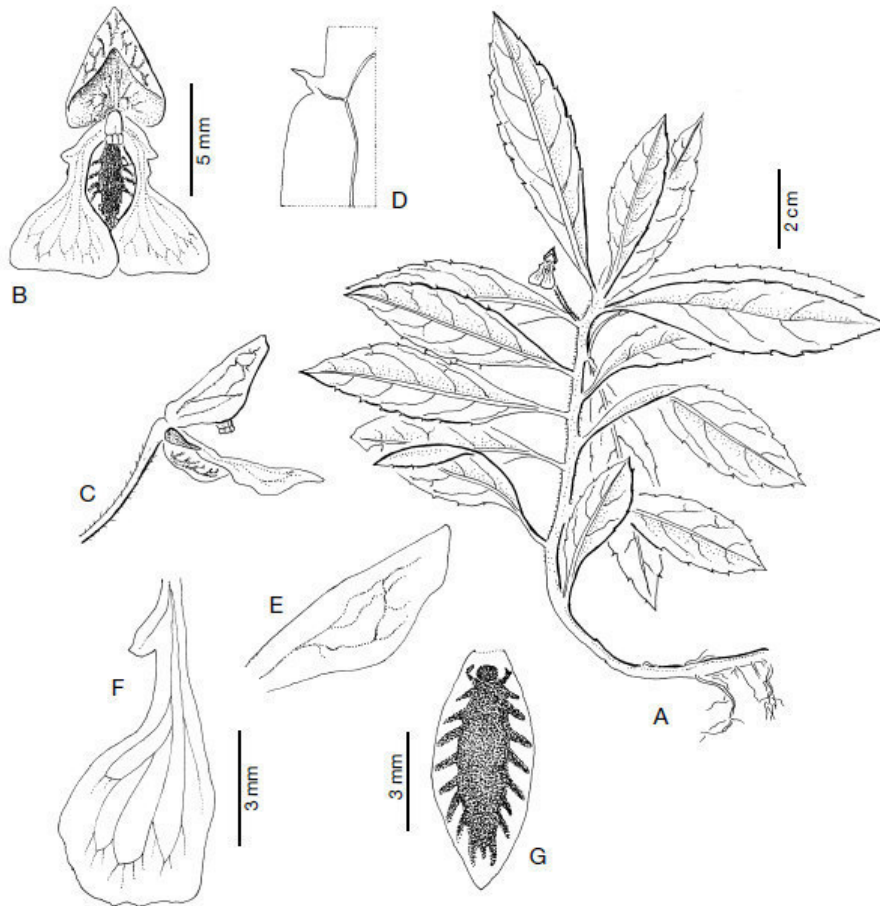


FIGURE 9. *Impatiens rivularis* Eb. Fisch., Wohlhauser & Rahelivololona: **A**, habit; **B**, flower, anterior view; **C**, flower, lateral view; **D**, leaf margin; **E**, dorsal petal; **F**, lateral united petals; **G**, lower sepal. (Purro & Wohlhauser 1018, NEU).

HABITAT— Montane evergreen forest, in streams, growing on stones.

DISTRIBUTION— Madagascar, only known from the type collection.

Impatiens rivularis is related to *I. ivohibensis* H. Perrier, but differs in the narrower dorsal petal, the ovate lower sepal, the longer and acuminate upper lateral petal and the pilose stems. *Impatiens ivohibensis* is restricted to the Pic d'Ivohibe in Central Madagascar.

Chapter 4

Balsaminaceae. In: Goodman, S.M. & Benstead, J.P. (eds.): The Natural History of Madagascar

This chapter has been published as:

Rahelivololona, E.,¹ Fischer, E.² & Wohlhauser, S.³ (2003): Balsaminaceae. In: Goodman, S.M. & Benstead, J.P. (eds.): The Natural History of Madagascar. The University of Chicago Press: 402-409.

¹ Parc botanique et zoologique de Tsimbazaza, BP 4096 Antananarivo (Madagascar), prota.madagascar@dts.mg

² Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany), efischer@uni-koblenz.de

³ Institut de Botanique, Université de Neuchâtel, Chantemerle 18, CH-2007 Neuchâtel, Suisse

Balsaminaceae

Balsaminaceae (two genera in the world) is a moderate-sized family of annual or perennial herbs or shrublets, mostly sciaphilous hygrophytes or epiphytes, that is basically Paleotropical in its distribution. The monospecific genus *Hydrocera* (Grey-Wilson 1981) from Indo-Malaysia is an erect marsh plant and differs from *Impatiens* by floral characters (its lateral free petals and its indehiscent berry).

Impatiens is easily recognized by its breakable and watery, semitranslucent upper stems, glandular toothed leaves (alternate to verticillate), peculiar irregular flowers, and explosive dehiscent capsule. This genus probably comprises something on the order of 1000 species and is diversified in southern India (Bhaskar 1975), the southeastern Himalayan zone, Africa (109 species; Grey-Wilson 1980), Madagascar (150 species), and southeastern Asia; some species extend to the

temperate zone of North America and Eurasia. In parallel, these "*Impatiens* hotspots" are associated with high levels of mostly local endemism. Some authors recognized two other monospecific genera (*Semeiocardium* from Indo-Malaysia and *Impatientella* from Madagascar), now better included in *Impatiens*. *Impatientella* was described by Perrier de la Bathie (1927) on the basis of its peculiar reproduction biology (cleistogamy, now documented for other species) and anther morphology.

Impatiens flowers are very diverse in shape (lower sepal with nectary-tipped spur or navicular without any spur) and color (sometimes even translucent), and these features have made them very well known among horticulturists. In contrast, they are known as a "terror for botanists" because of their fragile structure and very variable morphology. Apart from its floral diversification, this genus exhibits morphological variations (annual, perennial rhizomatous or tuberous, terrestrial, epiphytic or aquatic) that seemingly enable it to occur in a broad assortment of ecological niches (Grey-Wilson 1980).

Impatiens exhibit strong analogies with orchids associated with floral morphology (enormous diversity and androecium position), floral ontogeny (resupination), and diversified reproductive biology. The enormous diversification and speciation of *Impatiens* probably stem from the existence of various reproduction syndromes (some allowing autogamy controlled by environmental factors) or from the peculiar floral dimorphism (co-occurrence of small cleistogamous, fertile flowers with large open, often sterile ones).

Importance in the Malagasy Vegetation

In the Madagascar region, more than 150 species probably occur, including at least 2 in the Comoro Islands, 1 in the Seychelles, and 3 introduced ornamentals in Mauritius and La Reunion (Bossier et al. 1979). The family Balsaminaceae has yet to be treated in the *Flore de Madagascar et des Comores*. Nevertheless, recent studies on the Malagasy *Impatiens* (Fischer et al. 2003) have revealed about 50 new species and underlined the need for local biological and ecological studies in order to understand the species limits of the locally occurring *Impatiens*.

Most species of *Impatiens* are found in eastern humid (Andohahela, Ranomafana, Mangoro, Zahamena, Mananara, Masoala) or rainy high-elevation regions

(Andringitra, Betsileo, Vakinankaratra, Imerina, Tampoketsa Ankazobe, and Montagne d'Ambre, and Karthala in the Comoro Islands). The mountains of the northern highlands exhibit an impressive diversity of *Impatiens*. These include Marojejy with about 40 species (Koechlin et al. 1974), Manongarivo with about 20 species (Gautier 1999), and, according to recent collections, Anjanaharibe-Sud and the vast Tsaratanana Massif. A total of 27 species were found in Masoala during one mission (C. Purro pers. comm.), 10 of which were new to science. In the Western Domain, *Impatiens* are concentrated in locally wet microclimates (mostly orogenic), but some tuberose species have developed specific adaptations to very dry climates, as in the karstic Ankarana Massif (Bardot-Vaucoulon 1997) and the Montagne des Français.

Impatiens do not appear to play an important role in the structure of Malagasy vegetation types, but they can be a conspicuous element at the local level (this related to their strong microendemism). As they are a predominant element of moist forest undergrowth (from litter to upper branches), their role as floristic indicators is probably underestimated. Nevertheless, our knowledge of the genus will be insufficient to identify species groups or indicator attributes until important systematic affinities and biogeographic questions (discussed later) can be answered.

Systematic Relationships and Phylogeographic Affinities

As studies of *Impatiens* are scarce, sporadic, and localized, the systematics of the group suffers from a lack of infrageneric "perspectives." This gap in knowledge also weakens phylogeographic hypotheses at a local or global scale. Despite this problem, some authors have insisted on the originality of the Malagasy *Impatiens* and discussed some global biogeographic aspects based on differences in karyology (Jones and Smith 1966; Zinov'eva-Stahevitch and Grant 1985), palynology (Huynh 1968, 1974), or reproductive biology (Arisumi 1980). The degree of regional endemism (Table 1) and the range of speciation processes active in *Impatiens* (autogamy, hybridization) favor the concept of a "species complex of neo-endemics" proposed by Grey-Wilson.

Perrier recognized four sections in the genus based on floral morphology: *Humboldtianae*, *Vulgares*, *Trimorphopetalum*, and *Impatientella* - some of these

subdivisions are quite artificial but nonetheless practical. The *Trimorphopetalum* group (including *Impatientella*) is recognized by its spurless flowers and one to two ovulate ovaries and is of special interest because it is restricted to Madagascar and about half of the island's *Impatiens* belong to this group. All native species occurring in Madagascar and the Comoro Islands are endemic. Further, it is clear that many species remain to be discovered and described. Table 2 follows the evolution of the number of described species.

Plant-Animal Interactions

On the basis of the peculiar morphology of *Impatiens* flowers, straight pollination syndrome certainly occurs; the strong odor of some species also favors this hypothesis. Grey-Wilson (1980) observed systematic pollination of *Impatiens* flowers by butterflies, moths, honeybees, and sun-birds but stressed the difficulty of distinguishing between casual and true pollinators. Moreover, he hypothesized two flower pollination types: the "flat" type (shallow longer sepal and long filiform spur) and the "funnel" type (deeply navicular or saccate lower sepal and cucullate dorsal petal).

TABLE 1: Regional endemism in Malagasy *Impatiens*

Scientific name		Distribution in Madagascar				
		Eastern Domain	Central Domain		Western Domain	
Number of taxon new taxa		Eastern region	S and Central highlands	Montagne d'Ambré	South and center	North satellite
		Sambirano				
Genus <i>Impatiens</i> Linné (at least 149 species-all endemic)						
Subgenus <i>Impatiens</i>						
1. Section <i>Humblotianae</i> (at least 10 species)						
1	<i>Impatiens amoena</i> H. Perr.			X		
2	<i>I. antongiliana</i> H. Perr.	X				
3	<i>I. bicaudata</i> H. Perr.				X	
4	<i>I. catati</i> Drake dei Castillo	X				
5	<i>I. danguyana</i> H. Perr.			X		
6	<i>I. eriosperma</i> H. Perr.			X		
7	<i>I. fuschoides</i> H. Perr.		X	X		
8	<i>I. fulgens</i> H. Perr.		X			
9	<i>I. humblotiana</i> H. Perr.	X				
10	<i>I. perrieri</i> H. Perr.					

Chapter 4 — The Natural History of Madagascar. Balsaminaceae

2. Section Vulgares (at least 59 species)						
	1	<i>Impatiens analavelensis</i> H. Perr.	X			X
	2	<i>I. ankaizinensis</i> H. Perr.			X	
	3	<i>I. anovens</i> H. Perr.	X			
	4	<i>I. auricoma</i> Baillon			Mayotte	
	5	<i>I. baroni</i> Baker			X	
	6	<i>I. bidentata</i> H. Perr.				X
	7	<i>I. bisaccata</i> Warburg				X
	8	<i>I. boinensis</i> H. Perr.				
	9	<i>I. bulbosa</i> Eb. Fischer & Rahelivololona				
	10	<i>I. comorensis</i> Baker				X
	11	<i>I. delicatula</i> Baillon				
	12	<i>I. discolor</i> H. Perr.				X
	13	<i>I. echinosperma</i> H. Perr.		X	X	X
	14	<i>I. firmula</i> Baker	X	X	X	
	15	<i>I. geniculata</i> H. Perr.				
	16	<i>I. lachnosperma</i> H. Pen.			X	
	17	<i>I. lantziana</i> Baillon			X	
	18	<i>I. longepedunculata</i> H. Perr.			X	
	19	<i>I. lokohensis</i> H. Perr.				X
	20	<i>I. longicalcarata</i> H. Perr.				
	21	<i>I. lyallii</i> Baker	X		X	X
	22	<i>I. majungensis</i> H. Perr.				
	23	<i>I. manaharensis</i> Baillon	X			
	24	<i>I. manongarivensis</i> H. Perr.		X		X
	25	<i>I. marojejiensis</i> Humbert		X		
	26	<i>I. masoalensis</i> H. Perr.	X			
	27	<i>I. marivorahonensis</i> Humbert				
	28	<i>I. percrenata</i> H. Perr.	X			
	29	<i>I. ramenensis</i> H. Perr.		X		
	30	<i>I. rudicaulis</i> H. Perr.	X			
	31	<i>I. rutenbergi</i> H. Perr.			X	
	32	<i>I. sacculata</i> H. Perr.				X
	33	<i>I. sacculifera</i> H. Perr.	X			X
	34	<i>I. sambiranensis</i> H. Perr.		X		
	35	<i>I. spathulifera</i> H. Perr.	X			
	36	<i>I. torenioides</i> H. Perr.	X	X		
	37	<i>I. tricarinata</i> H. Perr.		X		
	38	<i>I. trichocarpa</i> H. Perr.		X		
	39	<i>I. truncicola</i> H. Perr.				X
	40	<i>I. tsaratanensis</i> H. Perr.				X
	41	<i>I. tuberosa</i> H. Perr.				
	42	<i>I. venusta</i> H. Perr.				X
	43	<i>I. viguieri</i> H. Perr.	X			
	44	<i>I. vilersi</i> Cost & Poisson.	X	X		
1	45	<i>I. papillosa</i> Humbert ex Eb. Fischer & Rahelivololona	X			
2	46	<i>I. betsomangae</i> Eb. Fischer & Rahelivololona	X			
3	47	<i>I. fuscopilosa</i> Eb. Fischer & Rahelivololona	X			

Chapter 4 — The Natural History of Madagascar. Balsaminaceae

4	48	<i>I. purroi</i> Eb. Fischer, Wohlhauser & Rahelivololona	X			
5	49	<i>I. mindiae</i> Eb, Fischer, Wohlhauser & Rahelivololona	X			
6	50	<i>I. wohlhauseri</i> Eb. Fischer & Rahelivololona	X			
7	51	<i>I. gautieri</i> Eb. Fischer & Rahelivololona		X		
8	52	<i>I. sp.</i> Eb. Fischer & Rahelivololona	X			
9	53	<i>I. sp.</i> Eb. Fischer, Wohlhauser & Rahelivololona	X			
10	54	<i>I. sp.</i> Eb. Fischer & Rahelivololona	X			
11	55	<i>I. antsirananae</i> Eb. Fischer & Rahelivololona			X	
12	56	<i>I. bemarahensis</i> Eb. Fischer & Rahelivololona				X
13	57	<i>I. megalantha</i> Eb. Fischer & Rahelivololona	X			
14	58	<i>I. andohahelae</i> Eb. Fischer & Rahelivololona	X			
15	59	<i>I. emiliae</i> Eb. Fischer & Rahelivololona X	X			
Subgenus Trimorphopetalum						
3. Section Trimorphopetalum (at least 80 species)						
	1	<i>Impatiens albopustulosa</i> H. Perr.	X			
	2	<i>I. alveolata</i> H. Perr.		X		
	3	<i>I. amphibia</i> H. Perr.	X			
	4	<i>I. andringitrensis</i> H. Perr.		X		
	5	<i>I. inaperta</i> H. Perr.		X		
	6	<i>I. arachnoides</i> H. Perr.	X			
	7	<i>I. asperipes</i> H. Perr.	X			
	8	<i>I. asperipetala</i> H. Perr.			X	
	9	<i>I. atro-rubra</i> H. Perr.	X			
	10	<i>I. atrolineata</i> H. Perr.	X			
	11	<i>I. biophytoides</i> H. Perr.	X			
	12	<i>I. bullata</i> H. Perr.	X			
	13	<i>I. celatiflora</i> H. Perr.	X			
	14	<i>I. celligera</i> H. Perr.	X			
	15	<i>I. coursiana</i> H. Perr.		X		
	16	<i>I. decaryana</i> H. Perr.		X		
	17	<i>I. dorstenoides</i> Warburg		X		
	18	<i>I. elatostemoides</i> H. Perr.	X	X		
	19	<i>I. fontinalis</i> H. Perr.	X			
	20	<i>I. furcata</i> H. Perr.	X			
	21	<i>I. gibbosa</i> H. Perr.	X			
	22	<i>I. geniorum</i> H. Perr.				
	23	<i>I. granulifera</i> H. Perr.		X		X
	24	<i>I. humberti</i> H. Perr.		X		
	25	<i>I. ivohibensis</i> H. Perr.		X		
	26	<i>I. imbricata</i> H. Perr.				
	27	<i>I. justicioides</i> H. Perr.	X			
	28	<i>I. lugubris</i> H. Perr.	X			
	29	<i>I. luteo-viridis</i> H. Perr.		X		
	30	<i>I. macradamia</i> Baillon	X		X	

Chapter 4 — The Natural History of Madagascar. Balsaminaceae

31	<i>I. meeuseiana</i> H. Perr.			
32	<i>I. nasuta</i> H. Perr.			X
33	<i>I. pallidissima</i> H. Perr.			X
34	<i>I. parvigaleata</i> H. Perr.			X
35	<i>I. paucisemina</i> H. Perr.			X
36	<i>I. pellucidinerva</i> H. Perr.			X
37	<i>I. peperomioides</i> H. Perr.		X	
38	<i>I. prasiniflora</i> H. Perr.		X	
39	<i>I. recurvinervia</i> H. Perr.		X	
40	<i>I. rhinoceros</i> H. Perr.		X	
41	<i>I. rubrolineata</i> H. Perr.	X		
42	<i>I. scripta</i> H. Perr.	X		X
43	<i>I. subabortiva</i> H. Perr.			X
44	<i>I. subrubriflora</i> H. Perr.	X		
45	<i>I. substerilis</i> H. Perr.		X	X
46	<i>I. substipulata</i> H. Perr.		X	X
47	<i>I. triandra</i> H. Perr.			X
48	<i>I. trichosperma</i> H. Perr.	X		
49	<i>I. urticoides</i> H. Perr.			X
50	<i>I. vesiculifera</i> H. Perr.	X	X	
	<i>I. falculaeformis</i> Humbert ex Eb.			
16	51 <i>Fischer & Rahelivololona</i>		X	
	<i>I. multilineolata</i> Humbert ex Eb.			
17	52 <i>Fischer & Rahelivololona</i>		X	
	<i>I. subpeltata</i> Eb. Fischer &			
18	53 <i>Rahelivololona</i>	X		
	<i>I. ombrophila</i> Humbert ex Eb.			
19	54 <i>Fischer & Rahelivololona</i>	X		
	<i>I. atrovenosa</i> Eb. Fischer &			
20	55 <i>Rahelivololona</i>	X		
	<i>I. capuroniana</i> Humbert ex Eb.			
21	56 <i>Fischer & Rahelivololona</i>		X	
	<i>I. cerasifera</i> Humbert ex Eb.			
22	57 <i>Fischer & Rahelivololona</i>	X		
	<i>I. doanyanalensis</i> Humbert ex Eb.			
23	58 <i>Fischer & Rahelivololona</i>		X	
	<i>I. humillima</i> Humbert ex Eb.			
24	59 <i>Fischer & Rahelivololona</i>		X	
	<i>I. octonotata</i> Humbert ex Eb.			
25	60 <i>Fischer & Rahelivololona</i>		X	
	<i>I. penicillata</i> Humbert ex Eb.			
26	61 <i>Fischer & Rahelivololona</i>		X	
	<i>I. perciliolata</i> Eb. Fischer &			
27	62 <i>Rahelivololona</i>		X	
	<i>I. peltata</i> Eb. Fischer &			
28	63 <i>Rahelivololona</i>	X		
	<i>I. silviana</i> Eb. Fischer, Wohlhauser			
29	64 & <i>Rahelivololona</i>	X		
	<i>I. belaokoensis</i> Eb. Fischer &			
30	65 <i>Rahelivololona</i>	X		
	<i>I. callmanderi</i> Eb. Fischer,			
31	66 Wohlhauser & <i>Rahelivololona</i>	X		
	<i>I. bevontsirae</i> Eb. Fischer &			
32	67 <i>Rahelivololona</i>	X		

Chapter 4 — The Natural History of Madagascar. Balsaminaceae

33	68	I. sp. Eb. Fischer, Wohlhauser & Rahelivololona	X	
34	69	I. malcomberi Eb. Fischer & Rahelivololona		X
35	70	I. ranomafanae Eb. Fischer & Rahelivololona	X	
36	71	I. translucida Eb. Fischer & Rahelivololona	X	
37	72	I. purpureolucida Eb. Fischer, Wohlhauser & Rahelivololona	X	
38	73	I. sp. aff. ivohibensis Eb. Fischer, Wohlhauser & Rahelivololona	X	
39	74	I. albopurpurea Eb. Fischer & Rahelivololona	X	
40	75	I. navicula Eb. Fischer & Rahelivololona		X
41	76	I. sp. Eb. Fischer & Rahelivololona spec. nov.		X
42	77	I. sp. aff. biophytoides Eb. Fischer & Rahelivololona spec. nov.	X	
43	78	I. sp. aff. arachnoides Eb. Fischer & Rahelivololona spec. nov.	X	
44	79	I. sp. aff. arachnoides Eb. Fischer & Rahelivololona spec. nov.	X	
45	80	I. sp. Eb. Fischer & Rahelivololona spec. nov.	X	
	?	<i>Impatiens</i> sp.		Comoro Islands
	?	I. sp.		Cornaro Islands
	?	I. sp.		La Réunion
	?	I. sp.		Mauritius

Flowers of the *Trimorphopetalum* group do not belong to any of these types, and pollinators are mostly unknown. Small flies have been observed visiting the flowers of *I. elatostemoides* (E. Fisher unpubl. data).

Some *Impatiens* fruits show a papillose structure that suggests animal fruit dispersal, but judging by the very efficient explosive dehiscence (throwing seeds around), only secondary seed dispersal (exochory) could be expected. This papillosed structure could also be interpreted as a key innovation to improve system sensitivity, as in the carnivorous *Drosera* papillose leaves. Seed dispersal by water is probably important for some species, especially for most of the *Trimorphopetalum* group that grow anchored to forest streambeds. Concerning *Impatiens* herbivory, the absence of data is somewhat singular, but *Impatiens* flowers and leaves frequently show signs of insect consumption.

Local Uses and Economic Importance

Flowers of *I. aff. baroni* are used to dye fingernails a yellow-orange color in the Betsileo area. Concerning medicinal uses, *I. baroni* is used to treat gonorrhoea or as a diuretic in decoction (Heckel 1910; Pernet 1957). One *Trimorphopetalum* species, named *famelona* in the Tolagnaro area, is apparently used in combination with other plants to treat mental illness.

Numerous people on Madagascar cultivate *Impatiens* in home gardens and sometimes sell them as ornamentals. Given the ease in cultivating these plants, this economic potential is underexploited. *Impatiens* could be a group worth considering in the valuation of biodiversity at a local and national level. Prospective feasibility studies should be initiated to propose nursery projects targeted on some species.

TABLE 2: The evolution of estimates of species diversity in Malagasy *Impatiens*

References	Number of <i>Impatiens</i> sensu lato species recognized	Number of species in <i>Trimorphopetalum</i> group
Warburg and Reiche (1895), Warburg (1897b), Costatin and Poisson (1907)	23	1
Perrier de la Bâthie (1933b, 1934b, 1948b)	83	48
Humbert and Perrier de la Bâthie (1955), Humbert (1956)	105	50
Fischer et al. (2003)	150 (45 new)	79 (29 new)

SOURCE: Derived from Fischer et al. (2003).

Chapter 5

New taxa of *Impatiens* (Balsaminaceae) from Madagascar III

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2004): New taxa of *Impatiens* (Balsaminaceae) from Madagascar III. *Adansonia* sér. 3, 26: 37-52.

¹ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany), efischer@uni-koblenz.de

² Parc botanique et zoologique de Tsimbazaza, BP 4096 Antananarivo (Madagascar), prota.madagascar@dts.mg

Abstract

The new endemic species *Impatiens renae*, *I. kuepferi*, *I. wohlhauseri*, *I. sidae-formis*, *I. vellela*, *I. mayae-valeriae* and *I. loki-schmidtiae* belonging to subgenus *Impatiens* and *I. stefaniae* from subgenus *Trimorphopetalum* are described and illustrated. Five nomina nova are proposed: *Impatiens elisettae* for *I. longicalcarata* H. Perrier, *I. grey-wilsonii* for *I. longicalcarata* (G.M. Schulze & Wilczek) Grey-Wilson, *I. delabathiana* for *I. trichocarpa* H. Perrier, *I. oniveensis* for *I. rubrolineata* H. Perrier and *I. lemuriana* for *I. gibbosa* H. Perrier.

Key words Balsaminaceae, *Impatiens*, Madagascar.

Résumé

Nouveaux taxons dans le genre Impatiens (Balsaminaceae) à Madagascar. III. Les espèces nouvelles endémiques Impatiens renae, I. kuepferi, I. wohlhauseri, I. sidaeformis, I. vellela, I. mayae-valeriae, I. loki-schmidtiae, appartenant au sous-genre Impatiens, et I. stefaniae du sous-genre Trimorphopetalum sont décrites et illustrées.

Cinq nouveaux noms sont proposés: *Impatiens elisettae* pour *I. longicalcarata* H. Perrier, *I. grey-wilsonii* pour *I. longicalcarata* (G.M. Schulze & Wilczek) Grey-Wilson, *I. delabathiana* pour *I. trichocarpa* H. Perrier, *I. oniveensis* pour *I. rubrolineata* H. Perrier et *I. lemuriana* pour *I. gibbosa* H. Perrier.

Mots clés Balsaminaceae, *Impatiens*, Madagascar.

Introduction

The genus *Impatiens* L. is highly diversified in Madagascar and shows a pattern of distribution similar to that of the palms (Dransfield & Beentje 1995), in which the number of species in Madagascar exceeds that of tropical Africa.

Approximately 120 species of *Impatiens* are known (Grey-Wilson 1980; Hallé & Louis 1989; Bos 1990; Fischer 1997; Cheek & Fischer 1999; Frimodt-Møller & Grey-Wilson 1999; Fischer *et al.* 2003), whereas in Madagascar, an estimated 170-190 species occur, with probably many new taxa that remain to be discovered.

During the preparation of a revision of *Impatiens* in Madagascar and the Comoro Islands, many new species have been described (see Fischer & Rahelivololona 2002; Fischer *et al.* 2003). One of the most species-rich areas seems to be the Masoala peninsula, where more than 40 taxa have been recorded. In a forthcoming paper the diversity of *Impatiens* in this area is analyzed. In the present paper, some conspicuous new species of *Impatiens* subg. *Impatiens* and one species of subg. *Trimorphopetalum* are described. Due to several later homonyms, five nomina nova are proposed.

A short history of exploration of *Impatiens* in Madagascar as well as details on terminology and measurements were provided by Fischer & Rahelivololona (2002).

Impatiens* subg. *Impatiens

Lower sepal with distinct spur.

Impatiens renae* Eb.Fisch. & Rahelivololona, *sp. nov.

Ab Impatienti humblotianae differt forma laminae, forma sepali inferioris et numero nectariorum extrafloralium.

TYPUS— *Miller & Lowry 4032*, Madagascar, Prov. Antsiranana, Réserve Naturelle de Marojejy, along the trail to the summit of Marojejy Est, NW of Mandena, wet, evergreen forest between the second and third camp, 1100-1200 m, 13 Feb. 1989 (holo-, TAN; iso-, P, MO).

Succulent herb, 15-30 cm tall, entirely glabrous. Leaves alternate, petiole 15-30 mm long, with 5-10 pairs of c. 2 mm long extrafloral nectaries, lamina succulent, rigid, reddish below with reticulum of tertiary veins, pale green above, ovate-lanceolate, base rounded-cordate, apex acuminate, 60-90 x 20-25 mm, margin with 6-9 pairs of fimbriae.

Inflorescence axillary, with 1-2(-3) flowers per leaf axill, pedicel up to 42-45 mm long, reddish. Flower entirely bright red with bluish to violet anthers and pollen, glabrous. Lateral sepals broadly ovate, acuminate, 4-5 x 2-2.5 mm. Lower sepal c. 15 mm long and 10-3 mm wide, with 30-32 mm overall length, spur spirally curved. Dorsal petal cucullate, 15 x 12 mm, dorsal crest with spur-like apicule. Lateral united petals 12-14 mm long, upper petal c. 5-8 x 6 mm, lower petal c. 5 x 3-5 mm. Anthers c. 8 mm long. Ovary c. 6-7 mm long. Fruit up to 10 mm long.— Fig. 1.

HABITAT— Submontane to montane rainforest, from (300-)1000 to 1700 m a.s.l.

DISTRIBUTION— Madagascar, only known from Marojejy Massif.

ETYMOLOGY— Dedicated to Mrs Rena-Stuck/Hildesheim on the occasion of her birthday.

Impatiens renae appears to be closely related to *Impatiens humblotiana* Baill., but differs in the shape of leaves which bear a cordate to rounded base, the number of extrafloral nectarines on petiole (5-10 pairs in *I. renae* and 1-2 pairs in *I. humblotiana*) and in the shape of the lower sepal with spur which is only gradually tapered towards spur. The plants from Marojejy are rather uniform and show no distinct variation. *Impatiens humblotiana* has a more southern distribution in the forests of eastern Madagascar. A forthcoming paper will deal with the Madagascan species related to *Impatiens humblotiana*.

PARATYPES— *Humbert 23524*, vallée de la Lokoho, Mont Beodroka au N de Maroambihy, 300 m, 17-22 Mar. 1949 (P); *23680*, pentes orientales du Massif de Marojejy, à l'ouest de la rivière Manantenina, affluent de la Lokoho, 1500-1700 m, 25-26 Mar. 1949 (P); *23690*, pentes orientales du

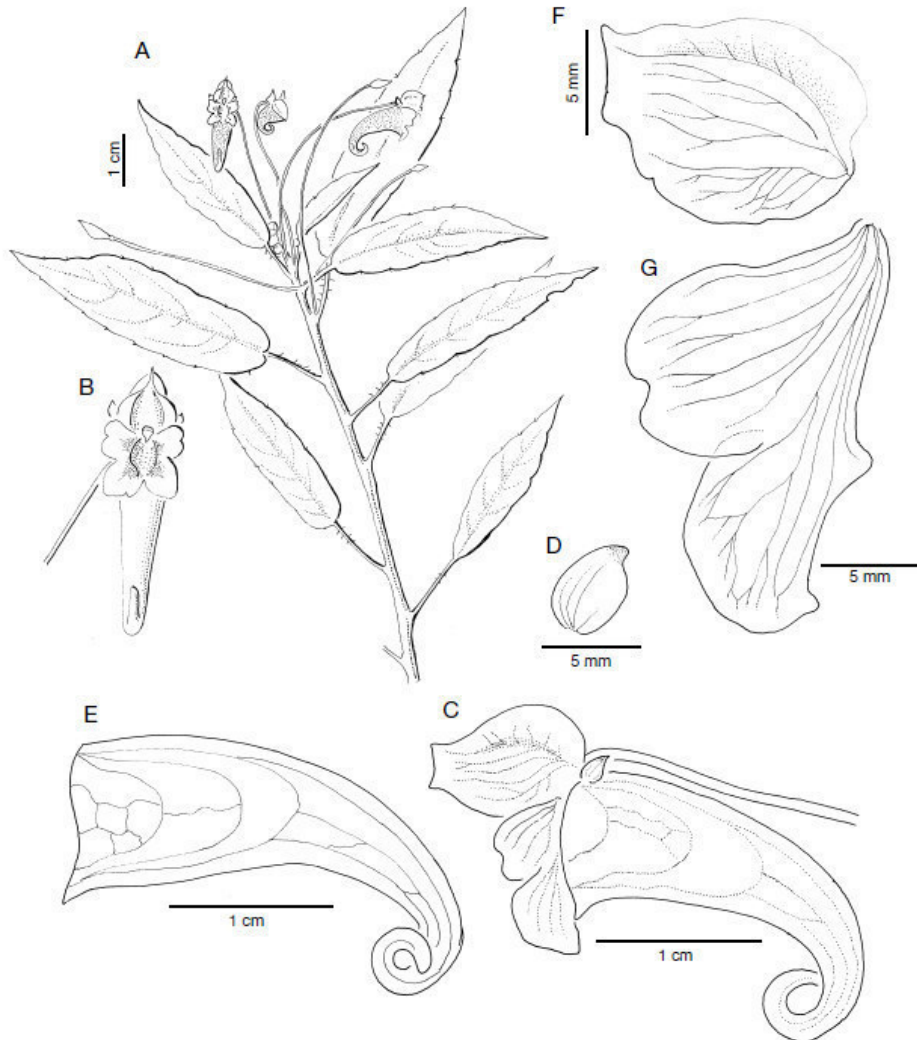


FIGURE 1. *Impatiens renae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, lateral sepal; **D**, **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Miller & Lowry 4032* (P).

Massif de Marojejy (Nord-Est), à l'ouest de la rivière Manantenina, affluent de la Lokoho, sylvie à lichens sur gneiss et quartzite, 1500-1700 m, 25-26 Dec. 1949 (P); *Randrianasolo 100*, Antsiranana, Réserve Nationale Marojejy, sentier qui mène au 3e Camp, au-dessus du village de Manantenina, 1150-1300 m, 26 Mar. 1990 (P, TAN); *Rasoavimbahoaka 569*, Antsiranana, Marojejy RNI, Sambava, environ à 13,5 km au nord-est de Maroambihy et à 9,5 km au nord-est du fokotany de Mandena, 1200 m,

29-31 Mar. 1995 (P, TAN, MO); *Wohlhauser & Pfund 1041*, Antsiranana, Marojejy Réserve Intégrale, camp 2-camp 3, on ridge, montane lichens sclerophyllous forest, mainly epiphyte, 1050 m, 27 Nov. 1995 (NEU, TAN).

Impatiens kuepferi Eb.Fisch. & Rahelivololona, **sp. nov.**

Impatiens wohlhauseri affinis, sed forma foliorum, forma sepalorum lateralium, forma sepalii inferioris et calcari valde differt.

TYPUS— *Rahelivololona, Saola & Scenario 137*, Madagascar, Prov. Toamasina, Masoala Peninsula, Ambanizana-Ambohitsitondroina, sous bois avant le campement et vers le sommet sur rochers, 500 m, 18. Feb. 2002 (holo-, TAN; iso-, NEU).

Perennial herb with creeping rhizome, glabrous. Stem up to 40 cm tall, greenish. Leaves alternate, petiole 10-13 mm long, with 1-2 pairs of obtuse extrafloral nectaries, lamina lanceolate, 135-148 x 36-44 mm, acuminate at apex, margin with 22-23 pairs of fimbriae.

Inflorescence axillary, clustered with 1-3 flowers, pedicel c. 20 mm long. Flower with greenyellowish dorsal petal, lateral petals red and pink at apex, with yellow spots, spur pink-whitish.

Lateral sepals 4, outer pair broadly ovate, 8-9 x c. 5 mm, inner pair ovate-lanceolate, c. 8 x 3 mm. Lower sepal navicular, sparsely hairy outside, 12 x 6 mm, spur clavate, constricted below apex, c. 5 mm long, obtuse. Dorsal petal sparsely hairy, cucullate, 7-8 x 6-7 mm. Lateral united petals c. 18 mm long, upper petal acuminate, c. 7 x 4-5 mm, lower petal rounded, c. 12 x 7 mm. Anthers c. 3 mm long. Ovary 4 mm long. Fruit unknown.— Fig. 2.

HABITAT— Submontane rainforest.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Philippe Kuepfer, Institut de Botanique, Université de Neuchâtel, outstanding botanist, for his research on *Impatiens*.

This species is nearly unique among Madagascan *Impatiens* as it bears four lateral sepals. The only apparent relative seems to be *I. wohlhauseri*, described below, which has also four lateral sepals but differs in leaf shape and the shape of the lateral sepals and lower sepal and spur. Both species occur on the Masoala Peninsula. Taxa with four lateral sepals have not been reported previously from Madagascar, but are known from Africa (e.g., *I. fischeri* Warb., *I. teitensis* Grey-Wilson, *I. tinctoria* A. Rich., *I. quadrisejala* Wilczek & Schulze).

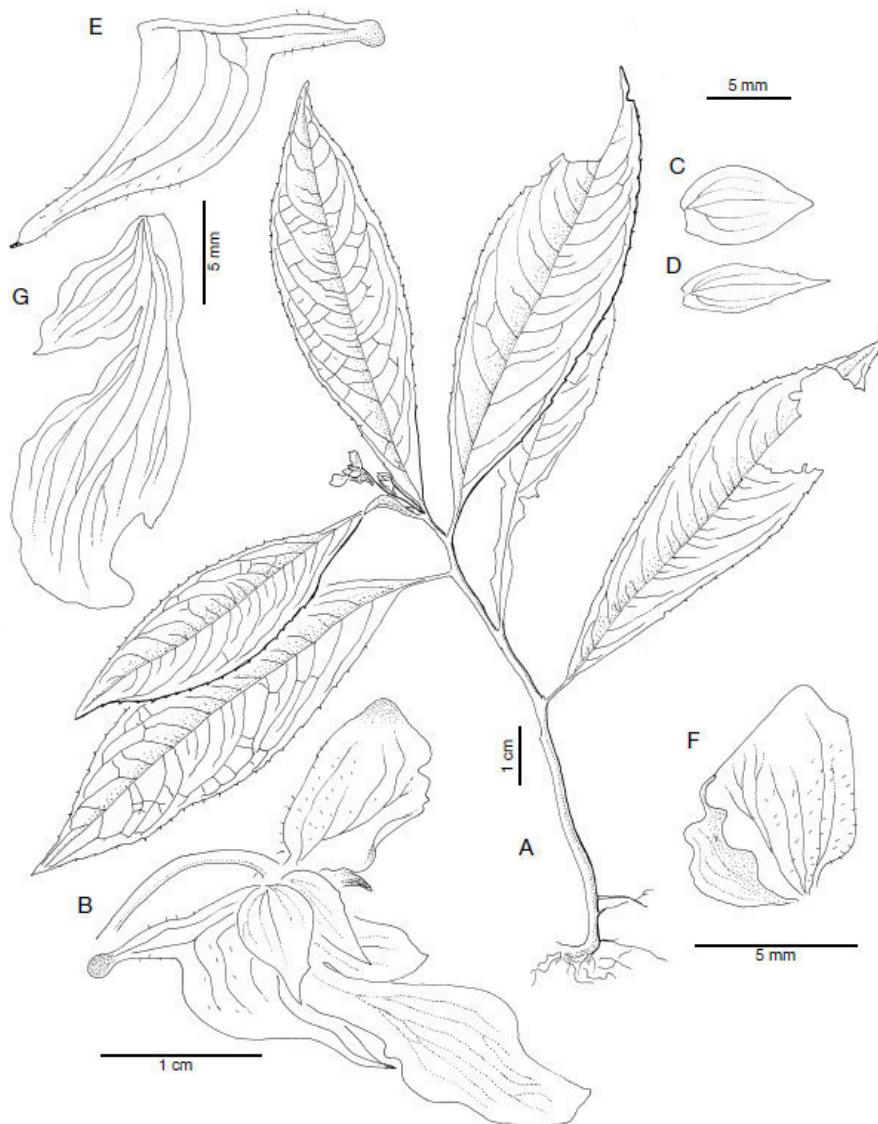


FIGURE 2. *Impatiens kuepferi* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, **D**, lateral sepals; **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Rahelivololona*, *Saola* & *Scenario 137* (TAN).

Impatiens wohlhauseri Eb.Fisch. & Rahelivololona, **sp. nov.**

Impatiens kuepferi affinis, sed forma foliorum, forma sepalorum lateralium, forma sepali inferioris et calcaris valde differt.

TYPUS— *Malcomber, Andriatsifera, Gerard & Moise 2715*, Madagascar, Prov. Toamasina, Masoala Peninsula, south of Ambanizana, Andranobe permanent plot, growing in forest gaps, 15°30'30"S 49°57'30"E, 300-400 m, 18-24 Mar. 1994 (holo-, TAN; iso-, MO, P).

Perennial herb up to 50 cm tall, entirely glabrous. Stem succulent. Leaves alternate, upper face dark green, lower face light green, petiole 15-30 mm long, lamina oblong-ovate, base attenuate-acuminate, apex rounded-obtuse at, becoming larger towards apex, 120-190 x 30-53 mm, margin with 8-9 pairs of fimbriae. Inflorescence with distinct axillary peduncle, up to 7-15 mm long, bracts linear-lanceolate, 3-4 x 1.5 mm, pedicel 32-40 mm long. Flower white, with pink lateral united petals. Lateral sepals 4, larger sepal ovate, distinctly acuminate, *c.* 7 x 3-4 mm, smaller sepal lanceolate, acuminate, 3-4 x 1-1.5 mm. Lower sepal 9-10 x 3-4 mm large, spur straight to slightly curved, with obtuse apex and indistinct furrows, 3 □ 1.5 mm. Dorsal petal with a distinct crest, *c.* 8 x 6-7 mm high. Lateral united petals *c.* 12 mm long, upper petal *c.* 3 x 2 mm, obtuse, lower petal *c.* 7 x 5 mm, obtuse. Anthers 3-4 mm long. Ovary *c.* 4 mm long. Fruit unknown.— Fig. 3.

HABITAT— Lowland to submontane rainforest.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Sebastien Wohlhauser, Institut de Botanique, Université de Neuchâtel, who studied the flora of Manongarivo and also collected numerous *Impatiens* on the Masoala Peninsula.

This is the second species from Madagascar with four lateral sepals (see discussion under *I. kuepferi*).

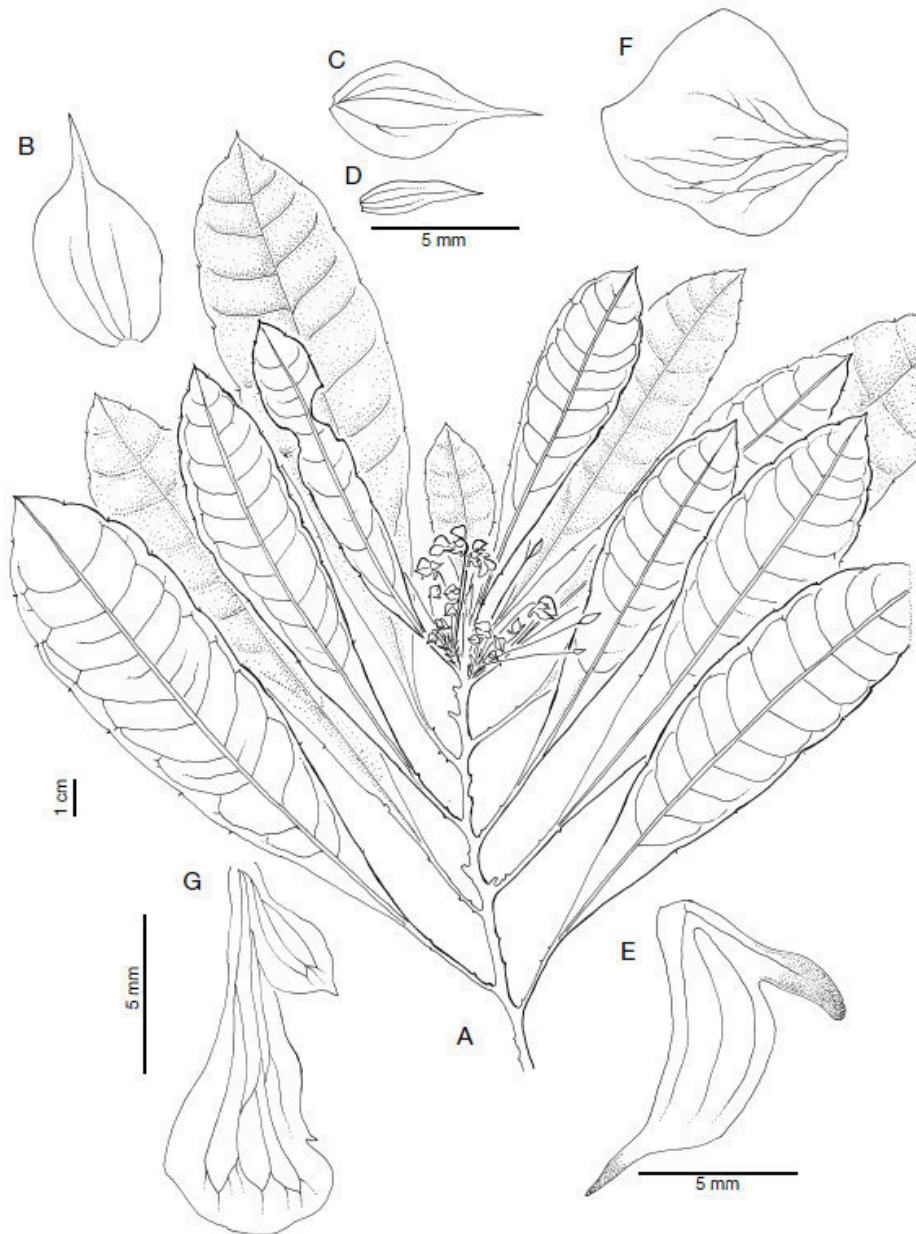


FIGURE 3. *Impatiens wohlhauseri* Eb.Fisch. & Rahelivololona: **A**, habit; **B-D**, lateral sepals; **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Malcomber, Andriatsifera, Gerard & Moise 2715* (P).

***Impatiens sidaeformis* Eb.Fisch. & Rahelivololona, sp. nov.**

Ab Impatiente sacculifera differt indumento foliorum petiolorumque et floribus minoribus.

TYPUS— *Rasoavimbahoaka* 704, Madagascar, Prov. Antsiranana, Andapa, Doany, Betsomanga, environ 11,2 km à vol d'oiseau au sud-est (14°) de Doany et à 7,5 km au nord-est (1°) d'Ambalamanasy II, entre la rivière d'Ampandrana et Betsomanga, au nord de Marojejy, 14°27'S, 49°34'E, 920-1040 m, 15-29 May 1995 (holo-, TAN; iso-, MO, P).

Prostrate to ascending richly branched herb up to 30 cm tall, densely covered with ferruginous brownish multicellular hairs. Stem rooting at nodes, densely pilose at least in upper parts. Leaves alternate, distant, petiole 50-100 mm long, with 1-4 pairs of extrafloral nectaries, lamina ovate or elliptic, base attenuate and rounded, apex acuminate, 45-50 x 15-20 mm, margin with 11-13 pairs of fimbriae. Inflorescence with 1-2 axillary flowers, bracts linear-lanceolate, acuminate, c. 4 x 0.8 mm. Pedicel 38-45 mm long. Flower white with yellow spur. Lateral sepals lanceolate-acuminate, c. 2 mm long, pilose. Lower sepal sparsely pilose, navicular, apiculate, c. 7 mm long, spur short and recurved, c. 2 mm long. Dorsal petal cucullate, with an apicule at apex, dorsal crest straight, descending towards base, sparsely pilose. Lateral united petals 13 mm long, upper petal bilobed, acuminate, with upper lobe smaller, lower petal bilobed.

Ovary glabrous. Fruit fusiform, c. 10 x 3-4 mm.— Fig. 4.

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Resembling a *Sida* (Malvaceae). The species appears to be closely related to *Impatiens sacculifera* H. Perrier, which is known from the bay of Antongil. However, *I. sidaeformis* differs in having densely tomentose indumentum on the stems and leaves (subglabrous in *I. sacculifera*), longer peduncles and generally smaller flowers with different shape of the lateral united petals.

Impatiens vellela Eb.Fisch. & Rahelivololona, **sp. nov.**

Impatiens mindiae affinis, sed forma petali dorsali et callo petali laterali inferioris valde differt.

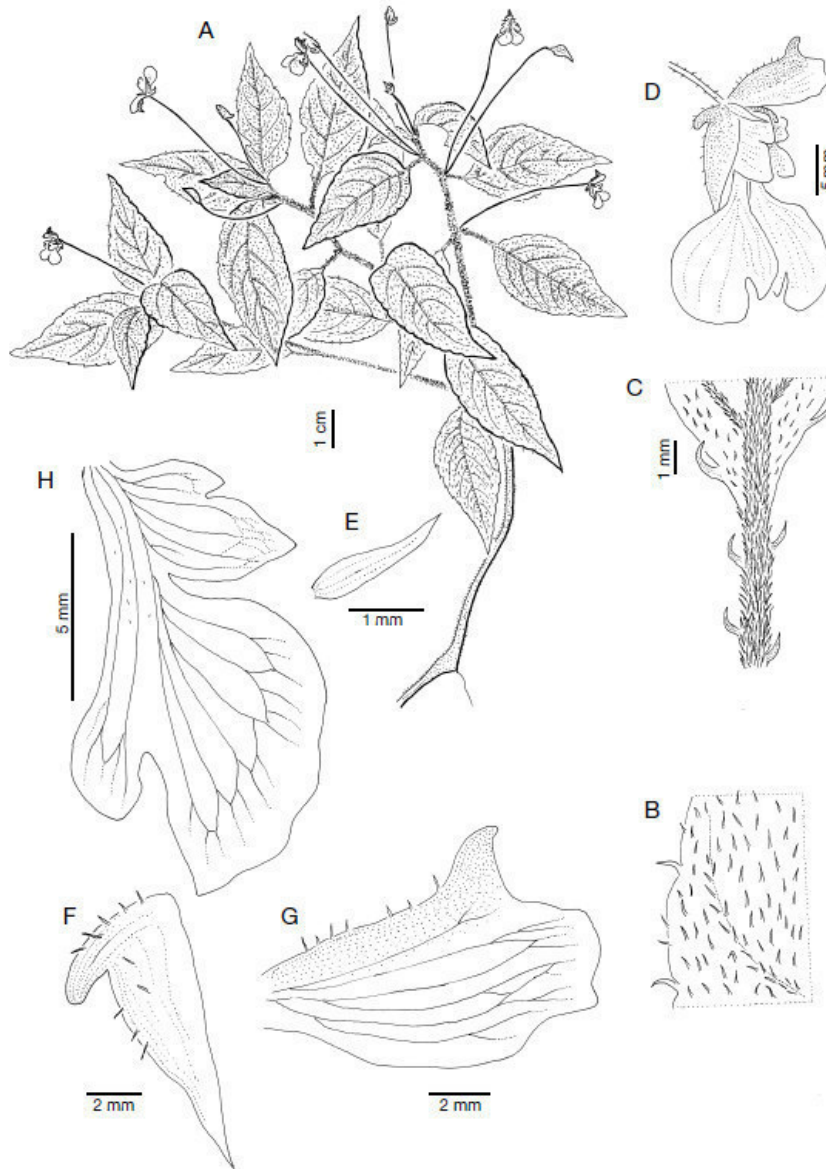


FIGURE 4. *Impatiens sidaeformis* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, detail of lamina; **C**, leaf base with petiole; **D**, flower, lateral view; **E**, lateral sepal; **F**, lower sepal and spur; **G**, dorsal petal; **H**, lateral united petals. *Rasoavimbahoaka* 704 (P).

TYPUS— *Rahelivololona*, *Saola & Scenario* 142, Madagascar, Prov. Toamasina, Masoala, Ambanizana-Ambohitsitondroina, montée vers sommet Ambohitsitondroina, vers 750-900 m, sous bois le long du ruisseau sur rocher ou épiphyte 2 m au-dessus d'un arbre, 19 Feb. 2002 (holo-, TAN; iso-, NEU).

Perennial herb, glabrous. Stem up to 50 cm tall. Leaves coriaceous and succulent, lower surface light green, upper surface green-reddish, petiole reddish and green, 12-17 mm long, with 2-3 pairs of extrafloral nectaries, lamina ovatelanceolate, apex acuminate, 55-85 x 17-25 mm, margin with (7-)8(-9) pairs of fimbriae. Inflorescence axillary, with a short peduncle, up to 3-4 mm long, bracts 2-3 x 0.8-1 mm, pedicel 30-50 mm long. Flower white to white-pink, lateral petals with yellow and red callus. Lateral sepals 2, ovate, acuminate, 5-6 x c. 3 mm. Lower sepal navicular, c. 13 mm long, spur curved, obtuse, 7-8 mm long. Dorsal petal cucullate, with a very broad and lobed lower margin, resembling a jelly-fish, 10-12 x 11-12 mm. Lateral united petals with an elongate callus, 23-24 mm long, upper petal bilobed, 11-12 x c. 6 mm, lower petal bilobed, c. 15 x 10 mm, inner lobe 5-6 x c. 4 mm. Anthers c. 6 mm long. Ovary 6-7 mm long. Fruit unknown.— Fig. 5.

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— The dorsal petal resembles a jelly-fish (Malagasy name “vellela”).

The species is related to *Impatiens mindiae* Eb. Fisch., Wohlhauser & Rahelivololona, but differs in having a dorsal petal with a distinct margin giving the impression of a jelly-fish, and in the shape of the lateral sepal and the presence of a callus on lower lateral petal. Both species are restricted to the Masoala Peninsula.

Impatiens mayae-valeriae Eb.Fisch. & Rahelivololona, **sp. nov.**

Impatiens manongarivensi affinis, sed floribus valde majoribus et forma sepalorum et petalorum differt.

TYPUS— Schatz, Goldblatt, Rakotozafy & Randrianasolo 2683, Madagascar, Prov. Toamasina, Réserve Intégrale 1 Betampona, approx. 3 km N of Fotsimavo, 17°55'S, 49°13'E, 500 m, 5 Apr. 1989 (holo-, TAN; iso-, P, BR, MO).

Chapter 5 — New taxa from Madagascar. III

Perennial herb with woody rhizome, entirely glabrous. Stem woody at base, up to 100 cm tall. Leaves alternate, distant, dark green above, light green below, petiole 2-3 cm long, with 1-4 obtuse extrafloral nectaries, c. 1 mm long, lamina oblong to oblanceolate, base attenuate and apex acuminate, 130-170 x 30-60 mm, margin with 13-15 pairs of fimbriae. Inflorescence axillary, with 1 to 3 flowers, peduncle 1 mm long, bracts obovate, c. 7 x 2.5 mm, pedicel 45-50 mm long. Flower with sepals white with very slight pink tinge, petals pink with dark red spots at base, lower sepal with nectar spur whitish pink outside, reticulate magenta inside. Lateral sepals broadly ovate, acuminate, c. 17 x 8 mm. Lower sepal c. 23 mm long, 20 mm deep, with filiform, obtuse, slightly to distinctly curved spur up to 32-37 mm long. Dorsal petal cucullate, c. 20 mm long and 16 mm deep. Lateral united petals c. 42 mm long, upper petal bifid, c. 20 x 14 mm, lower petal c. 30 x 26 mm. Anthers 9-10 mm long. Ovary c. 10 mm long. Fruit unknown.— Fig. 6.

HABITAT— Submontane rainforest.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Maya Valerie Stromberg/Neuss on the occasion of her birthday.

Impatiens mayae-valeriae appears to be related to *I. manongarivensis* H. Perrier, *I. emiliae* Eb.Fisch. & Rahelivololona and *I. bathiei* Eb.Fisch. & Rahelivololona, but differs distinctly in its leafshape, the size of flowers and shape of its sepals and petals. *Impatiens mayae-valeriae* has a more southern distribution than the other species which are restricted to northern Madagascar (Manongarivo, Tsaratanana).

PARATYPE— *Andrianarisata 112*, Madagascar, Prov. Toamasina, Réserve Naturelle Intégrale de Betampona, piste principale, 17°55'S, 49°13'E, 210-410 m, 22 Apr. 1994 (P, TAN, MO).

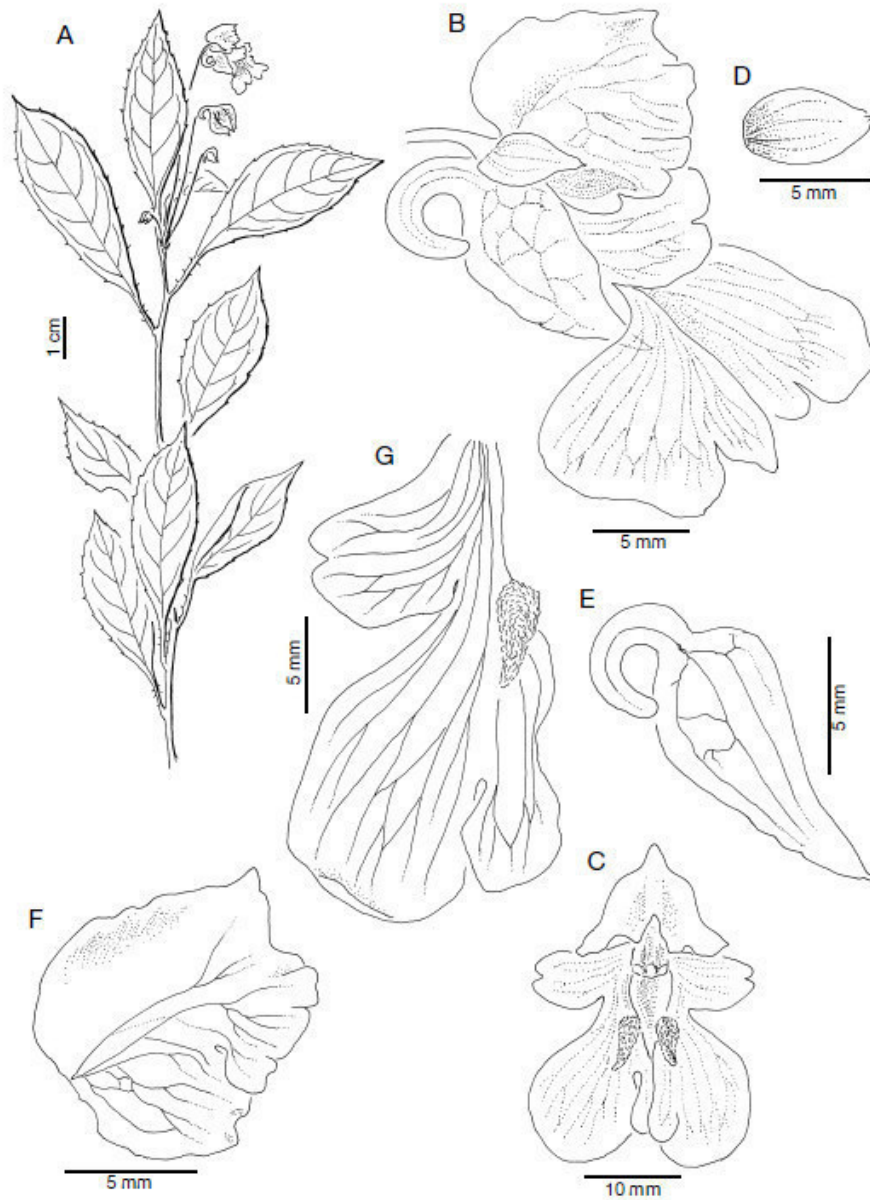


FIGURE 5. *Impatiens vellela* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, flower, frontal view; **D**, lateral sepal; **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Rahelivololona, Saola & Scenario 142* (TAN).

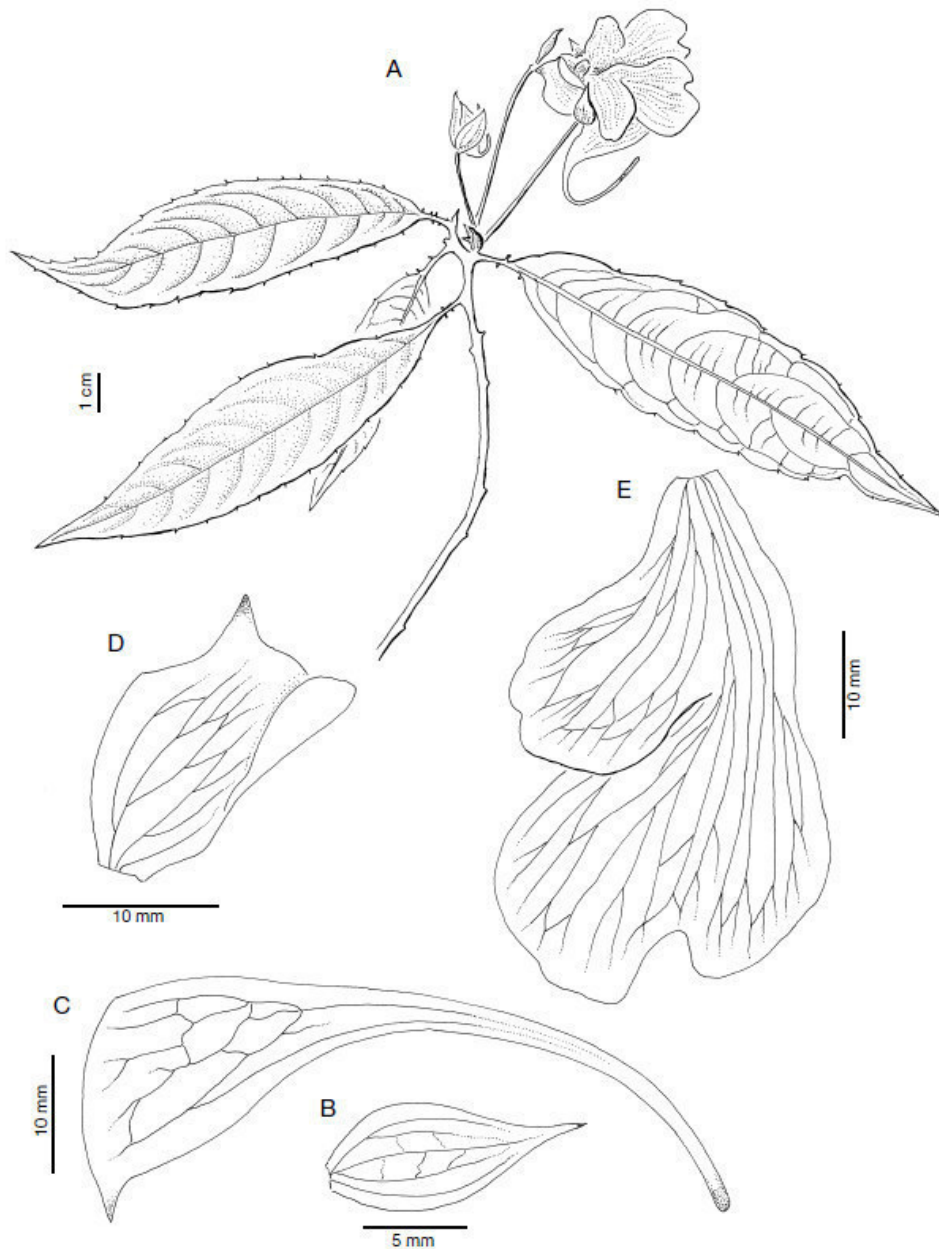


FIGURE 6. *Impatiens mayae-valeriae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, lateral sepal; **C**, lower sepal and spur; **D**, dorsal petal; **E**, lateral united petals. Schatz, Goldblatt, Rakotozafy & Randrianasolo 2683 (P).

Impatiens loki-schmidtiae Eb.Fisch. & Rahelivololona, **sp. nov.**

Ex affinitate Impatienti manongarivensi, sed pedicellis longis et nectariis extrafloralibus spinosis differt.

TYPUS— *Randriamampionona* 324, Madagascar, Prov. Toliara, Réserve Intégrale 11 Andohahela, Parcelle 1, vicinity of Eminiminy, 24°40'S, 46°48'E, 200-700 m, 4-24 May 1993 (holo-, TAN; iso-, P).

Perennial herb, densely pilose with multicellular, brownish hairs. Stem up to 100 cm tall. Leaves alternate, lanceolate-ovate, densely pilose, petiole 50-70 mm long, with 8-10 spine-like triangular extrafloral nectaries, lamina elliptic, base attenuate, apex acuminate, 85-130 x 38-55 mm, margin with 16-18 pairs of fimbriae. Inflorescence with single axillary flowers. Pedicel 75-95 mm long. Flower light red, whitish inside. Lateral sepals lanceolate, pilose, 4-5 x 1.5-2 mm. Lower sepal navicular, densely pilose outside, c. 10 x 6-10 mm, with a long filiform, pilose, curved spur c. 25-30 mm long. Dorsal petal with greenish crest and apicule, 15 mm long and 16-17 mm broad. Lateral united petals 23-25 mm long, upper petal bifid, c. 15 x 12-3 mm, lower petal 15-16 x 10-12 mm. Anthers 5-6 mm long. Ovary 5-7 mm long. Fruit 14-15 x 6-7 mm.— Fig. 7.

HABITAT— Submontane rainforest, on rocks.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— The species is dedicated to Loki Schmidt, renowned botanist and nature conserver, on the occasion of her 85th birthday.

Impatiens loki-schmidtiae is related to *Impatiens manongarivensis*, *I. emiliae* and *I. bathiei*, but can be easily distinguished by its long pedicels and the spine-like extrafloral nectaries on its petiole. It is the only representative of the group in southern Madagascar, while all other relatives occur in northern to eastern Madagascar (Manongarivo south to Toamasina).

PARATYPES— *Randriamampionona* 565, Toliara, Réserve Intégrale 11, Andohahela, Parcelle 1, southwest of Eminiminy, Manatavona River, 24°40'S, 46°48'E, 200-700 m, 9-26 Aug. 1993 (P, TAN, MO); *Du Puy, Du Puy, Rafamantanantsoa, Dransfield, Cheek & Cooke MB 527*, off Route Nationale XI, Andohahela Parcelle 1, path over Col Antanatana to Iminiminy, 24°44'S, 46°47'E, c. 800 m a.s.l., 7 Dec. 1989 (P, TAN, MO).

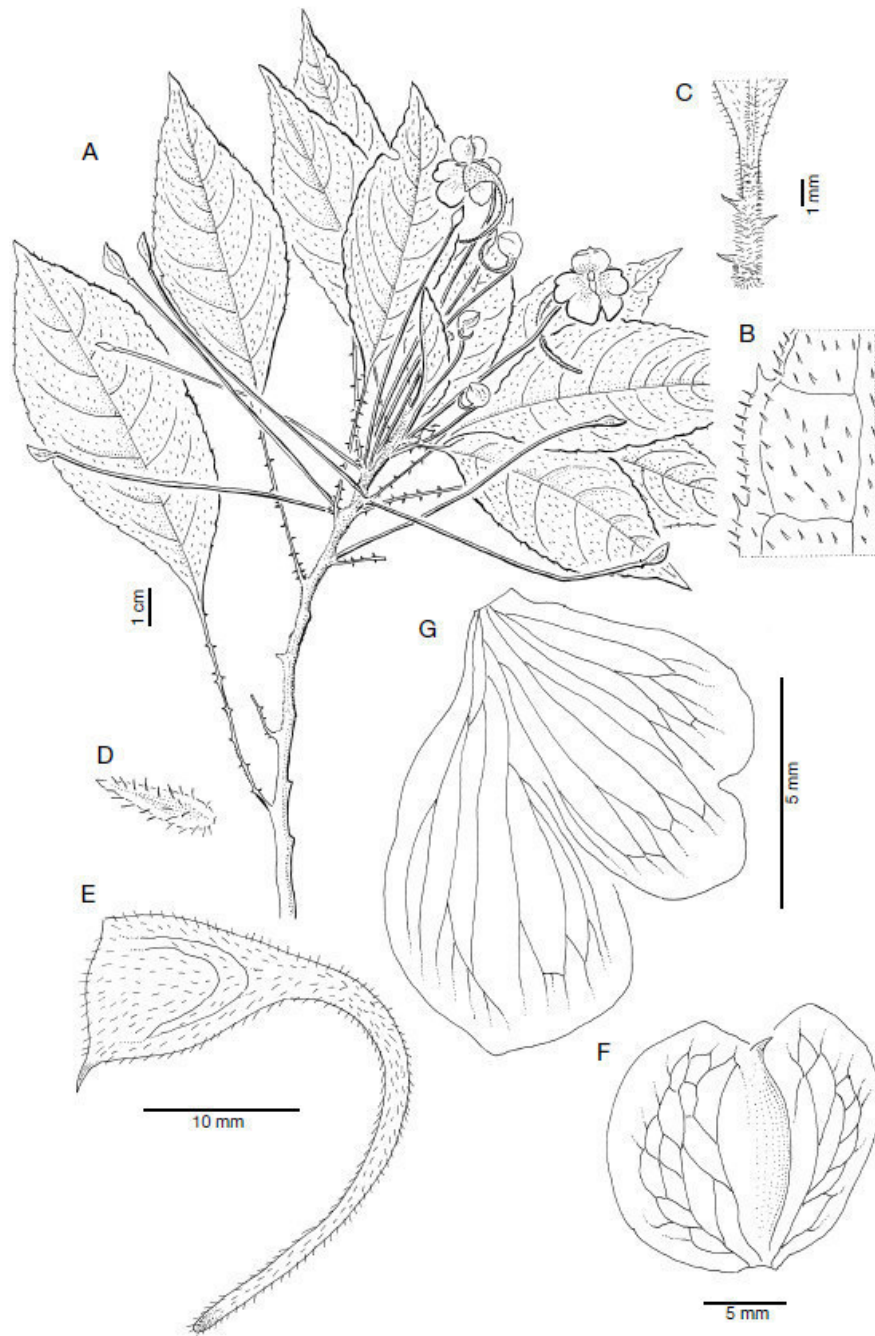


FIGURE 7. *Impatiens loki-schmidtiae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, detail of lamina; **C**, leaf-base and petiole; **D**, lateral sepal; **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Randriamampionona* 324 (P).

***Impatiens elisettae* Eb. Fisch., nom. nov.**

Impatiens longicalcarata H. Perrier, Mém. Acad. Sci. Paris, Sér. 2, 67, 2: 6 (1948), non *Impatiens longecalcarata* Tardieu, Not. Syst. 11: 184 (1944).

TYPUS— *Humbert 18333*, haute vallée du Sambirano, massif de Tsaratanana, vers 2000 m, Nov.-Dec. 1937 (holo-, P).

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Elisette Rahelivololona.

As the epithet *longicalcarata* of an East Asian species can be confused with *longicalcarata*, a new name had to be chosen for the Madagascan taxon according to article 53.3 of the St. Louis Code. *Impatiens elisettae* is related to *I. lokohensis* H. Humbert, *I. manongarivensis* H. Perrier, *I. mayae-valeriae* Eb.Fisch. & Rahelivololona and *I. loki-schmidtiae* Eb.Fisch. & Rahelivololona.

An African taxon, *Impatiens longicalcarata* (G.M. Schulze & Wilczek) Grey-Wilson had been raised to specific level. Here, another nomen novum is required, and the species is named in honour of Christopher Grey-Wilson who provided the first modern revision of *Impatiens* in Africa.

***Impatiens grey-wilsonii* Eb. Fisch., nom. nov.**

Impatiens longicalcarata (G.M. Schulze & Wilczek) Grey-Wilson, Kew Bull. 33: 644 (1979).

Impatiens congolensis G.M. Schulze & Wilczek var. *longicalcarata* G.M. Schulze & Wilczek, Bull. Jard. Bot. Brux. 29: 188 (1959).

TYPUS— *Michelson 706*, Congo-Kinshasa, Miki (holo-, BR).

***Impatiens delabathiana* Eb.Fisch. & Rahelivololona, nom. nov.**

Impatiens trichocarpa H. Perrier, Arch. Bot., Caen 7, Mém. 1: 52 (1934), non *Impatiens trichocarpa* Hook.f., Ic. Pl. t. 2914 (1910).

TYPUS— *Perrier de La Bâthie 5804*, 1700 m, massif de Manongarivo, May 1909 (holo-, P).

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Perrier de la Bâthie, the pioneer of research on Madagascan *Impatiens*.

As the epithet *trichocarpa* had been used yet for an Indian *Impatiens* species by Hooker, a new name had to be chosen for the Madagascan taxon. *Impatiens delabathiana* is related to *Impatiens firmula* Baker, *I. marivorahensis* H. Humbert and *I. sambiranensis* H. Perrier.

Subgenus Trimorphopetalum (Baker) Eb. Fisch.

Lower sepal without spur.

Impatiens stefaniae Eb.Fisch. & Rahelivololona, **sp. nov.**

Differt ab Impatiensi biophytoides et I. justicioides forma foliorum et forma petalorum lateralium.

TYPUS— *Rahelivololona, Saola & Scenario 135*, Madagascar, Prov. Toamasina. Masoala Peninsula, Ambanizana-Ambohitsitondroina, sous bois sur humus, ? chemin Campement, 300 m, 18 Feb. 2002 (holo-, TAN; iso-, NEU).

Perennial herb with creeping rhizome, glabrous, tinted with red. Stem erect, 19-50 cm tall. Leaves alternate, entirely green, petiole 7-13 mm long, lamina lanceolate, 49-72 x 11-19, margin with 6-8 pairs of fimbriae. Inflorescence with solitary axillary flowers, pedicel 5-8 mm, curved at apex. Flower green to greenish, lower sepal whitish to yellowish. Lateral sepals 2, linearlanceolate, 3-3.5 x 1 mm. Lower sepal ovate, acuminate at apex, c. 7 x 3 mm. Dorsal petal cucullate, 6-7 x 3 mm, with rounded spur-like apicule near base of crest. Lateral united petals 8 mm long, upper petal obtuse, 2-2.5 x 1-1.5 mm, lower petal 5 x 2 mm. Anthers 3 mm long. Ovary 3-4 mm long. Fruit unknown.— Fig. 8.

HABITAT— Lowland to submontane rainforest.

Chapter 5 — New taxa from Madagascar. III

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Dedicated to Stefanie Bender (Wiesbaden).

Impatiens stefaniae is related to *I. biophytoides* H. Perrier and *I. justicioides* H. Perrier, but differs in shape of leaves and shape of lateral united petals.

Impatiens oniveensis Eb.Fisch. & Rahelivololona, **nom. nov.**

Impatiens rubrolineata H. Perrier, Arch. Bot., Caen 7, Mém. 1: 84 (1934), non *Impatiens rubrolineata* Hook.f., Kew Bull. 1910: 300 (1910).

TYPUS— *Perrier de La Bâthie 17021*, aux environs du confluent du Mongoro et de l'Onivé, vers 700 m, Feb. 1925 (holo-, P).

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Named after the River Onivé.

As the epithet *rubrolineata* had been used yet for an Indian *Impatiens* species by Hooker, a new name had to be chosen for the Madagascan taxon. *Impatiens oniveensis* is related to *I. parvigaleata* H. Perrier and *I. asperipetala* H. Perrier.

Impatiens lemuriana Eb.Fisch. & Rahelivololona, **nom. nov.**

Impatiens gibbosa H. Perrier, Arch. Bot., Caen 7, Mém. 1: 85 (1934), non *Impatiens gibbosa* Arn., Comp. Bot. Mag. 1: 321 (1836) (= *I. leptopoda* Arn.).

TYPUS— *Perrier de La Bâthie 15383*, sur le Mt. Tsaratanana, vers 2000 m, Jan. 1923 (holo-, P).

DISTRIBUTION— Madagascar, only known from Mt. Tsaratanana.

ETYMOLOGY— Named after its “lemurian” distribution.

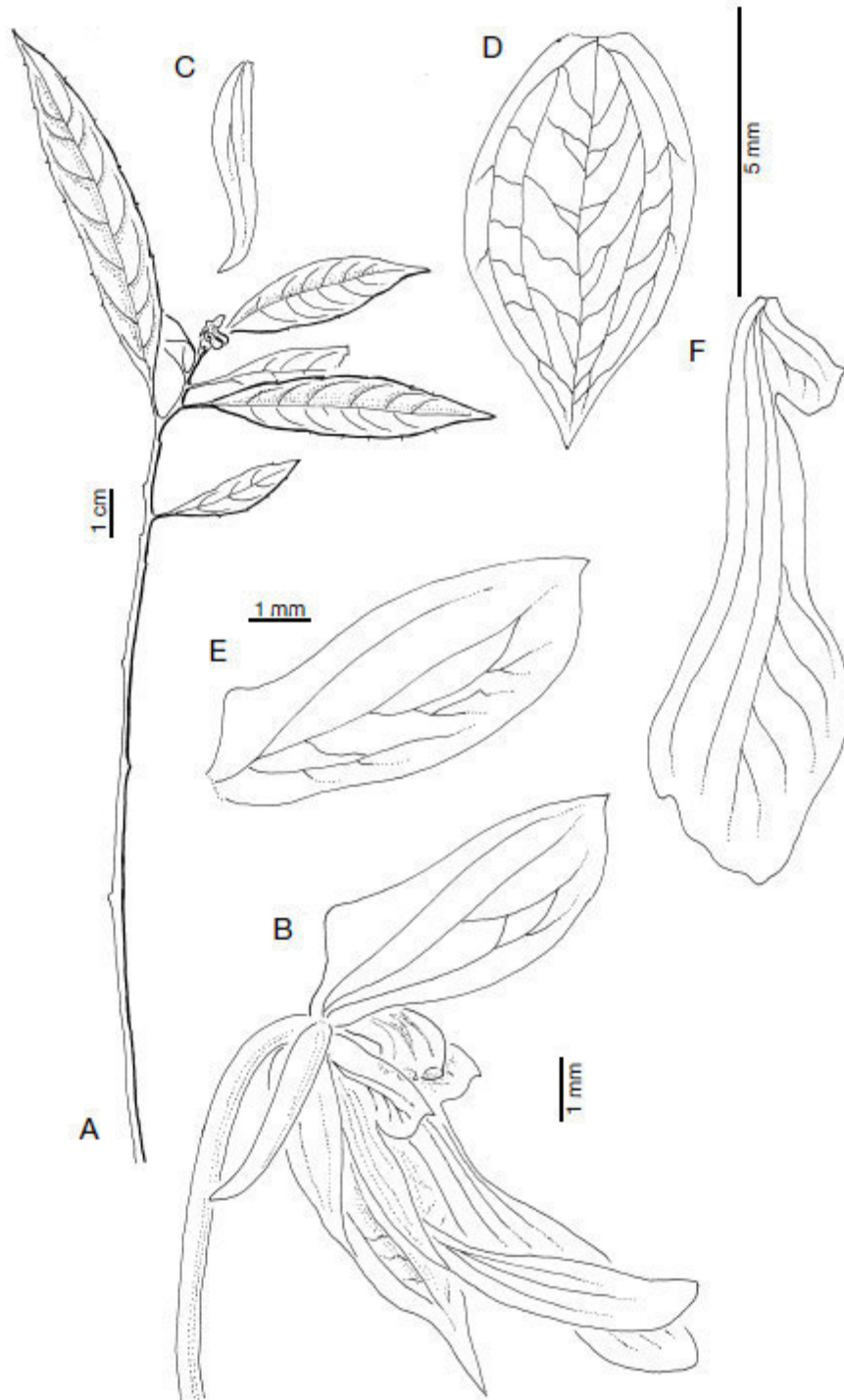


FIGURE 8. *Impatiens stefaniae* Eb.Fisch. & Rahelivololona; **A**, habit; **B**, flower; **C**, lateral sepal; **D**, lower sepal and spur; **E**, dorsal petal; **F**, lateral united petals. *Rahelivololona*, *Saola & Scenario 135* (TAN).

Chapter 5 — New taxa from Madagascar. III

As the epithet *gibbosa* had been used yet for an endemic *Impatiens* species from Sri Lanka, which is now considered to be a synonym of the Sri Lankan endemic *I. leptopoda*, a new name had to be chosen for the Madagascan taxon. *Impatiens lemuriana* is related to *Impatiens decaryana* H. Perrier, *I. silviana* Eb.Fisch. & Rahelivololona, *I. andohahelae* Eb.Fisch. & Rahelivololona, *I. luisae-echterae* Eb. Fisch., Wohlhauser & Rahelivololona, *I. callmanderi* Eb. Fisch., Wohlhauser & Rahelivololona and *I. humbertii* H. Perrier.

Acknowledgements

We would like to thank the director of the Herbarium, Muséum national d'Histoire naturelle (P), who kindly sent specimens on loan to the first author and who gave us permission to use the preliminary manuscript of Humbert. We also thank the directors of the following herbaria for loan of specimens (acronyms according to Holmgren *et al.* 1990): BR, G, K, NEU, TAN.

Chapter 6

A new epiphytic species of *Impatiens* (Balsaminaceae) from the Comoro Islands

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2004): A new epiphytic species of *Impatiens* (Balsaminaceae) from the Comoro Islands. *Adansonia sér.* 3, 26: 93-95.

¹ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany). efischer@uni-koblenz.de

² Parc botanique et zoologique de Tsimbazaza, BP 4096, Antananarivo (Madagascar). prota.madagascar@dts.mg

Abstract

The new species *Impatiens wibkeae* from the Comoro Islands is described and illustrated. It differs from *I. auricoma* Baill. in its epiphytic habit, red lateral sepals and generally larger flowers.

Key words Balsaminaceae, *Impatiens*, Comoro Islands.

Résumé

Une nouvelle espèce épiphyte d'Impatiens (Balsaminaceae) des Comores.

Une espèce nouvelle d'*Impatiens* des Comores (*I. wibkeae*) est décrite et illustrée. Elle diffère d'*I. auricoma* Baill. par le port épiphytique, les sépales latéraux rouges et les fleurs généralement plus grandes.

Mots clés Balsaminaceae, *Impatiens*, Comores.

Introduction

The Comoro Islands, in contrast to Madagascar (Fischer & Rahelivololona 2002), harbour only a few species of *Impatiens*. Up to now, two species are known, i.e. *Impatiens auricoma* Baill. which is also widely distributed in cultivation and *I. comorensis* Baker (= *I. macradenia* Baill.), a very distinctive species whose lower sepal bears two filiform spurs 30 mm in length. Despite recent regional inventories, the latter species has not been collected since more than 50 years ago and might even be extinct. In submontane rainforest on Moheli, an epiphytic *Impatiens* was collected by

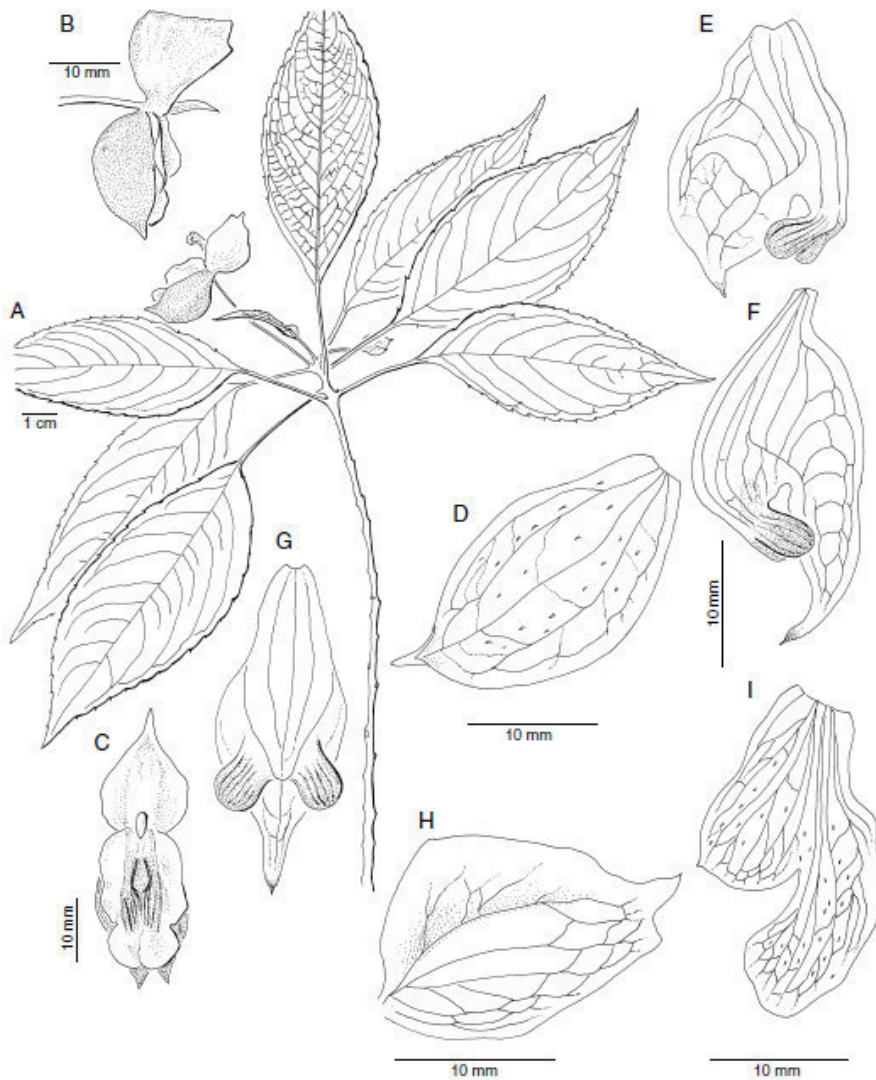


FIGURE. 1. *Impatiens wibkeae* Eb.Fisch. & Rahelivololona: **A**, habit; **B**, flower, lateral view; **C**, flower frontal view; **D**, lateral sepal; **E-G**, lower sepal and spur; **H**, dorsal petal; **I**, lateral united petals. *Labat et al.* 3215 (P).

Jean-Noël Labat, which was first considered to represent *I. auricoma*. The new material, however, differs from this taxon in many respects and represents a new species, which is described below. It is undoubtedly related to *I. auricoma* and is part of a group of taxa that are restricted to Madagascar and the Comoros, characterized by having two short spurs on lower sepal. In Madagascar, *I. bisaccata* Warb. From Montagne d'Ambre and *I. tuberosa* H. Perrier from Montagne des Français near Antsiranana belong to this group. The main differences between *I. auricoma* and the new species are listed in Table 1.

The study is based on herbarium material from P (acronyms according to Holmgren *et al.* 1990). The terminology used for measuring floral parts and in the descriptions follows Grey-Wilson (1980) and Fischer & Rahelivololona (2002). Thus the arrangement of floral parts is described after resupination.

***Impatiens wibkeae* Eb.Fisch. & Rahelivololona, sp. nov.**

Impatienti auricomae affinis sed habitu epiphytico, sepalis lateralibus rubris et majoribus, sepalo inferiore majori, calcare brevior et petalis lateralibus majoribus differt.

TYPUS— *Labat, Yahaya, Darouèche, Djoubieri & Mindhiri 3215*, Comores, Moheli, Miringoni, Vondrouvou, Chalet Saint-Antoine, 12°17'17"S, 43°39'50"E, 660 m, forêt dense humide de crête, riche en lichen à *Cyathea* et *Cynometra*, sol forestier noir sur basalte, 25 Nov. 1999 (holo-, P; iso-, herbier du Centre national de Documentation et de Recherche scientifique de Moroni, G, K, MO).

Epiphytic herb up to 60 cm tall. Stem succulent. Leaves dark green, petiole 26-35 mm long, with 1-2 pairs of extrafloral nectaries in apical part, lamina ovate-lanceolate, acuminate, 85-112 x 27-44 mm, margin with 16-18 pairs of fimbriae. Inflorescence axillary, bracts 2 x 0.5 mm, pedicel 42-45 mm long, reddish. Flower with yellow dorsal petal, bearing a long red-orange crest, lateral sepals red, lower sepal yellow with reddish venation, spur reddish. Lateral sepals broadly ovate, acuminate, 30 x 15 mm. Lower sepal navicular, 25-28 x 10 mm, with 2 globose, obtuse sacculate spurs, 4-5 x

Chapter 6 — New taxa from Comoro Islands

2-3 mm, with narrow longitudinal ridges. Dorsal petal cucullate, 20 x 15 mm, dorsal crest with spur-like apicule. Lateral united petals 24 mm long, upper petal 15 x 8-9 mm, lower petal 9 x 6-7 mm. Anthers 15 mm long. Ovary 14 mm long. Fruit c. 20-22 mm long, furrowed.— Fig. 1.

HABITAT— Submontane rainforest.

DISTRIBUTION— Comoro Islands, only known from the type locality on Moheli.

ETYMOLOGY— Dedicated to Wibke Briese.

TABLE 1. Distinction between *Impatiens wibkeae* and *I. auricoma*.

	<i>Impatiens wibkeae</i>	<i>Impatiens auricoma</i>
Habitat	epiphytic	terrestrial
Flower	yellow with red lateral sepals	yellow throughout
Lateral sepals	30 x 15 mm	20 x 10 mm
Lower sepal	25-28 x 10 mm	14 x 0.6 mm
Spurs	4-5 x 2-3 mm	6 x 1.5 mm
Dorsal petal	20 x 15 mm	9 x 5 mm
Lateral petals	24 mm long	15 mm long
Upper petal	15 x 8-9 mm	10 x 9 mm
Lower petal	9 x 6-7 mm	6 x 5 mm

Acknowledgements

First, we would like to thank the director of the Herbarium, Muséum national d'Histoire naturelle (P), who kindly sent specimens on loan to the first author. Special thanks go to Jean-Noël Labat (Paris) for kindly sending *Impatiens* from the Comoro Islands for identification.

Chapter 7

New taxa of *Impatiens* from Madagascar IV

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2007): New taxa of *Impatiens* from Madagascar IV. *Adansonia* 29: 613-616.

¹ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany). efischer@uni-koblenz.de

² Parc botanique et zoologique de Tsimbazaza, BP 4096, Antananarivo (Madagascar). prota.madagascar@dts.mg

Abstract

In a fourth paper as precursor to a revision of Balsaminaceae in Madagascar and the Comoro Islands, 11 species from subgenus *Impatiens* (*I. bardotiae*, *I. barthlottii*, *I. ankaranensis*, *I. tsingycola*, *I. nicolliae*, *I. academiae-moguntiae*, *I. betsomangae*, *I. guillaumetii*, *I. nomenyae*, *I. nusbaumeri*, and *I. laurentii*) and 18 species from subgenus *Trimorphopetalum* (*I. georgei-schatzii*, *I. nosymangabensis*, *I. paranyi*, *I. haingosonii*, *I. mahalevonensis*, *I. ambahatrensis*, *I. messmerae*, *I. andapensis*, *I. fianarantsoae*, *I. carlsoniae*, *I. rakotomalazana*, *I. druartii*, *I. ampokafoensis*, *I. rapanarivoi*, *I. befiananensis*, *I. tsararavina*, *I. maevae*, and *I. razanatsoa-charlei*) are described as new and illustrated.

Key words *Impatiens*, subgenus *Impatiens*, subgenus *Trimorphopetalum*, Balsaminaceae, Madagascar, new species.

Résumé

Nouveaux taxons dans le genre Impatiens (Balsaminaceae) à Madagascar IV.

Dans une quatrième publication effectuée dans le cadre de la préparation d'une révision des Balsaminaceae de Madagascar et des Comores, 11 espèces nouvelles du sous-genre *Impatiens* (*I. bardotiae*, *I. barthlottii*, *I. ankaranensis*, *I. tsingycola*, *I. nicolliae*, *I. academiae-moguntiae*, *I. betsomangae*, *I. guillaumetii*, *I. nomenyae*, *I. nusbaumeri*, et *I. laurentii*) et 18 espèces nouvelles du sous-genre *Trimorphopetalum* (*I. georgei-schatzii*, *I. nosymangabensis*, *I. paranyi*, *I. haingosonii*, *I. mahalevonensis*, *I. ambahatrensis*, *I. messmerae*, *I. andapensis*, *I. fianarantsoae*, *I. carlsoniae*, *I. rakotomalazana*, *I. druartii*, *I. ampokafoensis*, *I. rapanarivoi*, *I. befiananensis*, *I. tsararavina*, *I. maevae*, et *I. razanatsoa-charlei*) sont décrites et illustrées.

Mots clés *Impatiens*, sous-genre *Impatiens*, sous-genre *Trimorphopetalum*, Balsaminaceae, Madagascar, espèces nouvelles.

Introduction

Madagascar is one of the “hottest hotspots of biodiversity” (Ganzhorn *et al.* 2001) with a high percentage of endemism threatened by extinction. Numerous new plant species are described from the island every year and others still await description. During the revision of Balsaminaceae (Fischer & Rahelivololona 2002, 2004; Fischer *et al.* 2003) it became apparent that our knowledge of the diversity of *Impatiens* L. in Madagascar is far from satisfactory.

Perrier de la Bâthie (1934, 1948), Humbert & Perrier de la Bâthie (1955) and Humbert (1956) reported 105 species of *Impatiens* from Madagascar. Humbert also prepared, but never published a manuscript about the Balsaminaceae for *Flore de Madagascar et des Comores*, which remained unfinished at the time of Humbert's death in 1967. Since then, numerous new collections have been made, and 34 additional species have already been described by the present authors (Fischer & Rahelivololona 2002, 2004; Fischer *et al.* 2003). However, while studying collections from P, TAN, MO, NEU and G numerous previously undescribed taxa were detected, raising the total number of species to 231. *Impatiens* is thus the most species-rich genus of plants in Madagascar, followed by *Bulbophyllum* (Orchidaceae) with 197 species (G. Fischer pers. comm.), *Euphorbia* (Euphorbiaceae) with 170 species (Haevermans 2003), *Dypsis* (Arecaceae) with 140 species (Dransfield & Beentje 1995), *Gravesia*

(Melastomataceae) with 107 species (Almeda 2003) and *Pandanus* (Pandanaaceae) with about 100 species (Callmänder & Laivao 2003).

In this paper we describe some peculiar taxa of spurred balsams, four of which are restricted to the tsingy of Ankarana. While most *Impatiens* are found in rainforests, some species have adapted to seasonal habitats like the “tsingy”. Tsingy massifs are limestones submitted to long periods of karst processes, giving rise to jigsaw or knife-edged pinnacles overlying extensive cave systems (Bardot-Vaucoulon 1997). Tsingy massifs are found at Namoroka, Ankarana, and Bemaraha, and only in the latter two areas species of *Impatiens* could be recorded. *Impatiens bemaharensis* Eb.Fisch. & Raheliv. is an annual while *I. tuberosa* H.Perrier is a geophyte with large tubers. The four new taxa from the tsingy of Ankarana collected by M. Bardot-Vaucoulon comprise three annual herbs and one geophyte closely related to *I. tuberosa*. For a description of the vegetation of the Massif d’Ankarana see Bardot-Vaucoulon (1997). The remaining species of spurred balsams described in this paper are typical rainforest plants mainly from the Masoala Peninsula.

The spurless *Impatiens* species of subgenus *Trimorphopetalum* represent a highly diverse group endemic to Madagascar. During the preparation of the account of *Impatiens* for the *Flore de Madagascar et des Comores*, the authors could distinguish 117 taxa, of which 18 are described here as new. *Trimorphopetalum* is thus more species-rich in Madagascar than Subgenus *Impatiens* where 114 species are recorded. Another characteristic feature of *Trimorphopetalum*, beside the complete lack of a spur on lower sepal is the complete lack of extrafloral nectaries on the petiole. These are abundant in subgenus *Impatiens*.

A short history of exploration of *Impatiens* in Madagascar as well as details on terminology and measurements were provided by Fischer & Rahelivololona (2002).

Systematics

Genus *Impatiens* L., Subgenus *Impatiens* L.

Diagnostic characters— Lower sepal with spur, petiole usually with extrafloral nectaries (fimbriae).

Impatiens bardotiae Eb.Fisch. & Raheliv., sp. nov. (Fig. 1)

Impatiens baroni et *I. majungensi* affinis, sed floribus roseoviolaceis, calcare longiore et ovario glabro valde differt.

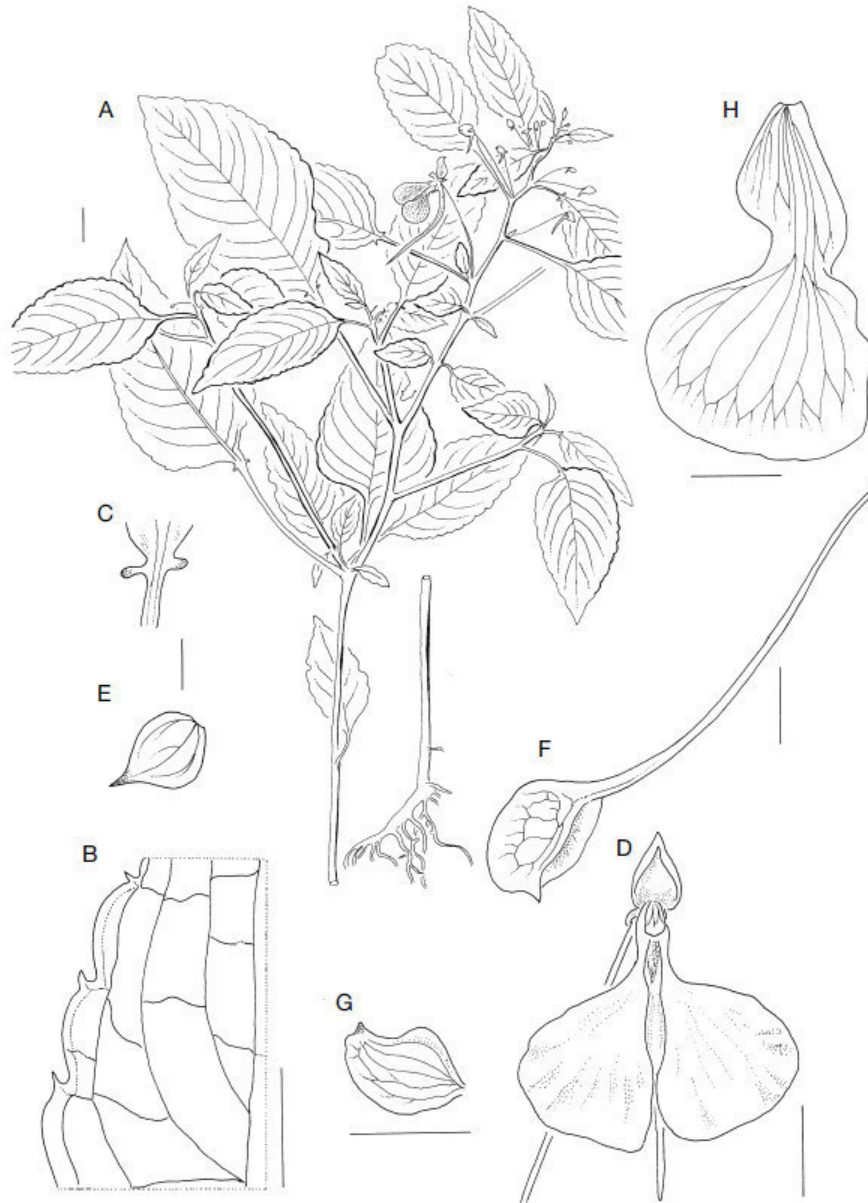


FIGURE 1. *Impatiens bardotiae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, extrafloral nectaries; **D**, flower; **E**, lateral sepal; **F**, lower sepal and spur; **G**, dorsal petal; **H**, lateral united petals. *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1141* (P). Scale bars: A, D, G, 1 cm; B, F, H, 5 mm; C, E, 1 mm.

TYPUS— Madagascar. Province d’Antsiranana, district d’Ambilobe, Matsamorimanga, Réserve Spéciale d’Ankarana, 2e canyon, bord de la rivière à l’entrée de la grotte de

la cathédrale, 12°56'S, 49°3'E, 10.I.2003, *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1141* (holo-, P; iso-, MO, TAN).

PARATYPE— Madagascar. Prov. de Diego Suarez, collines et plateaux calcaires de l'Ankarana du Nord, 30-350 m, 24.I-29.II.1960, *Humbert 32641* (P).

DESCRIPTION— Annual herb, erect, glabrous, richly branched. Stems reddish, up to 30 cm long. Leaves alternate, reddish, petiole 35-60 mm long, with 1 pair of extrafloral nectaries near base of lamina, lamina ovate, base rounded-attenuate, slightly decurrent, apex acuminate, 55-90 × 25-50 mm, margin dentate, with (14) 16-19 pairs of teeth with gland-tipped appendages. Inflorescence with solitary axillary flowers. Bracts filiform, 3 × 0.8 mm. Pedicels 35-40 mm long. Flowers pink-violet. Lateral sepals ovate, acuminate, 3.5 × 1 mm. Lower sepal 8 × 6-7 mm, with straight spur, 35-38 mm long. Dorsal petal cucullate, with short spur at apex, 8-9 × 5 mm. Lateral united petals 25 mm long, upper petal minute, 2 × 1-2 mm, lower petal rounded, 20-22 × 12 mm. Anthers 4-5 mm long. Ovary 4 mm long. Fruit not known.

REMARKS— *Impatiens bardotiae* is related to *I. baroni* and *I. majungensis*, but differs in the pink-violet flowers which are pale pink to white in *I. majungensis* and pink with yellow marks in *I. baroni*, the longer spur which is 10 to 12 mm long in the latter two species, and the smooth ovary, which is tuberculate in the latter two species. *Impatiens baroni* Baker occurs throughout Eastern Madagascar, often as a weedy species, and can also colonize temporary habitats on inselbergs or other rock outcrops. *Impatiens majungensis* H.Perrier is restricted to dry forest with calcareous rocks around Majunga.

HABITAT— Dry deciduous forest on Jurassic calcareous rocks, on alluvial loamy to sandy soils at bottom of a canyon in the tsingy.

DISTRIBUTION— Madagascar, Tsingy of Ankarana, only known from the type collection.

ETYMOLOGY— Named after Martine Bardot-Vaucoulon who collected the type specimen.

Impatiens barthlottii Eb.Fisch. & Raheliv., sp. nov. (Fig. 2)

Impatiens tuberosae affinis sed tuberibus elongatis cum caule singulare, petiolo sine glandibus, floribus albo-luteaceis et calcare brevior differt.

TYPUS— Madagascar. Province d'Antsiranana, district d'Ambilobe, Matsamorimanga, Réserve Spéciale d'Ankarana, grotte d'Ambohimalaza, 12°58'S, 49°5'E, 8.II.2003, *Bardot-Vaucoulon, Toly & Manesy 1397* (holo-, P; iso-, MO, TAN).

PARATYPES— Madagascar. Tsingy Ankarana, lac Vert, 24.IV.1990, *Bardot-Vaucoulon 24* (P)— Province d'Antsiranana, district d'Ambilobe, Matsamorimanga, Réserve Spéciale d'Ankarana, premier canyon, zone de tsingy à droite avant la descente à la rivière, 12°56'20"S, 49°4'62"E, 160 m, 11.I.2003, *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1162* (P, TAN, MO)— Province d'Antsiranana, district d'Ambilobe, Matsamorimanga, Réserve Spéciale d'Ankarana, forêt de Manapisanga à l'ouest de la rivière Besaboba, 180 m, 12°54'625"S, 49°10'167"E, 11.II.2003, *Bardot-Vaucoulon & Manesy 1430* (P, TAN).

DESCRIPTION— Perennial herbs, erect, glabrous. Stems succulent, reddish, with elongated tuber at base, up to 20-70 cm long. Leaves alternate, petiole reddish, without extrafloral nectaries, up to 50 mm long, lamina ovate, elliptic-acute at base and apex, net of tertiary veins invisible, 50-110 × 25-52 mm, margin dentate, with up to 15 pairs of teeth with gland-tipped appendages. Inflorescence with 2 axillary flowers per leaf. Bracts lanceolate-filiform, membranaceous, 4 × 2 mm. Pedicels up to 55 mm long. Flowers white with yellow spot on lateral united petals. Lateral sepals 2, ovate, apiculate, cucullate, 6 × 6 mm. Lower sepal navicular, acuminate at apex, 11 × 4 mm, spur divided at apex into 2, obtuse, 2 mm long free parts, reddish at apex and striate with red veins, 4 × 1.5 mm. Dorsal petal cucullate, dorsal crest with 1 mm long spur at apex, 9 × 6 mm. Lateral united petals 15 mm long, upper petal rounded, 7 × 3 mm, lower petal rounded, 8 × 7 mm. Anthers 2-3 mm long. Ovary 3-4 mm long. Fruit not known.

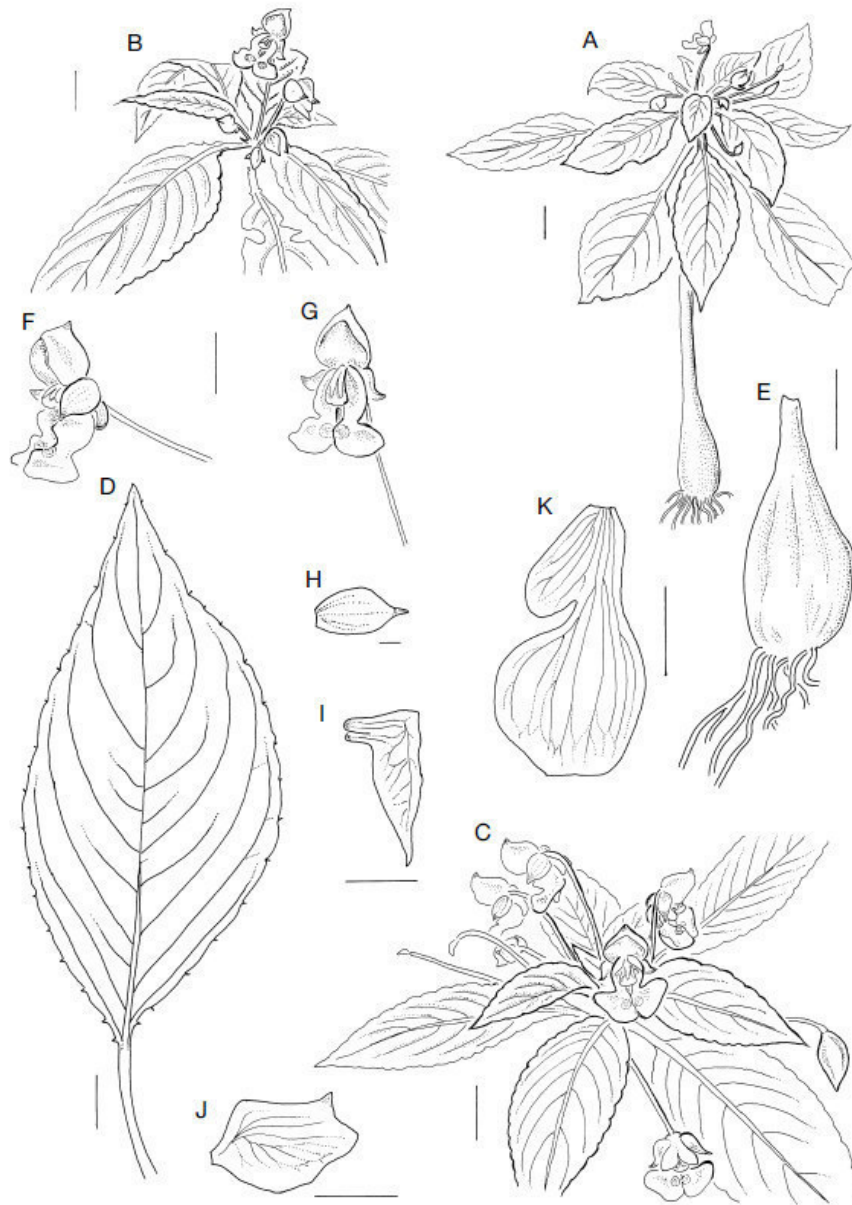


FIGURE 2. *Impatiens barthlottii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, habit, detail; **D**, leaf; **E**, tuber in dry season; **F**, **G**, flower; **H**, lateral sepal; **I**, lower sepal and spur; **J**, dorsal petal; **K**, lateral united petals. *Bardot-Vaucoulon, Toly & Manesy 1397 (P)*. Scale bars: A-G, 1 cm; H, 1 mm; I-K, 5 mm.

REMARKS— *Impatiens barthlottii* is related to *I. tuberosa* H.Perrier which is endemic to the Montagne des Français near Antsiranana. It differs, however, in the elongated tuber which bears usually only one stem (numerous stems in *I. tuberosa*), the petiole without extrafloral nectaries, the whitish-cream colour of the flowers (pink with darker marks in *I. tuberosa*), the different length of spur (7-10 mm in *I. tuberosa*, 2 mm in *I. barthlottii*) and the lateral united petals (upper petal larger than lower petal in *I. tuberosa*, upper petal smaller than lower petal in *I. barthlottii*).

HABITAT— In fissures of Jurassic calcareous rocks, surviving the dry season with its tuber, while stem and leaves are decaying, in a deciduous dry forest. At the end of the flowering period, the leaves drop down and finally the stem dies down. Thus only the tube survives the dry season (Bardot-Vaucoulon 1997).

DISTRIBUTION— Madagascar, Tsingy of Ankarana.

ETYMOLOGY— Named after Wilhelm Barthlott on occasion of his 60th birthday and for his outstanding research on biodiversity.

Impatiens ankaranensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 3)

Impatienti sacculiferae affinis sed habitu annuo, calcare inflato et callo petalorum inferiorum differt.

TYPUS— Madagascar. Province d'Antsiranana, district d'Ambilobe, Matsamorimanga, Réserve Spéciale d'Ankarana, 2e canyon, bord de la rivière à l'entrée de la grotte de la cathédrale, 12°56'S, 49°3'E, 10.I.2003, *Bardot- Vaucoulon, Andrianantoanina, Toly & Manesy 1140* (holo-, P; iso-, TAN, MO, K).

PARATYPE— Madagascar. Plateaux calcaires de l'Ankarana, nord d'Ambilobe, forêt tropophile sur calcaire jurassique, 200-250 m, 4-9.III.1951, *Humbert 25532* (P).

DESCRIPTION— Annual herbs, erect, glabrous. Stems succulent, richly branched, up to 30 cm long. Leaves alternate, petiole up to 50 mm long, lamina attenuate, round at base, slightly decurrent, acuminate at apex, acumen up to 7 mm long, widest in lower third, 35-60 × 20-35 mm, margin dentate, with 10-14 pairs of teeth with gland-tipped appendages. Inflorescence with solitary axillary flowers. Pedicels up to 30 mm long. Flowers pale pink, lower sepal greenish with transversal red veins. Lateral sepals acuminate, 2 × 0.5 mm. Lower sepal navicular, 7 × 3 mm, spur curved at nearly right angle, inflated at middle to 1.5 mm of width, 2.8 mm long. Dorsal petal cucullate, dorsal crest with short spur at apex, 4 × 3.5-4 mm. Lateral united petals 8-10 mm long, upper petal rounded, 3.5 × 1.5 mm, lower petal rounded, 4.5-6 × 5 mm, with callus-like crest towards the interior. Anthers 2-3 mm long. Ovary 3 mm long. Fruit not known.

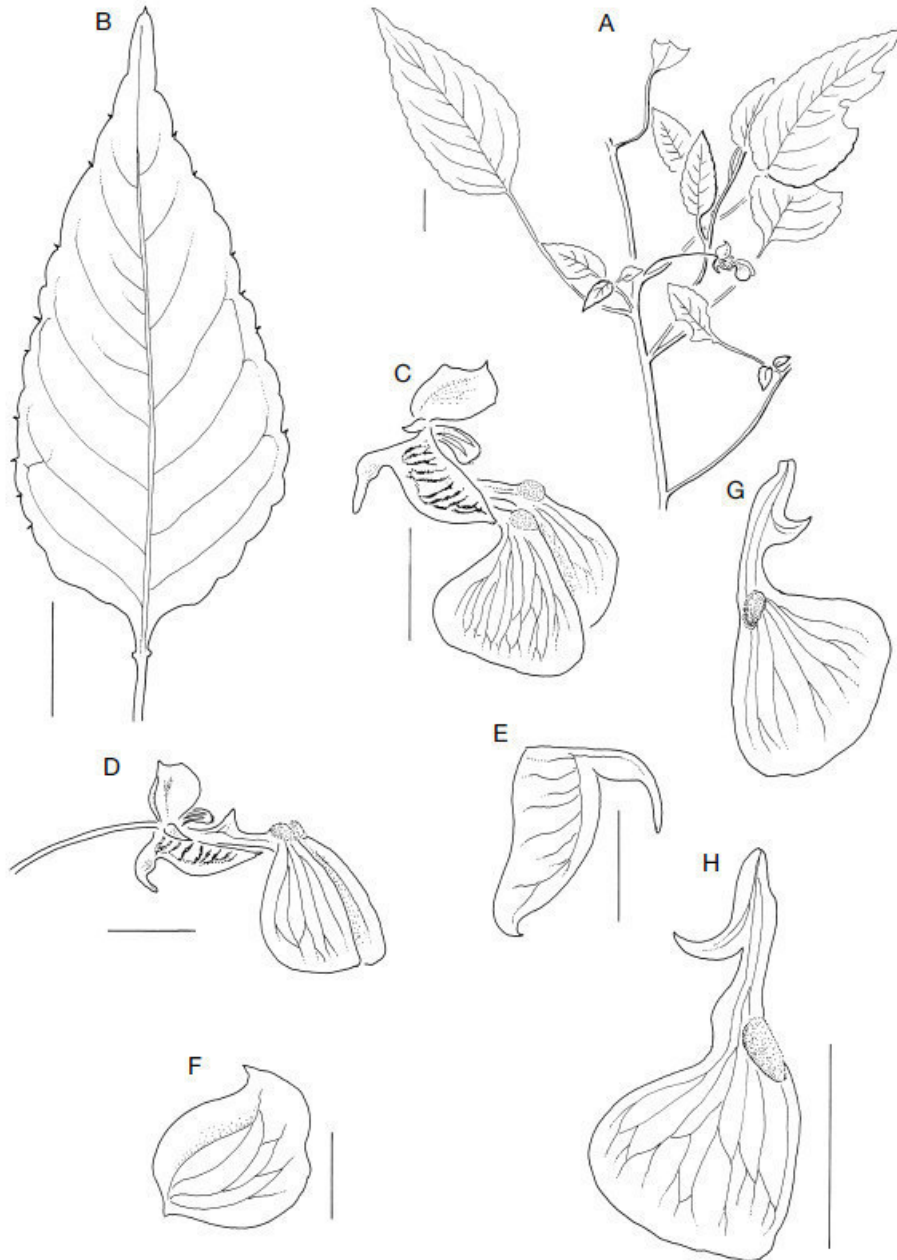


FIGURE 3. *Impatiens ankaranensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, **D**, flower; **E**, lower sepal and spur; **F**, dorsal petal; **G**, **H**, lateral united petals. A-D, G, *Humbert 25533* (P); E, F, H, *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1140* (P). Scale bars: A, B, 1 cm; C-E, G, H, 5 mm; F, 2 mm.

REMARKS— *Impatiens ankaranensis* is a unique plant that can readily be distinguished by its habitat in the tsingy and its annual habit. It resembles *I. sacculifera* H.Perrier, a perennial plant from rainforest around the Bay of Antongil, but differs in the longer inflated spur below apex (cylindric, gradually tapering towards apex, 1×0.8

mm in *I. sacculifera*) and the presence of a yellow callus-like crest on lateral united petals.

HABITAT— Clearings in dry deciduous forest with calcareous Jurassic rocks.

DISTRIBUTION— Madagascar, Tsingy of Ankarana.

Impatiens tsingycola Eb.Fisch. & Raheliv., sp. nov. (Fig. 4)

Impatiens bisaccatae affinis sed floribus valde minoribus et apice saccato petalorum inferiorum differt.

TYPUS— Madagascar. Province d'Antsiranana, district d'Ambilobe, Matsamorimanga, Réserve Spéciale d'Ankarana, Mahoro, sentier botanique, partie NE, 12°51'507"S, 49°13'630"E, 22.I.2003, *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1260* (holo-, MO; iso-, TAN).

DESCRIPTION— Annual herbs, erect, glabrous. Stems succulent, richly branched, up to 30 cm long. Leaves alternate, petiole up to 20 mm long, with 4 or 5 pairs of extrafloral nectaries, lamina attenuate at base, slightly decurrent, acuminate at apex, widest at middle, 55-81 × 25-30 mm, margin dentate, with 15-21 pairs of teeth with gland-tipped appendages. Inflorescence with 2 or 3 axillary flowers. Pedicels up to 20 mm long. Flowers pale pink, lower sepal greenish with transversal red veins. Lateral sepals acuminate, 2.5 × 1-1.5 mm. Lower sepal navicular, 7 × 3 mm, with 1.8-2 mm long, deeply bifid and recurved spur. Dorsal petal cucullate, dorsal crest with short, 1 mm long spur at apex, 6 × 3.5-4 mm. Lateral united petals 8-10 mm long, upper petal rounded, 4 × 4-5 mm, lower petal rounded, 3-3.5 × 5 mm, with short saccate spur-like projection at apex of lower petal. Anthers 3-4 mm long. Ovary 4 mm long. Fruit 10 × 4.5 mm.

REMARKS— *Impatiens tsingycola* is related to *I. bisaccata* Warb., an endemic rainforest plant from Montagne d'Ambre, but differs in the much smaller flowers (e.g., lower sepal 12-15 mm long in *I. bisaccata*, 7 mm in *I. tsingycola*, lateral sepals 5-7 × 3-5 mm in *I. bisaccata*, 2.5 × 1-1.5 mm in *I. tsingycola*, lateral united petals 25 mm long

in *I. bisaccata*, 9 mm in *I. tsingycola*) and the unique saccate spur at apex of lower petal.

HABITAT— Clearings in dry deciduous forest with calcareous Jurassic rocks, in rock fissures.

DISTRIBUTION— Madagascar, Tsingy of Ankarana.

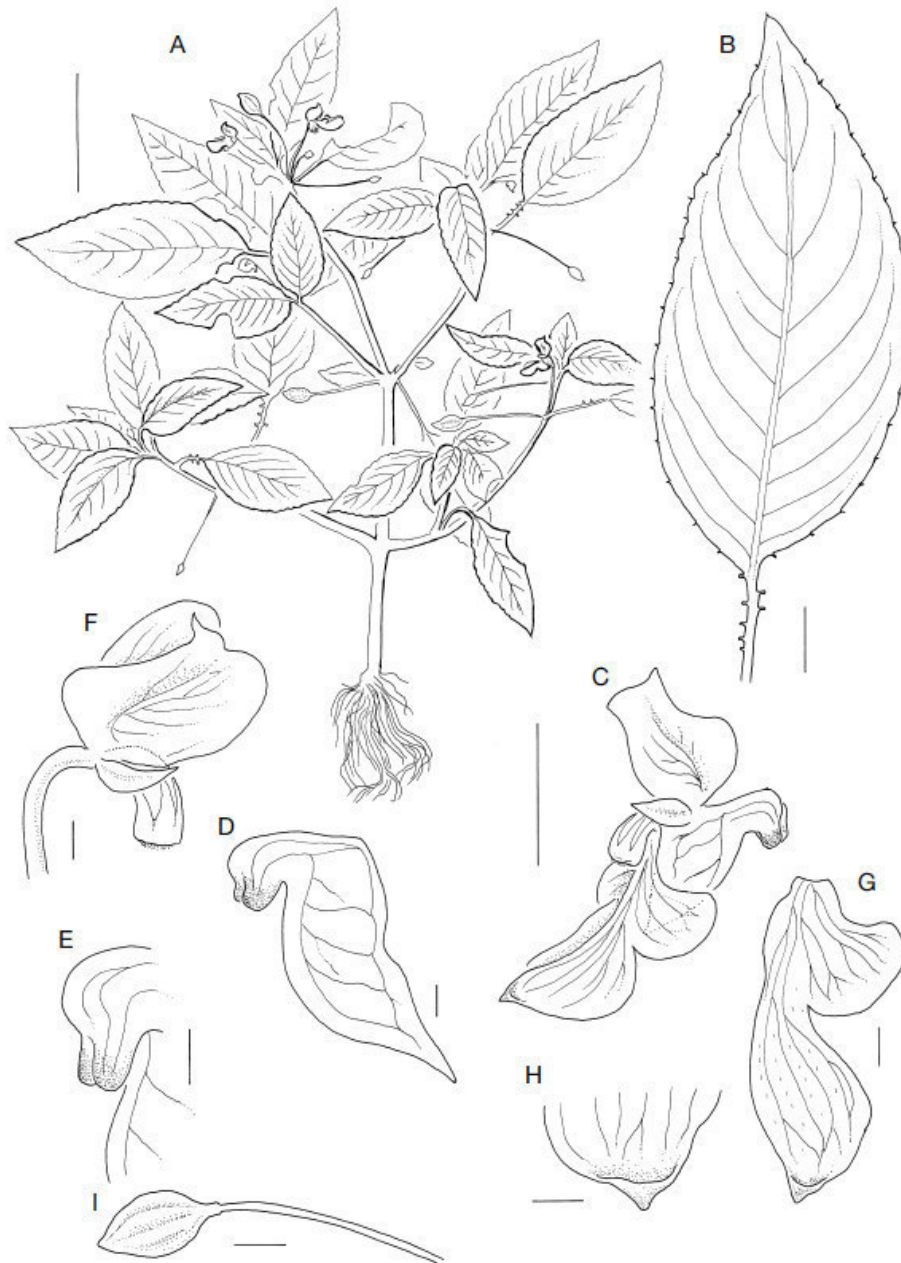


FIGURE 4. *Impatiens tsingycola* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, flower, lateral view; **D**, lower sepal and spur; **E**, spur; **F**, dorsal petal with pedicel, lateral sepal and androecium; **G**, lateral united petals; **H**, apex of lower petal; **I**, fruit. *Bardot-Vaucoulon, Andrianantoanina, Toly & Manesy 1260 (P)*. Scale bars: A, 5 cm; B, 1 cm; C, I, 5 mm; D-H, 1 mm.

Impatiens nicolliae Eb.Fisch. & Raheliv., sp. nov. (Fig. 5)

Impatiens mindiae affinis sed foliis ovatis nervibus tertiariis distinctis et calcare petali dorsalis brevior differt. Ab *I. vellela* differt forma petali dorsalis haud crenulata sicut caput Medusae.

TYPUS— Madagascar. Masoala peninsula, Ambanizana, on beach path leading south, several individuals growing in small damp valley. Eastern lowland coastal rainforest, 25 m, 15°37'S, 49°57'E, 12.IV.1987, Nicoll, Rakotozafy, Schatz & Suzon 540 (holo-, MO; iso-, BR, TAN).

DESCRIPTION— Perennial herb, glabrous. Stem up to 30 cm tall, semisucculent. Leaves with red-tinged petioles and light green lamina, petiole 14-27 mm long, with 3 or 4 pairs of extrafloral nectaries, lamina broadly ovate, attenuate at base and acuminate at apex, 82-95 × 43-48 mm, margin with 7-9 pairs of teeth with gland-tipped appendages. Inflorescence with solitary axillary flowers. Bracts linear-lanceolate, 3.5 × 1 mm. Pedicel up to 55 mm long. Flowers with greenish white dorsal petal, lateral petals pink and white with red dot, lower sepal ochre yellow inside. Lateral sepals 2, linear-lanceolate, 5 × 1.5 mm. Lower sepal 7-8 mm long and 3-4 mm deep, spur obtuse, straight, 1.3-1.5 mm long. Dorsal petal cucullate, with distinct dorsal crest and spur, 12 × 7 mm. Lateral united petals 18-20 mm long, upper petal slightly bifid, 8-9 × 7 mm, lower petal 12 × 7-8 mm. Anthers 2-3 mm long. Ovary 3 mm long. Fruit unknown.

REMARKS— *Impatiens nicolliae* is related to *I. mindiae* Eb.Fisch., Wohlh. & Raheliv. and *I. vellela* Eb.Fisch. & Raheliv., both endemics from Masoala Peninsula, but differs from *I. mindiae* in the leaves which are broadly ovate (lanceolate-ovate, 50-70 × 23-27 mm in *I. mindiae*, 82-95 × 43-48 mm in *I. nicolliae*) and show a distinct net of tertiary veins (tertiary veins nearly invisible in *I. mindiae*), in the number of the secondary veins (4 or 5 in *I. mindiae*, 8-10 in *I. nicolliae*), the number of extrafloral nectaries on petiole (0 or 1 in *I. mindiae*, 3 or 4 pairs in *I. nicolliae*), the much shorter spur on dorsal petal, and the much shorter spur on lower sepal (5 mm long in *I. mindiae*, 1.3-1.5 mm in *I. nicolliae*). It differs from *I. vellela* in the shape of the dorsal petal which is crenulated, resembling a jelly-fish, the shorter spur on lower sepal (7-8 mm in *I. vellela*), and the lack of a peduncle (short peduncle of 3-4 mm length in *I. vellela*).

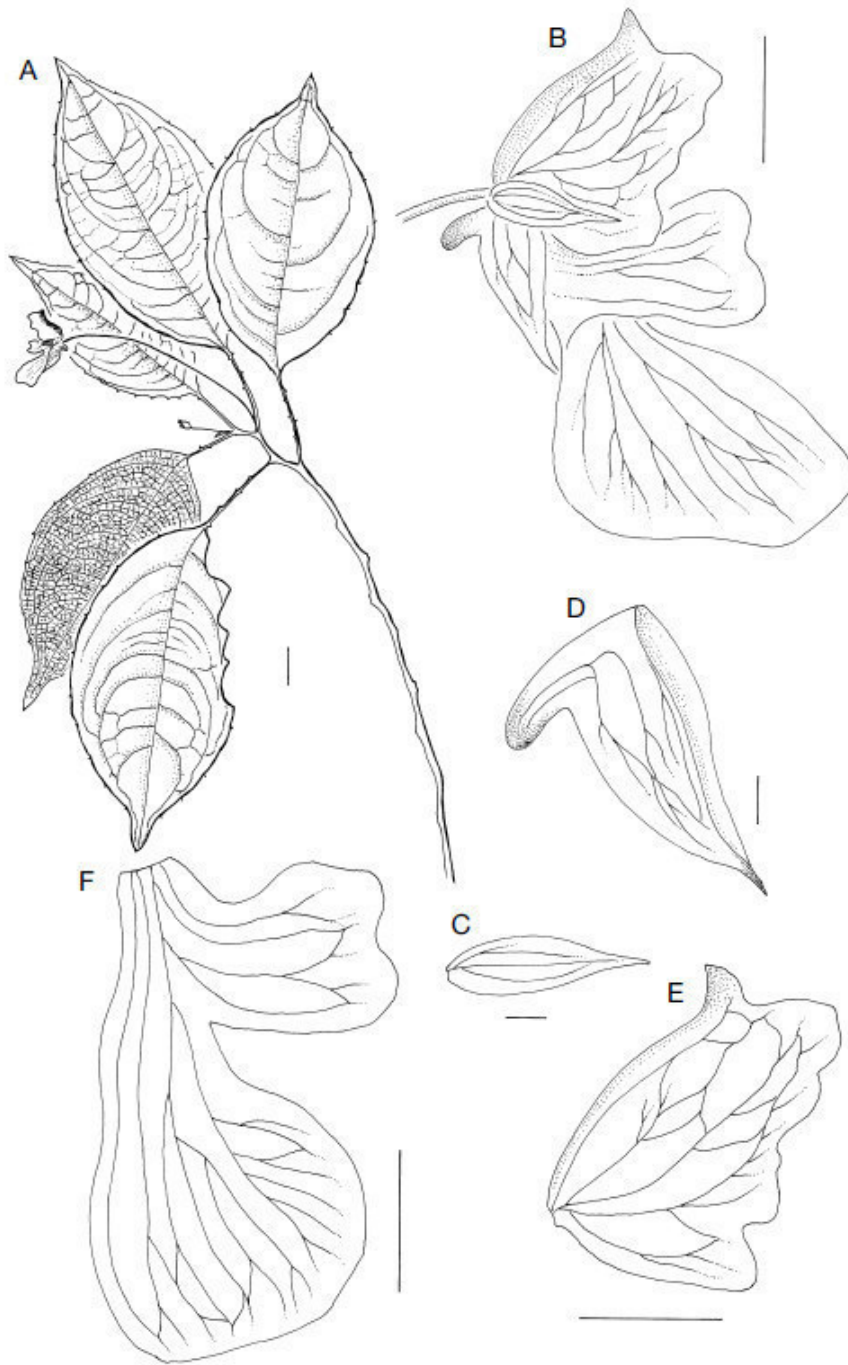


FIGURE 5. *Impatiens nicolliae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, flower, lateral view; **C**, lateral sepal; **D**, lower sepal and spur; **E**, dorsal petal; **F**, lateral united petals. *Nicoll, Rakotozafy, Schatz & Suzon 540* (BR). Scale bars: A, 1 cm; B, E, F, 5 mm; C, D, 1 mm.

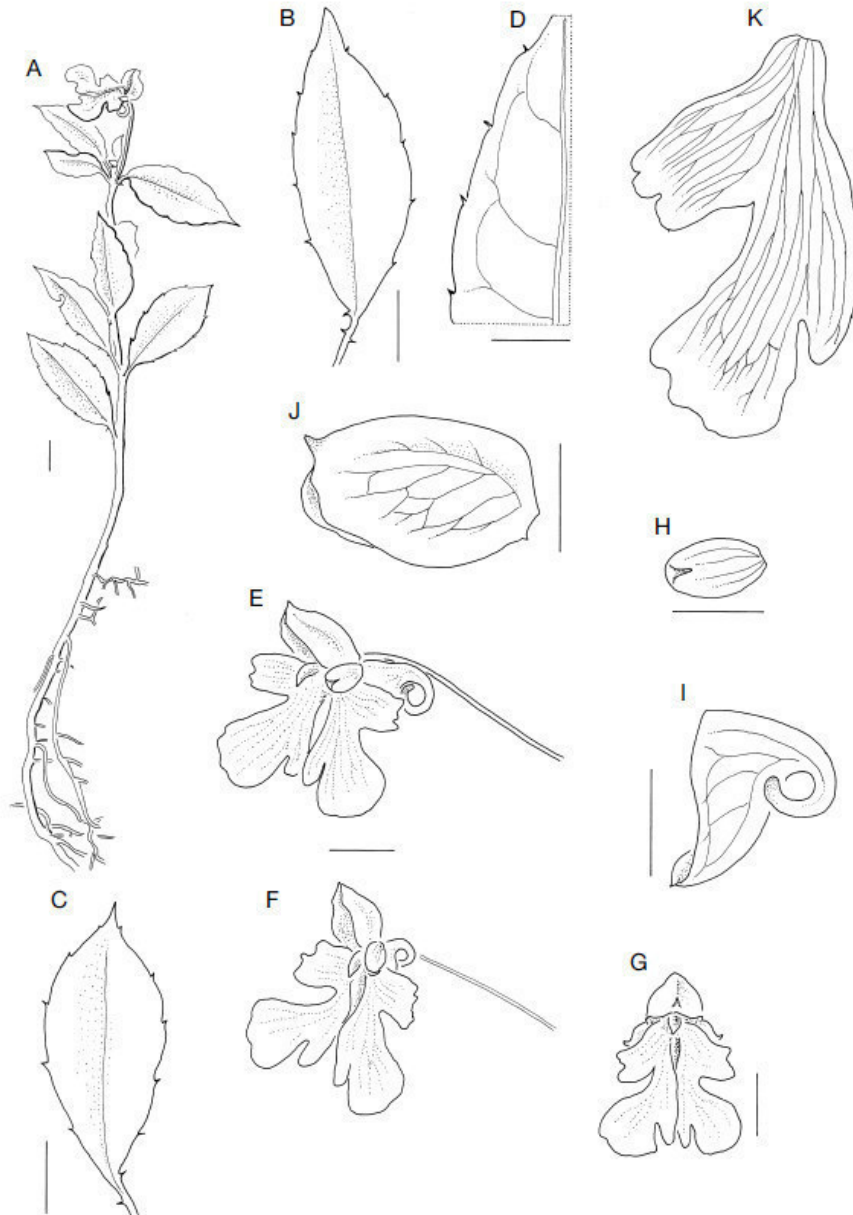


FIGURE 6. *Impatiens academiae-moguntiae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, leaves; **D**, detail of leaf margin; **E-G**, flower; **H**, lateral sepal; **I**, lower sepal and spur; **J**, dorsal petal; **K**, lateral united petals. *Rabenantroandro, Amdriamparany, Aridy & Toto 221 (P)*. Scale bars: A-C, E-G, 1 cm; D, H-K, 5 mm.

HABITAT— Lowland coastal rainforest, 25 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after Marion Nicoll who collected the type specimen.

Impatiens academiae-moguntiae Eb.Fisch. & Raheliv., sp. nov. (Fig. 6)

Impatiens mindiae affinis sed habitu epiphytico repente, floribus albis et calcare petali dorsalis brevior differt.

TYPUS— Madagascar. Toamasina, Parc National de Masoala, Maroantsetra, Anjahana, Ambanizana, piste d'Analambolo, à 10 km au nord-est d'Ambanizana, suivant la rivière Ambanizana, vers l'ancien relais d'Ambohitsidondrona, forêt sclérophylle de montagne, 1090 m, 15°34'27"S, 50°00'35"E, 24.VII.2000, Rabenantroandro, Amdriamparany, Aridy & Toto 221 (holo-, P; iso-, TAN, MO).

DESCRIPTION— Perennial epiphytic herb, glabrous except for sparse whitish scales. Stem climbing, up to 30 cm long, semi-succulent. Leaves with lamina dark green on upper face and light green on lower face, petiole up to 10 mm long, with 1, 2 pairs of extrafloral nectaries, partly on base of lamina, lamina ovate, attenuate-acute at base and acuminate at apex, 48-55 × 20-21 mm, margin with 5 pairs of teeth with gland-tipped appendages. Inflorescence with solitary axillary flowers. Pedicel up to 35 mm long. Flowers white with pink. Lateral sepals 2, ovate, 6 × 4 mm. Lower sepal 9 mm long and 3-4 mm deep, spur obtuse, curved, 7-8 mm long. Dorsal petal cucullate, with distinct dorsal crest and spur, 11 × 6 mm. Lateral united petals 25-28 mm long, upper petal slightly bifid, 11-12 × 7-8 mm, lower petal bilobed, obtuse, 18 × 13-14 mm, inner lobe with free part 5 × 3-4 mm. Anthers 3-4 mm long. Ovary 3 mm long. Fruit unknown.

REMARKS— The new species is a climbing epiphyte which is related to *Impatiens mindiae*. It differs, however, in the growth form, the nearly entirely white flowers (rose with yellow and white in *I. mindiae*), the smaller lower sepal (13 mm long in *I. mindiae*, 9 × 3-4 mm in *I. academiae-moguntiae*) and the much shorter spur on dorsal petal.

HABITAT— Climbing epiphyte in montane rainforest, at 1090 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after the Academy of Science and Literature, Mainz who supported the first author's research on the diversity of *Impatiens*.

Impatiens betsomangae Eb.Fisch. & Raheliv., sp. nov. (Fig. 7)

Impatiens manaharensis affinis sed pilis et squamulis fuscis valde instructa et quoque calcare brevior differt.

TYPUS— Madagascar. Antsiranana, Andapa, Doany, Betsomanga, à environ 11,2 km à vol d'oiseau au sud-est de Doany et à 7,5 km au nord-est d'Ambalamanasy II, entre la rivière d'Ampandrana et Betsomanga, au nord de Marojejy, 14°27'S, 49°34'E, 920-1040 m, 15-29.V.1995, *Rasoavimbahoaka 705* (holo-, P; iso-, TAN, MO).

DESCRIPTION— Perennial herb, densely covered with brownish multicellular hairs. Stem 30-50 cm tall. Leaves alternate, lanceolate, dentate, petiole 28-40 mm long, with 4-6 pairs of obtuse extrafloral nectaries, lamina oblong to elliptic, 85-120 × 25-40 mm, attenuate at base, acuminate at apex, margin with 16-20 teeth with gland-tipped appendages. Inflorescence axillary with 2-4 clustered flowers. Pedicel 20-35 mm long, bract filiform, pilose, 4 mm long. Flowers violet-whitish. Lateral sepals 2, lanceolate, densely pubescent, 9.5 × 2-2.5 mm. Lower sepal pilose outside, 7 × 4.5 mm, with darker violet, short and obtuse, 1.5 mm long spur. Dorsal petal pilose, crest indistinct, 9 × 6 mm. Lateral united petals 12-13 mm long, upper petal acuminate, 6 × 1-1.5 mm, lower petal 6-7 × 5 mm. Anthers 3-4 mm long. Ovary 4 mm long. Fruit unknown.

REMARKS— *Impatiens betsomangae* is related to *I. manaharensis* Baill. from North-Eastern Madagascar or *I. guillaumetii* from Mananara, but differs distinctly in the very short spur (9 mm long in *I. manaharensis*, 4-6 × 1.5 mm in *I. guillaumetii*) the lack of a peduncle (1 mm long peduncle in *I. guillaumetii*) and the brownish scale-like hairs.

HABITAT— Montane rainforest, at 920-1040 m.

DISTRIBUTION— Madagascar, Marojejy area, only known from the type collection.

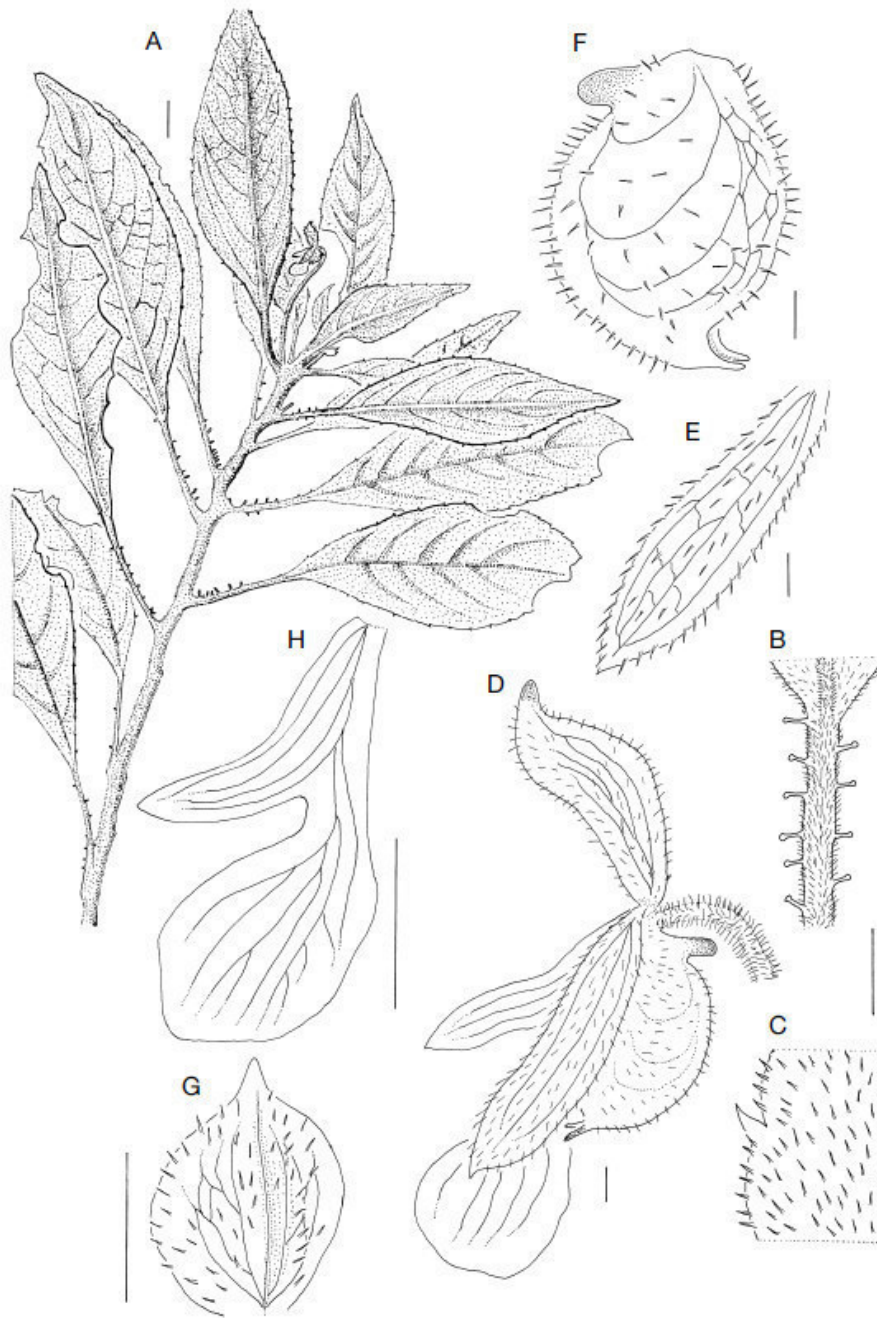


FIGURE 7. *Impatiens betsomangae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, petiole with extrafloral nectaries; **C**, detail of leaf margin; **D**, flower, lateral view; **E**, lateral sepal; **F**, lower sepal and spur; **G**, dorsal petal; **H**, lateral united petals. *Rasoavimbahoaka* 705 (P). Scale bars: A, 1 cm; B, C, G, H, 5 mm; D-F, 1 mm.

Impatiens guillaumetii Eb.Fisch. & Raheliv., sp. nov. (Fig. 8)

Impatiens lachnospermae affinis sed nectaribus extrafloralibus distinctis et calcare sub angulum rectum curvato differt.

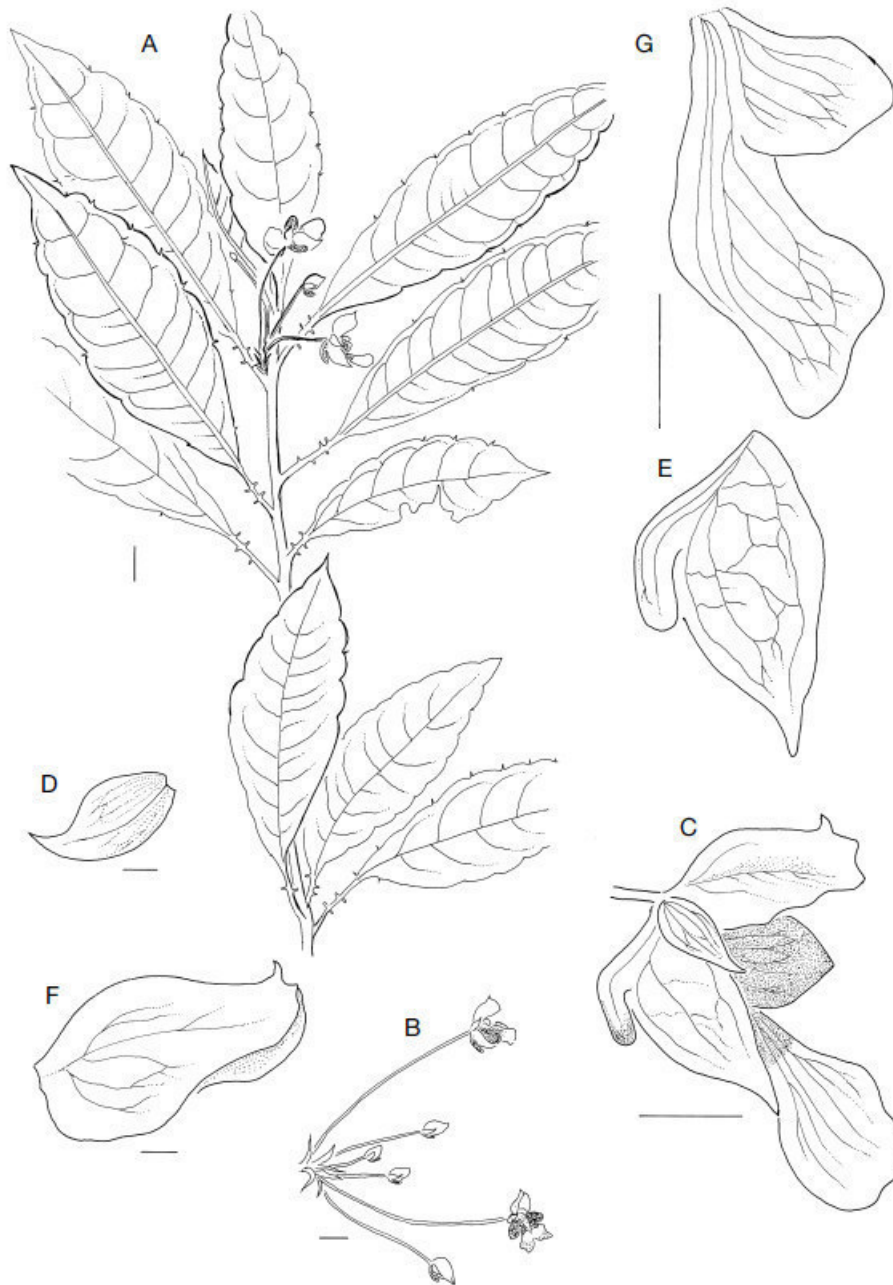


FIGURE 8. *Impatiens guillaumetii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, axillary inflorescence; **C**, flower, lateral view; **D**, lateral sepal; **E**, lower sepal and spur; **F**, dorsal petal; **G**, lateral united petals. *Guillaumet 3008bis* (P). Scale bars: A, B, 1 cm; C, E, G, 5 mm; D, F, 1 mm.

TYPUS— Madagascar. Forêt de Manomba 20 km S de Mananara, forêt dense humide de basse altitude, 1.VI.1969, *Guillaumet 3008bis* (holo-, P).

DESCRIPTION— Robust perennial erect herb, entirely glabrous. Stem woody at base, up to 30-40 cm tall. Leaves alternate, dark green above, light green below, petiole 10-

30 mm long, with 3-6 pairs of extrafloral nectaries, lamina oblong, attenuate at base and acuminate-attenuate at apex, 95-130 × 30-35 mm, margin with 7-10 pairs of teeth with gland-tipped appendages. Inflorescence axillary, umbellate, with 6 flowers, peduncle short, up to 1 mm long. Bracts linear-lanceolate, 5-6 × 1-1.5(-3) mm. Pedicels 39-42 mm long. Flowers with dorsal petal white with rose margin, lateral petal purple, lower petal with white spot and dark pink apex. Lateral sepals 2, ovate, acuminate, 5-6 × 1.8-2(-3) mm. Lower sepal 11-12 mm long and 4-5(-6) mm deep, spur curved forward through 90° and obtuse with darker apex, 4-6 × 1.5 mm. Dorsal petal cucullate, with distinct apical spur, 8-11 mm long and 4-6 mm high, spur 1 mm long. Lateral united petals 14-20 mm long, upper petal 5-9 × 5-6 mm, shortly mucronate at apex, lower petal 8-14 × 4-5 mm. Anthers 3-4(-6) mm long. Ovary 4 mm long. Young fruit 10-11 × 3 mm.

REMARKS—*Impatiens guillaumetii* is related to *I. lachnosperma* H.Perrier from Manongarivo, but differs in the distinct extrafloral nectaries on petiole (absent or only 1 or 2 in the latter species) and the longer spur which is curved forward at an angle of 90° (2.5 × 1 mm, slightly curved in *I. lachnosperma*).

HABITAT— Lowland rainforest, at 270 m.

DISTRIBUTION— Madagascar, Mananara region.

ETYMOLOGY— Named after Jean-Louis B. Guillaumet who collected the type specimen.

Impatiens nomenyae Eb.Fisch. & Raheliv., sp. nov. (Fig. 9)

Impatiens benitae affinis sed forma petali dorsalis, petalo superiore valde minore et fructu squamulis albis instructa valde differt.

TYPUS— Madagascar. Réserve Nationale 12 Marojejy, sentier qui mène au 2e camp, au-dessus du village de Manantenina, 300-760 m, 24.III.1990, *Randrianasolo 54* (holo-, P; iso-, MO, TAN).

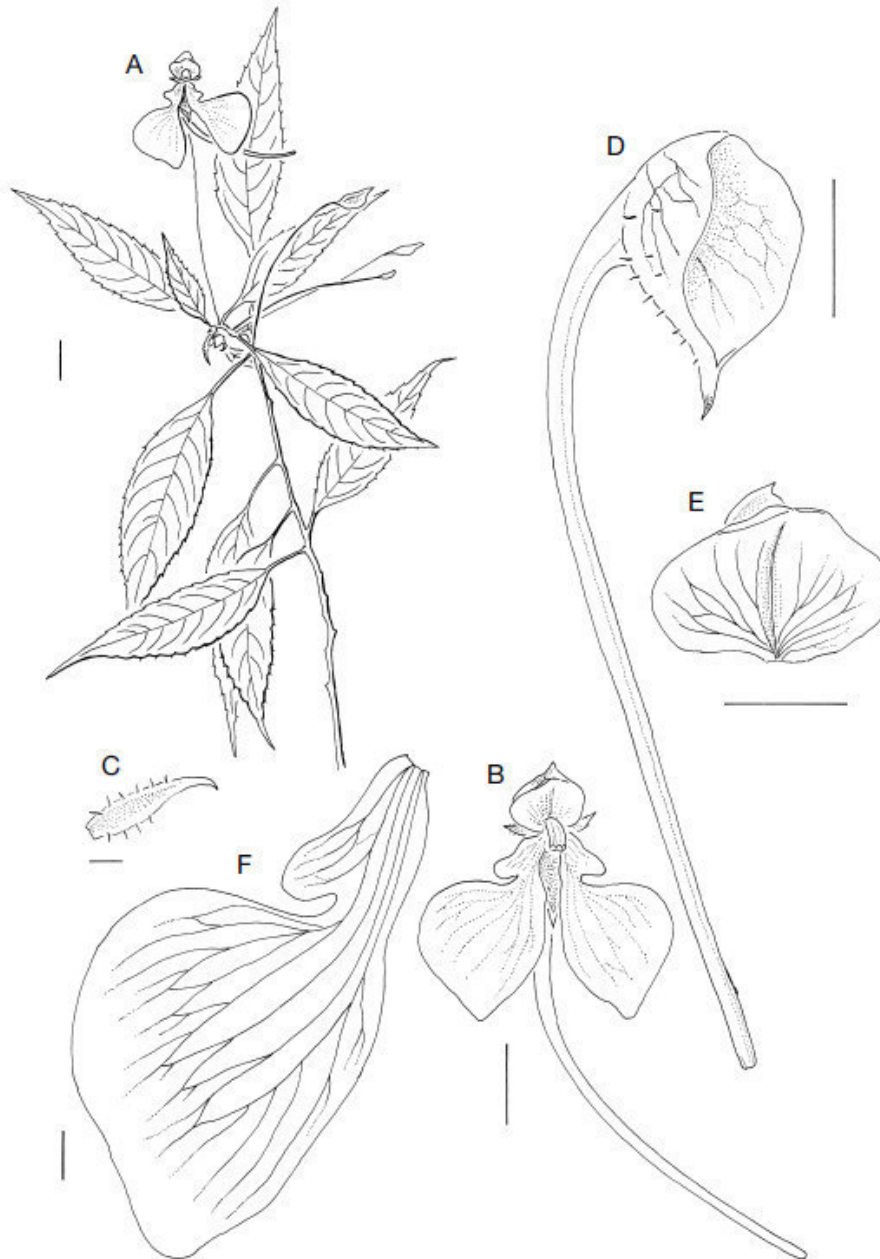


FIGURE 9. *Impatiens nomenyae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, flower; **C**, lateral sepal; **D**, lower sepal and spur; **E**, dorsal petal; **F**, lateral united petals. *Randrianasolo 54 (P)*. Scale bars: A, 1 cm; B, D, E, 5 mm; C, F, 1 mm.

DESCRIPTION— Perennial herb, glabrous. Stem slightly succulent, up to 17 cm tall. Leaves alternate, petiole 16-19 mm long, with 4 pairs of linear, 1 mm long fimbriae, lamina with sparse whitish hairs, oblong-lanceolate, attenuate-acuminate at base and acuminate at apex, 60-75(-130) × 16-20(-50) mm, margin with 13-17(-30) pairs of teeth with gland-tipped appendages. Inflorescence with 1 or 2 axillary flowers per leaf,

peduncle up to 1 mm long. Bracts filiform, 2 × 0.4 mm. Pedicels 45-60 mm long. Flowers with dorsal petal white with greenish crest, lower sepal with spur white, lateral united petals with upper petal white and lower petal pink. Lateral sepals 2, linear-lanceolate, pilose, 4 × 1 mm. Lower sepal acuminate, sparsely pubescent, 10 mm long and 4-5 mm broad, with 39-40 mm long, filiform spur. Dorsal petal with distinct crest and short apicule, 7 mm long and 8-9 mm broad. Lateral united petals 25 mm long, upper petal 2-3 × 2-3 mm, lower petal 18 × 13 mm. Anthers 4-6 mm long. Ovary 5-6 mm long. Fruit 11-18 × 6-8 mm, with whitish scales.

REMARKS— *Impatiens nomenyae* resembles *I. benitae* Eb.Fisch., Wohlh. & Raheliv. from Masoala and Marojejy, but differs clearly in the shape of the dorsal petal (9 × 6 mm in *I. benitae*, 7 × 8-9 mm in *I. nomenyae*), the upper petals which are much smaller than the lower petals (upper petal 2-3 × 2-3 mm, lower petal 18 × 13 mm in *I. nomenyae*, upper petal 10 × 6-7 mm, lower petal 10-11 × 6-7 mm in *I. benitae*), the longer spur (39-40 mm in *I. nomenyae*, 25 mm in *I. benitae*) the fruits with whitish scales (smooth and glabrous in *I. benitae*).

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Marojejy, only known from the type locality.

VERNACULAR NAME— “Benja marokely”.

ETYMOLOGY— Named after Nomeny, the late daughter of the second author.

Impatiens nusbaumeri Eb.Fisch. & Raheliv., sp. nov. (Fig. 10)

Impatiens nomenyae affinis sed floribus albis et calcare valde brevior differt.

TYPUS— Madagascar. Province de Diego-Suarez/Antsiranana, sous-préfecture de Vohemar, commune rurale de Daraina, forêt de Binara, 13°13.96'S, 49°35.34'E, 1100 m, 10.XII.2005, Nusbaumer & Ranirison LN 1761 (holo-, G; iso-, TAN).

DESCRIPTION— Perennial herb, erect, glabrous except for upper surface of lamina. Stems erect, up to 50 cm long. Leaves alternate, upper surface dark green, with sparse

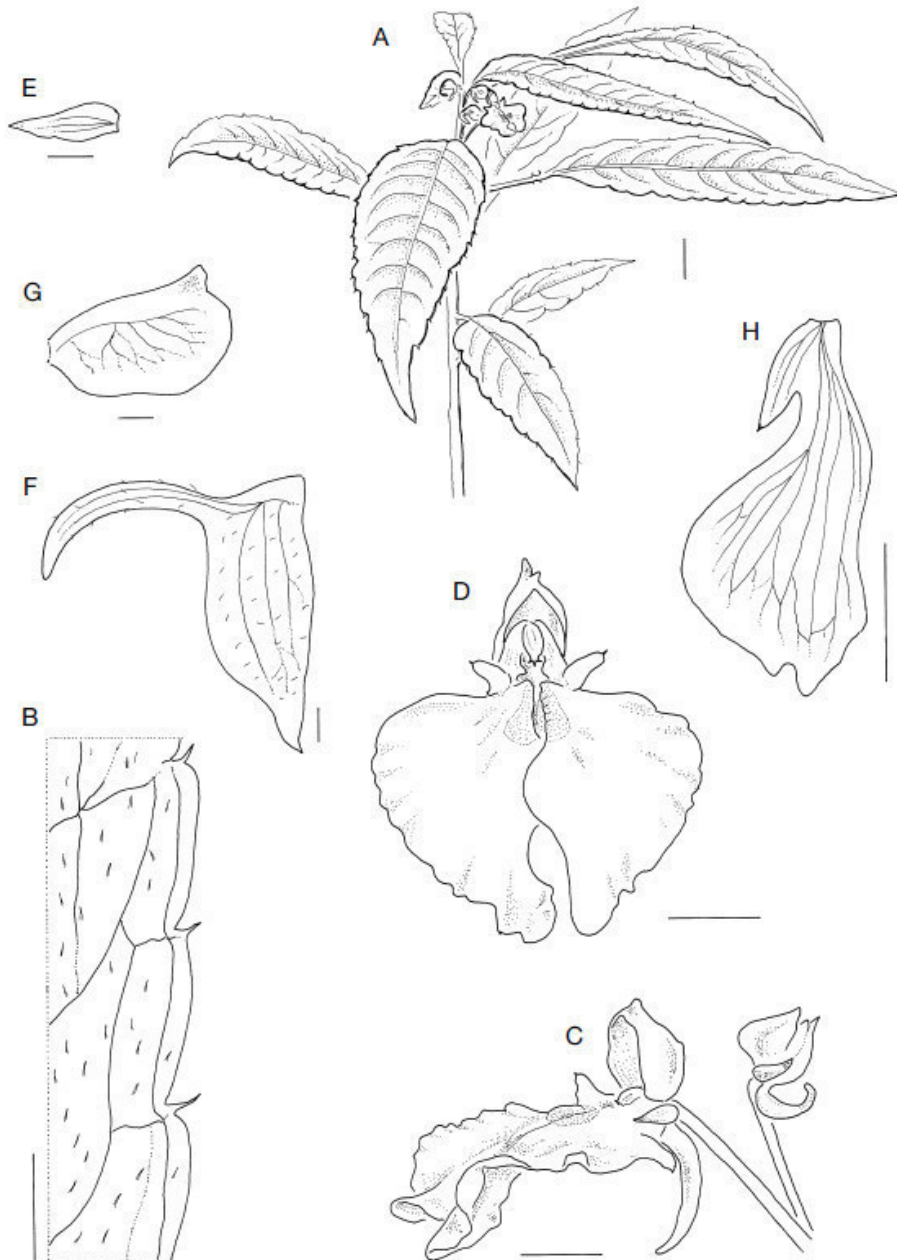


FIGURE 10. *Impatiens nusbaumeri* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal and spur; **G**, dorsal petal; **H**, lateral united petals. *Nusbaumer & Ranirison LN 1761* (G). Scale bars: A, 1 cm; B-D, H, 5 mm; E-G, 1 mm.

hairs, lower surface light green, glabrous, petiole 20-33 mm long, with 2 (3) pairs of extrafloral nectaries, lamina lanceolate, attenuate-acute at base, slightly decurrent, attenuate-acuminate at apex, 90-150 × 20-24 mm, margin dentate, with 12-15 pairs of teeth with gland-tipped appendages. Inflorescence with 2 or 3 axillary flowers. Bracts filiform, 3-4 × 0.5 mm. Pedicels 40-48 mm long. Flowers white, with yellow spot on

Chapter 7 — New taxa from Madagascar IV

lower petal. Lateral sepals ovate, acuminate, 2 × 1 mm. Lower sepal navicular, 13-14 mm long and 2-3 mm deep, spur curved, obtuse at apex, 6-8 mm long. Dorsal petal cucullate, with short spur at apex, 6-7 × 4 mm. Lateral united petals 13-14 mm long, upper petal acute, 3 × 1 mm, lower petal rounded, 11 × 5 mm. Anthers 3 mm long. Ovary 2-3 mm long. Fruit 8 × 3 mm in immature stage.

REMARKS— *Impatiens nusbaumeri* resembles *I. nomenyae* Eb.Fisch. & Raheliv. from Marojejy, but differs in the entirely white flowers with yellow spots (white with pink lateral petals in *I. nomenyae*), the much shorter spur (6-8 mm in *I. nusbaumeri*, 39-40 mm in *I. nomenyae*), and the shorter lateral united petals (13-14 mm long in *I. nusbaumeri*, 25 mm long in *I. nomenyae*).

HABITAT— Montane rainforest, 1100 m.

DISTRIBUTION— Madagascar, Daraina region, only known from the type collection.

ETYMOLOGY— Named after Louis Nusbaumer, Geneva, who collected the type specimen.

Impatiens laurentii Eb.Fisch. & Raheliv., sp. nov. (Fig. 11)

Ab omnibus speciebus madagascariensibus forma petali superioris valde differt.

TYPUS— Madagascar. Province de Diego-Suarez/Antsiranana, sous-préfecture de Vohemar, commune rurale de Daraina, forêt de Binara, camp I, 13°15'S, 49°37'E, 1,3 km WSW du camp, 700 m, 8.XI.2001, *Gautier & Ravelonarivo LG 4122* (holo-, G; iso-, TAN).

PARATYPE— Madagascar. Province de Diego-Suarez/Antsiranana, sous-préfecture de Vohemar, commune rurale de Daraina, forêt d'Antsahabe, 13°13'S, 49°33'E, rivière Antsahabe, 460 m, 9.III.2003, *Gautier, Wohlhauser & Nusbaumer LG 4285* (G, TAN).

DESCRIPTION— Perennial herb, erect, glabrous throughout. Stems succulent, branched, up to 100-150 cm long. Leaves alternate, petiole with 3 or 4 pairs of c. 2 mm long extrafloral nectaries, up to 50 mm long, lamina coriaceous, obovate, elliptic, acute, acuminate and slightly decurrent at base and attenuate-acute at apex, net of tertiary

veins nearly invisible, 85-150 × 25-55 mm, margin with 24 pairs of gland-tipped teeth. Inflorescence with solitary axillary flowers. Bracts ovate, 2 × 1 mm. Pedicels up to 75

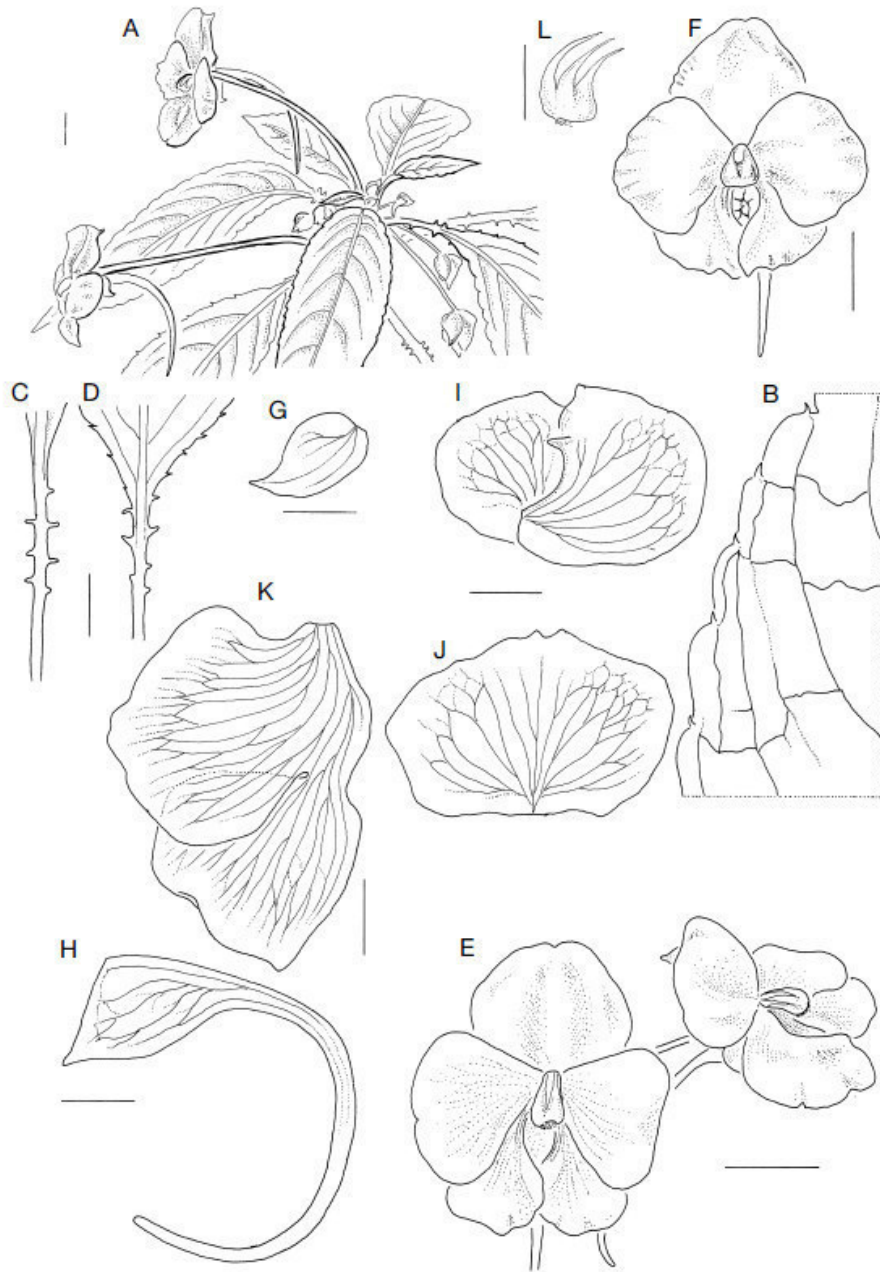


FIGURE 11. *Impatiens laurentii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, **D**, petiole; **E**, **F**, flowers in different pollination stages; **G**, lateral sepal; **H**, lower sepal and spur; **I**, dorsal petal, dorsal view; **J**, dorsal petal, ventral view; **K**, lateral united petals; **L**, androecium. A-E, G-L, *Gautier & Ravelonarivo* LG 4122 (G); F, *Gautier, Wohlhauser & Nusbaumer* LG 4285 (G). Scale bars: A, C-F, 1 cm; B, G-L, 5 mm.

mm long. Flowers with lower sepal white with red veins, dorsal petal magenta with green spur at apex, lateral united petals magenta except internal part which is white with red veins. Lateral sepals broadly ovate, distinctly acuminate, 8 × 7 mm. Lower sepal acuminate, 15 mm long and 7 mm broad, with 30-40 mm long, filiform and curved spur. Dorsal petal with distinct crest and short, 1 mm long apicule, 16 mm long and 18-19 mm broad. Lateral united petals 20-23 mm long, upper petal ovate, obtuse, 15 × 15-16 mm, lower petal 20 × 13-14 mm. Anthers 7 mm long. Ovary 6-7 mm long. Fruit 10 × 3 mm.

REMARKS— *Impatiens laurentii* is a very showy species. It looks superficially similar to *I. lyallii* Baker, but differs in the number of extrafloral nectaries (0-2 in *I. lyallii*, 3 or 4 in *I. laurentii*), the longer spur (25-30 mm in *I. lyallii*, 30-40 mm in *I. laurentii*), and the distinct reticulate pattern on lower sepal. It differs from all Malagasy *Impatiens* in the upper lateral petals which are triangular at apex.

HABITAT— Dense evergreen rainforest, in ravines with large rocks, 460-700 m.

DISTRIBUTION— Madagascar, region of Daraina.

ETYMOLOGY— Named after Laurent Gautier, Geneva, who collected the type specimen.

Subgenus *Trimorphopetalum* (Baker) Eb.Fisch.

DIAGNOASTIC CHARACTERS— Lower sepal without spur, extrafloral nectaries on petiole lacking.

***Impatiens georgei-schatzii* Eb.Fisch. & Raheliv., sp. nov. (Fig. 12)**

Impatiens perfecundae affinis sed indumento denso valde differt. Ab *I. albopurpurea* et *I. rivulari* petalo superiore longiore vel aequilongo differt.

TYPUS— Madagascar. Toamasina, Masoala Peninsula, c. 3 km NE of Antalavia, along Antalavia River, 15°47'S, 50°02'E, 200-380 m, 13-16.XI.1989, Schatz, Dransfield & Du Puy 2797 (holo-, MO; iso-, P, TAN).

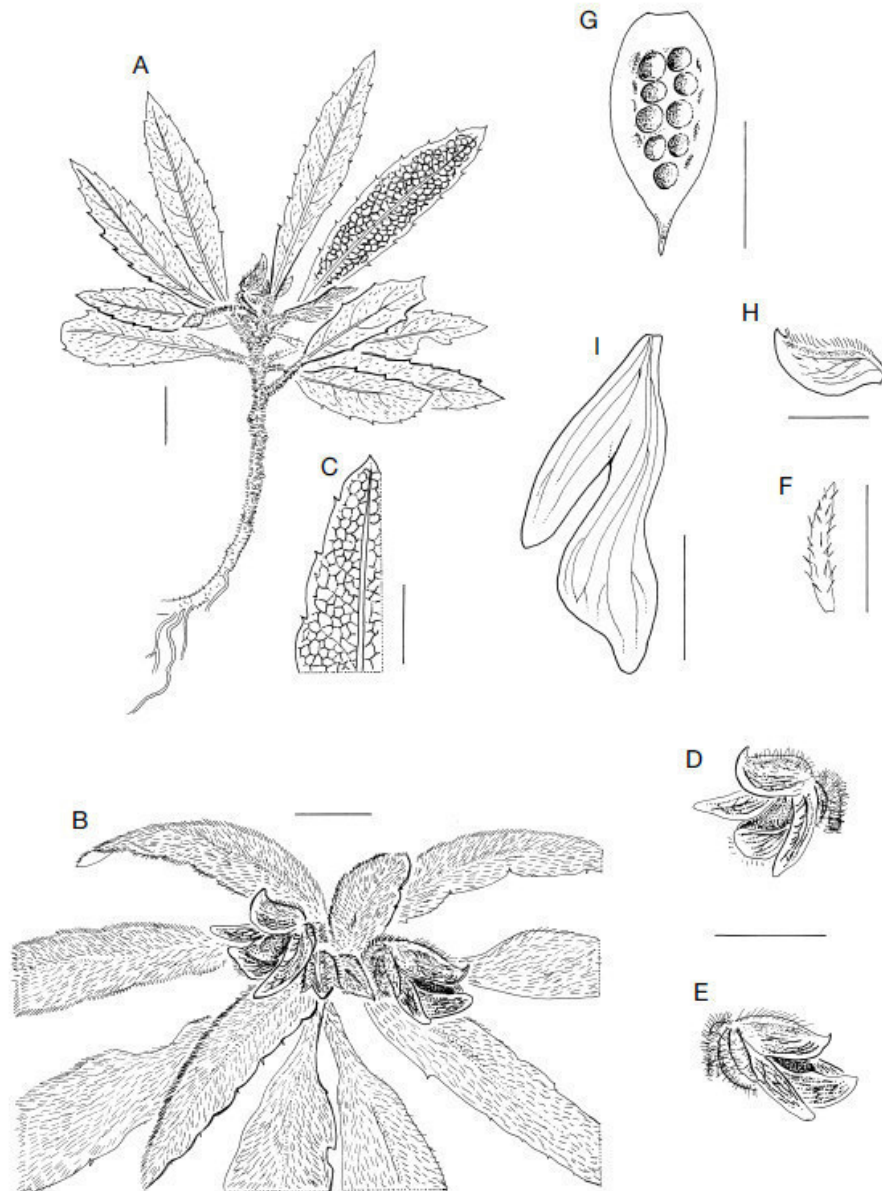


FIGURE 12. *Impatiens georgei-schatzii* Eb.Fisch. & Raheliv.: **A, B**, habit; **C**, detail of leaf margin; **D, E**, flower; **F**, lateral sepal; **G**, lower sepal; **H**, dorsal petal; **I**, lateral united petals. *Schatz, Dransfield & Du Puy 2797* (MO). Scale bars: A-E, 1 cm; F-I, 5 mm.

DESCRIPTION— Perennial herbs, ascending to erect with creeping rhizome, densely hairy throughout. Stems 4-6(-8) cm long. Leaves medium green above, whitish below, densely covered with whitish hairs, petiole up to 10 mm long, lamina narrow lanceolate, attenuateacute at base and attenuate-acuminate at apex, net of tertiary veins visible on lower surface, 35-50 × 8-10 mm, margin dentate, with 6 or 7 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Pedicels medium green, up to 14 mm long. Flowers with sepals clear translucent, petals light

green translucent but with dense dark purple reticulations thus appearing nearly black (in living specimens). Lateral sepals linear-filiform, hairy, 5 × 0.5 mm. Lower sepal ovate with distinct acumen at apex, with “bee-nest”-like reticulations comprising a net of holes, glabrous at upper surface, densely hairy at lower surface, 9 × 3-4 mm. Dorsal petal helmet-like, dorsal crest with short, 3 mm long spur, hairy outside, 8 × 4 mm. Lateral united petals 16-17 mm long, upper petal acute at apex, 11 × 2 mm, lower petal 13 × 2.5 mm. Anthers 2 mm long. Ovary 2-3 mm long. Fruit 7 × 3.5 mm, densely hairy.

REMARKS— *Impatiens georgei-schatzii* is related to *I. albopurpurea* Eb.Fisch. & Raheliv., *I. rivularis* Eb.Fisch., Wohlh. & Raheliv. from Masoala Peninsula and *I. perfecunda* H.Perrier from the Bay of Antongil. It differs from *I. perfecunda* in the densely hairy indumentum, the translucent-purple flowers (white-yellowish in *I. perfecunda*), the lanceolate lateral sepals (5 × 0.5 mm in *I. georgei-schatzii*, 3-4.5 × 1.4-1.8 mm in *I. perfecunda*), the longer dorsal petal (9 mm in *I. georgei-schatzii*, 5 mm in *I. perfecunda*), and the longer lateral united petals (16-17 mm in *I. georgei-schatzii*, 10 mm in *I. perfecunda*). It differs from *I. albopurpurea* and *I. rivularis* in the longer lateral united petals (10-11 mm in *I. albopurpurea*, 7 mm in *I. rivularis*), and the upper petal which is equaling or larger than lower petal (upper petal 11 × 2 mm and lower petal 13 × 2.5 mm in *I. georgei-schatzii*, smaller than lower petal in *I. albopurpurea* with upper petal 4 × 1.5 mm and lower petal 6 × 2.5-3 mm, and *I. rivularis* with upper petal 1 × 0.5 mm and lower petal 4 × 3 mm).

HABITAT— Rocks in river bed in lowland rainforest at 200-380 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after the collector George Schatz, St. Louis.

Impatiens nosymangabensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 13)

Impatiens carlsoniae affinis sed nervibus prominentibus sepali inferioris, colore petalorum et forma petali dorsalis differt.

TYPUS— Madagascar. Tamatave, Nosy Mangabe, a 520 ha island 5 km from Maroantsetra in the Bay of Antongil, 15°30'S, 49°46'E, 0-330 m, 12.X.1987, *Schatz 1640* (holo-, MO; iso-, TAN).

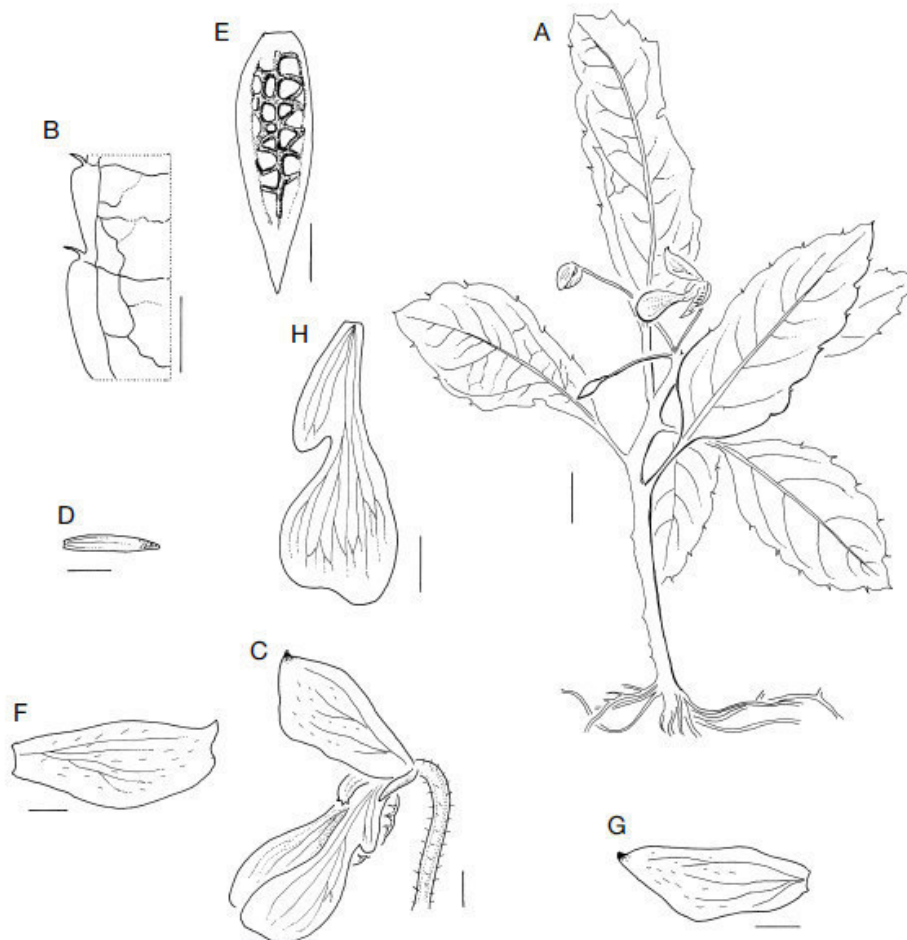


FIGURE 13. *Impatiens nosymangabensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, flower; **D**, lateral sepal; **E**, lower sepal; **F**, **G**, dorsal petal; **H**, lateral united petals. *Schatz 1640* (MO). Scale bars: A, 5 mm; B-H, 1 mm.

DESCRIPTION— Perennial herb, creeping to ascending and erect. Stems succulent, branched, up to 20 cm long, young part covered with white hairs, later glabrescent. Leaves alternate, medium green above, lighter whitish green below, the venation below darker green evident, petiole hairy, up to 10 mm long, lamina ovate-lanceolate, attenuate at base and obtuse at apex, 30-45 × 15 mm, margin dentate, with 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Pedicels up to 10 mm long, hairy. Flowers with sepals green, translucent with

purple markings, petals greenish bronze, translucent. Lateral sepals linear-lanceolate, up to 2 mm long. Lower sepal lanceolate, distinctly acuminate, with “beenest”- like prominent ornamentation of dark purple midrib and 6 or 7 pairs of rib-like structures surrounding holes, 6 × 2.5 mm. Dorsal petal helmet like, dorsal crest with short spur at apex, 6 × 2 mm. Lateral united petals 7 mm long, upper petal obtuse at apex, 2.5-3 × 1.3 mm, free part 0.5 × 0.8 mm, lower petal rounded at apex, 4.5-5 × 5 mm. Anthers 2 mm long. Ovary 2-3 mm long. Fruit not known.

REMARKS— *Impatiens nosymangabensis* is related to *I. carlsoniae* Eb.Fisch. & Raheliv., also restricted to the island of Nosy Mangabe. It differs in the prominent ornamentation on lower sepal (non prominent veins in *I. carlsoniae*), the greenish bronze petals (translucent in *I. carlsoniae*), the shape of the dorsal petal with shorter spur (0.1 mm in *I. nosymangabensis*, 0.5 mm in *I. carlsoniae*), and the shorter upper petal (2.5-3 × 1.3 mm in *I. nosymangabensis*, 3.5 × 1.5 mm in *I. carlsoniae*).

HABITAT— On rocks in streams in lowland rainforest at 0-330 m.

DISTRIBUTION— Madagascar, Nosy Mangabe, only known from the type collection.

Impatiens paranyi Eb.Fisch. & Raheliv., sp. nov. (Fig. 14)

Impatiens naviculae affinis sed foliis lanceolatis, tuberculis petali inferioris, margine petali inferioris non recurvato et ornameto sepalis inferioris differt.

TYPUS— Madagascar. Province de Diego-Suarez/Antsiranana, sous-préfecture d’Andapa, commune rurale de Doany, fokontany de Betsomanga, Marojejy, NW, camp II, 14°26’S, 49°37’E, c. 0.5 km à l’est du point coté 1349, 1150 m, 29. X. 2001, *Gautier, Andriamparany & Ravelomantsoa LG 3967* (holo-, G; iso-, TAN).

PARATYPE— Madagascar. Partie occidentale du massif de Marojejy (Nord-Est), de la vallée de l’Ambatoharanana au bassin supérieur de l’Antsahaberoka, 800-1200 m, forêt ombrophile sur argile latéritique de gneiss et granite, 9.XI-2.XII.1959, *Humbert & Saboureau 31430* (P).

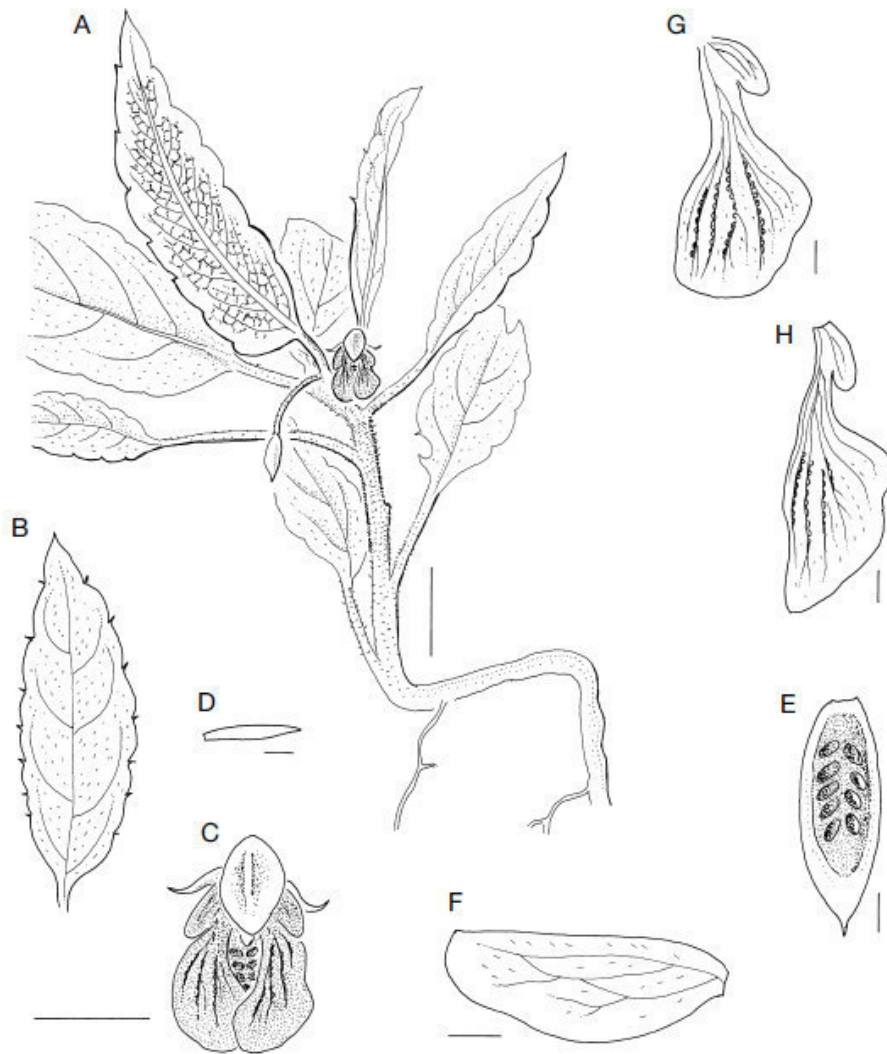


FIGURE 14. *Impatiens paranyi* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, flower; **D**, lateral sepal; **E**, lower sepal; **F**, dorsal petal; **G**, **H**, lateral united petals. *Gautier, Andriamparany & Ravelomantsoa LG 3967 (G)*. Scale bars: A, B, 1 cm; C, 5 mm; D-H, 1 mm.

DESCRIPTION— Perennial herb, ascending to erect. Stems hairy, semisucculent, 5-10(-15) cm long. Leaves alternate, petiole with sparse hairs, up to 20 mm long, lamina subglabrous, hairy in young stage, later glabrescent, ovate-elliptic, obtuse-rounded at base and acute at apex, net of darker tertiary veins visible on lower surface, 35-50 × 15-20 mm, margin dentate, with 7 or 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts linear-filiform, up to 0.5 mm long. Pedicels with dense whitish hairs, up to 7 mm long. Flowers dark purple. Lateral sepals lanceolate, 3 × 1 mm. Lower sepal ovate-lanceolate, with “bee-nest”-like prominent dark purple ornamentation surrounding c. 5 pairs of holes, 6 × 3 mm.

Dorsal petal helmet-like, 5 × 2.5 mm. Lateral united petals 8 mm long, upper petal obtuse, 2.5 × 0.5 mm, lower petal obtuse-rounded, with tubercle-like crests along the veins, 5.5 × 2.5 mm. Anthers 2 mm long. Ovary 2 mm long. Fruit glabrous, 5 × 3 mm.

REMARKS— *Impatiens paranyi* differs from *I. navicula* Eb.Fisch. & Raheliv. also from Marojejy in the lanceolate leaves (35-50 × 15-20 mm in *I. paranyi*, 18-19 × 18 mm in *I. navicula*), the tubercle-like crests on veins of lower petal (absent in *I. navicula*), the non recurved margin of lower petal (recurved in *I. navicula*), and the different ornamentation pattern on lower sepal.

HABITAT— On wet rocks in ravine of a montane rainforest at 800-1200 m.

DISTRIBUTION— Madagascar, Marojejy.

ETYMOLOGY— Named after the second collector Andriamparany.

Impatiens haingosonii Eb.Fisch. & Raheliv., sp. nov. (Fig. 15)

Impatiens naviculae affinis sed basi foliorum acuminato et ornamento sepali inferioris differt. Ab *I. paranyi* differt margine petali inferioris non recurvato et ornamento sepali inferioris.

TYPUS— Madagascar. Partie occidentale du massif de Marojejy (Nord-Est), de la vallée de l'Ambatoharanana au bassin supérieur de l'Antsahaberoka, 1400 m, forêt ombrophile sur latérite de gneiss et granite, 9.XI-2.XII.1959, *Humbert & Saboureau 31448* (holo-, P).

DESCRIPTION— Perennial herb, erect to ascending with creeping rhizome, densely hairy throughout. Stems up to 6 cm long, slightly woody at base. Leaves alternate, petiole up to 10 mm long, lamina slightly obtuse to acuminate at base and acute at apex, hairs on upper surface more dense than on lower surface, upper surface dark green and lower surface light green to whitish, margin crenate-dentate with 6 or 7 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts linear-lanceolate, hairy, up to 1.5 mm long. Pedicels up to 10 mm long, hairy. Flowers dark red to brownish-red. Lateral sepals linear-filiform, hairy up to 2 mm

long. Lower sepal ovate, dark red, with “bee-nest”-like ornamentation forming deep holes, surrounded by a membranaceous margin, 6 × 5 mm, hairy on lower surface. Dorsal petal helmet-like, hairy, 5 × 3 mm. Lateral united petals 11 mm long, upper petal rounded, 4 × 2 mm, free part 2 × 2 mm, lower petal 9 × 6 mm, acuminate at apex and bearing a short curved sinus towards the centre of the flower, margin of lower petal folded upwards thus resembling a leguminose navicula. Anthers 1 mm long. Ovary 1-2 mm long, hairy. Fruit 3 × 2 mm in young stage, hairy.

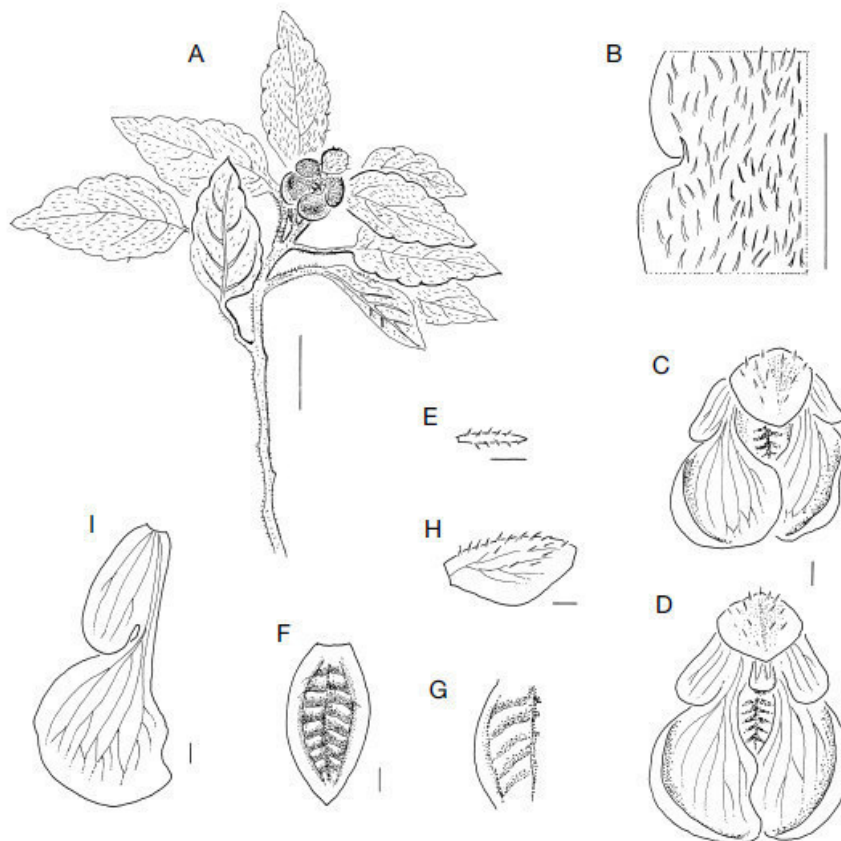


FIGURE 15. *Impatiens haingosonii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, detail of lower sepal; **H**, dorsal petal; **I**, lateral united petals. *Humbert & Saboureau 31448* (P). Scale bars: A, 1 cm; B, 5 mm; C-I, 1 mm.

REMARKS— *Impatiens haingosonii* is related to *I. navicula* and *I. paranyi*, both restricted to the Marojejy massif. It differs from *I. navicula* in the acuminate leaf-base, the more lanceolate leaves (18-26 × 8-10 mm in *I. haingosonii*, 18-19 × 18 mm in *I. navicula*), the rib-like ornamentation on lower sepal, and the shorter lateral united petals (11 mm long in *I. haingosonii*, 8-9 mm in *I. navicula*), and from *I. paranyi* in the more lanceolate leaves (35-50 × 15-20 mm in *I. paranyi*), the shorter lateral sepals (2

mm in *I. haingosonii*, 3 × 1 mm in *I. paranyi*), the longer lateral united petals (11 mm in *I. haingosonii*, 8 mm in *I. paranyi*), the non-recurved margin of the lower petal, and the ornamentation of the lower sepal.

HABITAT— Montane rainforest at 1400 m.

DISTRIBUTION— Madagascar, Marojejy, only known from the type collection.

ETYMOLOGY— Named after Dr Andriamialison Haingoson, Director of the Parc botanique et zoologique de Tsimbazaza.

Impatiens mahalevonensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 16)

Impatienti urticoidi et I. furcatae affinis sed petalis lateralibus aequo longo differt. Ab I. scripta differt petiolo longiore, petalo inferiore atro-violaceo et indumento foliorum.

TYPUS— Madagascar. Toamasina, Masoala National Park, E slope of Ambohitsitondroinan'Mahalevona, ESE of village of Mahalevona, perhumid forest along small creek, 15°26'09"S, 49°57'29"E, 1160 m, 24.II.2003, *Lowry, Schatz & Be 6154* (holo-, MO; iso-, TAN).

PARATYPE— Madagascar. Masoala Peninsula Réserve Intégrale, 200 m before the Ambohitsitondroina summit, 15°25'956"S, 49°57'563"E, 1100 m, 22.IX.1996, *Purro & Wohlhauser 1011* (NEU, TAN).

DESCRIPTION— Perennial herb, erect with creeping rhizome, densely hairy throughout. Stems with dense whitish hairs, up to 15 cm long. Leaves alternate, reddish to dark green, tinged pink below, with hairs in dense tufts on upper surface, lower surface densely hairy but without tufts, petiole 15-20 mm long, lamina ovate, rounded at base and acute at apex, 30-35 × 15-20 mm, margin dentate with 12 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Pedicels up to 5-10 mm long, densely hairy. Flowers reddishbrown, vinous to deep brownish purple. Lateral sepals linear-lanceolate, hairy, with dark brown apex, 2.5 × 1 mm. Lower sepal lanceolate, acuminate at apex, with prominent dark red midrib and 4 pairs of rib-like prominent ridges, 7 × 3 mm, glabrous on upper surface and with

whitish hairs on lower surface. Dorsal petal helmet-like, with whitish hairs, 6 × 2 mm. Lateral united petals 9.5 mm long, upper petal 6.5 × 1.5 mm, acuminate to obtuse at apex, lower petal 6.5 × 3 mm, obtuse at apex. Anthers c. 1 mm long. Ovary c. 2 mm long. Fruit not known.

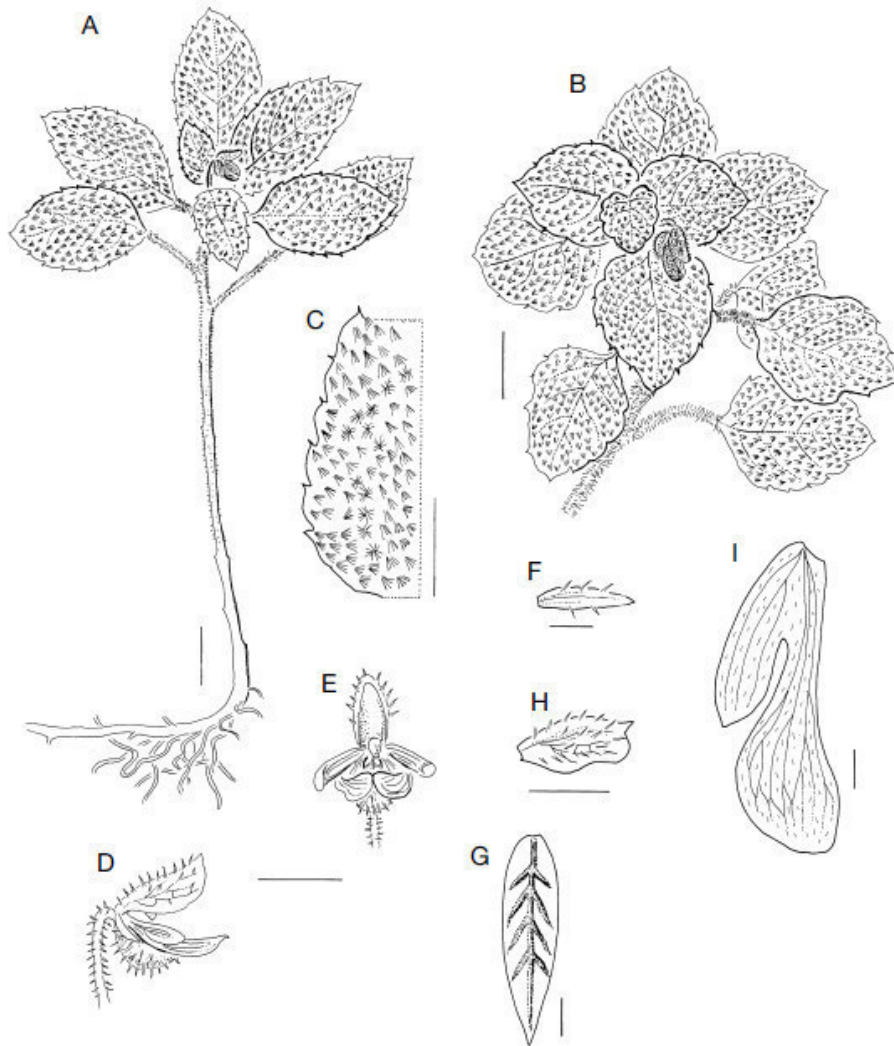


FIGURE 16. *Impatiens mahalevonensis* Eb.Fisch. & Raheliv.: **A, B**, habit; **C**, detail of leaf margin; **D, E**, flower; **F**, lateral sepal; **G**, lower sepal; **H**, dorsal petal; **I**, lateral united petals. A, C, F-I, *Lowry, Schatz & Be 6154* (MO); B, D, E, *Purro & Wohlhauser 1011* (NEU). Scale bars: A, B, 1 cm; C-E, H, 5 mm; F, G, I, 1 mm.

REMARKS— *Impatiens mahalevonensis* is related to *I. furcata* H.Perrier, *I. urticoides* H.Perrier and *I. scripta* H.Perrier from North-Eastern Madagascar. It differs from *I. urticoides* and *I. furcata* in the lateral united petals which are of equal length (upper petal shorter than lower petal in *I. urticoides*, upper petal longer than lower petal in *I.*

furcata), and from *I. scripta* in the longer petiole (15-20 mm versus 3-12 mm in *I. scripta*) and the brownish-purple lower petal (vivid yellow in *I. scripta*) and the hairs on leaves, forming a whitish script-like pattern in *I. scripta* (dense regular tufts in *I. mahalevonenis*).

HABITAT— Montane rainforest at c. 1100 m.

DISTRIBUTION— Madagascar, Masoala Peninsula.

Impatiens ambahatrensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 17)

Ab omnibus speciebus madagascariensibus subgeneris Trimorphopetali cum laminis lanceolatis atque ornamento prominente sepali inferioris differt foliis subsessilibus.

TYPUS— Madagascar. Antsiranana, Réserve Spéciale de Manongarivo, Ambahatra, cours supérieur, 13°59'S, 48°26'E, bassin de l'Ambahatra (bras gauche, à l'ouest d'Andetryfotsy), 450 m, tombant suintant couvert de mousses, 9.VI.2000, *Wohlhauser & Gautier SW 60300* (holo-, G; iso-, TAN).

PARATYPE— Madagascar. Antsiranana, Masoala Peninsula Réserve Intégrale, between camp 3 and Ilampy, in the Andranomaloto basin, 23.IX.1996, *Purro & Wohlhauser 1020* (NEU, TAN).

DESCRIPTION— Perennial (?) herb, ascending to erect with creeping rhizome, glabrous throughout. Stems simple, 20-40 cm long. Leaves alternate, petiole not exceeding 5 mm, lamina ovate-lanceolate, attenuate-acute and decurrent at base, attenuate-obtuse at apex, net of tertiary veins invisible, 40-55 × 10-14 mm, margin dentate with 6 or 7 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts ovate-lanceolate, 1 mm long. Pedicels up to 20 mm long. Flowers yellowish translucent with dark vinous-purple veins. Lateral sepals lanceolate, 3 × 1 mm. Lower sepal ovate-lanceolate, acute at apex, with prominent "bee-nest"-like dark purple ornamentation with midrib and rib-like structures surrounding holes, 7 × 3 mm. Dorsal petal helmet-like, with short spur at apex of dorsal crest, 5 × 2 mm. Lateral united petals 9 mm long, upper petal 3.2 × 1-1.5 mm, free part

Chapter 7 — New taxa from Madagascar IV

1.2 × 1 mm, lower petal obtuse, slightly emarginated, with tubercle-like crests along the veins, 7 × 3 mm. Anthers 2-3 mm long. Ovary 2-3 mm long. Fruit 7 × 3 mm.

REMARKS— *Impatiens ambahatrensis* differs from all members of subgenus *Trimorphopetalum* with lanceolate leaves and prominent ornamentation on lower sepal in the nearly sessile leaves with petioles not exceeding 5 mm in length.

HABITAT— Mossy rainforest at 450 m, in streams stuck to stones.

DISTRIBUTION— Madagascar, Manongarivo and Masoala Peninsula.

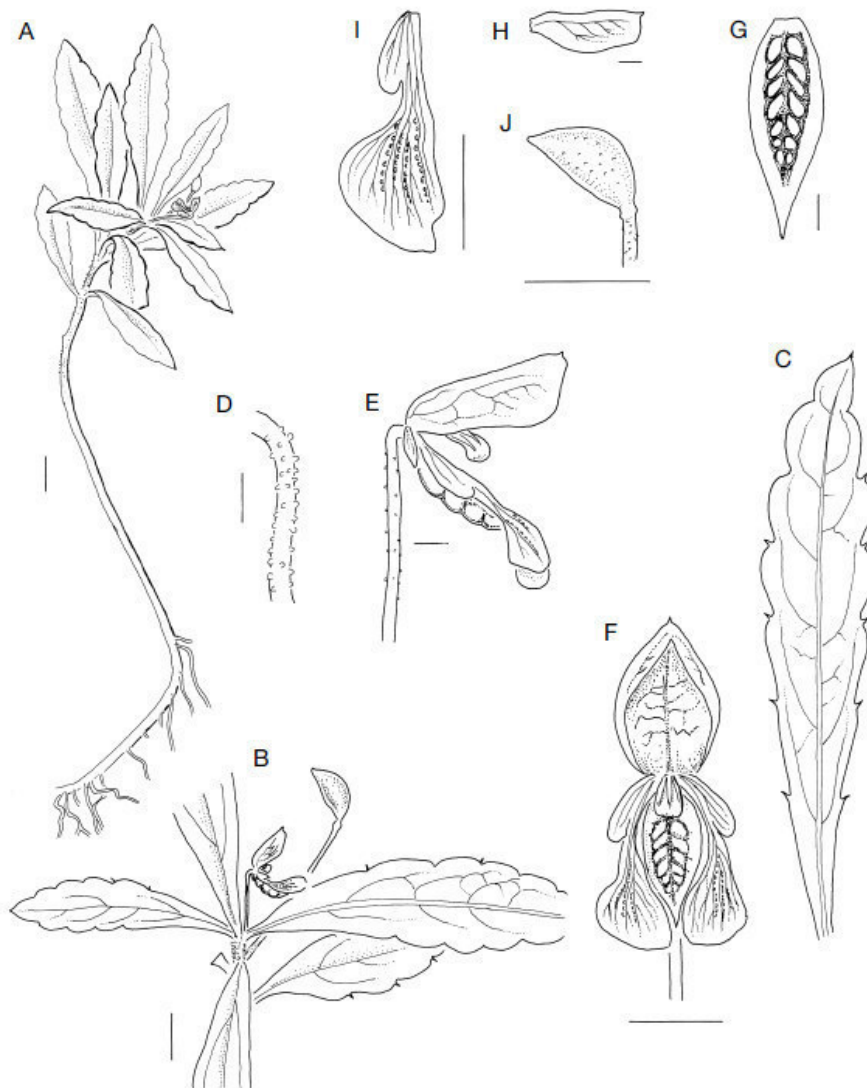


FIGURE 17. *Impatiens ambahatrensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of habit; **C**, leaf; **D**, detail of pedicel showing white scales; **E**, **F**, flower; **G**, lower sepal; **H**, dorsal petal; **I**, lateral united petals; **J**, fruit. *Wohlhauser & Gautier SW 60300* (G). Scale bars: A, C, 1 cm; B, F, I, J, 5 mm; D, E, G, H, 1 mm.

Impatiens messmerae Eb.Fisch. & Raheliv., sp. nov. (Fig. 18)

Impatiens silvianae et *I. luisae-echterae* affinis sed sepalo inferiore sine ornamento valde differt.

TYPUS— Madagascar. Antsiranana, Marombihy, Mandena, Parc National de Marojejy, le long d'un affluent de la rivière de Manantenina, 10 km NW du village Manantenina, Campement Nr. 2, 750 m, 14°26.0'S, 49°45.7'E, 22.X.1996, *Messmer, Rakotomalaza, Ravelonarivo NM 256* (holo-, G; iso-, TAN).

DESCRIPTION— Perennial herb, erect, glabrous except for small whitish scales. Stems up to 60 cm long. Leaves alternate, petiole up to 30 mm long, lamina elliptic, attenuate-acute at base and attenuate acute at apex, ending in a short mucro, net of tertiary veins visible, 100-145 × 35-45 mm, margin dentate, with 12 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1-3 axillary flowers, peduncle short, flattened. Bracts linear, with white hairs, 2.5 mm long. Pedicels up to 50 mm long. Flowers whitish-greenish, lateral united petals white with orange line. Lateral sepals linear-filiform, glabrous, 5 × 1 mm. Lower sepal lanceolate, acuminate, without ornamentation, 18 × 5 mm. Dorsal petal helmet-like, dorsal crest with 3 mm long spur at apex, dilated to a triangle at middle, 15 × 7.5 mm. Lateral united petals 20 mm long, upper petal rectangular, 8 × 3 mm, lower petal obtuse, 14 × 8 mm. Anthers 3 mm long. Ovary 3-4 mm long. Fruit with whitish scales, 15 × 2.5 mm.

REMARKS— *Impatiens messmerae* resembles *I. silviana* Eb.Fisch. & Raheliv. and *I. luisae-echterae* Eb.Fisch., Wohlh. & Raheliv. from Masoala Peninsula or *I. lemuriana* Eb.Fisch. & Raheliv. from Tsaratanana, but differs in the lower sepal completely lacking any ornamentation (distinct and prominent ornaments in the other species), the flower colour (whitish-greenish in *I. messmerae*, translucent with yellow and purple in *I. silviana* and *I. luisae-echterae*), the size of the dorsal petal (15 × 7.5 mm in *I. messmerae*, 17 × 6 mm in *I. silviana*, 26 × 7-8 mm in *I. luisae-echterae*, 8 × 4 mm in *I. lemuriana*), and the length of the lateral united petals (20 mm in *I. messmerae*, 24 mm in *I. silviana*, 12 mm in *I. lemuriana*).

HABITAT— Montane rainforest at 750 m.

DISTRIBUTION— Madagascar, Marojejy, only known from the type collection.

ETYMOLOGY— Named after the collector Nicole Messmer.

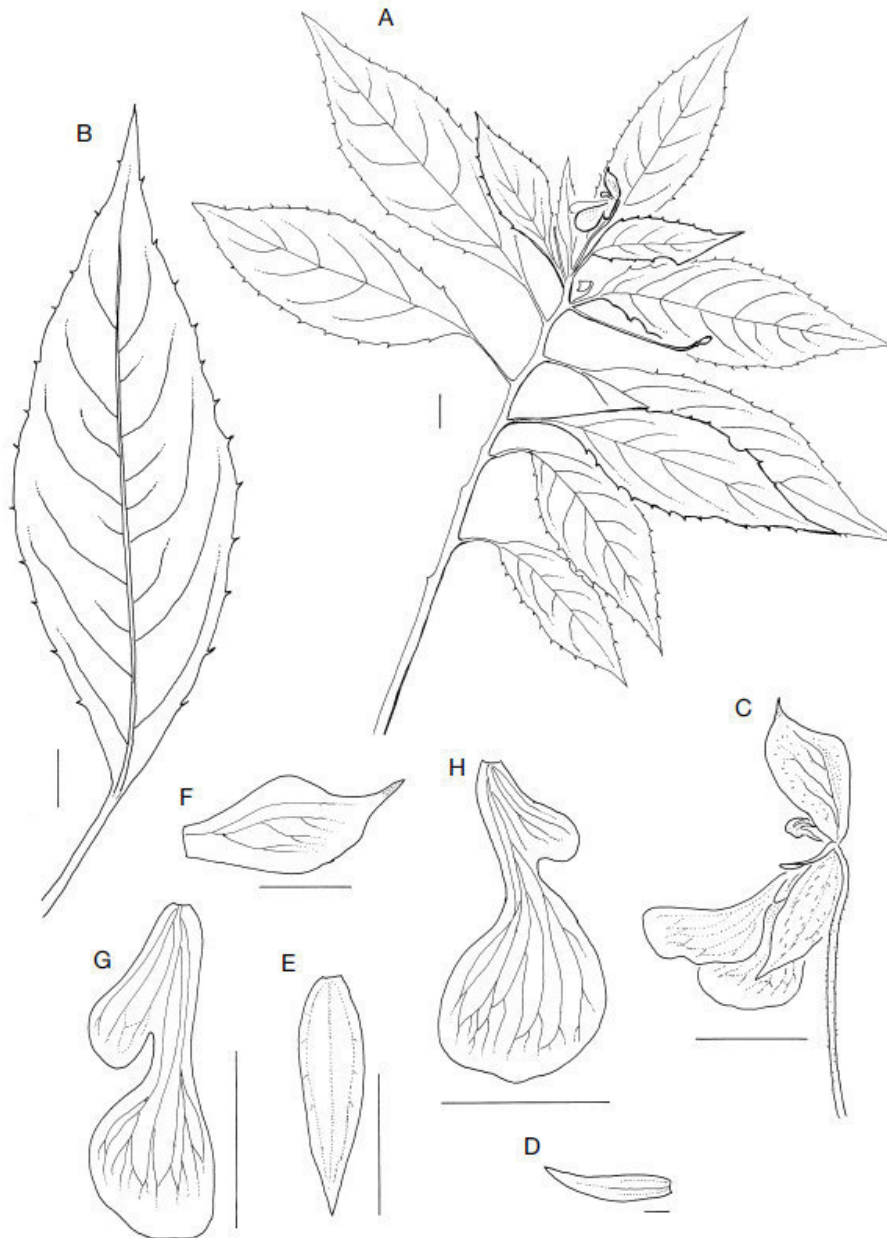


FIGURE 18. *Impatiens messmerae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, flower; **D**, lateral sepal; **E**, lower sepal; **F**, dorsal petal; **G**, **H**, lateral united petals. *Messmer, Rakotomalaza, Ravelonarivo NM 256 (G)*. Scale bars: A-C, E, G, H, 1 cm; D, 1 mm; F, 5 mm.

Impatiens andapensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 19)

Impatiens callmanderi, *I. luisae-echterae* et *I. ivohibensis* affinis sed ornameto sepali inferioris nidu-apis simile differt.

TYPUS— Madagascar. Pentes occidentales du massif de Marojejy (Nord-Est), bassin de la Lokoho à l'est d'Ambalamanasy II, district d'Andapa, forêt ombrophile sur latérite de gneiss, 800-1000 m, 30.XI-4.XII.1948 *Humbert & Capuron 22192* (holo-, P).

DESCRIPTION— Perennial robust erect herb, glabrous throughout. Stems succulent, simple, up to 30 cm long. Leaves alternate, petiole up to 25 mm long, lamina obovate, attenuate-acute at base and attenuate-acute to acuminate at apex, net of tertiary veins hardly visible, 85-150 × 30-55 mm, margin dentate, with 9 or 10 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Bracts filiform, 2 mm long. Pedicels up to 20 mm long. Flowers with dorsal petal green with purple veins, lateral united petals green-yellowish with purple veins and spots. Lateral sepals filiform, 7 × 1 mm. Lower sepal lanceolate, distinctly acuminate, with dark purple midrib and 6 (7) prominent rib-like structures, margin membranaceous, 13 × 6 mm. Dorsal petal helmet-like, dorsal crest with short spur at apex, dilated to a triangle at middle, 13 × 6.5 mm. Lateral united petals 16 mm long, upper petal 5 × 2.5 mm, lower petal 11 × 8 mm. Anthers c. 2 mm long. Ovary c. 3-4 mm long. Fruit not known.

REMARKS— *Impatiens andapensis* is related to *I. callmanderi* Eb.Fisch., Wohlh. & Raheliv., *I. luisae-echterae* Eb.Fisch., Wohlh. & Raheliv. and *I. ivohibensis* H.Perrier but differs in the prominent “bee-nest”-like ornamentation of the lower sepal, the size of the dorsal petal (13 × 6.5 mm in *I. andapensis*, 15 × 10 mm in *I. callmanderi*, 26 × 7-8 mm in *I. luisae-echterae*, 8 × 3 mm in *I. ivohibensis*), and the length of the lateral united petals (16 mm in *I. andapensis*, 19 mm in *I. callmanderi*, 20 mm in *I. luisae-echterae*, and 12 mm in *I. ivohibensis*). The specimen had been misidentified by H. Humbert as *Impatiens decaryana* H.Perrier.

HABITAT— Montane rainforest at 800-1000 m.

DISTRIBUTION— Madagascar, Marojejy, only known from the type collection.

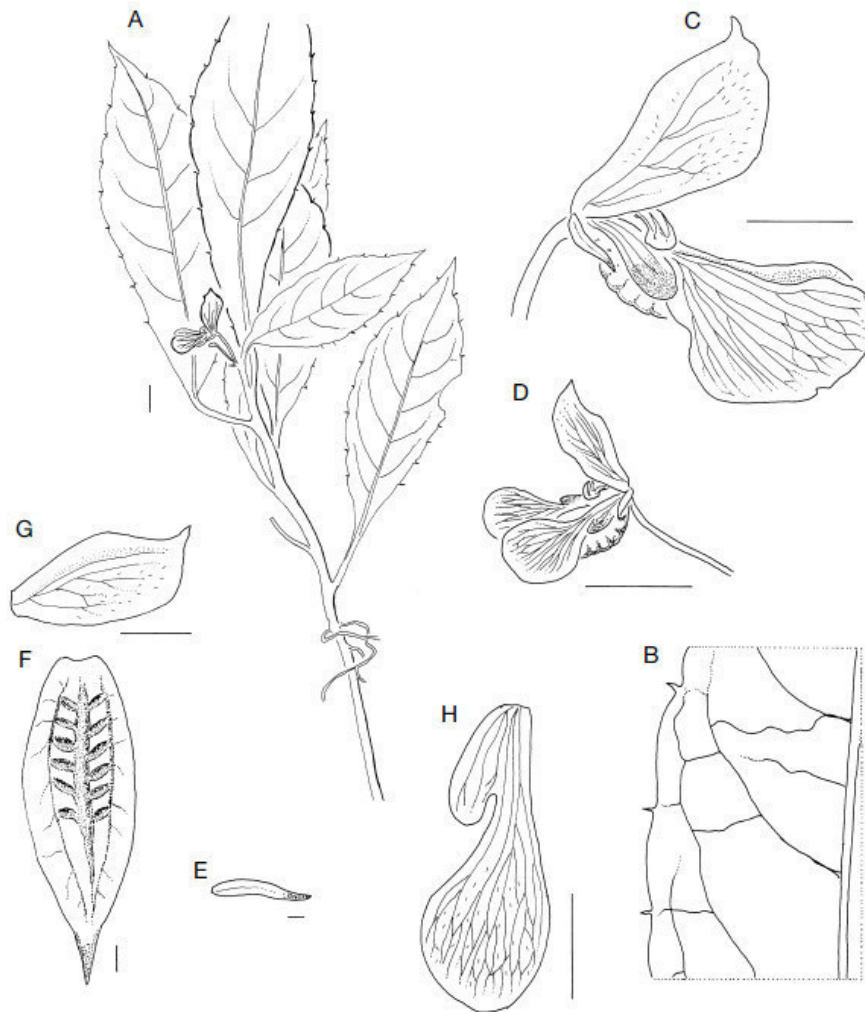


FIGURE 19. *Impatiens andapensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Humbert & Capuron 22192* (P). Scale bars: A, B, D, 1 cm; C, G, H, 5 mm; E, F, 1 mm.

Impatiens fianarantsoae Eb.Fisch. & Raheliv., sp. nov. (Fig. 20)

Impatienti biophytoidi affinis sed indumento sparse-hirsuto, foliis sublobatis, sepalo inferiore cum nervibus atro-violaceis, petalo superiore distincto et acuminato fructibusque cum 7-10 seminibus differt.

TYPUS— Madagascar. Fianarantsoa, Parc National de Ranomafana, Parcelle III, Vatoharanana, 21°16'S, 47°26'E, 900-1100 m, VII.1992, *Rakoto 113* (holo-, TAN; iso-, P, MO).

PARATYPE— Madagascar. Fianarantsoa, Parc National de Ranomafana, X.2001, *Rahelivololona RNM 9* (TAN).

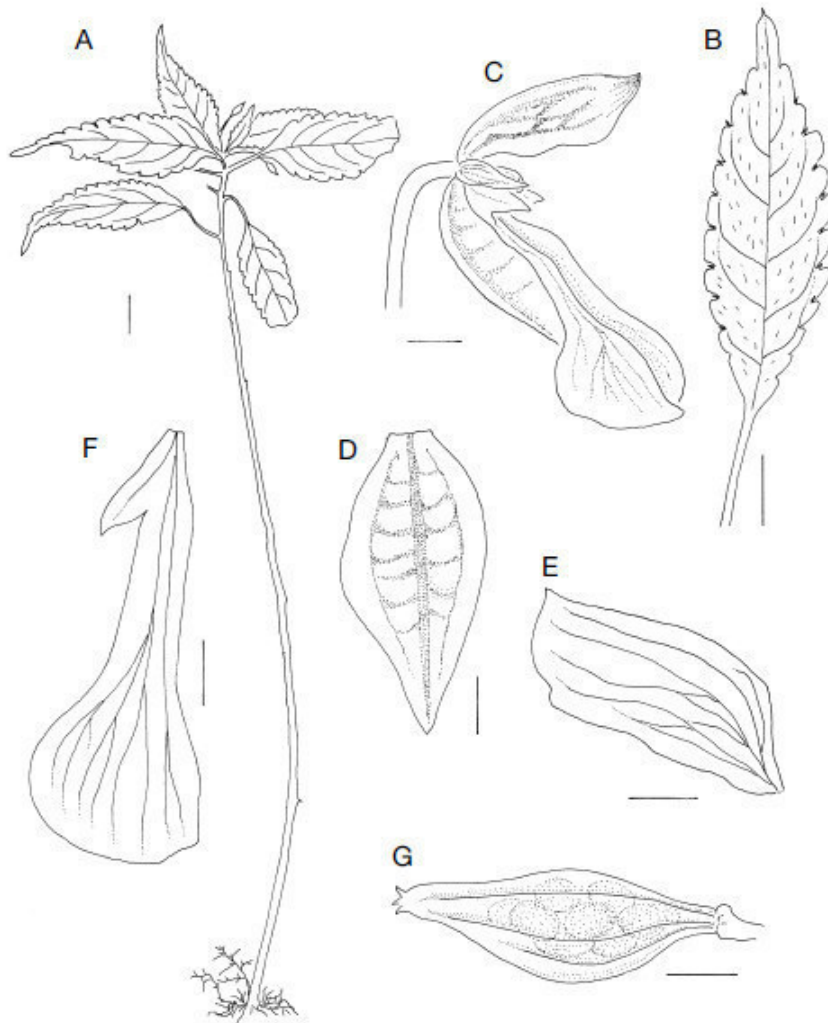


FIGURE 20. *Impatiens fianarantsoae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, flower; **D**, lower sepal; **E**, dorsal petal; **F**, lateral united petals; **G**, fruit. *Rahelivololona RNM 9* (TAN). Scale bars: A, B, 1 cm; C-G, 1 mm.

DESCRIPTION— Annual (?) herb, erect, glabrous except for sparse whitish hairs on upper surface of the lamina. Stems simple, up to 20-30 cm long. Leaves alternate, petiole up to 15 mm long, lamina lanceolate, acute to rounded-decurrent at base and acuminate to acute at apex, net of tertiary veins visible, 40-70 × 12-20 mm, margin broadly dentate-sinuate, with 8-16 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Bracts triangular, acute, 1 mm long. Pedicels up to 15 mm long. Flowers yellow, with dark red veins. Lateral sepals linear-lanceolate, 2 × 1 mm. Lower sepal lanceolate, acuminate, with dark red midrib and 7

pairs of hardly visible dark red ribs, 5-7 × 2-2.5 mm. Dorsal petal helmet-like, with short apicule at apex of crest, and small triangle at lower third of the dorsal crest 4-5 × 1.5-2.5 mm. Lateral united petals 6-7(-10) mm long, upper petal 1 × 0.5 mm, shortly acute or obtuse, lower petal 4-5 × 2 mm, obtuse. Anthers 1-2 mm. Fruit glabrous, 4-5 × 2-3 mm, with 7-10 smooth seeds.

REMARKS— *Impatiens fianarantsoae* is related to *I. biophytoides* H.Perrier from Anjanaharibe and Maroantsetra, but differs in the size of the leaves (40-70 × 12-20 mm in *I. fianarantsoae*, 15-36 × 4-9 mm in *I. biophytoides*), in the sparse hairs, the only slightly lobed leaves, the lower sepal with dark rib-like veins (veins not prominent in *I. biophytoides*), the upper petal distinct and acuminate (slightly emarginate in *I. biophytoides*), and the fruit with 7-10 seeds (2 or 3 seeds in *I. biophytoides*).

HABITAT— Montane rainforest at 900-1000 m.

DISTRIBUTION— Madagascar, Ranomafana.

Impatiens carlsoniae Eb.Fisch. & Raheliv., sp. nov. (Fig. 21)

Impatiens nosymangabensi affinis sed ornamento nonprominente sepali inferioris, petalis lateralibus luteistranslucentibus et forma petali dorsalis cum calcare longiore differt.

TYPUS— Madagascar. Toamasina, island of Nosy Mangabe, 5 km S of Maroantsetra in the bay of Antongil, 15°29'S, 49°45'E, 14.VI.1990, *Carlson 331* (holo-, MO; iso-, TAN).

DESCRIPTION— Perennial herb, erect to ascending. Stems hairy, up to 5-10 cm long, slightly suffrutescent. Leaves alternate, petiole hairy, up to 10 mm long, lamina ovate, acute at base and apex, sometimes obtuse at apex, pubescent on veins of lower surface, upper surface glabrous, net of tertiary veins visible, 25-35 × 10-15 mm, margin dentate, with 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Pedicels hairy, up to 10-mm long. Flowers with lateral united petals transparent, centre with fine garnet stripes across lobe, small hook bends down from midpoint under lower petal, hood folded, also translucent. Lateral sepals

lanceolate, obtuse at apex, 2.5 × 1 mm. Lower sepal ovate, distinctly acuminate at apex, net of darker veins not prominent, 5 × 2.5 mm. Dorsal petal helmet-like, dorsal crest with 0.5 mm long spur at apex, 5 × 2.5 mm. Lateral united petals 6.5 mm long, upper petal obtuse, 3.5 × 1.5 mm, free part 1 × 1 mm, lower petal 4 × 3 mm, obtuse. Anthers 2 mm long. Ovary 2-3 mm long. Fruit not known.

REMARKS— *Impatiens carlsoniae* is related to *I. nosymangabensis* Eb.Fisch. & Raheliv., also restricted to the island of Nosy Mangabe. It differs in the non-prominent ornamentation on lower sepal (prominent veins in *Impatiens carlsoniae*), the yellowish-translucent petals (greenish bronze in *I. nosymangabensis*), the shape of the dorsal petal with longer spur (0.5 mm in *I. carlsoniae*, 0.1 mm in *I. nosymangabensis*), and the longer upper petal (3.5 × 1.5 mm in *I. carlsoniae*, 2.5-3 × 1.3 mm in *I. nosymangabensis*).

HABITAT— Lowland rainforest, on rocks in wet stream bed.

DISTRIBUTION— Madagascar, Nosy Mangabe, only known from the type collection.

ETYMOLOGY— Named after the collector Elisabeth “Betsy” Carlson.

Impatiens rakotomalazana Eb.Fisch. & Raheliv., sp. nov. (Fig. 22)

Impatiens humbertii affinis sed lamina basi rotundata, margine profunde lobato et petalo superiore mucronato differt.

TYPUS— Madagascar. Fianarantsoa, Réserve Spéciale d’Ivohibe, 8 km NE d’Ivohibe, 5.5 km SE d’Angodongodona, camp 4, dans le corridor de la forêt, 22°25’18”S, 46°53’54”E, 1260 m, s.dat., *Rakotomalaza, Messmer & Rakotovao 1520* (holo-, MO; iso-, TAN).

DESCRIPTION— Perennial herb, erect with creeping rhizome, glabrous throughout. Stems up to 25 cm long. Leaves alternate, petiole up to 30-40 mm long, lamina rounded-orbicular at base and attenuate-acute at apex with distinct acumen, tertiary veins slightly visible, 65 × 17-25 mm, margin dentate-crenate with 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts

filiform, up to 3 mm long. Pedicels not exceeding 20 mm. Flowers green-translucid with purple venation. Lateral sepals filiform, purple at apex, up to 3 × 0.5 mm. Lower sepal ovate, 6 (excl. spur) × 3 mm, with distinct, 2.5 mm long filiform spur, net of dark purple non-prominent veins on upper surface. Dorsal petal helmet-like, 12 (excl. spur) × 3 mm, distinctly spurred at apex, spur filiform and up to 10 mm long. Lateral united petals 11 mm long, upper petal 3 × 1.5 mm, apiculate with short filiform mucro, lower petal 8 × 6 mm, obtuse-rounded. Anthers 2 mm long. Ovary 2-3 mm long. Fruit not known.

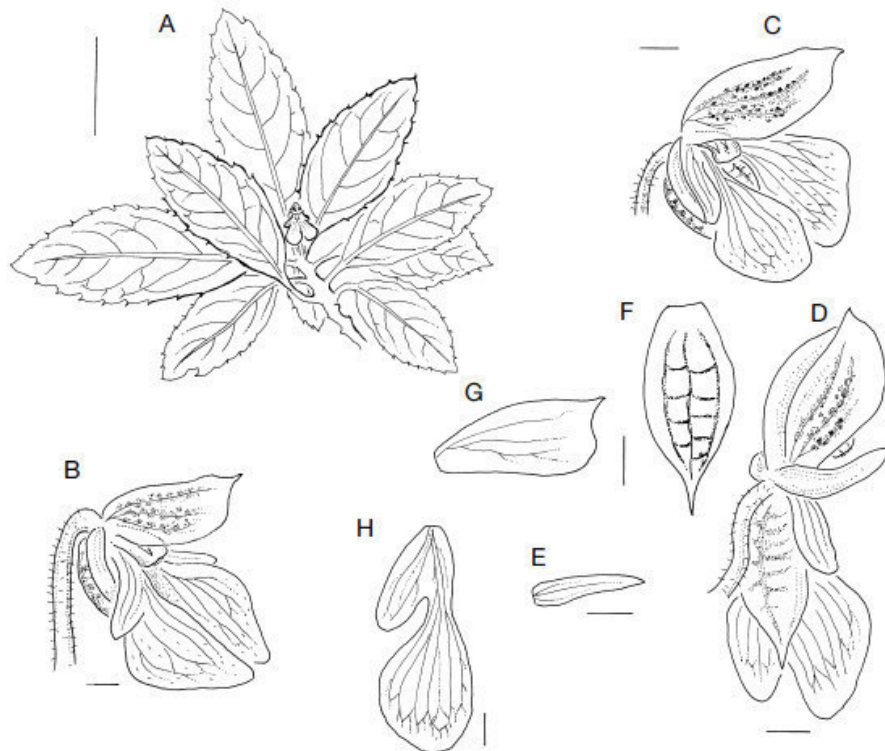


FIGURE 21. *Impatiens carlsoniae* Eb.Fisch. & Raheliv.: **A**, habit; **B-D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Carlson 331* (MO). Scale bars: A, 1 cm; B-H, 1 mm.

REMARKS— *Impatiens rakotomalazana* is related to *Impatiens humbertii* H.Perrier, which is also restricted to the Pic d'Ivohibe. It differs in the leaf lamina rounded at base, the margin deeply lobate, with lobes nearly rectangular (not lobate in *I. humbertii*), the flower colour (green-translucent with purple veins in *I. rakotomalazana*, yellow with purple veins in *I. humbertii*), the dorsal petal larger with longer spur (12 × 3 mm, with 10 mm long spur in *I. rakotomalazana*, 10 × 3 mm, with 5-8 mm long spur in *I. humbertii*), and the lateral united petals with mucronate upper petal (not mucronate in *I. humbertii*).

HABITAT— Montane rainforest at 1260 m.

DISTRIBUTION— Madagascar, Ivohibe, only known from the type collection.

ETYMOLOGY— Named after the collector Rakotomalaza.

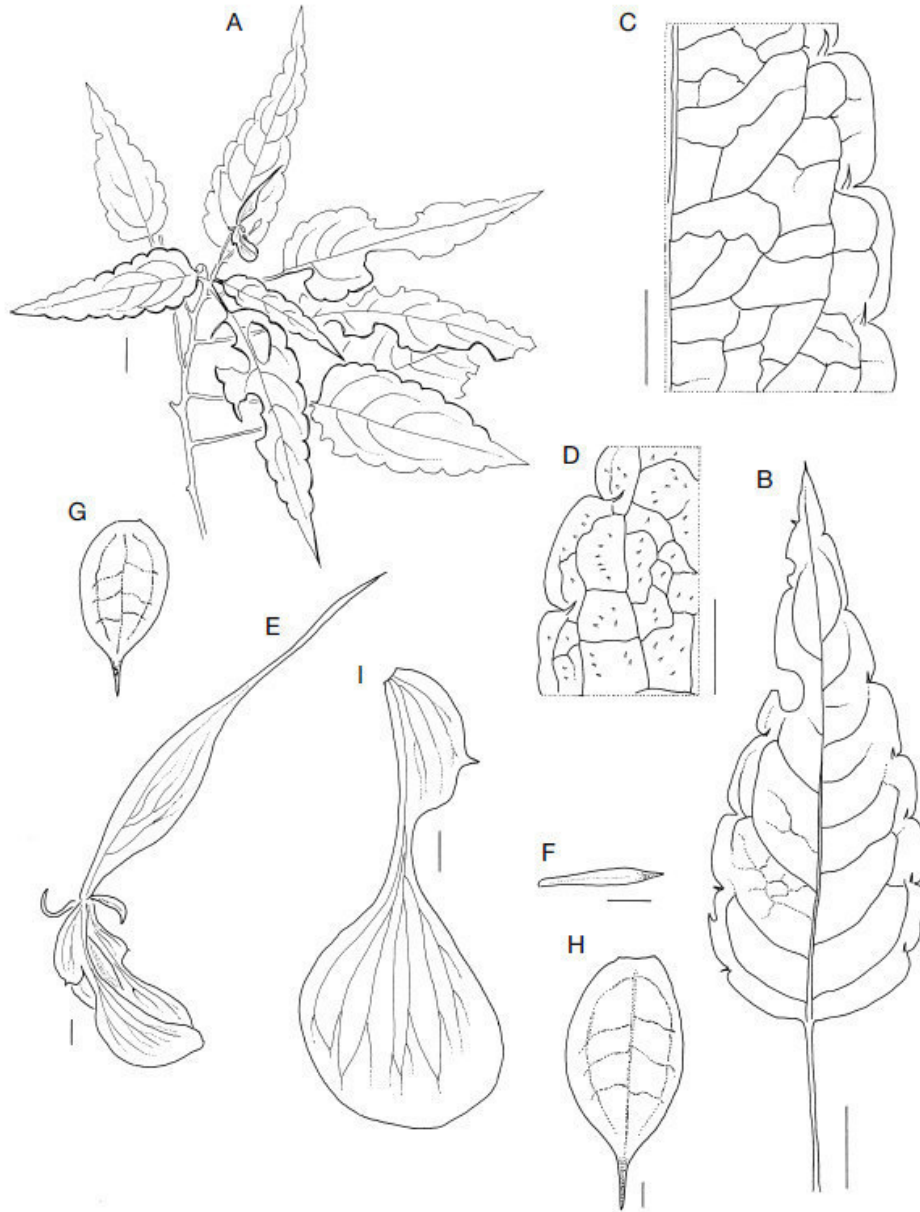


FIGURE 22. *Impatiens rakotomalazana* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, **D**, detail of leaf margin; **E**, flower; **F**, lateral sepal; **G**, **H**, lower sepal; **I**, lateral united petals. *Rakotomalaza*, Messmer & Rakotovao 1520 (MO). Scale bars: A, B, 1 cm; C, D, 5 mm; E-I, 1 mm.

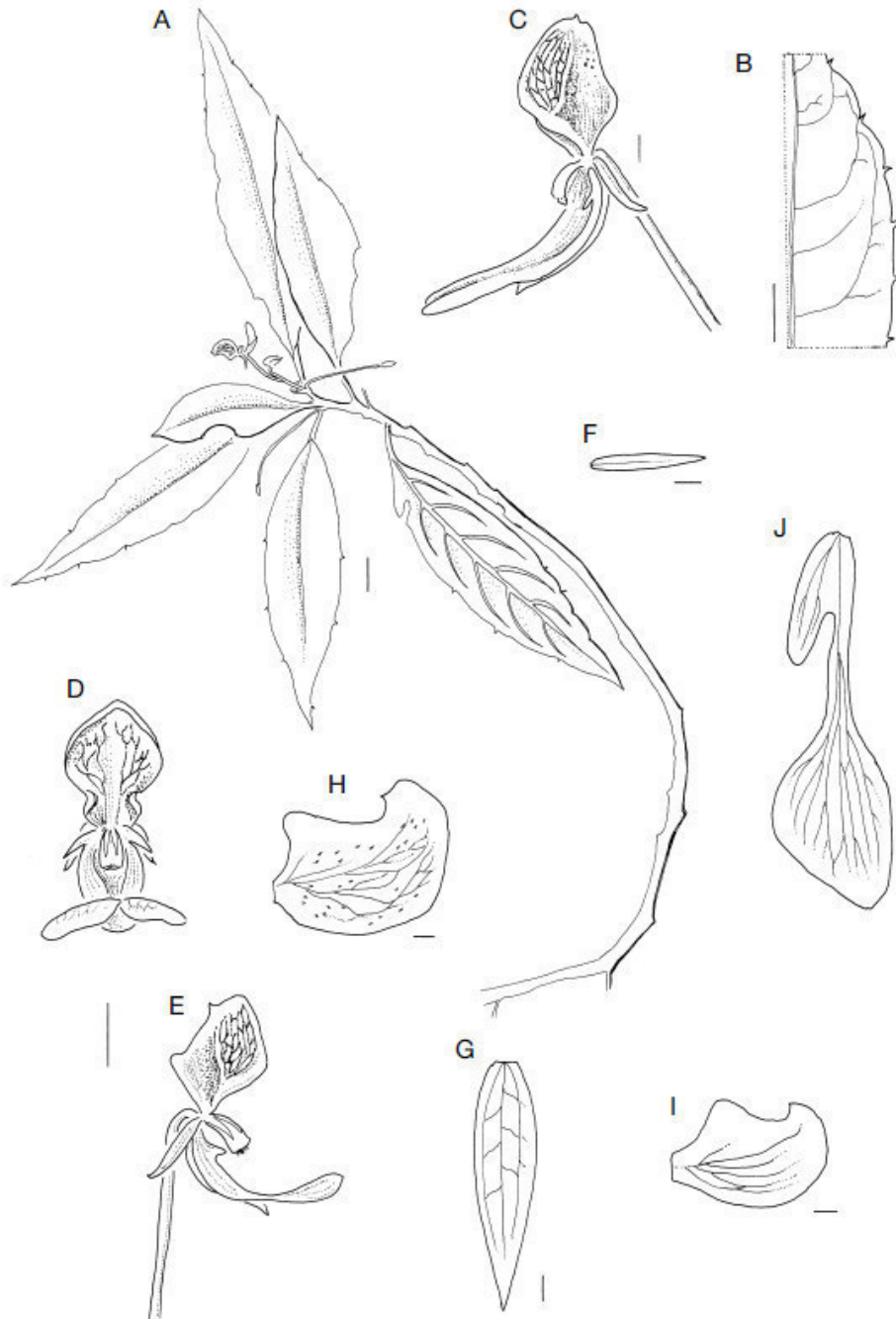


FIGURE 23. *Impatiens druartii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, detail of leaf margin; **C-E**, flower; **F**, lateral sepal; **G**, lower sepal; **H, I**, dorsal petal; **J**, lateral united petals. *Purro & Wohlhauser 1010* (NEU). Scale bars: A, B, 1 cm; C, F-J, 1 mm; D, E, 5 mm.

Impatiens druartii Eb.Fisch. & Raheliv., sp. nov. (Fig. 23)

Impatienti lemuriana affinis sed sepalo inferiore luteo et petalis lateralibus angustioribus valde differt.

Chapter 7 — New taxa from Madagascar IV

TYPUS— Madagascar. Antsiranana, Masoala Peninsula Réserve Intégrale, camp 2, épiphyte, 15°25'956"S, 49°57'563"E, 1100 m, 22.IX.1996, *Purro & Wohlhauser 1010* (holo-, NEU; iso-TAN).

DESCRIPTION— Perennial herb, erect to ascending with creeping rhizome, glabrous except for slightly pubescent stem and sparse whitish scales on leaves. Stems succulent, up to 40 cm long, branched. Leaves alternate, dark green on upper surface and light green on lower surface, petiole up to 20 mm long, lamina elliptic, attenuate-acute at base and attenuate-acute to acuminate at apex, 80-120 × 24-30 mm, margin dentate, with 8-10 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Bracts linear, 2 × 0.5 mm. Pedicels up to 30 mm long. Flowers orange-yellow, red-veined. Lateral sepals linear-filiform, 5 × 1 mm. Lower sepal lanceolate, distinctly acute at apex, without ornamentation or darker veins, 12 × 3 mm. Dorsal petal helmet-like, dorsal crest with apical spur of 1-3 mm of length and distinctly dilated to a triangle at lower third, with net of bordeaux-red veins, 9 × 6 mm. Lateral united petals 16 mm long, orange, upper petal obtuse, 4.2 × 1 mm, free part 2.2 × 1 mm, lower petal 14 × 5 mm, obtuse. Anthers *c.* 2-3 mm long. Ovary *c.* 3 mm long. Fruit not known.

REMARKS— *Impatiens druartii* is related to *I. lemuriana* from Tsaratanana, but differs immediately in the larger yellow to orange lower sepal (12 × 3 mm in *I. druartii*, 10 × 5 mm and yellow greenish in *I. lemuriana*), and the longer and narrow lateral united petals (16 mm in *I. druartii*, 12 mm in *I. lemuriana*).

HABITAT— Montane rainforest at 1100 m, growing as epiphyte.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after P. Druart, Neuchâtel, who collected *Impatiens* with the second author.

Impatiens ampokafoensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 24)

Ab omnibus speciebus madagascariensibus subgeneris Trimorphopetali differt foliis subrhombicis distantibus, petalo dorsali cum triangulo distincte et petalis lateralibus angustibus.

TYPUS— Madagascar. Antsiranana, Masoala Peninsula Réserve Intégrale, W of Ampokafo, before the hard descent on Ampokafo valley, c. 900 m, 15°19'300"S, 50°02'300"E, transition between moss altitudinal and humid rainforest, 25.IX.1996, *Purro & Wohlhauser 1023* (holo-, NEU; iso-, TAN).

PARATYPE— Antsiranana, Masoala Peninsula Réserve Intégrale, W of camp 3, 1174 m, 15°25'900"S, 49°58'140"E, on small ridge, moss forest, 23.IX.1996, *Purro & Wohlhauser 1017* (NEU, TAN).

DESCRIPTION— Perennial herb, ascending to erect with creeping rhizome, rooting at the nodes, glabrous throughout. Stems up to 15-20 cm long. Leaves alternate, petiole up to 4 mm long, lamina ovate, attenuate at base at apex, tertiary veins indistinct, 28-30 × 12-16 mm, margin dentate with 4 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Pedicels up to 12 mm long. Flowers dark yellow, purple-blackish spots and veins on dorsal petal and lateral united petals. Lateral sepals lanceolate, acuminate, 1.2 mm long. Lower sepal lanceolate, acute-mucronate at apex, entirely yellow, 7 × 3 mm. Dorsal petal helmet-like, with short apicule, crest dilated to small triangle in lower third, 3 × 4 mm. Lateral united petals 9 mm long, upper petal obtuse at apex, 4 × 1 mm, free part 3 × 1 mm, lower petal obtuse at apex, 7 × 1-1.5 mm. Anthers 1-2 mm. Fruit 3-4 × 1-2 mm.

REMARKS— *Impatiens ampokafoensis* has a unique set of characters with the small, nearly rhombic leaves dispersed on the stem, the dorsal crest of the dorsal petal dilated to a distinct triangle and the narrow lateral united petals. There is apparently no close relative except for a species already identified by H. Humbert (*Impatiens capuroniana* Humbert ex Eb.Fisch. & Raheliv. ined.) on Marojejy but never published. That species will be validated in a future paper. It differs from *I. ampokafoensis* especially in the lack of a dilated triangle on dorsal petal.

HABITAT— Transition between moss altitudinal and humid rainforest at 900-1174 m.

DISTRIBUTION— Madagascar, Masoala Peninsula.

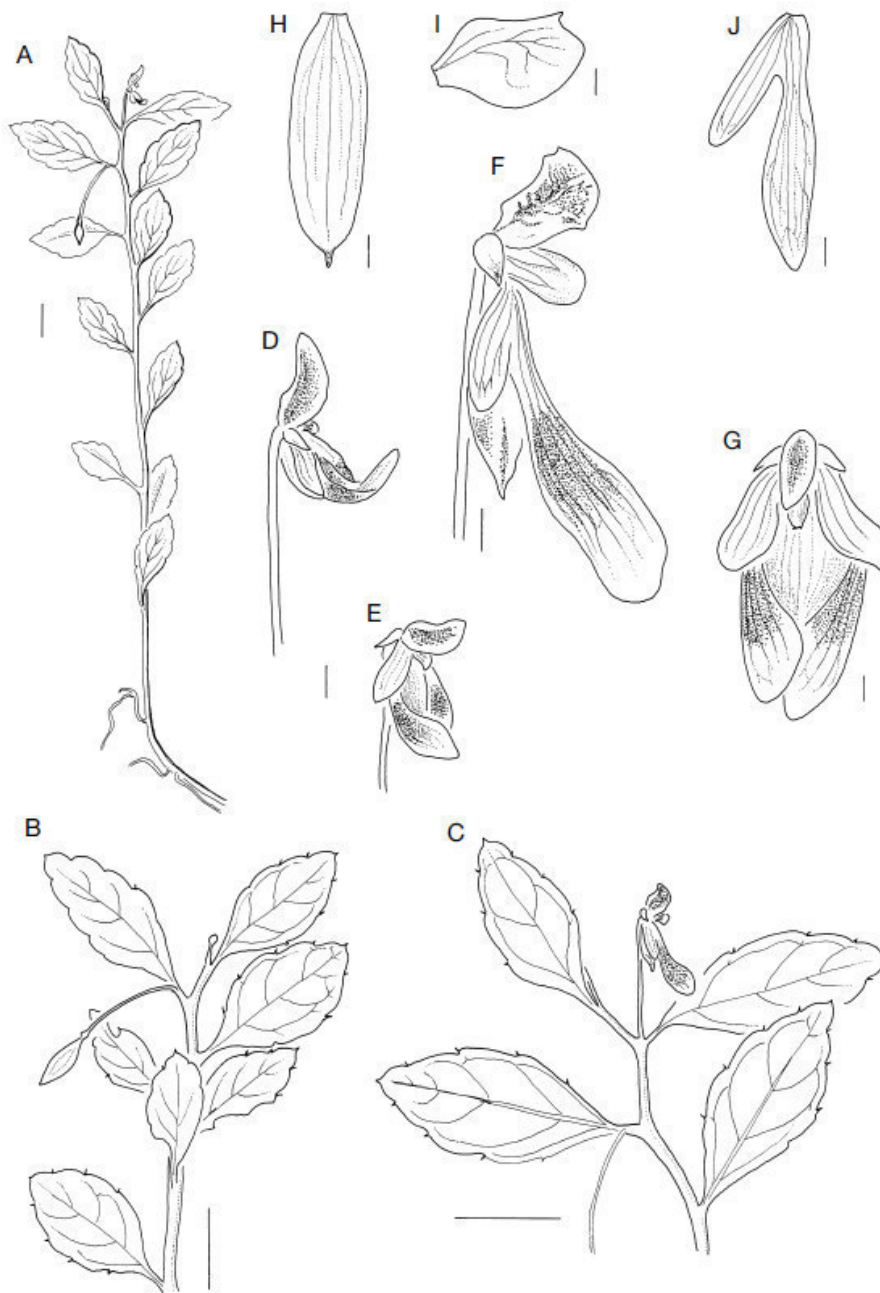


FIGURE 24. *Impatiens ampokafoensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, habit, details; **D-G**, flower; **H**, lower sepal; **I**, dorsal petal; **J**, lateral united petals. *Purro & Wohlhauser 1023* (NEU). Scale bars: A-C, 1 cm; D-J, 1 mm.

Impatiens rapanarivoi Eb.Fisch. & Raheliv., sp. nov. (Fig. 25)

Impatiens spathuliferae et *I. justicioidi* affinis sed sepalo inferiore sine nervibus rubris, forma petali dorsalis et petalo superiore distincte differt.

TYPUS— Madagascar. Fianarantsoa, disturbed natural forest on E side of hills, 1 hour walking from Antoetra, 20°45'48"S, 47°20'30"E, 1710 m, 13.V.1993, *Jongkind & Rapanarivo 882* (holo-, P; iso-, MO, TAN).

DESCRIPTION— Perennial herb, glabrous throughout. Stems prostrate to ascending, richly branched, up to 15-20 cm long. Leaves alternate, petiole up to 7 mm long, lamina elliptic, attenuate-acute at base and acute at apex, upper surface darker than lower surface which is covered with small whitish scales, 18-22 × 5-8 mm, tertiary veins indistinct, margin with 6 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 flowers per leaf axill. Bracts linear-filiform, c. 0.5 mm long, with red apex. Pedicels up to 8 mm long. Flowers green. Lateral sepals linear-filiform, with red apex, up to 1 mm long. Lower sepal ovate, without any ornamentation, with 0.5 mm long red filiform mucro, 3 × 1.5 mm. Dorsal petal cucullate, with distinct keel, apex with 0.3 mm long filiform apicule, 2 × 0.8 mm. Lateral united petals 4 mm long, upper petal acute, 1.5-2 × 0.5 mm, free part 1 × 0.5 mm, lower petal obtuse, 2.5 × 1.5 mm. Anthers c. 1 mm long. Fruit green to red, c. 3 × 1.5 mm.

REMARKS— *Impatiens rapanarivoi* is related to *I. spathulifera* H.Perrier from the basin of the Mangoro and *I. justicioides* H.Perrier from Analamazoatra and Beforona. It differs in the absence of red veins on the lower sepal, the smaller lower sepal (3 × 1.5 mm in *I. rapanarivoi*, 4 × 1.6 mm in *I. spathulifera*, 4 × 2 mm in *I. justicioides*), the smaller dorsal petal (2 × 0.8 mm in *I. rapanarivoi*, 5 × 2 mm in *I. spathulifera*, 4 × 3 mm in *I. justicioides*), the shape of the dorsal petal with apical spur and the distinct upper petal (indistinct in the two other species).

HABITAT— Montane rainforest at 1710 m, in bamboo dominated part of forest.

DISTRIBUTION— Madagascar, Fianarantsoa region, only known from the type collection.

ETYMOLOGY— Named after Dr Solo Rapanarivo, Tsimbazaza, who collected the type specimen.

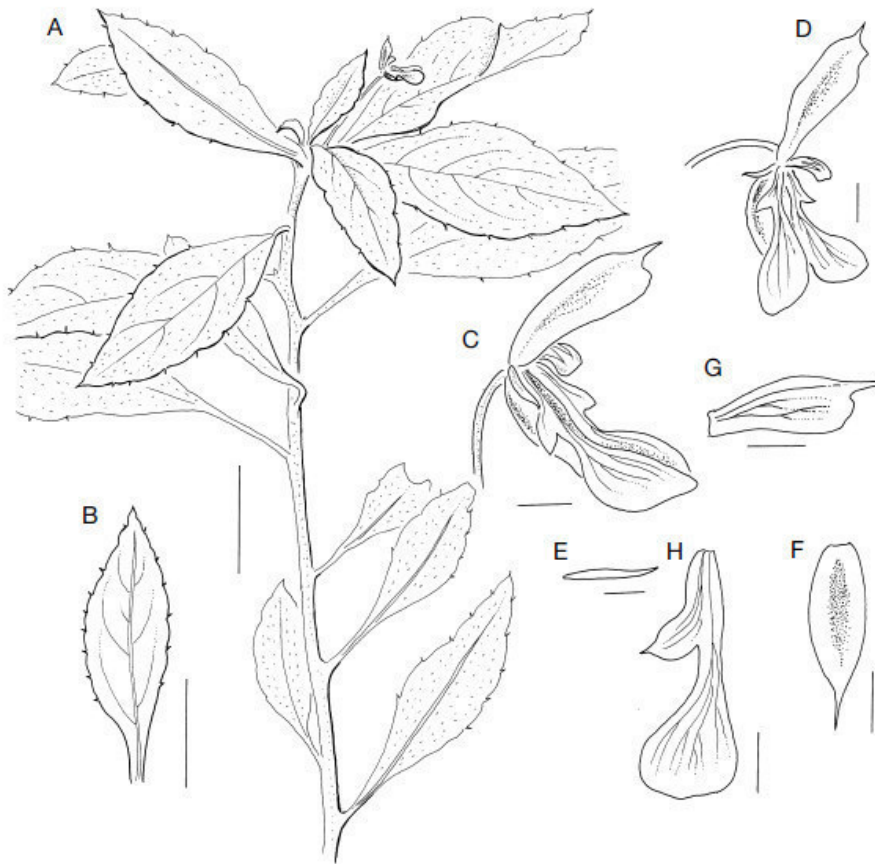


FIGURE 25. *Impatiens rapanarivoi* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Jongkind & Rapanarivo 882* (P). Scale bars: A, B, 1 cm; C, D, F-H, 1 mm; E, 0.5 mm.

Impatiens befiananensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 26)

Impatiens pauciseminae affinis sed *calcare brevioris sepalis inferioris differt. Ab I. celatiflora differt petiolo longiore et petalo dorsali majore.*

TYPUS— Madagascar. Antsiranana, Masoala Peninsula Réserve Intégrale, Massif de Bevontsira, Antsahabefiana basin, 28.IX.1996, *Purro & Wohlhauser 1030* (holo-, NEU; iso-, TAN).

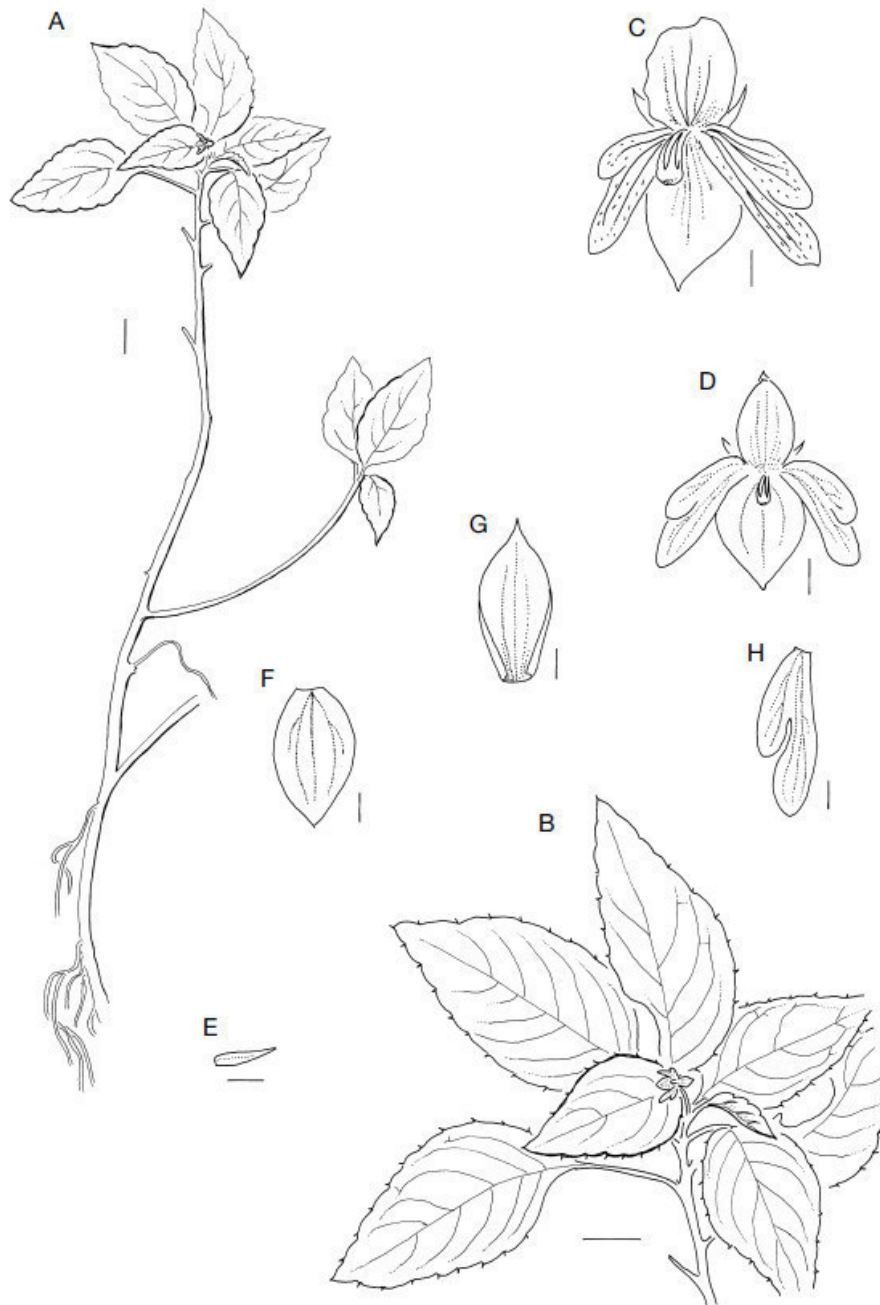


FIGURE 26. *Impatiens befiananensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, habit, detail; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Purro & Wohlhauser 1030* (NEU). Scale bars: A, B, 1 cm; C-H, 1 mm.

DESCRIPTION— Perennial herb, erect to ascending with creeping rhizome, glabrous throughout except for scattered whitish scales. Stems succulent, branched, up to 30 cm long. Leaves alternate, petiole up to 25-35 mm long, lamina ovate, widest at base, rounded at base and acute at apex, net of tertiary veins visible, 35-47 × 18-25 mm, margin dentate with 9 pairs of teeth with a short gland-tipped appendage. Inflorescence

with solitary axillary flowers. Bracts linear-filiform, up to 2 mm long. Pedicels not exceeding 7 mm. Flowers translucent, greenish. Lateral sepals linear-filiform, up to 1.5 mm long. Lower sepal ovate, acute at apex, without ornamentation, 3.5 × 2.2 mm. Dorsal petal not plicate, lanceolate, with 0.5 mm long spur at apex, 4.5 × 2 mm. Lateral united petals 4 mm long, upper petal 3 × 1-1.5 mm, obtuse, lower petal 2 × 1 mm, obtuse. Anthers c. 1 mm long. Ovary c. 1.5 mm long. Fruit not known.

REMARKS— *Impatiens befiananensis* is related to *I. paucisemina* H.Perrier from Tsaratanana and *I. celatiflora* H.Perrier from Betampona. It differs from *I. paucisemina* in the shorter spur at apex of lower sepal, the smaller lower sepal (3.5 × 2.2 mm in *I. befianensis*, 5 × 4 mm in *I. paucisemina*), and the shorter lateral sepal (1.5 mm in *I. befianensis*, 4.5 mm in *I. paucisemina*), and from *I. celatiflora* in the longer petiole (25-35 mm in *I. befiananensis* and not exceeding 20 mm in *I. celatiflora*) and the larger dorsal petal (4.5 mm long in *I. befiananensis* and 1.5-2 mm in *I. celatiflora*).

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

Impatiens tsararavina Eb.Fisch. & Raheliv., sp. nov. (Fig. 27)

Differt ab Impatienti alveolata foliis distantibus apice rotundato-obtuso. Impatienti coursianae affinis sed petalo superiore valde majore differt.

TYPUS— Madagascar. Antsiranana, Réserve Spéciale de Manongarivo, Andranomalaza, crête séparant le bassin versant d'Ambahatra de celui de l'Andranomalaza, 600 m au NW du point coté 1728, 1660 m, 8.VI.1998, *Gautier, Messmer & Wohlhauser LG 3340* (holo-, G; iso-, TAN).

DESCRIPTION— Perennial herb, prostrate to ascending, glabrous throughout. Stems up to 30-40 cm long, branched. Leaves alternate, petiole up to 15-20 mm long, lamina acute at base and rounded-obtuse at apex, net of tertiary veins nearly invisible, 25-28 × 20-25 mm, margin dentate, with 5 or 6 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts linear-filiform, up to 3

mm long. Pedicels up to 17 mm long. Flowers entirely green-translucent. Lateral sepals linear-lanceolate, 5×0.6 mm. Lower sepal ovate, acute at apex, without ornamentation, 7×4 mm. Dorsal petal not plicate, with dorsal keel and short spur at apex, 6.5×3.5 mm. Lateral united petals 6.5 mm long, upper petal ovate, with short spur-like mucro at apex, 2.5×2 mm, lower petal emarginated, 3.5×2.2 mm. Anthers 2 mm long. Ovary 2 mm long. Fruit not known.

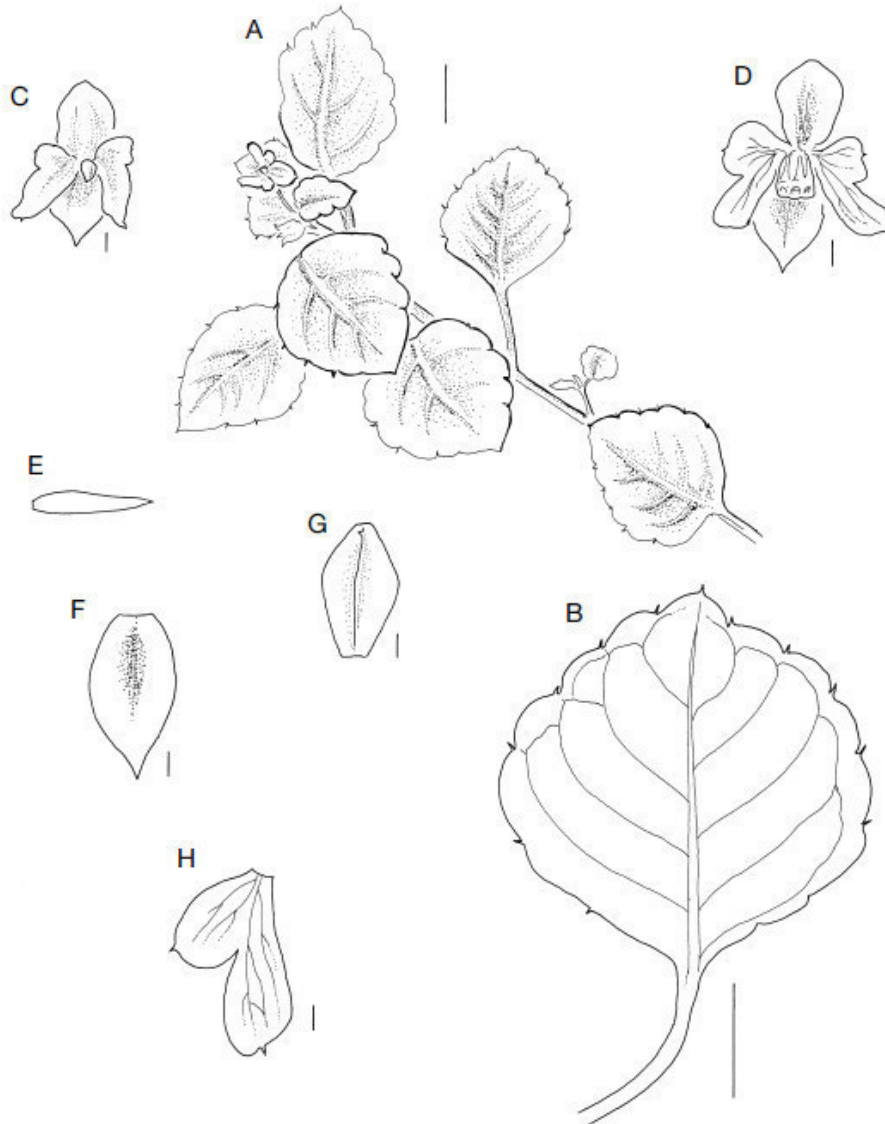


FIGURE 27. *Impatiens tsararavina* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. Gautier, Messmer & Wohlhauser LG 3340 (G). Scale bars: A, B, 1 cm; C-H, 1 mm.

REMARKS— *Impatiens tsararavina* is related to *I. alveolata* H.Perrier from Ankaizina and *I. coursiana* H.Perrier from Zahamena. It differs from *I. alveolata* in the leaves that

are rounded-obtuse at apex and dispersed on the stem (acute at apex and condensed at stem apex in *I. alveolata*), and the shorter lateral united petals (6.5 mm in *I. tsararavina*, 10 mm in *I. alveolata*), and from *I. coursiana* in the lateral united petals with upper petal 2.5 × 2 mm (lateral united petals with upper petal very small and reduced to 0.5 × 0.3 mm in *I. coursiana*).

HABITAT— Montane rainforest at 1660 m.

DISTRIBUTION— Madagascar, Manongarivo, only known from the type collection.

ETYMOLOGY— Tsararavina is the Malagasy word for beautiful leaf.

Impatiens maevae Eb.Fisch. & Raheliv., sp. nov. (Fig. 28)

Impatiens subabortivae affinis sed callo obscuro sepali inferioris deficiente differt.

TYPUS— Madagascar. Diego-Suarez, Réserve Spéciale de Manongarivo, Massif de Manongarivo, 14°03,617'S, 48°24,567'E, crête bordant la cuvette d'Antsahakolana, 1719 m, 26.XI.2000, *Wohlhauser, Callmander, Rakotomamonjy & Andrianjaka SW 395* (holo-, G; iso-, TAN).

DESCRIPTION— Annual (?) herb, glabrous throughout. Stems creeping to ascending and erect, branched, up to 20 cm long. Leaves alternate, petiole up to 20 mm long, lamina rounded to acute at base and obtuse at apex, 30-35 × 20-25 mm, widest towards base, margin crenate with 7 or 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts linear-lanceolate, up to 2 mm long. Pedicels up to 15 mm long. Flowers greenish, transparent, entirely glabrous. Lateral sepals linear-lanceolate, 4.5 × 0.5 mm. Lower sepal ovate, 7 × 4 mm, at apex with 1 mm long apicule. Dorsal petal lanceolate, acute at apex, 7 × 3 mm. Lateral united petals 7 mm long, upper petal rounded at apex, 3.5 × 1.5 mm, lower petal 4.5 × 2 mm. Ovary 1-2 mm long. Fruit not known.

REMARKS— *Impatiens maevae* is related to *I. subabortiva* H.Perrier from Tsaratanana but differs in the larger lower sepal lacking a dark callus (7 × 4 mm in *I.*

maevae, 5.5 × 2 mm in *I. subabortiva*), and the larger dorsal petal (7 × 3 mm in *I. maevae*, 4 × 2.5 in *I. subabortiva*).

HABITAT— Montane bamboo rainforest at 1719 m.

DISTRIBUTION— Madagascar, Manongarivo, only known from the type collection.

ETYMOLOGY— Named after Ms. Maeva who collected with the second author.

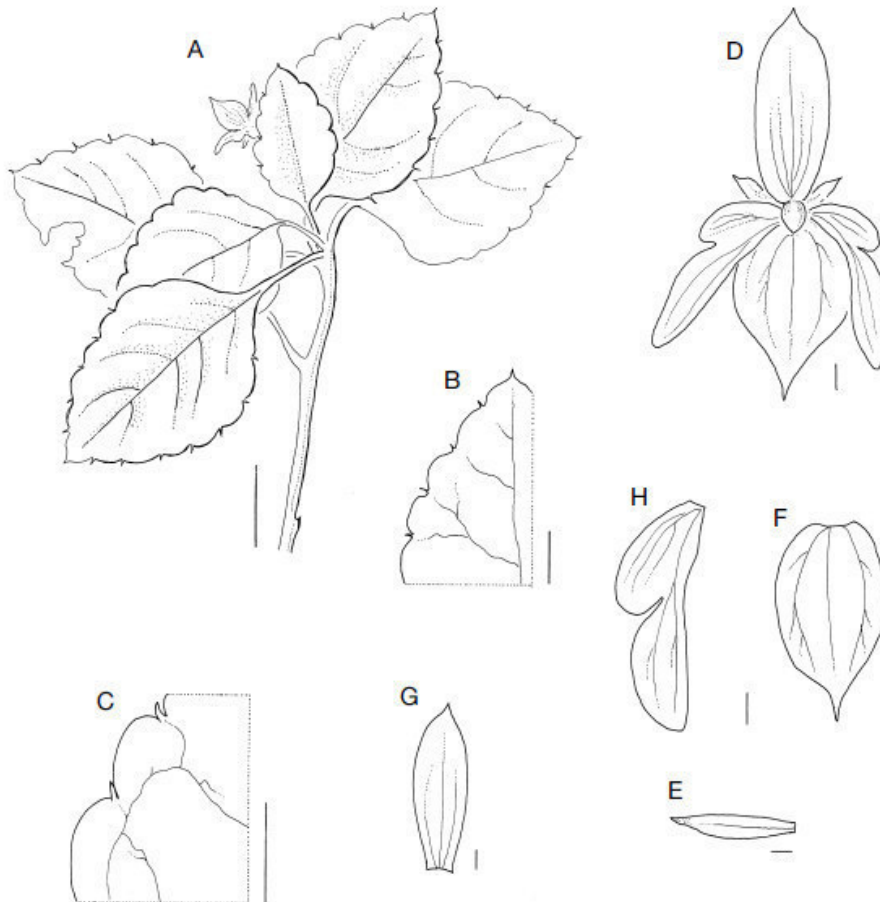


FIGURE 28. *Impatiens maevae* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, details of leaf margin; **D**, flower, lateral view; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Wohlhauser, Callmander, Rakotomamonjy & Andrianjaka SW 395* (G). Scale bars: A, 1 cm; B, C, 5 mm; D-H, 1 mm.

Impatiens razanatsoa-charlei Eb.Fisch. & Raheliv., sp. nov. (Fig. 29)

Impatienti lemuriana affinis sed sepalo inferiore luteo sine ornamento differt. Ab *I. druartii* differt foliis latioribus et petalibus lateralibus longioribus.

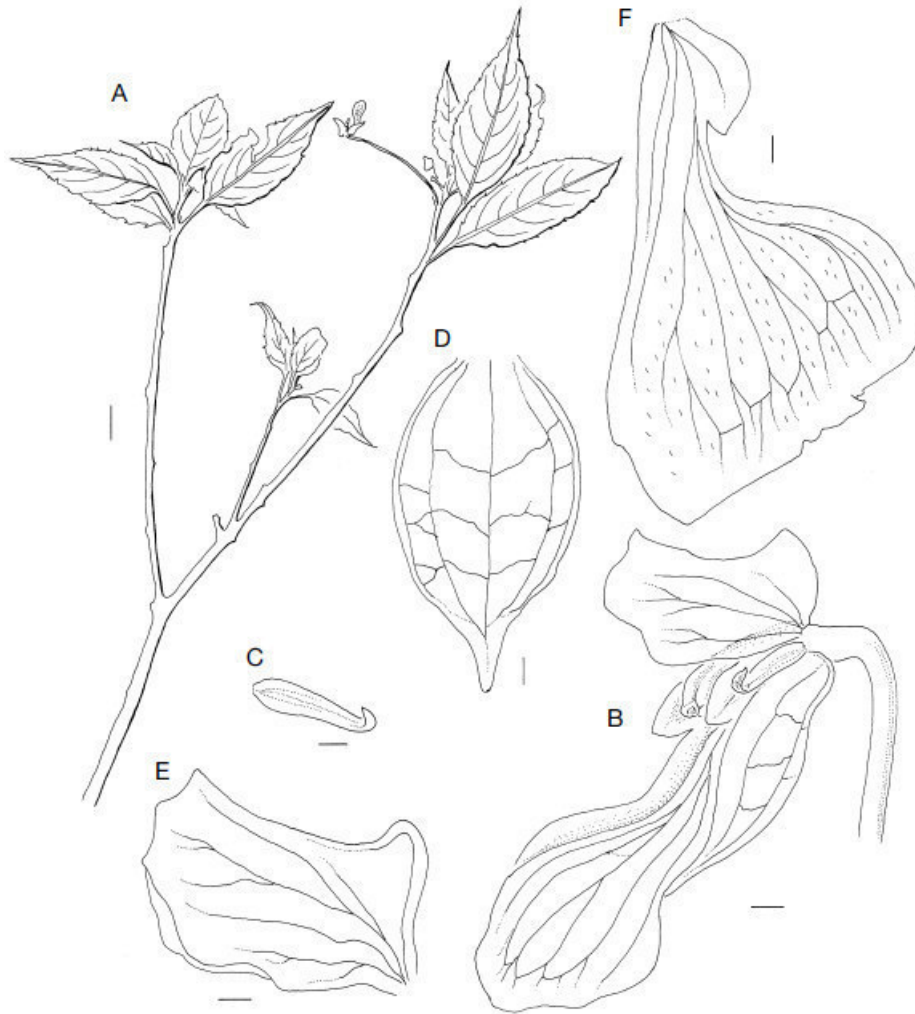


FIGURE 29. *Impatiens razanatsoa-charlei* Eb.Fisch. & Raheliv.: **A**, habit; **B**, flower; **C**, lateral sepal; **D**, lower sepal; **E**, dorsal petal; **F**, lateral united petals. *Rahelivololona T9* (TAN). Scale bars: A, 1 cm; B-F, 1 mm.

TYPUS— Madagascar. Tsaratanana, fond de ruisseau, vers 1850 m, IX.2001, *Rahelivololona T9* (holo-, TAN).

DESCRIPTION— Perennial herb, erect, glabrous except for small whitish scales. Stems branched, up to 30-40 cm long. Leaves alternate, petiole up to 13-16 mm long, lamina ovate, attenuate-acute at base at apex, with distinct acumen at apex, net of tertiary veins indistinct, 53-64 × 20-23 mm, margin dentate, with 7-9 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers on short peduncle. Bracts filiform, up to 0.5 mm long. Pedicels up to 36-40 mm long. Flowers greenish-yellowish, with darker veins. Lateral sepals linear-filiform, 6 × 1 mm. Lower

sepal ovate, with distinct acumen at apex, without ornamentation, 12-13 × 5 mm. Dorsal petal helmet-like, dorsal crest with short spur at apex, dilated to a triangle at lower third, 8-9 × 4-5 mm. Lateral united petals 19 mm long, upper petal acute, 5-6 × 3-4 mm, lower petal obtuse to shortly acute, 10 × 7 mm. Anthers up to 5 mm long. Ovary up to 5 mm long. Fruit not known.

REMARKS— *Impatiens razanatsoa-charlei* is related to *I. lemuriana* from Tsaratanana and *I. druartii* from Masoala, sharing the distinct dilated triangle on the crest of the dorsal petal. It differs, however, from *I. lemuriana* in the yellow lower sepal without ornamentation, the longer lateral united petals (19 mm in *I. razanatsoa-charlei*, 12 mm in *I. lemuriana*), the larger lower sepal (12-13 × 5 mm in *I. razanatsoa-charlei*, 10 × 5 mm in *I. lemuriana*), and from *I. druartii* in the narrower leaves (53-64 × 20-23 mm in *I. razanatsoa-charlei*, 80-120 × 24-30 mm in *I. druartii*), and the longer lateral united petals (16 mm in *I. druartii*). *Impatiens druartii* is an epiphyte while *I. razanatsoa-charlei* is growing as a terrestrial herb.

HABITAT— Montane rainforest at 1850 m, growing along stream.

DISTRIBUTION— Madagascar, only known from the type collection.

ETYMOLOGY— Named after the parents of the second author.

Acknowledgements

We would like to thank the director of the herbarium, Muséum national d'Histoire naturelle (P), who kindly sent specimens on loan to the first author and who gave us permission to use the preliminary manuscript of Humbert. We also thank the directors of the following herbaria for loan of specimens: BR, G, K, NEU, TAN. Special thanks go to M. Bardot-Vaucoulon (Paris) and L. Gautier (Geneva), for kindly sending specimens for identification. Thanks are due to Martin Cheek and Thierry Deroin for valuable comments on the manuscript.

Chapter 8

New taxa of *Impatiens* from Madagascar V. New species of *Impatiens* from Masoala Peninsula.

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2007): New taxa of *Impatiens* (Balsaminaceae) from Madagascar. V. New species of *Impatiens* from Masoala Peninsula. *Adansonia* 29: 317-332.

¹ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz (Germany). efischer@uni-koblenz.de

² Parc botanique et zoologique de Tsimbazaza, BP 4096, Antananarivo (Madagascar). prota.madagascar@dts.mg

Abstract

Nine new species of *Impatiens* from Masoala Peninsula are described and illustrated (*Impatiens scenarioi*, *I. ambanizanensis*, *I. salifii*, *I. nanatonaensis*, *I. tafononensis*, *I. nidus-apis*, *I. saolana*, *I. mamyi*, and *I. volatiana*). *Impatiens scenarioi* belongs to subgenus *Impatiens* and is related to *I. wohlhauseri* and *I. kuepferi*, while the remaining species belong to subgenus *Trimorphopetalum*. *Impatiens ambanizanensis* is related to *I. salifii*, *I. nanatonaensis* to *I. tafononensis*, *I. nidus-apis* to *I. celligera*, *I. saolana* to *I. luteoviridis*, *I. mamyi* to *I. stefaniae* and *I. volatiana* to *I. oniveensis*.

Key words Balsaminaceae, *Impatiens*, subgenus *Impatiens*, subgenus *Trimorphopetalum*, Masoala, Madagascar, espèces nouvelles.

Résumé

Nouveaux taxons dans le genre Impatiens (Balsaminaceae) à Madagascar V. Espèces nouvelles d'Impatiens de la péninsule de Masoala. Neuf espèces nouvelles du genre *Impatiens* de la péninsule de Masoala sont décrites et illustrées (*Impatiens scenarioi*, *I. ambanizanensis*, *I. salifii*, *I. nanatonaensis*, *I. tafononensis*, *I. nidus-apis*, *I. saolana*, *I. mamyi*, et *I. volatiana*). *Impatiens scenarioi* est membre du sous-genre *Impatiens* et relié à *I. wohlhauseri* et *I. kuepferi*. Les autres espèces sont membres du sous-genre *Trimorphopetalum*, et *Impatiens ambanizanensis* est proche d'*I. salifii*, *I. nanatonaensis* d'*I. tafononensis*, *I. nidus-apis* d'*I. celligera*, *I. saolana* d'*I. luteoviridis*, *I. mamyi* d'*I. stefaniae* et *I. volatiana* d'*I. oniveensis*.

Mots clés Balsaminaceae, *Impatiens*, sous-genre *Impatiens*, sous-genre *Trimorphopetalum*, Masoala, Madagascar, new species.

Introduction

The most important centre of diversity for *Impatiens* L. in Madagascar is situated in the Masoala Peninsula where about 50% of all species have been recorded. The present paper contains descriptions of new taxa collected and studied by the second author within a project between the Laboratoire de Phanérogamie, University of Neuchâtel, under the direction of Philippe Kuepfer, the University of Koblenz-Landau and the Parc botanique et zoologique de Tsimbazaza/Antananarivo.

For a short history of the exploration of *Impatiens* in Madagascar as well as details on terminology and measurements, see Fischer & Rahelivololona (2002).

Systematics

Genus *Impatiens* L., Subgenus *Impatiens* L.

DIAGNOSTIC CHARACTERS— Lower sepal with spur, petiole usually with extrafloral nectaries (fimbriae).

Impatiens scenarioi Eb.Fisch. & Raheliv., sp. nov. (Fig. 1)

Chapter 8 — New taxa from Madagascar V

Impatiens wohlhauseri affinis sed forma foliorum et 2 sepalis lateralibus valde differt.
Ab *I. kuepferi* differt pedunculo deficiente et 2 sepalis lateralibus.

TYPUS— Madagascar. Masoala, Ambanizana, sousbois un peu plus haut vers le campement, c. 350-400 m, 18.II.2002, *Rahelivololona, Saola & Scenario 136* (holo-, TAN).

DESCRIPTION— Perennial herb, erect, glabrous. Stem semi-succulent, 25-50 cm tall. Leaves alternate, petiole 10-15 mm long, with 1 or 2 pairs of linear, 2 mm long extrafloral nectaries, lamina oblong-lanceolate, with a distinctly acuminate apex, attenuate at base, widest at upper third, 65-110 × 23-31 mm, margin with 7 or 8 pairs of teeth, each with a gland-tipped appendage. Inflorescence axillary, with up to 20 flowers, peduncle short, up to 5-20 mm long. Bracts 3-5 × 0.8 mm. Pedicel 12-14 mm long. Flowers with yellow brown dorsal petal, lower sepal with red brown veins, spur with red apex. Lateral sepals 2, broadly ovate, acuminate, 4-5 × 2-2.5 mm. Lower sepal navicular, 10-11 × 5-6 mm, acuminate at base, spur bottle-shaped, constricted below apex, 4-4.5 mm long, 2 mm large at base and 1 mm at apex, obtuse. Dorsal petal cucullate, 7-8 × 5 mm. Lateral united petals 2, 12-13 mm long, upper petal narrow, acuminate, 4 × 1.5 mm, lower petal rounded, 5 × 3 mm. Anthers 2-3 mm long. Ovary 3-4 mm long. Fruit unknown.

REMARKS— *Impatiens scenarioi* is related to *I. wohlhauseri* Eb.Fisch. & Raheliv. and *I. kuepferi* Eb.Fisch. & Raheliv., both also restricted to the Masoala Peninsula, but lacks a second pair of lateral sepals. It differs, however, from *I. kuepferi* in the presence of a peduncle and the shorter lateral united petals (12-13 mm in *I. scenarioi*, 18 mm in *I. kuepferi*), and from *I. wohlhauseri* in the shape of the leaves (65-110 × 23-31 mm in *I. scenarioi*, 120-190 × 3-53 mm in *I. wohlhauseri*).

HABITAT— Submontane rainforest, 350-400 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after the collector Scenario.

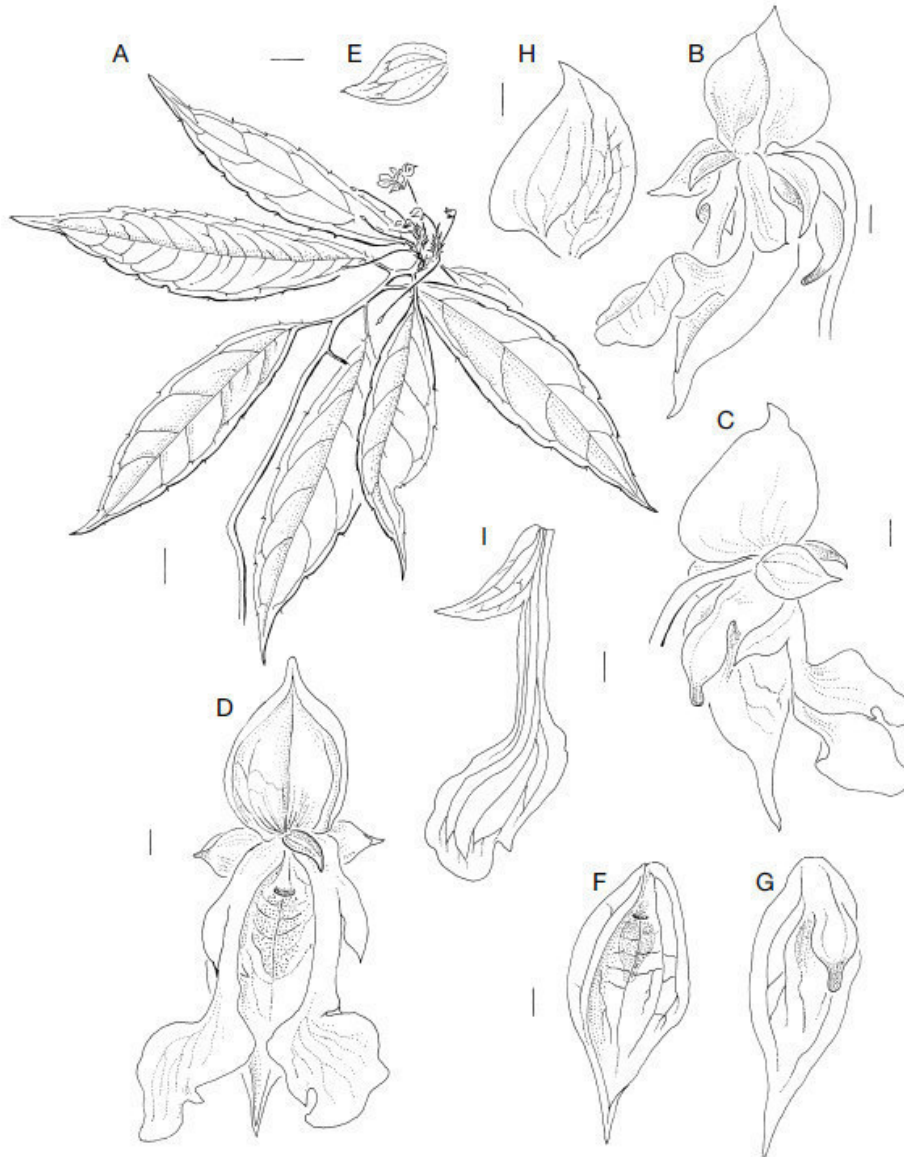


FIGURE 1. *Impatiens scenarioi* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, flower, lateral view; **D**, flower, frontal view; **E**, lateral sepal; **F**, **G**, lower sepal and spur; **H**, dorsal petal; **I**, lateral united petals. *Rahelivololona, Saola & Scenario 136* (TAN). Scale bars: A, 1 cm; B-I, 1 mm.

Subgenus *Trimorphopetalum* (Baker) Eb.Fisch.

DIAGNOSTIC CHARACTERS— Lower sepal without spur, extrafloral nectaries on petiole lacking.

Impatiens ambanizanensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 2)

Impatiens salifii affinis sed ornamento sepali inferioris et petalibus lateralibus cum petalo superiore indistincte breviora quam petalo inferiore differt.

TYPUS— Madagascar. Masoala, Ambanizana-Ambohitsitondroina, au pied d'Ambohitsitondroina vers 900 m, 19.II.2002, *Rahelivololona, Saola & Scenario 145* (holo-, TAN).

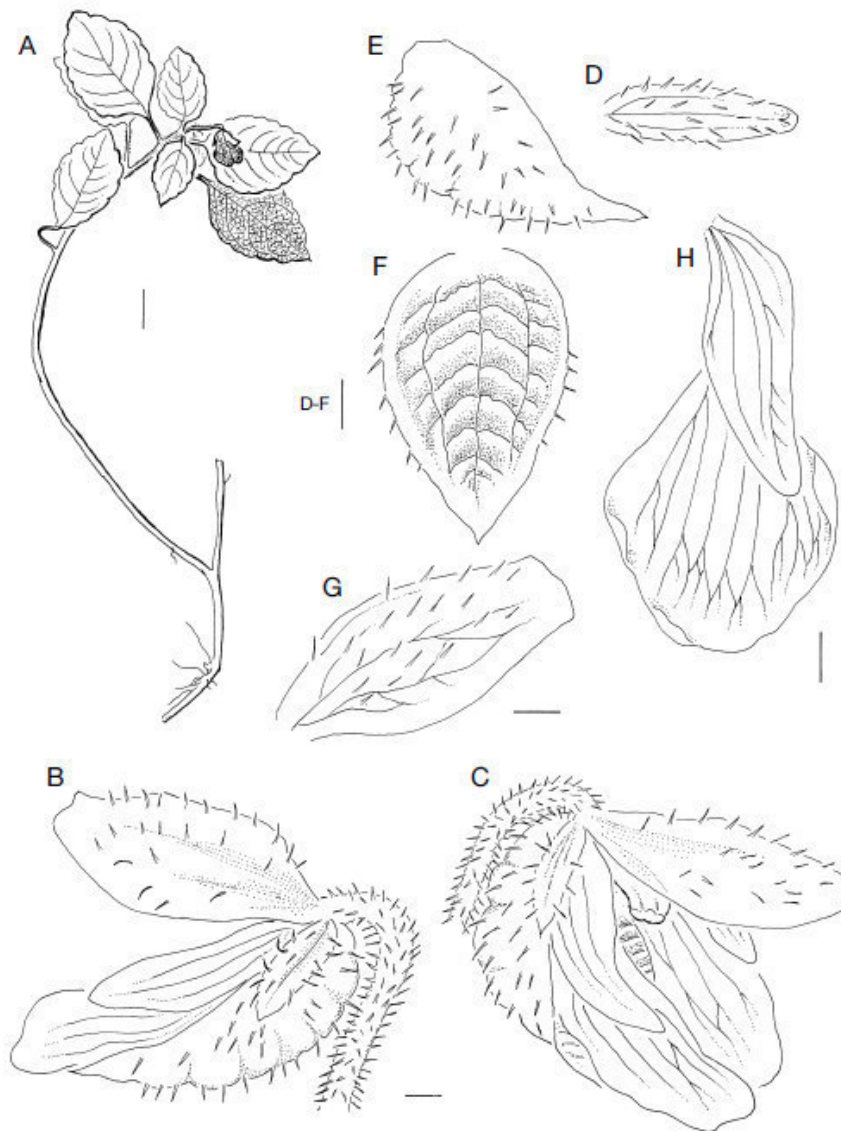


FIGURE 2. ***Impatiens ambanizanensis*** Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, flower; **D**, lateral sepal; **E**, **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Rahelivololona, Saola & Scenario 145* (TAN). Scale bars: A, 1 cm; B-H, 1 mm.

DESCRIPTION— Perennial herb, with creeping rhizome entirely pubescent. Stem ascending to erect, up to 10-12 cm tall. Leaves alternate, greenish with darker reddish veins, petiole 9-13 mm long, lamina ovate, 23-30 × 12-20 mm, margin crenate, with 4 or 5 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Pedicel up to 5-6 mm long, curved at apex, pubescent. Flower with greenish lateral sepals, petals entirely maroon. Lateral sepals lanceolate, pilose outside, 2-3 × 1 mm. Lower sepal navicular, broadly ovate, pilose outside, inside with distinct ornamentation, producing broad rib-like crests on the secondary nerves, 5-6 × 5 mm. Dorsal petal cucullate, pilose outside, 8 × 3.5 mm. Lateral united petals glabrous, 10 mm long, upper petal 5-6 × 1-1.5 mm, lower petal 7 × 4-4.5 mm. Anthers 3 mm long. Ovary 3 mm long. Fruit unknown.

REMARKS— *Impatiens ambanizanensis* is related to *I. salifii* Eb.Fisch. & Raheliv. from Masoala Peninsula, but differs in the ornamentation of the lower sepal producing broad rib-like crests on the secondary nerves (lower sepal with central ridge and 7 or 8 rib-like crests surrounding c. 7 holes on each side in *I. salifii*) and the lateral united petals with upper petal only slightly shorter than lower petal (upper petal distinctly shorter in *I. salifii*).

HABITAT— Montane rainforest at 900 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

Impatiens salifii Eb.Fisch. & Raheliv., sp. nov. (Fig. 3)

Impatienti ambanizanensi affinis sed ornameto sepali inferioris et petalibus lateralibus cum petalo superiore distincte brevior quam petalo inferiore differt.

TYPUS— Madagascar. Masoala, Ambanizana-Ambohitsitondroina, poussant sur rocher le long d'un ruisseau venant du sommet vers 750-800 m, 19.II.2002, *Rahelivololona, Saola & Scenario 141* (holo-, TAN).

DESCRIPTION— Perennial herbs, ascending with creeping rhizome hairy throughout. Stems 5-7 cm long. Leaves alternate, petiole not exceeding 15 mm in length, lamina

ovate, 20-30 × 15-18 mm, dark green above, light green with purplish venation below, margin crenate with 5 pairs of filiform fimbriae. Inflorescence with solitary axillary flowers. Pedicels not exceeding 6-13 mm of length. Flowers greenish with dark purple venation. Lateral sepals lanceolate, acuminate, 2 × 1 mm, hairy. Lower sepal broadly ovate, 7 × 5 mm, with central ridge and 7 or 8 rib-like crests, glabrous, surrounding c. 7 holes on each side, glabrous. Dorsal petal helmet-like, with dorsal ridge, 6 × 2.5 mm, hairy outside. Lateral united petals 8-9 mm long, slightly hairy, upper petal acuminate, 3 × 1.5-2 mm, curved backwards, lower petal 6 × 3-4 mm, obtuse to subacute. Anthers c. 1 mm long. Ovary 3 mm long. Fruit not known.

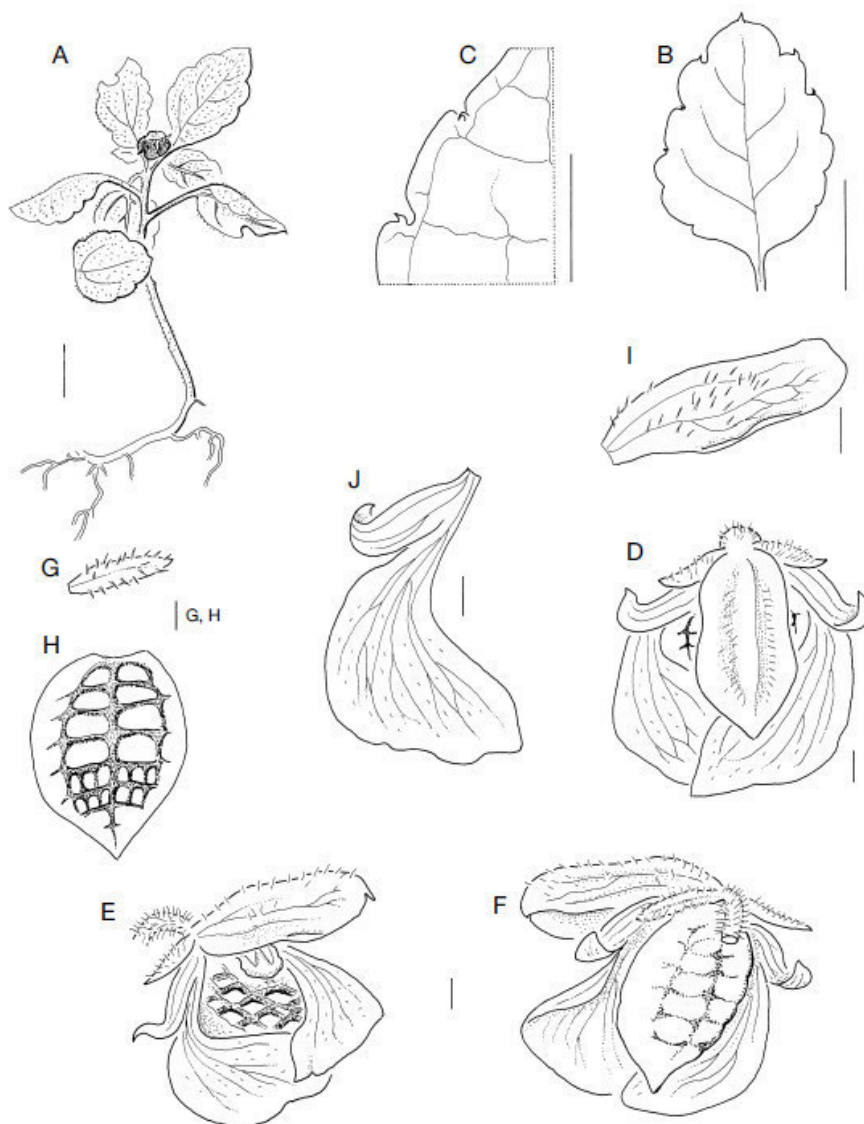


FIGURE 3. *Impatiens salifii* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, detail of leaf margin; **D-F**, flower; **G**, lateral sepal; **H**, lower sepal; **I**, dorsal petal; **J**, lateral united petals. *Rahelivololona, Saola & Scenario 141* (TAN). Scale bars: A, B, 1 cm; C, 5 mm; D-J, 1 mm.

REMARKS— *Impatiens salifii* is related to *I. ambanizanensis* Eb.Fisch. & Raheliv. from Masoala Peninsula, but differs in the ornamentation of the lower sepal with central ridge and 7 or 8 rib-like crests surrounding c. 7 holes on each side (lower sepal producing broad rib-like crests on the secondary nerves in *I. ambanizanensis*) and the lateral united petals with upper petal distinctly shorter than lower petal (only slightly shorter in *I. ambanizanensis*).

HABITAT— Rocks along stream in montane rainforest at 750- 800 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after Salifi, who supported the second author.

Impatiens nanatonanensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 4)

Impatienti tafononensi affinis sed petalo superiore acuminato et tuberculis petali inferioris valde differt.

TYPUS— Madagascar. Masoala, forêt de Nanatonana, on rocks in Tafonona river, 15.IX.2003, *Rahelivololona, Triponez, Arnold & Mamy Tfa 2b* (holo-, TAN).

DESCRIPTION— Perennial herbs, ascending to erect, with creeping rhizome rooting at the nodes, with whitish hairs throughout. Stems branched, up to 7-15 cm long. Leaves purple to darker red, petiole 5-20 mm long, lamina ovate, attenuate at base, broadly obtuse at apex, 50-60 × 17-20 mm, margin dentate, with 6 or 7 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Bracts densely hairy, linear-filiform, up to 0.5 mm long. Pedicels up to 17 mm long. Flowers whitish-yellowish with rose to purple venation. Lateral sepals linear-lanceolate, acute at apex, hairy, 2-2.5 × 1 mm. Lower sepal ovate, acuminate, hairy on lower surface, glabrous on upper surface, with dark purple “bee-nest”-like prominent crest and 6 or 7 pairs of rib-like ridges with 7 holes in between, 10-11 × 4 mm. Dorsal petal helmet-like, hairy 9 × 3 mm. Lateral united petals 9-10 mm long, only with sparse whitish hairs, upper petal acuminate, 4-5 × 2 mm, lower petal 7 × 4 mm, obtuse, with

tubercle-like ridges along the veins. Anthers 2-3 mm long. Ovary 3-4 mm long, densely hairy. Fruit not known.

REMARKS— *Impatiens nanatonanensis* is related to *I. tafononensis* Eb.Fisch. & Raheliv. from Masoala Peninsula, but differs in the flower colour (yellowish with rose to purple veins in *I. nanatonanensis*, whitish-transparent with purple veins in *I. tafononensis*), the acuminate upper petal 4-5 × 2 mm, and the obtuse lower petal 7 × 4 mm, with tubercle-like ridges along the veins (upper petal broadly obtuse, 5.5-6 × 3 mm, and lower petal obtuse, 7 × 5 mm, smooth in *I. tafononensis*).

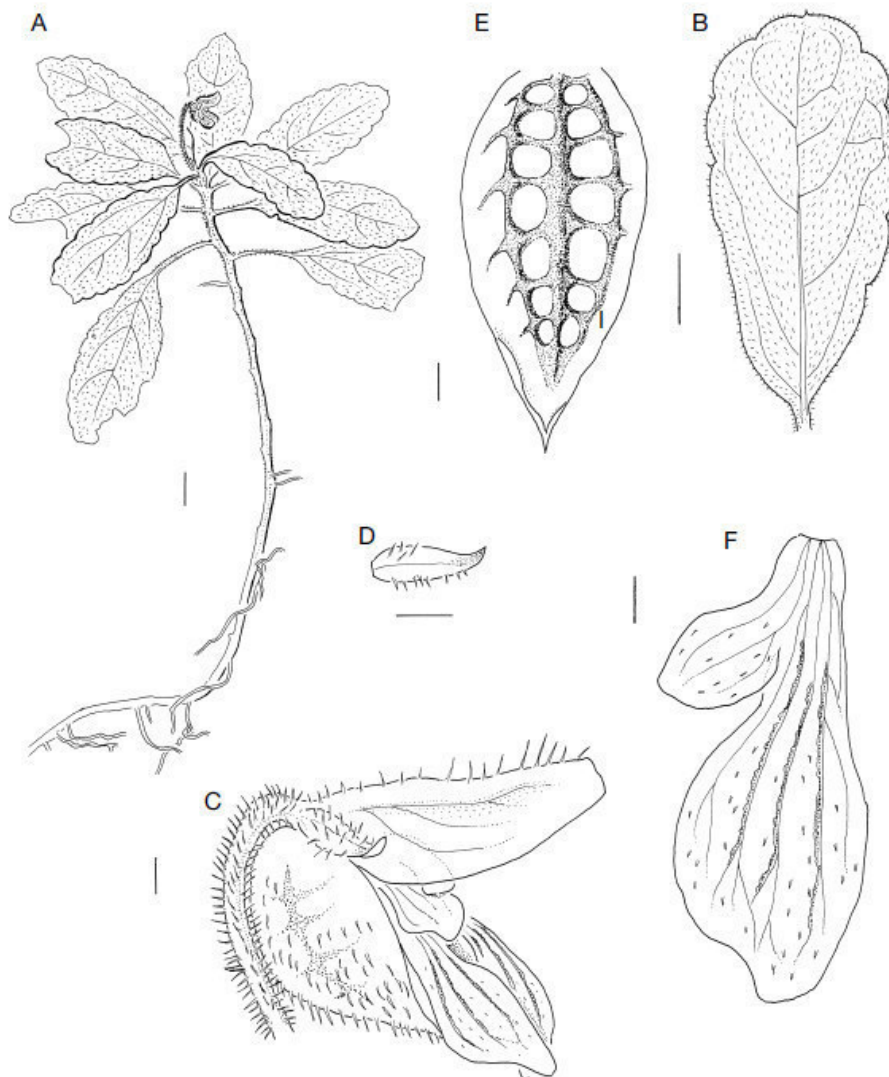


FIGURE 4. *Impatiens nanatonanensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, flower; **D**, lateral sepal; **E**, lower sepal; **F**, lateral united petals. *Rahelivololona, Triponez, Arnold & Mamy Tfa 2b* (TAN). Scale bars: A, B, 1 cm; C-F, 1 mm.

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

Impatiens tafononensis Eb.Fisch. & Raheliv., sp. nov. (Fig. 5)

Impatienti nanatonanensi affinis sed petalo superiore obtuso majore et tuberculis petali inferioris deficientibus valde differt.

TYPUS— Madagascar. Masoala, forêt de Nanatonana, on rocks in Tafonona river, 18.IX.2003, *Rahelivololona, Triponez, Arnold & Mamy Tfa 6* (holo-, TAN).

DESCRIPTION— Perennial herb, ascending to erect with creeping rhizome, rooting at the nodes, whitish-hairy throughout. Stems up to 20(-30) cm long, branched. Leaves dark greenish, with whitish hairs, petiole 7-14 mm long, lamina ovate, attenuate at base, broadly obtuse at apex, 60-65 × 19-22 mm, margin dentate, with 9 or 10 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Pedicels up to 16 mm long. Flowers with dorsal petal whitish-transparent with purple veins, lower sepal and lateral united petals yellowish with dark purple veins. Lateral sepals linear-lanceolate, 3.5 × 1 mm, acute at apex, with whitish hairs. Lower sepal ovate, acute at apex, hairy on lower surface, glabrous on upper surface, with “bee-nest”-like prominent crest and 7 pairs of rib-like ridges with 7 or 8 holes in between, 9 × 4-5 mm. Dorsal petal helmet-like, with whitish hairs, short apicule at apex of dorsal crest, 8 × 5 mm. Lateral united petals 10 mm long, subglabrous and only with sparse whitish hairs, upper petal broadly obtuse, 5.5-6 × 3 mm, lower petal obtuse, 7 × 5 mm. Anthers 1-2 mm long. Ovary 2-3 mm long, hairy. Fruit not known.

REMARKS— *Impatiens tafononensis* is related to *I. nanatonanensis* from Masoala Peninsula, but differs in the flower colour (whitish-transparent with purple veins in *I. tafononensis*, yellowish with rose to purple veins in *I. nanatonanensis*), in the broadly obtuse upper petal, 5.5-6 × 3 mm, and the obtuse and smooth lower petal, 7 × 5 mm (upper petal acuminate, 4-5 × 2 mm, and obtuse lower petal 7 × 4 mm, with tubercle-like ridges along the veins in *I. nanatonanensis*).

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

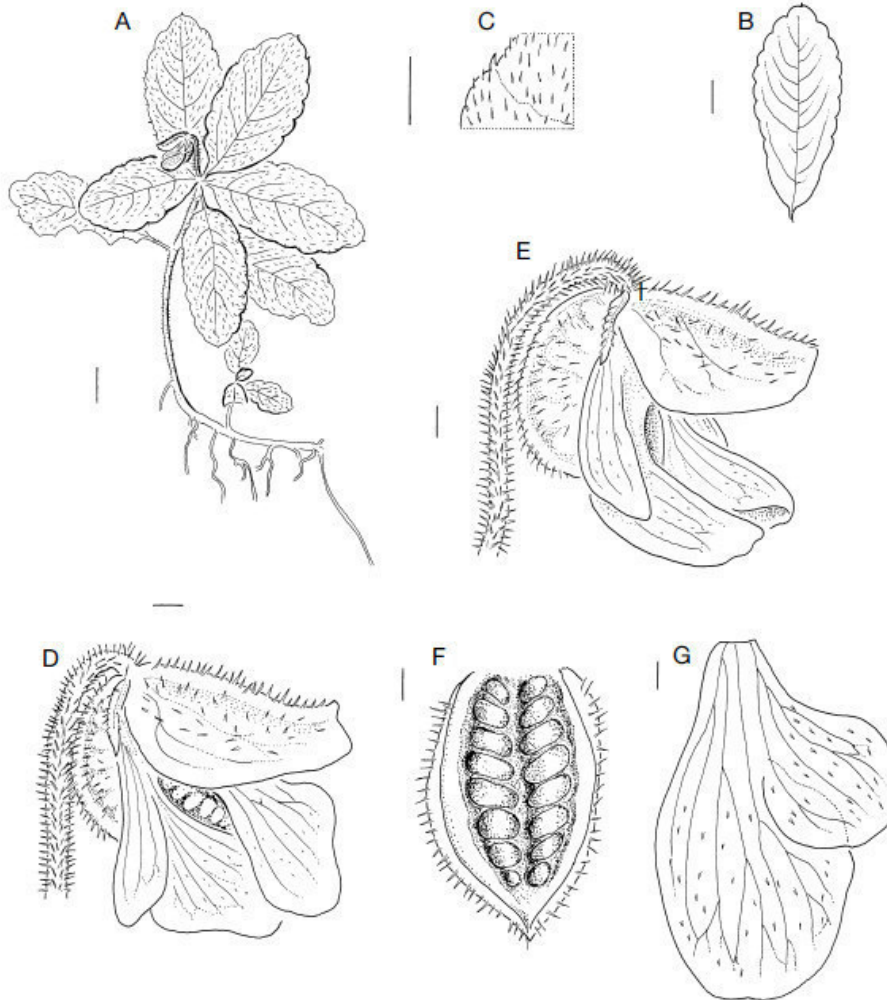


FIGURE 5. *Impatiens tafanonensis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, detail of leaf margin; **D**, **E**, flower; **F**, lower sepal; **G**, lateral united petals. *Rahelivololona, Triponez, Arnold & Mamy Tfa 6* (TAN). Scale bars: A, B, 1 cm; C, 5 mm; D-G, 1 mm.

Impatiens nidus-apis Eb.Fisch. & Raheliv., sp. nov. (Fig. 6)

Impatienti celligerae affinis sed ornamento sepali inferioris forma nidus apis valde differt.

Typus— Madagascar. Masoala, Ambanizana-Ambohitsitondroina, poussant sur rocher le long d'un ruisseau venant du sommet vers 750-800 m, 19.II.2002, *Rahelivololona, Saola & Scenario 143* (holo-, TAN).

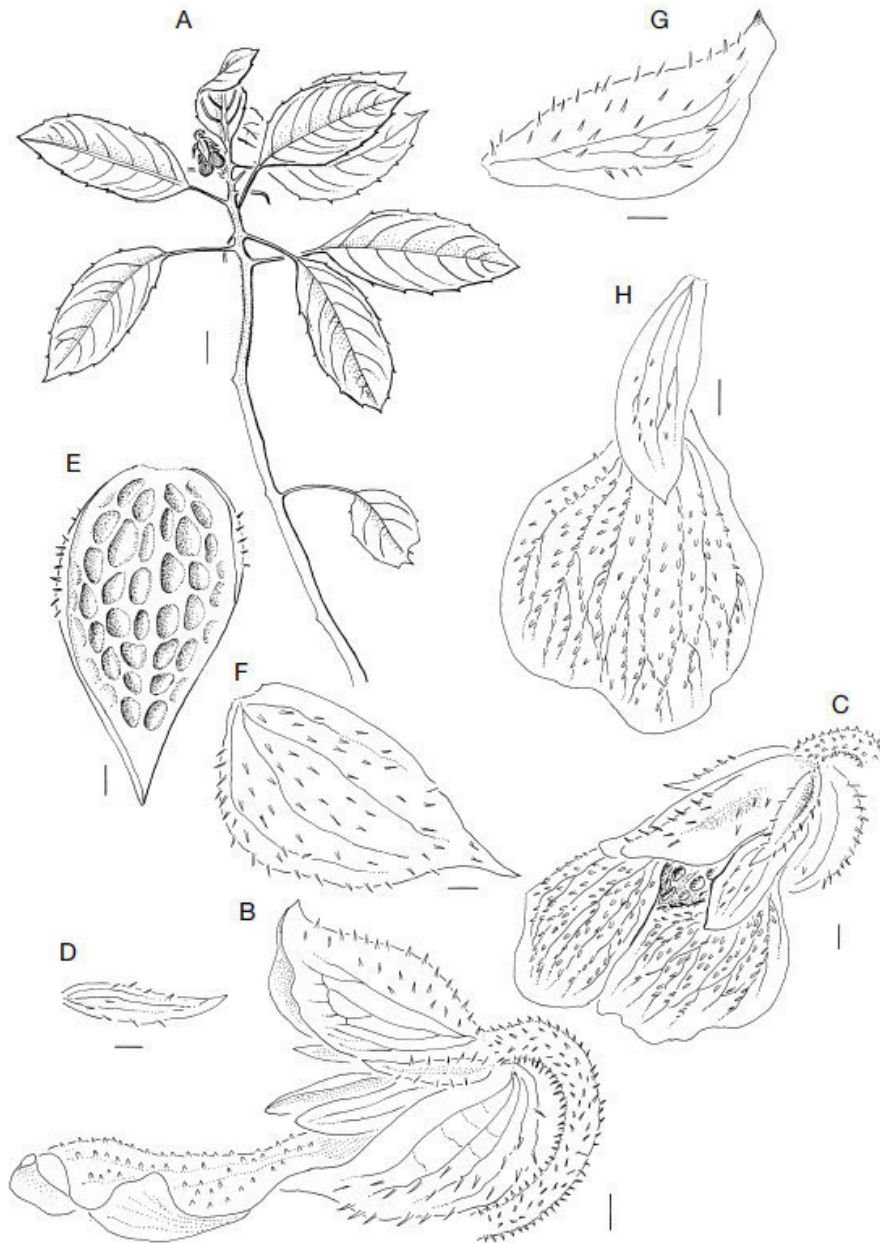


FIGURE 6. *Impatiens nidus-apis* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, flower; **D**, lateral sepal; **E**, **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Rahelivololona, Saola & Scenario 143* (TAN). Scale bars: A, 1 cm; B-H, 1 mm.

DESCRIPTION— Perennial herb, entirely pubescent. Stem erect, up to 18-20 cm tall, green and succulent. Leaves alternate, petiole reddish, 14-25 mm long, lamina ovate-

lanceolate, acuminate at apex, green on upper surface and reddish on lower surface, 55-61 × 22-24 mm, margin with 6-8 pairs of filiform glandtipped appendages. Inflorescence with solitary axillary flowers. Pedicel up to 13 mm long, curved at apex, pubescent. Flower with lower sepal yellow and maroon veins and apex, dorsal petal greenish outside and maroon inside, lateral petals entirely maroon. Lateral sepals 2, linear-lanceolate, 6 × 1.5-2 mm, sparsely pilose. Lower sepal navicular, outside with whitish hairs, inside with distinct reticular ornamentation, 12 × 8-9 mm. Dorsal petal cucullate, outside with whitish hairs, apiculate, 9 × 4-5 mm. Lateral united petals densely covered with papillae on the veins, 14-15 mm long, upper petal acuminate, 7 × 3 mm, lower petal broadly obtuse, 8-9 × 7 mm. Anthers 3-4 mm long. Ovary 4 mm long, pubescent. Fruit unknown.

REMARKS— *Impatiens nidus-apis* resembles *I. celligera* H.Perrier from the Masoala Peninsula but differs in the smaller leaves (55-61 × 22-24 mm in *I. nidus-apis*, 83-105 × 22-23 mm in *I. celligera*), the flower colour (yellow with maroon veins in *I. nidus-apis*, reddish in *I. celligera*), the shorter lateral sepals (6 × 1.5-2 mm in *I. nidus-apis*, 8 × 1.8 mm in *I. celligera*), and the shorter lateral united petals (14-15 mm in *I. nidus-apis*, 17 mm in *I. celligera*). *Impatiens nidus-apis* has a unique “bee-nest”-like ornamentation on its lower sepal.

HABITAT— Montane rainforest at 750-800 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

Impatiens saolana Eb.Fisch. & Raheliv., sp. nov. (Fig. 7)

Impatienti luteoviridi affinis sed sepalo inferiore sine ullo ornamento vel colore differt.

TYPUS— Madagascar. Masoala, Ambanizana-Ambohitsitondroina, sur rocher et mousse le long d'une rivière descendant vers riv. Ambanizana, 200 m, 18.II.2002, *Rahelivololona, Saola & Scenario 134* (holo-, TAN).

DESCRIPTION— Perennial erect herb, with creeping rhizome, with pubescent stem, petiole and pedicels. Stem erect, up to 5-10 cm tall. Leaves alternate, petiole 3-8 mm

long, lamina ovate-lanceolate, 30-40 × 12-19 mm, margin broadly crenate, with 8-10 pairs of teeth with a short gland-tipped appendage. Inflorescence with single axillary flowers. Pedicel 4-6 mm long, curved at apex. Flower greenish with dark red veins. Lateral sepals 2, pubescent, lanceolate, 2 × 1 mm. Lower sepal ovate-lanceolate, acuminate at apex, pubescent outside, 7 × 3 mm. Dorsal petal cucullate, pubescent, 7 × 3 mm. Lateral united petals with pubescent lower petal, 8 mm long, upper petal 1-2 × 1 mm, obtuse, lower petal 5 × 4 mm. Anthers 3 mm long. Ovary 3 mm long. Fruit unknown.

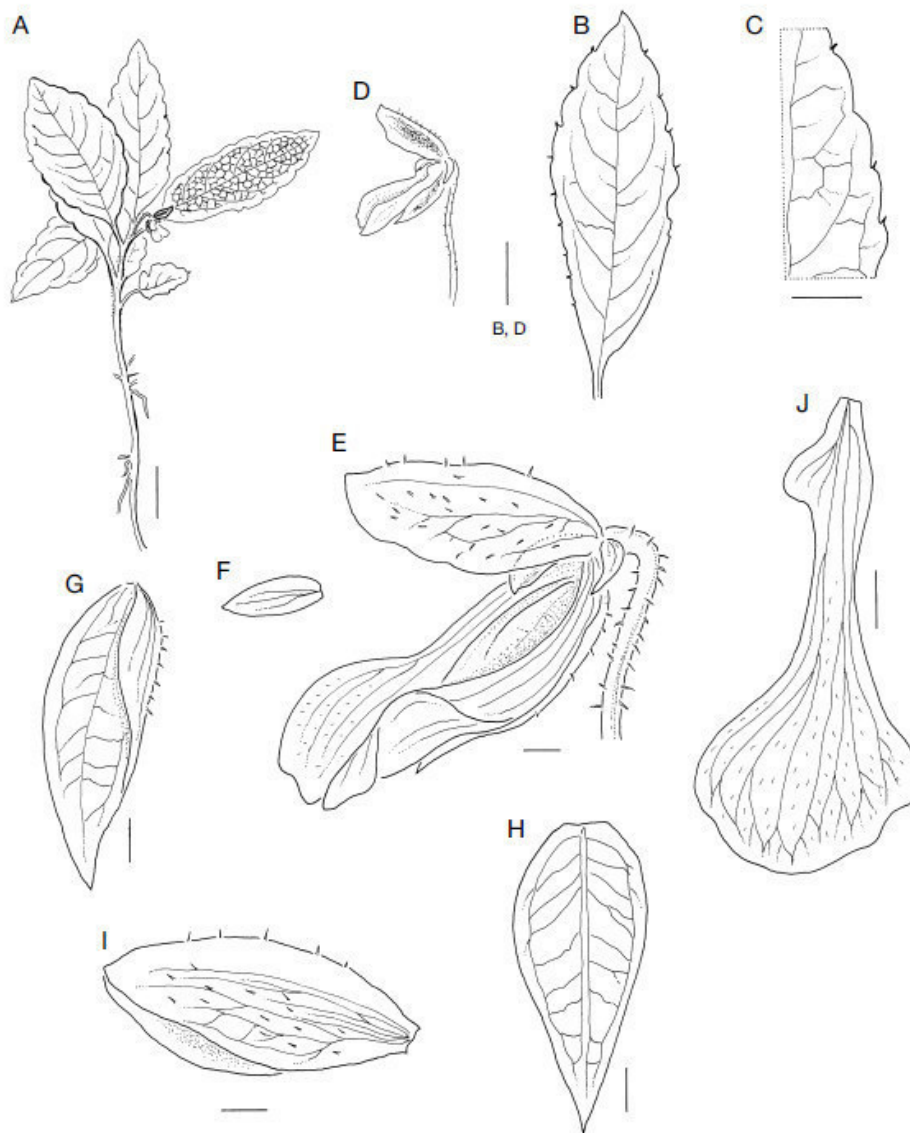


FIGURE 7. *Impatiens saolana* Eb.Fisch. & Raheliv.: **A**, habit; **B**, leaf; **C**, detail of leaf margin; **D**, **E**, flower; **F**, lateral sepal; **G**, **H**, lower sepal; **I**, dorsal petal; **J**, lateral united petals. *Rahelivololona, Saola & Scenario 134* (TAN). Scale bars: A, B, D, 1 cm; C, 5 mm; E-J, 1 mm.

REMARKS— *Impatiens saolana* is related to *I. luteoviridis* H.Perrier from Analamaitso, but differs immediately in smaller leaves (30-40 × 12-19 mm in *I. saolana*, 40-100 × 17-40 mm in *I. luteoviridis*), the shorter lateral sepals (2 × 1 mm in *I. saolana*, 6 × 0.7 mm in *I. luteoviridis*), the lower sepal without any ornamentation or colour, and the shorter lateral united petals (8 mm in *I. saolana*, 10-11 mm in *I. luteoviridis*).

HABITAT— Lowland rainforest at 200 m.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after the collector Saola.

Impatiens mamyi Eb.Fisch. & Raheliv., sp. nov. (Fig. 8)

Impatiens stefaniae affinis sed petalo superiore acuminato et sepalo inferiore ovato differt.

TYPUS— Madagascar. Masoala, forêt de Nanatonana, on rocks in Tafonona river or occasionally epiphytic, 15.IX.2003, *Rahelivololona, Triponez, Arnold & Mamy Tfa 5* (holo-, TAN).

DESCRIPTION— Perennial herb, erect with creeping rhizome, glabrous throughout except for small whitish scales on leaves and flower. Stems up to 30(-50) cm long. Leaves dark green on upper surface and whitish on lower surface, petiole not exceeding 7-10 mm, lamina lanceolate, acute at base and apex, net of tertiary veins nearly invisible, 60-90 × 8-15 mm, margin dentate with 7 or 8 pairs of teeth with a short gland-tipped appendage. Inflorescence with solitary axillary flowers. Bracts linear, 1 mm long. Pedicels up to 12-17 mm long. Flowers with greenish lateral sepals, whitish lower sepal and dorsal petal with purple veins, and pale yellow lateral united petals with purple veins. Lateral sepals linear-lanceolate, 2.5-3 × 0.8 mm. Lower sepal lanceolate-ovate, with distinct acumen, with dark red centre, 7-8 × 3-3.5 mm. Dorsal petal helmet-like, dorsal crest with 0.5 mm long spur at apex and dilated to a triangle at lower third, 8 × 3.2-4 mm. Lateral united petals 10-11 mm long, upper petal acute,

4 × 0.5-1 mm, free part 0.5 × 0.5 mm, lower petal obtuse, 7-8 × 3.5 mm. Anthers 3 mm long. Ovary 3-4 mm long. Fruit glabrous, 12 × 4 mm.

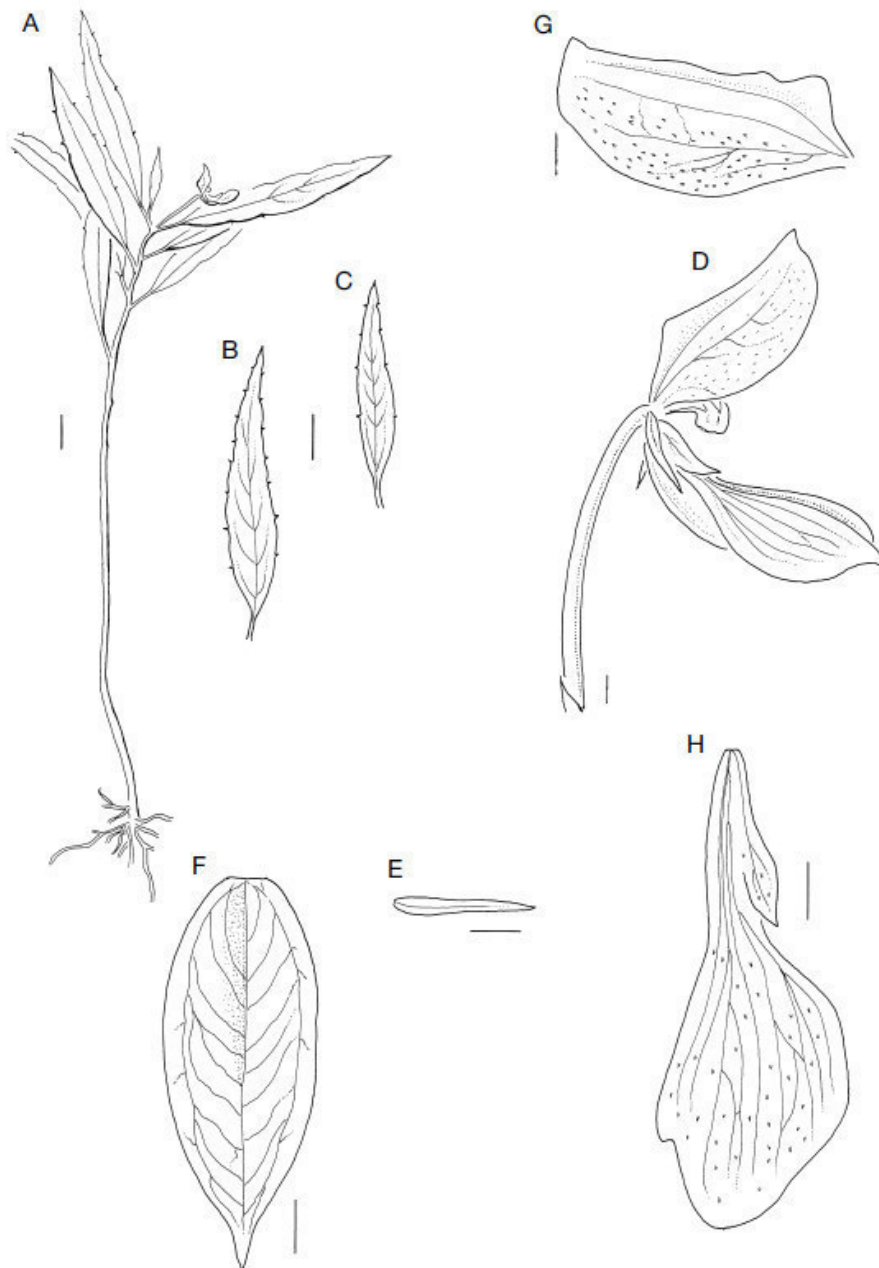


FIGURE 8. *Impatiens mamyi* Eb.Fisch. & Raheliv.: **A**, habit; **B**, **C**, leaves; **D**, flower; **E**, lateral sepal; **F**, lower sepal; **G**, dorsal petal; **H**, lateral united petals. *Rahelivololona*, Triponez, Arnold & Mamy Tfa 5 (TAN). Scale bars: A-C, 1 cm; D-H, 1 mm.

REMARKS— *Impatiens mamyi* is related to *I. stefaniae* Eb.Fisch. & Raheliv. from Masoala Peninsula, but differs in flower colour (yellowish with purple veins in *I. mamyi*, greenish in *I. stefaniae*), the longer lateral united petals (10-11 mm in *I. mamyi*, 8 mm

in *I. stefaniae*), the acuminate upper petal (rounded obtuse in *I. stefaniae*) and the broadly ovate lower sepal (lanceolate-ovate in *I. stefaniae*).

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after the collector Mamy.

Impatiens volatiana Eb.Fisch. & Raheliv., sp. nov. (Fig. 9)

Impatiens oniveensis affinis sed foliis late-ovatis et petalo inferiore ovato-lanceolato differt.

TYPUS— Madagascar. Masoala, forêt de Nanatonana, on rocks in Tafonona river, 15.IX.2003, *Rahelivololona, Triponez, Arnold & Mamy Tfa 4* (holo-, TAN).

DESCRIPTION— Perennial herbs, ascending to erect with creeping rhizome, rooting at the nodes, glabrous except for small whitish scales throughout. Stems up to 30 cm long. Leaves alternate, dark green or purple, petiole up to 10 mm long, lamina oblong-rounded, shortly attenuate at base and apex, net of tertiary veins hardly visible, 45-60 × 22-40 mm, margin dentate, with 5 pairs of teeth with a short gland-tipped appendage. Inflorescence with 1 or 2 axillary flowers per leaf. Bracts linear, up to 1 mm long. Pedicels up to 15-20 mm long. Flowers pale yellow with dark purple veins. Lateral sepals linear, 3 × 1.2 mm. Lower sepal with a net of non-prominent darker veins, 7-8 × 3-4 mm. Dorsal petal helmet-like, dorsal crest with 1 mm long spur at apex, dilated to a slight triangle below middle, 9-10 × 4 mm. Lateral united petals 11 mm long, upper petal with obtuse to emarginated apex, 3-4 × 1 mm, lower petal obtuse, ovate-lanceolate, 7 × 4 mm. Anthers 2 mm long. Ovary 2.5 mm long. Fruit with white scales, 11 × 5 mm.

REMARKS— *Impatiens volatiana* is related to *I. oniveensis* Eb.Fisch. & Raheliv. from the Onive Basin, but differs in the broadly ovate leaves and the smaller ovate-lanceolate lower petal (7-8 × 3-4 mm in *I. volatiana*, lower petal broad and rounded,

12 × 4-5 mm in *I. oniveensis*), the smaller dorsal sepal (9-10 × 4 mm in *I. volatiana*e, 12 × 3 in *I. oniveensis*), and the shorter lateral united petals (11 mm in *I. volatiana*e, 15 mm in *I. oniveensis*).

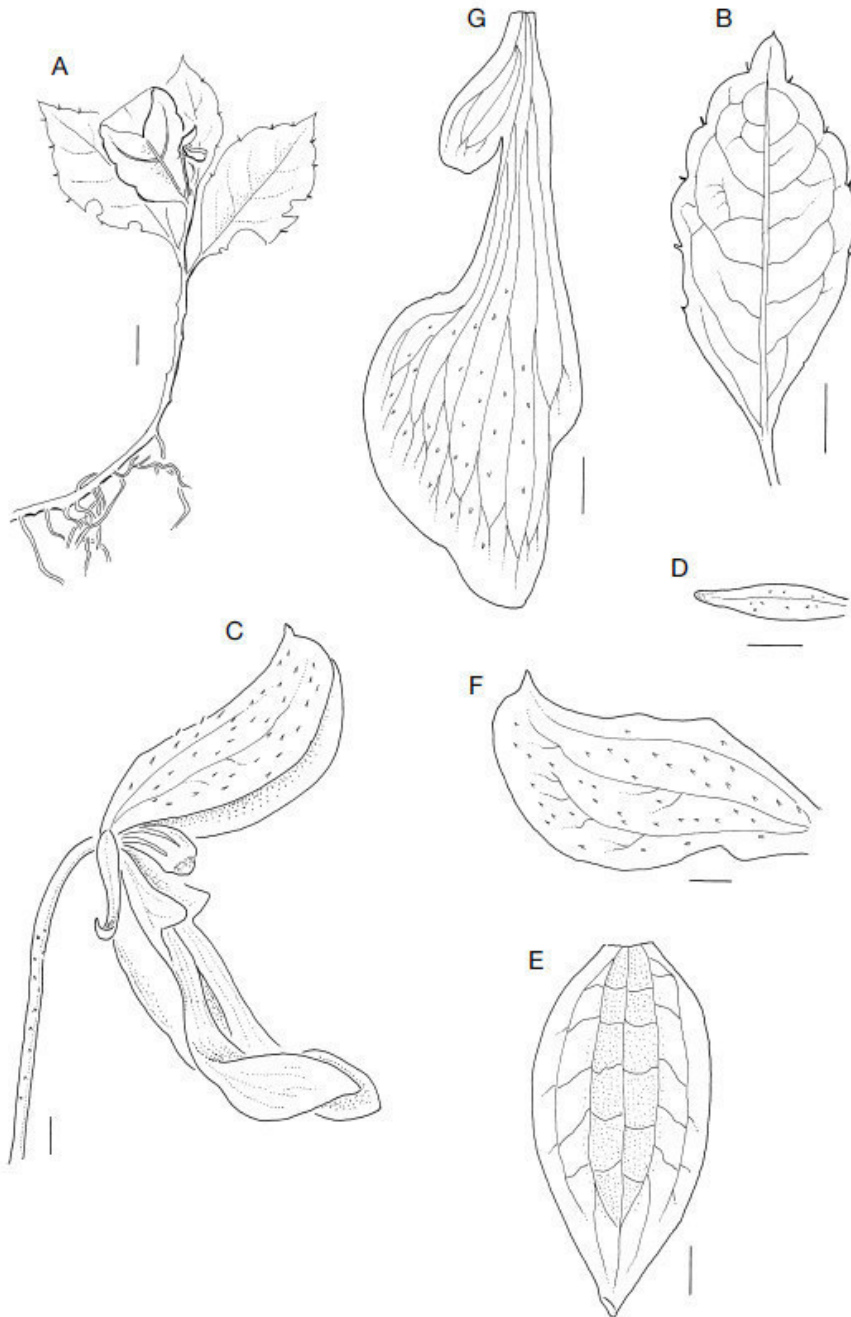


FIGURE 9. *Impatiens volatiana*e Eb.Fisch. & Rahelivololona: **A**, habit; **B**, leaf; **C**, flower; **D**, lateral sepal; **E**, lower sepal; **F**, dorsal petal; **G**, lateral united petals. *Rahelivololona*, Triponez, Arnold & Mamy *Tfa* 4 (TAN). Scale bars: A, B, 1 cm; C-G, 1 mm.

HABITAT— Montane rainforest.

DISTRIBUTION— Madagascar, Masoala Peninsula, only known from the type collection.

ETYMOLOGY— Named after Volatiana, daughter of the second author.

Acknowledgements

We would like to thank the director of the Herbarium, Muséum national d'Histoire naturelle (P), who kindly sent specimens on loan to the first author and who gave us permission to use the preliminary manuscript of Humbert. We also thank the directors of the following herbaria for loan of specimens: BR, G, K, NEU, TAN. The second author's thanks go as well to the Laboratoire de Phanérogamie de l'Université de Neuchâtel for the technical and financial help given to her. Thanks are due to Martin Cheek and Thierry Deroin for valuable comments on the manuscript.

Chapter 9

New taxa of *Impatiens* (Balsaminaceae) from Madagascar VI. *Impatiens otto-eleonorae*, a new species from Masoala Peninsula, and notes on the taxonomic relationships of *Impatiens firmula* and *I. hildebrandtii*

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, E.² (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VI. *Impatiens otto-eleonorae*, a new species from Masoala Peninsula, and notes on the taxonomic relationships of *Impatiens firmula* and *I. hildebrandtii*. *Phytotaxa* 217: 155-163.

¹ Institut für Integrierte Naturwissenschaften – Biologie, Universität Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany; e-mail: efischer@uni-koblenz.de

² Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo & Université de Mahajanga, République de Madagascar; e-mail: rmarielisette@yahoo.fr

Abstract

The new species *Impatiens otto-eleonorae* Eb.Fischer & Rahelivololona from Masoala Peninsula is described. It is related to *Impatiens hildebrandtii* Baill. from Eastern Central Madagascar, but differs in the larger habit and flowers. The types of *Impatiens firmula* Baker and *I. hildebrandtii* are reinvestigated. Both taxa, previously considered to be identical, represent different species, and *Impatiens hildebrandtii* is reinstated here.

Key words: *Impatiens otto-eleonorae* Eb.Fischer & Rahelivololona, *Impatiens firmula* Baker, *Impatiens hildebrandtii* Baill., endemism, Madagascar

Introduction

Madagascar is one of the “hottest hotspots of biodiversity” (Ganzhorn *et al.* 2001) with a high percentage of endemism threatened by extinction. Numerous new plant species from Madagascar are being described every year. During the revision of Balsaminaceae (Fischer & Rahelivololona 2000, 2004, 2007a, b, Fischer *et al.* 2003) it has become apparent that the general knowledge of the diversity of the genus *Impatiens* Linnaeus (1753: 937) in Madagascar is far from being satisfactory.

Perrier de la Bâthie (1934, 1948) and Humbert (1956) reported 105 species of *Impatiens* from Madagascar. However, while studying collections from P, TAN, MO, NEU and G numerous previously undescribed taxa were detected, raising the total number of species to more than 260. In this paper we describe a peculiar species from the Masoala Peninsula, which harbours 52 species of *Impatiens*, Linnaeus mostly restricted to lowland and montane rainforest. Only Mt. Marojejy has a similarly high number with 47 species recorded. The present study is based on the investigation of living and dried specimens. A short history of the exploration of *Impatiens* in Madagascar as well as details on terminology and measurements were provided by Fischer & Rahelivololona (2002).

Taxonomy

***Impatiens otto-eleonorae* Eb.Fischer & Rahelivololona, sp. nov. (Fig. 1, 2)**

Impatienti hildebrandtii affinis sed habitu valde majore, foliis majoribus margine appendicis distinctis, inflorescentiis cum 2–5 floribus et floribus valde majoribus differt.

Type— MADAGASCAR. Masola National Park, E slope of Ambohit-sitondroinan’Mahalevona, ESE of village of Mahalevona, 15°26’13’’S 049°57’26’’E, 23 February 2003, alt. 1140 m, *P.P.Lowry II, G.E.Schatz & J.R.Be* 6133 (holotype TAN!; isotypes P!, MO!).

Perennial herb, erect, glabrous. Stems succulent, green, up to 100 cm tall. Leaves alternate, dark green, shining, 12–17 cm long, petiole 10–20 mm long, with 1–2 pairs of extrafloral nectaries near base of lamina, lamina lanceolate-ovate, widest in upper third, base attenuate, slightly decurrent, apex acuminate, 11.5–14.5 × 3–4 cm,

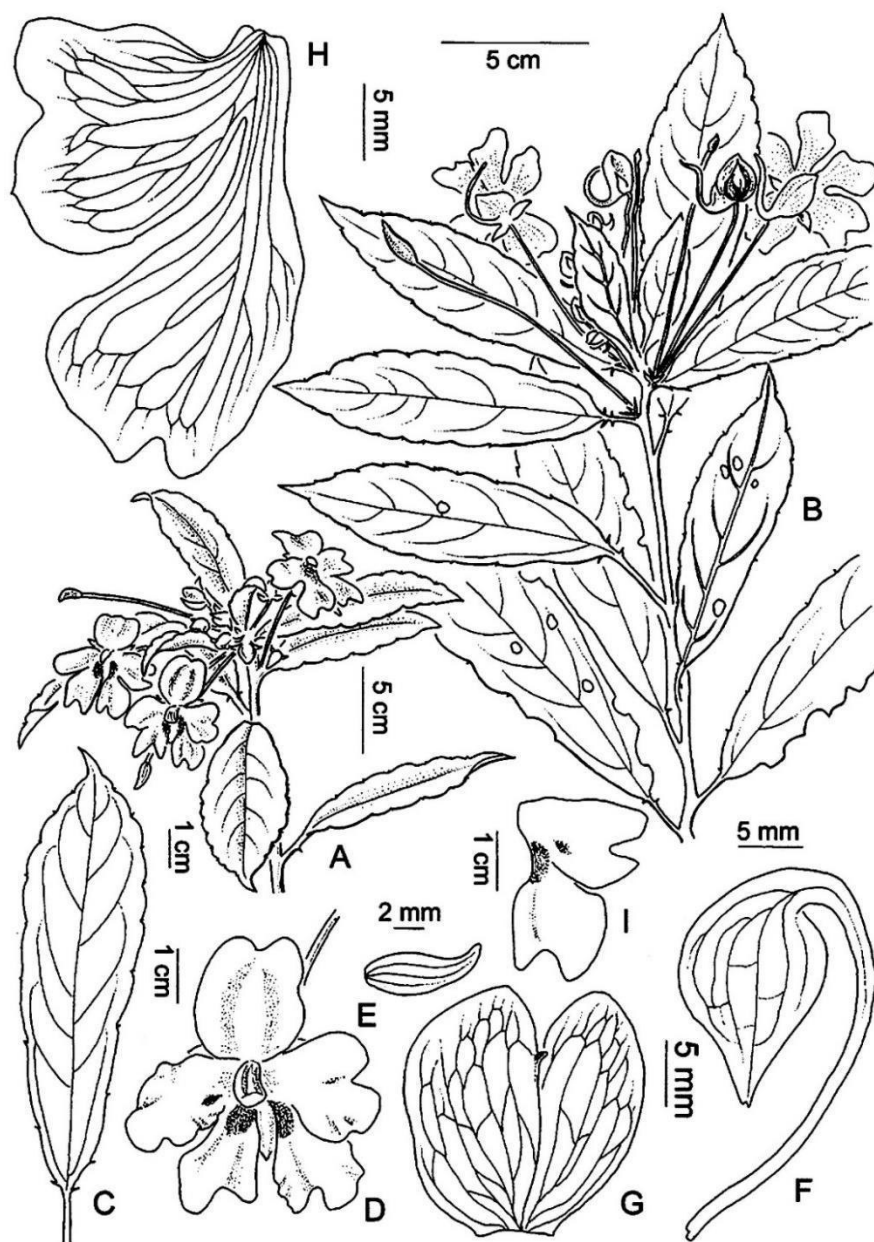


FIGURE 1. *Impatiens otto-eleonorae*. A, B, habit, C, leaf, D, flower, E, lateral sepal, F, lower sepal and spur, G, dorsal petal, H, I, lateral united petals. All drawn from the type by E. Fischer.

margin dentate, with (10) 12 pairs of teeth with gland-tipped appendages, acumen at apex 8–12 mm long. Inflorescence axillary, with (2) 5–6 flowers. Peduncle 2–3 mm long. Bracts linear-lanceolate, 6–7 × 1 mm. Pedicels 6.5–8.2 cm long, reddish. Flowers pinkish-purple with red mark on lower petals, spur violet. Lateral sepals ovate, acuminate, 7–8 × 2 mm. Lower sepal navicular, 15 × 8 mm, with curved spur, 20–25 mm long. Dorsal petal cucullate, with short spur at apex, 23–26 × 18–20 mm. Lateral united petals 35 mm long, upper petal deeply emarginated at apex, 20 × 14 mm, lower

deeply emarginated at apex, 30 × 15 mm. Anthers 4–5 mm long. Ovary 4–5 mm long. Fruit elongate, 20 × 4–5 mm.

Habitat— Perhumid montane forest along creek, 1140 m.

Distribution— Madagascar, Masoala Peninsula, only known from the type collection.

Etymology— dedicated to Otto and Eleonore Gunthilde Karolina Schweizer by the family of Andreas Schweitzer on the occasion of the 80th birthday of Eleonore for the generous support of taxonomic research.

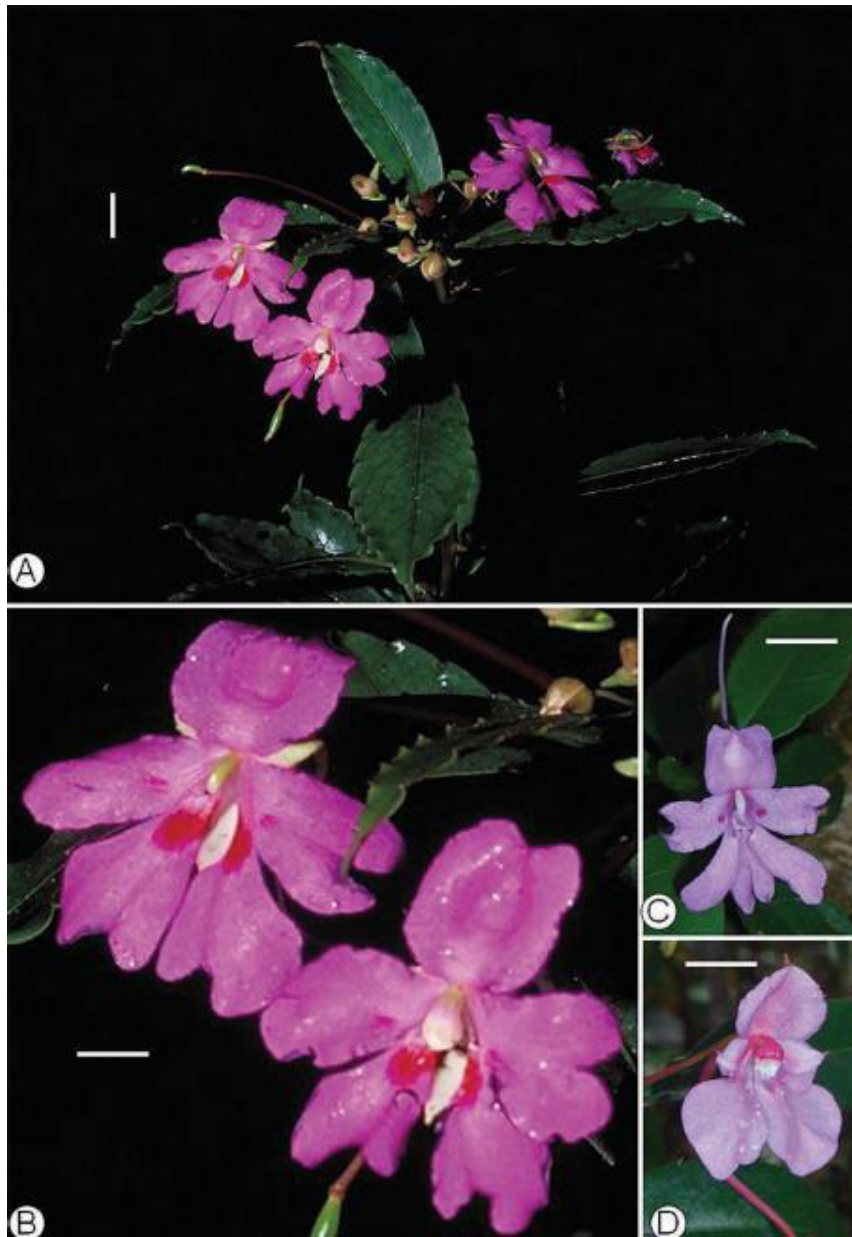


FIGURE 2. *Impatiens otto-eleonorae*. **A**, habit with inflorescence. **B**, flowers. *Impatiens hildebrandtii*. **C**, flower. *Impatiens firmula*. **D**, flower. A, B, phot. P.P.Lowry, Masoala, C, D, phot. E. Fischer, Angavokely, Andasibe. Scale bar A: 2 cm, B–D: 1 cm.

Notes— *Impatiens otto-eleonorae* is related to *Impatiens hildebrandtii* Baillon (1886: 595), which was considered as a synonym of *Impatiens firmula* Baker (1883: 114) by Perrier de la Bathie (1934). It differs, however, in several features (Table 1), e.g., larger habit, the larger leaves, the inflorescences with up to 6 flowers and the larger flowers. *Impatiens hildebrandtii* occurs in Eastern Central Madagascar in rainforests (e.g. Andasibe and Ranomafana). *Impatiens otto-eleonorae* is restricted to perhumid montane forests on Masoala Peninsula.

TABLE 1. Comparison of *Impatiens otto-eleonorae*, *I. hildebrandtii* and *I. firmula*

Character	<i>Impatiens otto-eleonorae</i>	<i>Impatiens hildebrandtii</i>	<i>Impatiens firmula</i>
Stem	c. 100 cm	c. 40 cm	c. 50 cm
af lamina	11–14.5 × 3–4 cm	3.5–4.5 × 1.5–2.2 cm	(3) 5–5.5 × 1–1.8 cm
Marginal teeth	(10) 12 pairs	5 pairs	8 pairs
Petiole length	10–20 mm	1–6 mm	8–10 mm
Extrafloral nectaries	1–2 pairs 1.5–2 mm long	1 pair 1 mm long	1–2 pairs 1–2 mm long
Peduncle length	2–3 mm	1 mm	1 mm
Bracts	6–7 × 1 mm	1 × 0.5 mm	1 × 0.5 mm
Pedicle length	6.5–8.2 cm	1.5–2 cm	2–4.5 mm
Lateral sepals	7–8 × 2 mm	3 × 1 mm	2–3 × 1.5 mm
Lower sepal	15 × 8 mm	5–6 × 2 mm	6–8 × 4 mm
Spur length	2–2.5 cm, curved	1.8–2 cm, straight	1.7–2.2 cm, curved
Dorsal petal	23–26 × 18–20 mm, flat	6–8 × 5 mm, flat	6–8 × 5–6, helmet-shaped
Lateral petals length	3.5 cm	1.5 cm	1.3 cm
Upper petal	20 × 15 mm	8–9 × 3–4 mm	4–5 × 3 mm
Lower petal	30 × 15 mm	10 × 6–7 mm	10 × 5–6 mm
Ovary length	4–5 mm	1.5–2 mm	2 mm
Fruit	20 × 4–5 mm	10 × 2–3 mm	10–11 × 2–4 mm

The taxonomic relationship of *Impatiens firmula* Baker and *Impatiens hildebrandtii* Baill

Impatiens firmula was described from Central Madagascar. In the protologue Baker states “gathered long ago by Bojer and distributed as *Impatiens capensis*, and by Lyall (no 50). Sent lately by Mr. Baron and by Dr. Parker from the forest of Andrangaloaka. I presume it is *I. leptopoda* var. *madagascariensis* Hoffmann (1882: 335); but the Ceylon plant is a flaccid annual herb, and this is a perennial with woody lower branches.” (Baker 1883:115). This comment is probably the source for the erroneous citation of *Impatiens capensis* Bojer ex Baker (1883: 115), mentioned e.g. in Perrier (1934) and clarified by Day *et al.* (2012). Baker, however, did not validate Bojer’s name in the publication. Wenceslas Bojer (1795–1856) was an Austrian naturalist, explorer and horticulturist who collected, together with Carl Theodor Hilsenberg (1802–1824) in Madagascar from 1821 to 1823 where they were received by King Radama I. together with James Hastie (Dorr 1997). *Impatiens capensis* Thunberg (1794: 41) is a later

homonym of the North American *I. capensis* Meerburgh (1775: t. 10), which was only erroneously reported from “Promontorium Bonae Sp.” (Fuchs 1963). *Impatiens capensis* Thunberg is nowadays considered to be a synonym of *Impatiens hochstetteri* Warburg (1895: 48, Grey-Wilson 1980) which is not present in Madagascar.



FIGURE 3. *Impatiens firmula*. A–D, lectotype, K. E, isotype of *Impatiens filipes*, K. Scale bar: 1 cm.

Impatiens hildebrandtii is quite different from the typical *I. firmula* which is by far not that variable as Perrier (1934) stated: “Elle est très variable quant à la forme et aux dimensions des feuilles et des différentes pièces de la fleur et quant au nombre des

ovules de l'ovaire. Dans cette gamme assez étendue de variations, il est impossible de distinguer les formes qu'on a nommées *I. filipes* et *I. Hildebrandtii*". We have studied the original material of *Impatiens firmula* at K which had also been investigated by J.D.Hooker who added drawings and annotations. It consists of three sheets, the first bearing three stems (Fig. 3). Two stems are annotated as "*Impatiens capensis* Thunb. Hab: Madagascar Bojer", the third stem above right is labelled "Central Madagascar R. Baron 2640". We have selected the two specimens of Bojer and designate them here as lectotype, as they closely match the description in the protologue. The drawing by Hooker (Fig. 3) clearly shows a slender and curved spur. The second sheet is annotated as "*Balsamina capensis* 50 Dr. Lyall", and the third sheet as "*Impatiens*

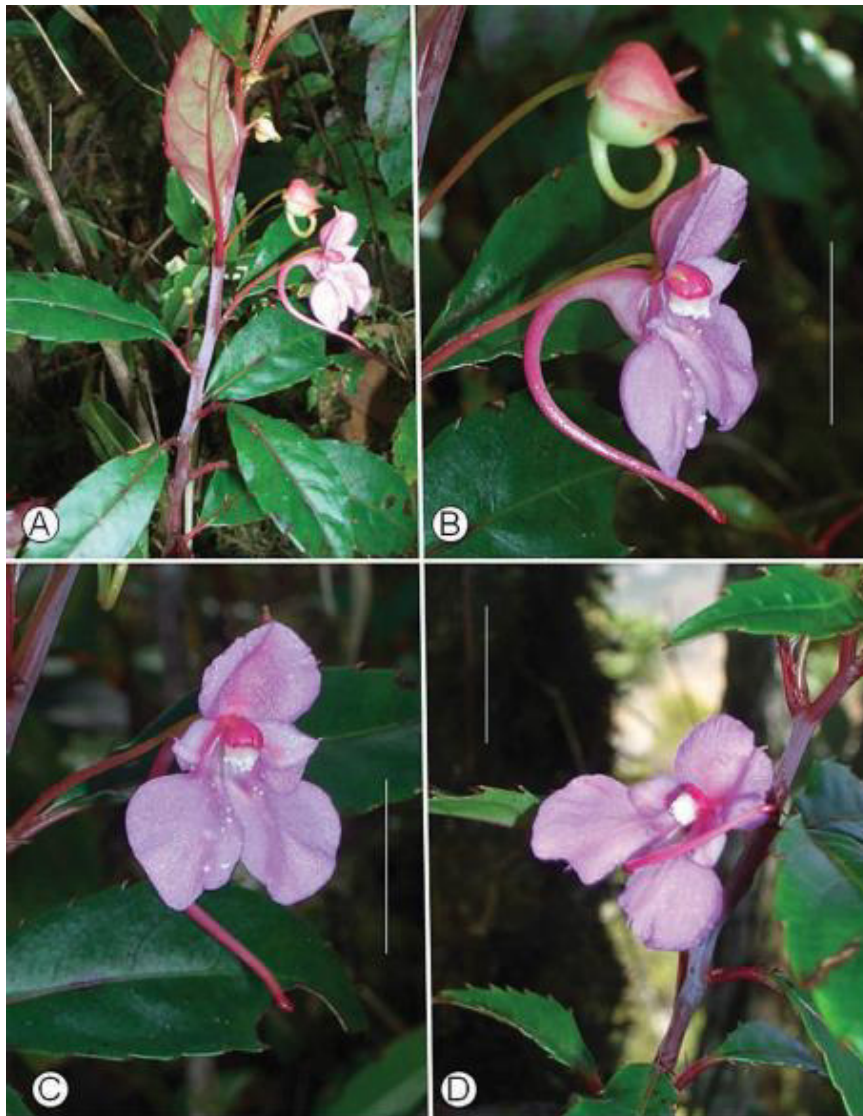


FIGURE 4. *Impatiens firmula*. A, habit. B–D, flower. A–D, phot. E. Fischer, Angavokely. Scale bar: 1 cm.

firmula Madagascar Dr. Lyall. during field work at Angavokely (South of Antananarivo) we came across an *Impatiens* which exactly matches the type of *Impatiens firmula* (Fig. 4). The type of *Impatiens filipes* Baillon (1886: 594) (Fig. 3) closely resembles *I. firmula* and is clearly identical as already Perrier (1934) assumed.

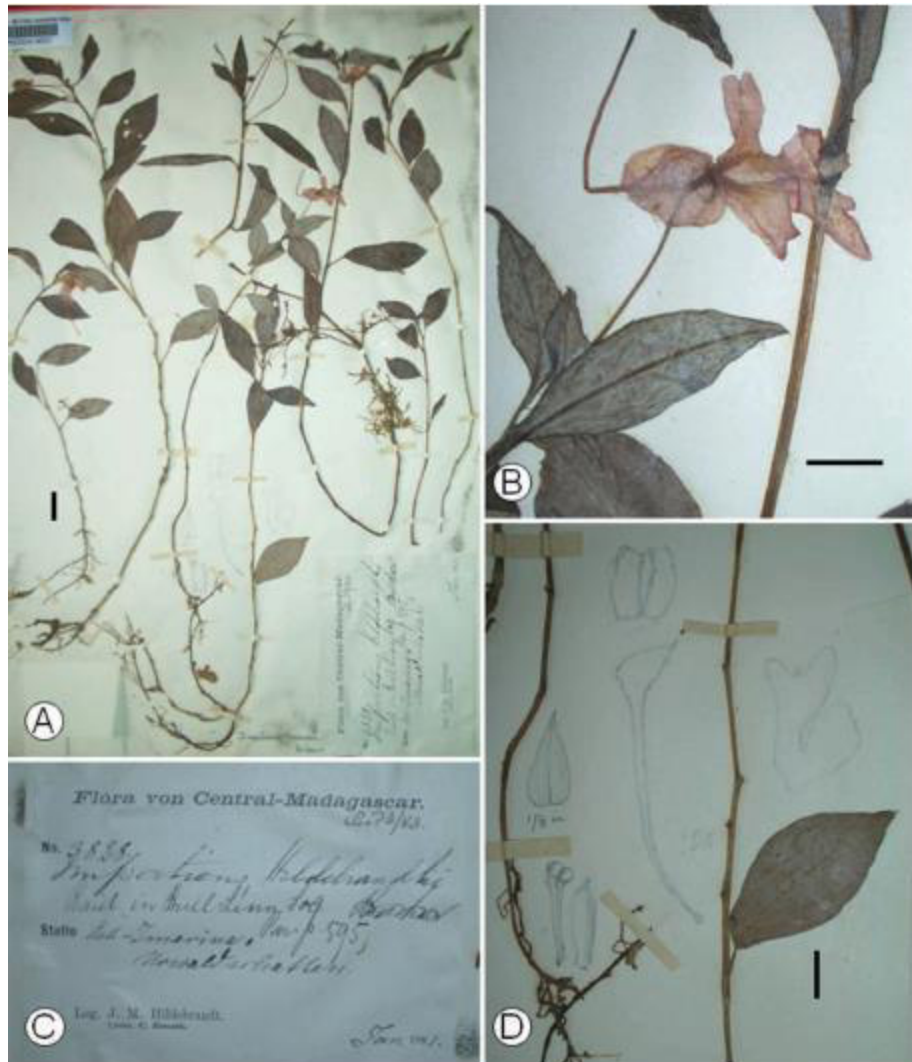


FIGURE 5. *Impatiens hildebrandtii*. A–D, isotype, K. A, D: scale bar 1 cm, B: scale bar 5 mm.

Impatiens hildebrandtii differs from typical *I. firmula* in the slender and straight spur, the shape of the dorsal petal, the shape of the lateral united petals, and the shape of the leaves. The type (Fig. 5) collected in the Central and Eastern Highlands (“Imerina”), albeit without precise locality closely matches specimens from Andasibe National Park (Fig. 6). Thus we consider *Impatiens firmula* and *Impatiens hildebrandtii* as two distinct species. *Impatiens hildebrandtii* has a puzzling nomenclatural history. It first comprised two different species that were merged by Baillon (1886: 595). The first specimen *Hildebrandt 3828* (Fig. 5) is the validly described *Impatiens hildebrandtii*. In the

protologue Baillon also cites *Hildebrandt 3382* from “Ambohitsi (Ambergebirge)” (= Montagne d’Ambre). Baker (1887) already recognized that this specimen is different from *Impatiens hildebrandtii*, but he assumed that it represents *Impatiens emirnensis* Baker (1883: 115), which is currently regarded as a synonym of *Impatiens baroni* Baker (1882: 49). The specimen *Hildebrandt 3382* was subsequently described as *Impatiens sacculata* Warburg (1897: 53).

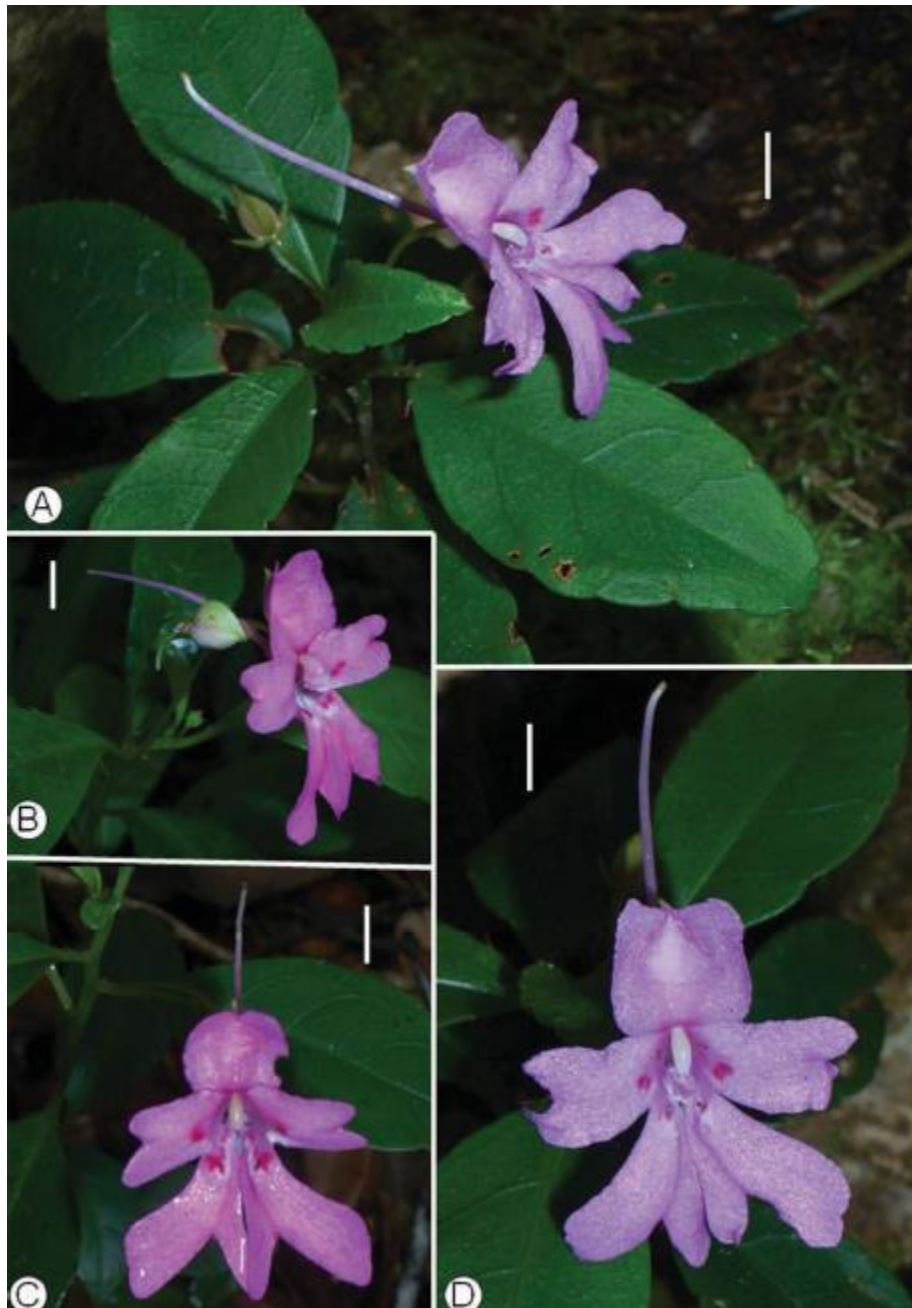


FIGURE 6. *Impatiens hildebrandtii*. A, habit. B–D, flower. A–D, phot. E. Fischer, Andasibe. Scale bar: 5 mm.

***Impatiens firmula* Baker (1883: 114)**

Type— hab. In sylvis Be-fouroum insula Madagascar, *Bojer s.n.* (K lectotype selected here, P isolectotype)

***Impatiens hildebrandtii* Baillon (1886: 595)**

Type— Ost-Imerina, Urwaldschatten, January 1881, *Hildebrandt 3828* (P holotype, b, KW, JE, isotypes)

Conservation status— *Impatiens firmula* has at present only been observed at Angavokely Forest Station (S18°55'37.9" E47°44'22.1") at 1776 m. The species may be rare and endangered, as many montane forests in the central highlands of Madagascar have been heavily logged but it is considered by the authors as Data Deficiency (DD). The locality observed in 2008 at the summit of a hill was already destroyed in 2014 due to antenna constructions.

Impatiens hildebrandtii is at least present in large populations in the reserve Speciale Analamazotra near Andasibe-Perinet National Park. The new *Impatiens otto-eleonorae* is only known from the type locality at Masoala Peninsula. Both are local endemics occurring in protected areas and could be classified as Endangered (EN).

Acknowledgements

We thank the Directors of the following herbaria for loan of specimens (acronyms according to Holmgren *et al.* 1990): BR, G, K, NEU, TAN. Special thanks go to Porter P. Lowry II/Paris for kindly allowing us to use the photograph of *Impatiens otto-eleonorae*.

Chapter 10

New taxa of *Impatiens* (Balsaminaceae) from Madagascar VII. Two new species of *Impatiens* from Mt. Marojejy, Madagascar.

This chapter has been published as:

Fischer, E.^{1*} & Rahelivololona, M.E.² (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VII. Two new species of *Impatiens* from Mt. Marojejy, Madagascar. *Phytotaxa* 239: 213-222.

¹ Institut für Integrierte Naturwissenschaften – Biologie, Universität Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany. efischer@uni-koblenz.de*

² Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo & Université de Mahajanga, République de Madagascar.

Abstract

Two new species, *Impatiens susan-nathansoniae* and *I. hendrikii*, from Mt. Marojejy, Madagascar, are described. *Impatiens susan-nathansoniae* is related to *I. humblotiana* from eastern central Madagascar, but differs in the shape of the lower sepal with spur, the dorsal petal and the lateral united petals. *Impatiens hendrikii* is related to *I. fuchsioides*, but differs in the straight stem, the larger leaves, the broader lateral sepals, the broader lateral united petals with different shape, and the glabrous lower sepal gradually tapering into a short, saccate, whitish red spur.

Key words: endemism, flora, forest, *Impatiens hendrikii*, *Impatiens susan-nathansoniae*, ornithophily, taxonomy

Introduction

From a taxonomic point of view, *Impatiens* Linnaeus (1753: 937) is amongst the most

difficult genera of flowering plants. For Madagascar, 110 species were known, mainly described by Perrier de la Bâthie (1934, 1948) and Humbert (1956) (for a short account of taxonomic history see Fischer & Rahelivololona 2002). During a revision of the Balsaminaceae for the “Flore de Madagascar et des Comores”, many new species were discovered of which several have already been described (Fischer & Rahelivololona 2002, 2004, 2007a, b, 2015; Fischer *et al.* 2003).

Based on the presence of a bucciniform lower sepal with spur and a cucullate dorsal petal, numerous *Impatiens* species from Africa, Madagascar and India were artificially assembled into one taxonomic group (Warburg & Reiche 1895). Although its representatives seem to be a closely related and well-circumscribed unit (see Grey-Wilson 1980), molecular data suggest that they evolved in different clades and simply share the ornithophilous syndrome (Yuan *et al.* 2004; Janssens *et al.* 2006). Usually, the flowers are red, orange, yellow or rarely greenish. The first Madagascan species with these characters to be described were *I. humblotiana* Baillon (1881: 286) and *I. catati* Drake (1896: pl. 170a). Until the fundamental paper of Perrier de la Bâthie (1934), only these two species of the group were known from Madagascar. In 1934, Perrier de la Bâthie added *I. amoena* Perrier de la Bâthie (1934: 17), *I. antongiliana* Perrier de la Bâthie (1934: 14), *I. danguyana* Perrier de la Bâthie (1934: 12), *I. eriosperma* Perrier de la Bâthie (1934: 11), *I. fuchsoides* Perrier de la Bâthie (1934: 18) and *I. fulgens* Perrier de la Bâthie (1934: 13). Humbert (1956) described *I. perrieri* Humbert (1956: 113). Since that time, several new species have been collected on Madagascar. It is noteworthy that *I. humblotiana* only occurs in the mid-elevation rainforest of eastern Madagascar, while the specimens from Mt. Marojejy growing at mid-elevation (950–1200 m) belong to a rather uniform, recently described taxon, *I. renae* Fischer & Rahelivololona (2004: 38). Above 1200 m, two further new species have now been collected and these are described in the present contribution. Herbarium acronyms follow Holmgren *et al.* 1990.

Impatiens susan-nathansoniae Eb.Fisch. & Raheliv., *sp. nov.* (Figs. 1, 2)

Impatiens humblotianae affinis sed forma petali dorsalis, forma petalorum lateralium et forma sepalis inferioris calcarisque valde differt.

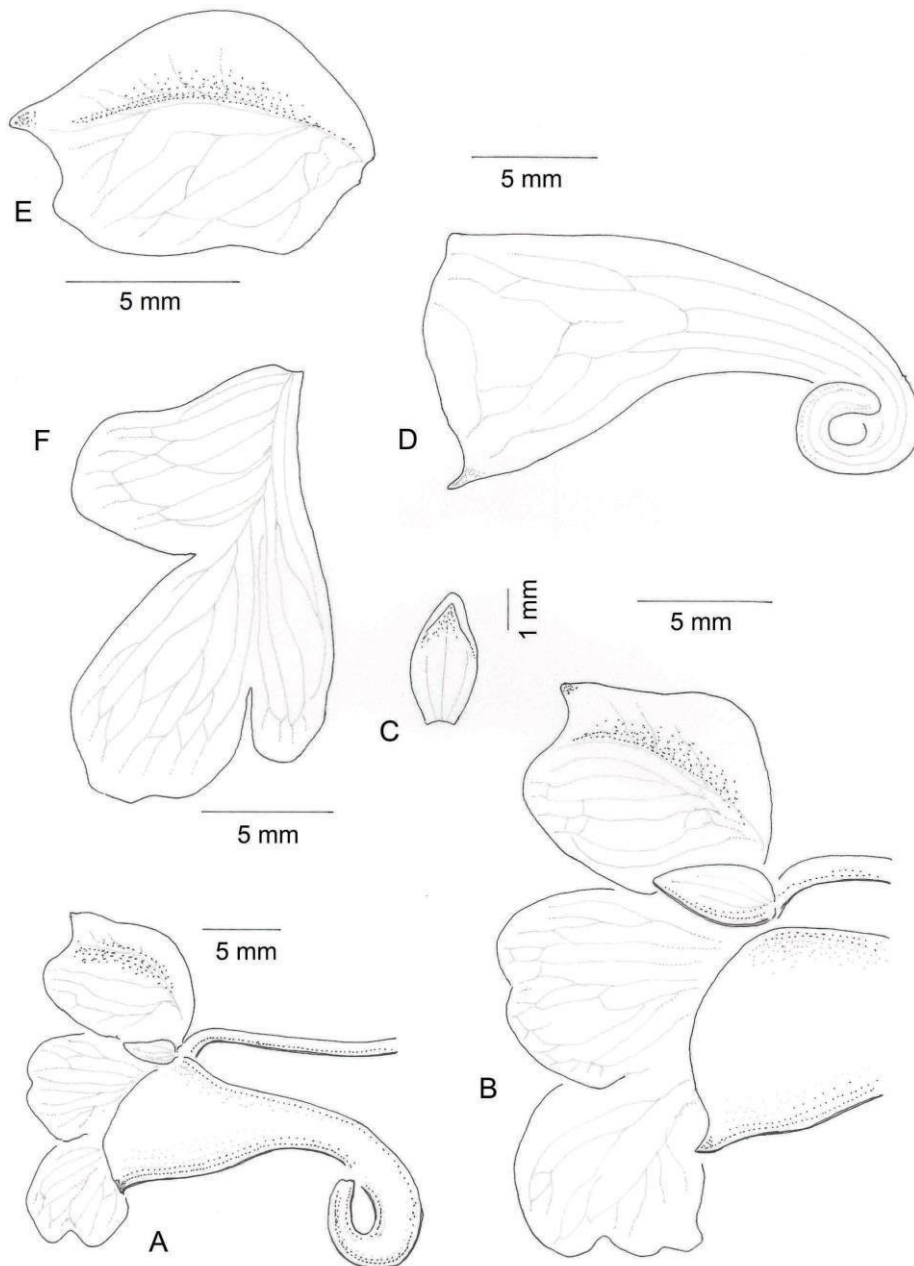


FIGURE 1. *Impatiens susan-nathansoniae*. **A**, flower, **B**, Detail of flower with lateral sepals, dorsal petal and lateral united petals, **C**, lateral sepal, **D**, lower sepal with spur, **E**, dorsal petal, **F**, lateral united petals. All drawn from the type, *Wohlhauser & Pfund 1044*. artist: E. Fischer.

TYPE— MADAGASCAR. Antsiranana, Marojejy National Park, above camp 3, 14°26'17"S 049°44'64"E, 27 November 1995, 1400 m, *Wohlhauser & Pfund 1044* (holotype TAN!, isotype NEU!).

Suffrutescent herb, 300–900 mm tall, entirely glabrous. Stem succulent, woody at base. leaves alternate, petiole 8–11 mm long, sometimes with 1 pair of extrafloral nectaries at base of lamina, lamina succulent-coriaceous, rigid, vivid green below, dark green above, ovate-lanceolate, acuminate at base and obtuse at apex, widest at apex, 42–80 × 20–31 mm, margin with 7 or 8 pairs of fimbriae. Inflorescence axillary, bracts

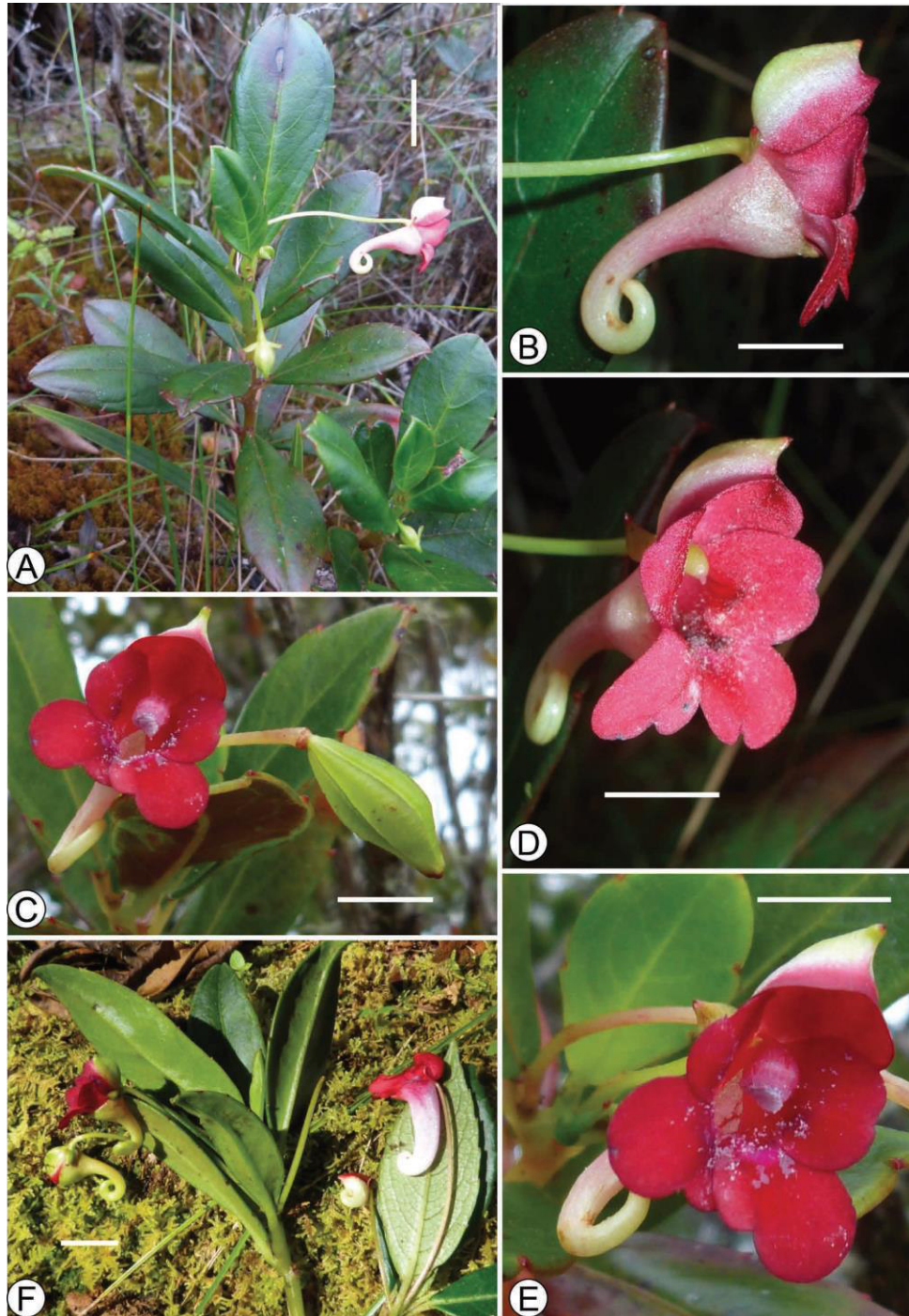


FIGURE 2. *Impatiens susan-nathansoniae*. A, habit with inflorescence. B–E, flower, F, *I. susan-nathansoniae* (left), *I. hendrikii* (right). Scale bar A: 2 cm, B–D: 1 cm. Photographs E. Fischer, Marojejy.

1–2 × 0.8–1 mm, pedicel up to 50–70 mm long, peduncle less than 1 mm long. Flowers with wine-red to purple dorsal petal, bearing a long greenish white crest, lateral sepals wine-red, lower sepal and spur whitish red, lateral united petals wine-red. lateral sepals broadly ovate, acuminate, 3–4 × 1.5 mm. Lower sepal navicular, 16–22 × 10 mm, 3–4 mm diameter at middle, abruptly tapering into curved narrow obtuse saccate spur 4–5.5 × 1.5 mm. Dorsal petal cucullate, 9–10 × 7–8 mm, dorsal crest 3 mm high, with spur-like apiculum 1 mm long. Lateral united petals 16–19 mm long, upper petal 8–12 × 5 mm, lower petal 13 × 10 mm, distinctly bilobed at apex. Anthers 5 mm long. Ovary 5 × 2.5 mm. Fruit 22 × 5–6 mm.

HABITAT— Montane forest along crest, 1400–1545 m.

DISTRIBUTION— Madagascar, Marojejy National Park, only known from the type locality (Fig.3).

CONSERVATION STATUS— *Impatiens susan-nathansoniae* is restricted to Mt. Marojejy National Park. despite the occurrence in a protected area, the species should be considered as vulnerable.

PHENOLOGY— Flowers have been recorded in March, October and November.

EPONYMY— Dedicated to Mrs. Susan Nathanson by Michael Nathanson.

ADDITIONAL COLLECTION (PARATYPE)— MADAGASCAR. Antsiranana, Marojejy National Park, path from Mandena to the summit of Marojejy, above Camp 3, 1540 m, 14°26'23"S 49°44'28"E, 20 October 2014, *Fischer, Andriamiarisoa, Sérusiaux, Goffinet & Ertz 202a* (TAN!, Kobl!).

NOTES— *Impatiens susan-nathansoniae* is related to *I. humblotiana* (Fig. 3), but differs in the shape of the dorsal petal which is only slightly rounded at the crest (*vs.* with rounded and higher crest in *I. humblotiana*), the lateral united petals where the lower petal exceeds the upper petal (*vs.* lower petal smaller than upper petal), and the shape of the lower sepal which abruptly narrows into the spur (*vs.* gradually tapering into the spur). *Impatiens humblotiana* occurs in eastern central Madagascar in rain forest (e.g., Andasibe, Betampona). *Impatiens susan-nathansoniae*, on the other hand, is restricted to montane forests on Mt. Marojejy (Fig. 3).

Impatiens hendrikii Eb.Fisch. & Raheliv., *sp. nov.* (Figs.5, 6)

Impatiens fuchsioidei affinis sed caule recto, foliis majoribus, pedicello piloso, sepalis lateralibus latioribus, forma petalorum lateralium, et sepalo inferiore glabro cum calcare albo-rubro sacculato valde differt.

TYPE— MADAGASCAR. Antsiranana, Marojejy National Park, path from Mandena to the summit of Marojejy, collections around camp 3, ridge-top forest, 14°26'13"S 49°44'37"E, 29 November–3 October 1994, Lewis, Rasoavimbahoaka & Rastefanononirina 1169 (holotype TAN!, isotype MO!).

Suffrutescent herb, 300–600 mm tall, with dense scale-like hairs on stem, petiole, lower surface of leaves and pedicel. Stem succulent, woody at base, densely tomentose with scale-like hairs. Leaves alternate, petiole 8–11 mm long, sometimes with 1 pair of extrafloral nectaries at base of lamina, lamina succulent-coriaceous, rigid, pale green below, dark green above, ovate-lanceolate, acuminate at base and obtuse at apex, widest at apex, 45–80 (100) × 20–31 (50) mm, margin with 7 or 8 pairs of fimbriae, petiole and lower surface of lamina with dense scale-like hairs. Inflorescence axillary, bracts 2 × 1 mm, pedicel up to 50–60 mm long, peduncle less than 1 mm long. Flowers with entirely winered to purple dorsal petal, lateral sepals wine-red, lower sepal and spur red becoming whitish red towards apex, lateral united petals vivid red, glabrous. Lateral sepals broadly ovate, acuminate, 5–5.5 × 3 mm. Lower sepal navicular, 23–26 × 12 mm, 5–7 mm diameter at middle, gradually tapering towards curved whitish red obtuse saccate spur 6–7 × 1.5 mm. Dorsal petal cucullate, 11 × 7.5–8 mm, dorsal crest 2.5 mm high, with spur-like apiculum 1 mm long. Lateral united petals 18–19 mm long, upper petal 4 × 5 mm, obtuse, lower petal 10 × 12–13 mm, distinctly bilobed at apex. Anthers 6 mm long. Ovary 4–5 × 2.5 mm. Fruit not known.

HABITAT— Upper montane forest to ericaceous zone, 1000–1850 m.

DISTRIBUTION— Madagascar, Mt. Marojejy, only known from type locality (Fig. 3).

CONSERVATION STATUS— *Impatiens hendrikii* is restricted to Mt. Marojejy National Park. Despite the occurrence in a protected area the species should be considered as vulnerable.

Chapter 10 — New taxa from Madagascar VII

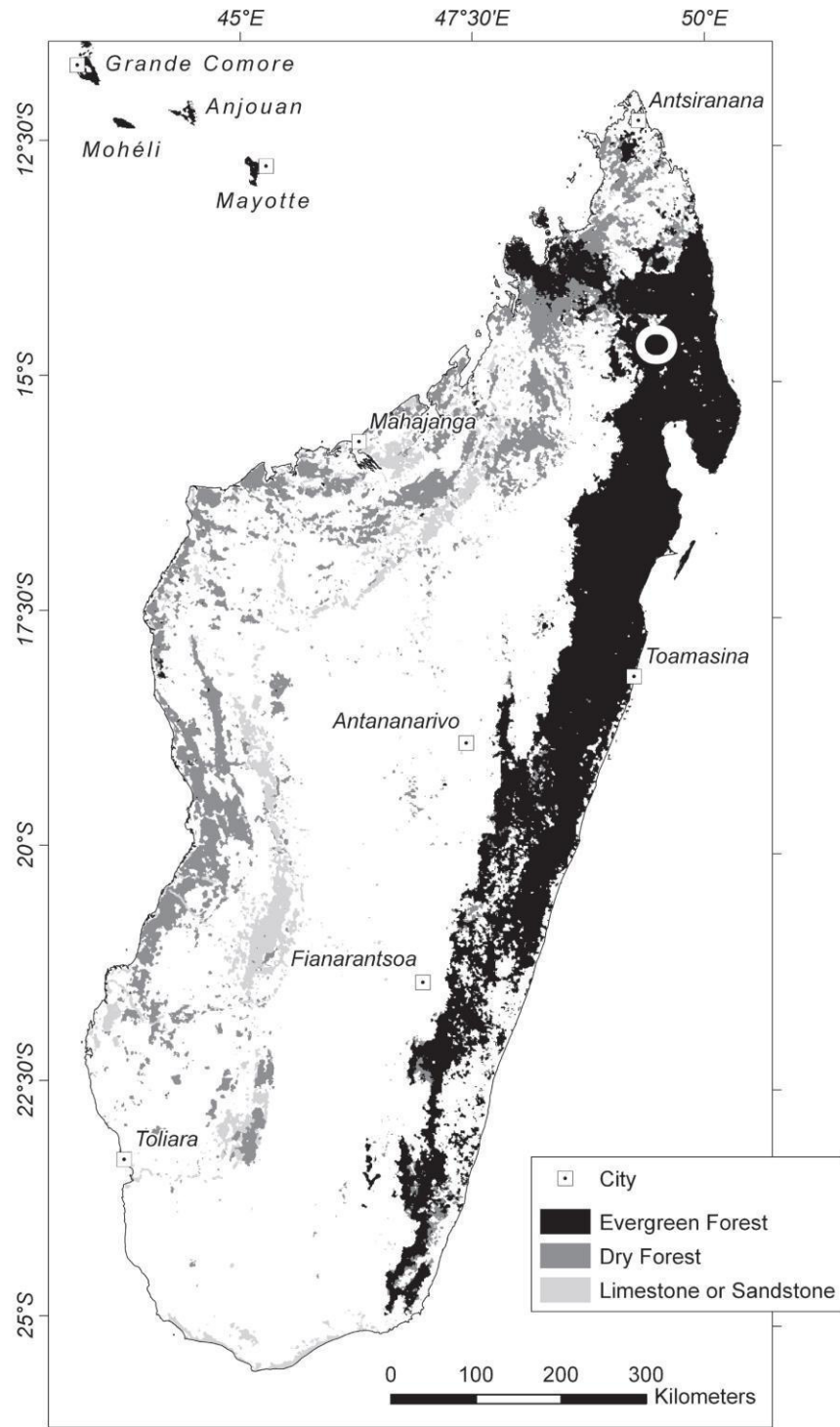


FIGURE 3. Map of Madagascar showing cover of rain forest (black). The location of Mt. Marojejy is indicated by a circle.

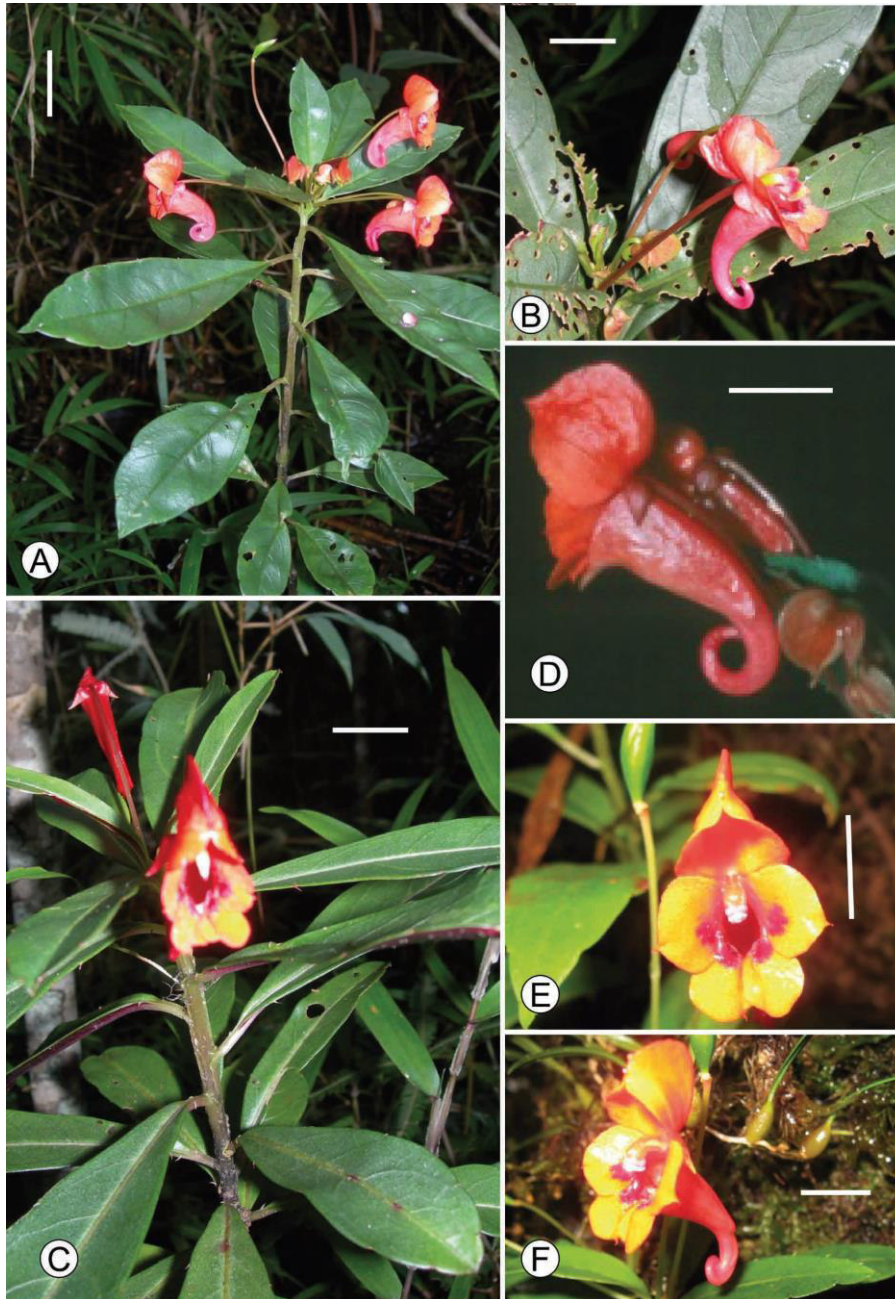


FIGURE 4. *Impatiens humblotiana*. **A, C**, habit. **B, D–F**, flower. A–C. Scale bar A: 2 cm, B–F: 1 cm. Photographs: P. Cribb, Andasibe (A–C), F. Almeda, Andasibe (d), Razanatsima, Alaotra (E–F).

PHENOLOGY— Flowers have been recorded in October and November.

EPONYMY— Dedicated by Mr. Karsten Lutz to his godson, Hendrik Sander.

ADDITIONAL COLLECTION (PARATYPE)— MADAGASCAR. Antsiranana, Marojejy National Park, path from Mandena to the summit of Marojejy, above Camp 3, 1644 m, 14°26'29''S 49°44'18''E, 21 October 2014, Fischer, Andriamiarisoa, Sérusiaux, Goffinet & Ertz 209a (TAN!, KOBL!).

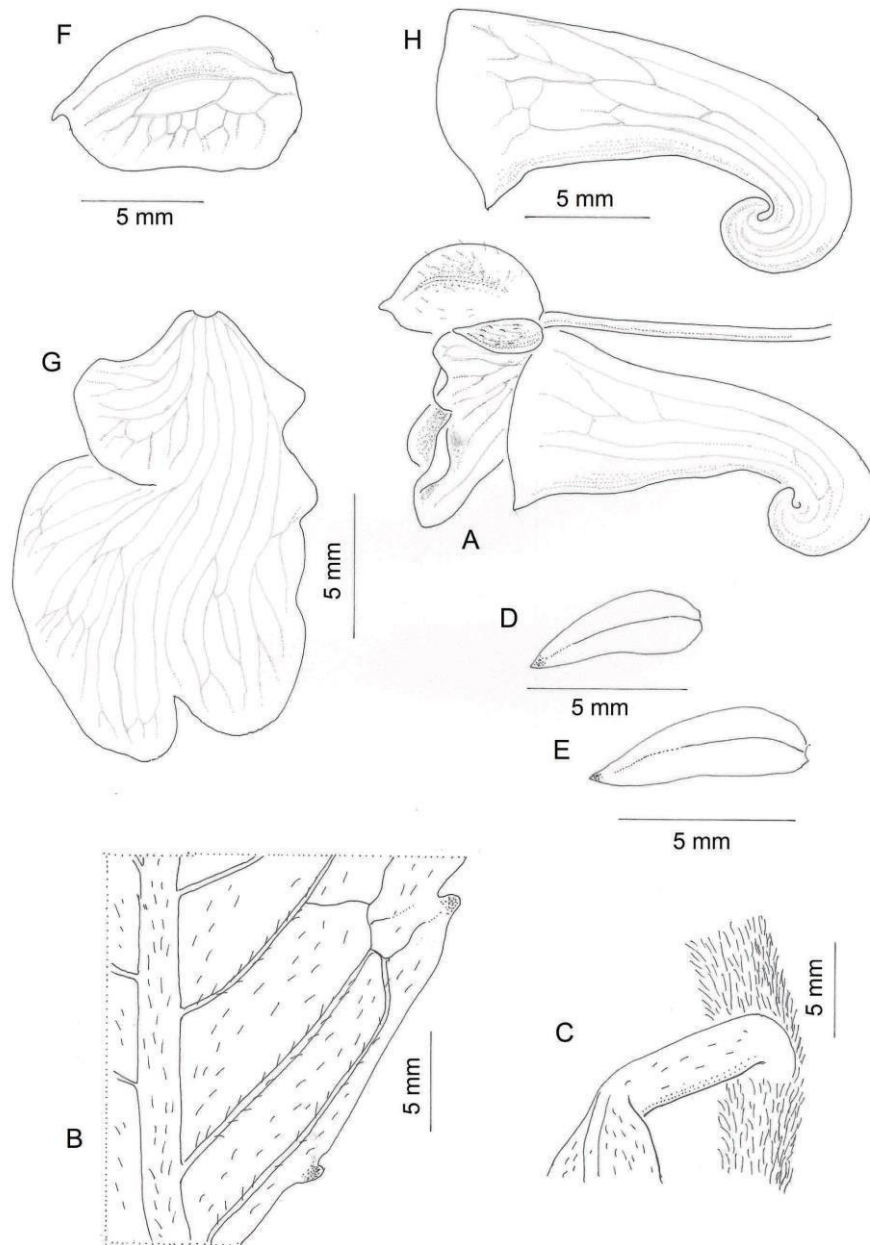


FIGURE 5. *Impatiens hendrikii*. **A**, flower, **B**, detail of leaf lamina, **C**, detail of stem with petiole, **D**, **E**, lateral sepal, **F**, dorsal petal, **G**, lateral united petals, **H**, lower sepal with spur. All drawn from the type, Lewis, Rasoavimbahoaka & Rastefanononirina 1169. Artist: E. Fischer.

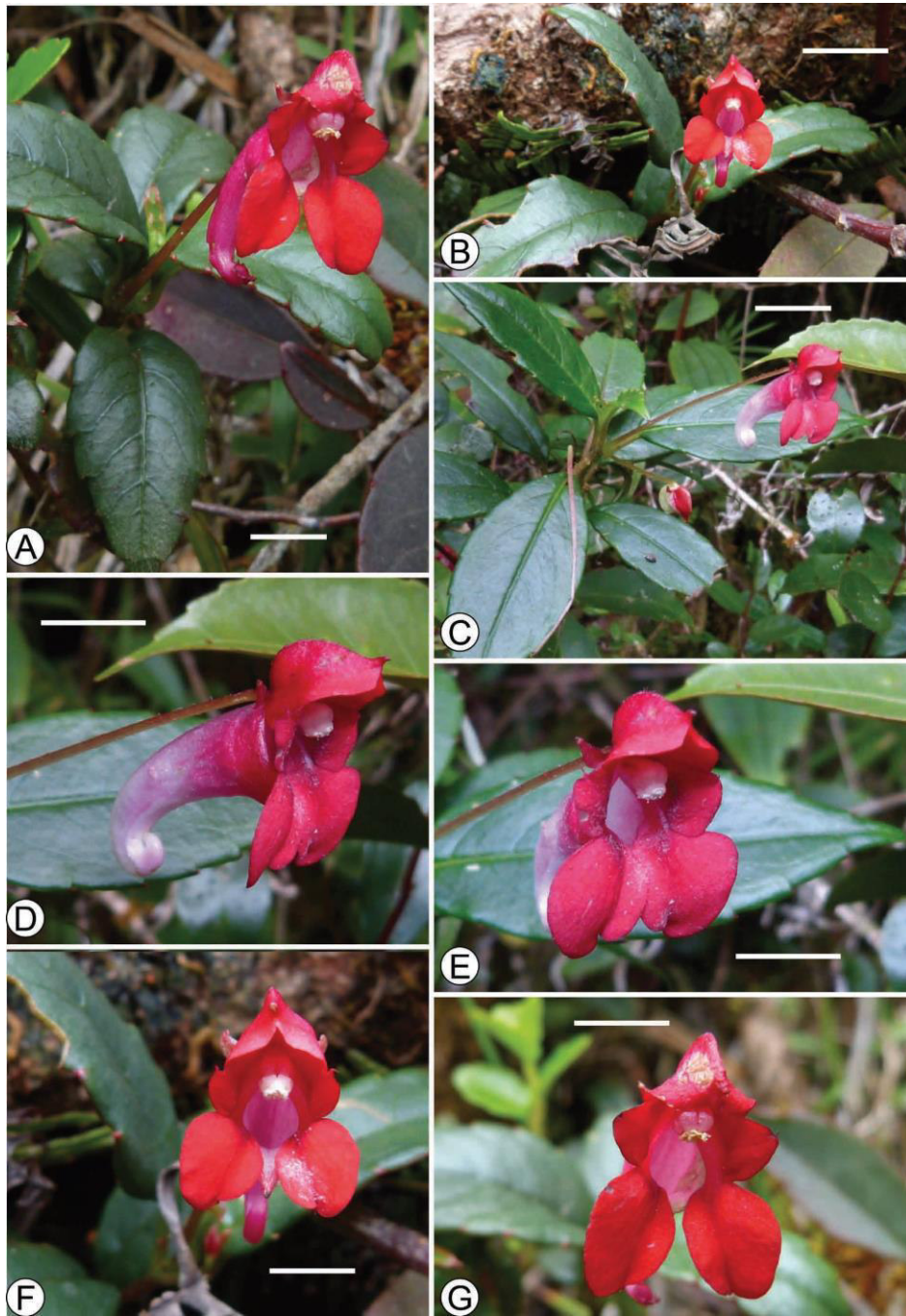


FIGURE 6. *Impatiens hendrikii*. A–C, habit. D–G, flower. A–G.. Scale bar A, D–G: 1 cm, B–C: 2 cm. Photographs: E. Fischer, Marojejy.

NOTES— *Impatiens hendrikii* is related to *I. fuchsioides*, but differs in the straight stem (vs. zig-zag-like in *I. fuchsioides*), the larger leaves, 45–80(–100) × 20–31(–50) mm (vs. 34–40 × 8–20 mm), the broader lateral sepals, 5–5.5 × 3 mm (vs. 4 × 1.5 mm), the broader lateral united petals with different shape (18–19 mm long, upper petal 4 × 5 mm, obtuse, lower petal 10 × 12–13 mm, distinctly bilobed at apex vs. 9–10 mm long,

upper petal 5 × 3 mm, lower petal 4 × 3 mm, not bilobed at apex), and the glabrous lower sepal gradually tapering into a short saccate whitish red spur (vs. densely hairy lower sepal abruptly tapering into a longer orange-red spur). *Impatiens fuchsioides* is only known from the zone of ericaceous shrub on Mt. Tsaratanana. *Impatiens hendrikii* is restricted to montane forest and ericaceous shrub on Mt. Marojejy. It occurs sympatrically with *I. renae* and *I. susan-nathansoniae* between 1000 and 1545 m. Above 1545 m it becomes more abundant and is observed up to the border of the ericaceous zone at 1850 m, which forms the forest line, where it is the only representative of the *I. humblotiana*-group. Provisional molecular evidence (unpublished data) suggests that *Impatiens susan-nathansoniae* and *I. hendrikii* are not closely related.

Acknowledgements

We thank the Directors of the following herbaria for the loan of specimens: BR, G, K, MO, NEU and TAN. We are indebted to the Missouri Botanical Garden, the Parc Botanique Zoologique Tsimbazaza and the Agence Nationale pour la Gestion des Aires Protégées (ANGAP) for research and collection permissions. The Akademie der Wissenschaften und Literatur Mainz kindly sponsored the field trip of the first author. Special thanks go to our colleagues Damien Ertz (Meise), Bernard Goffinet (Connecticut), Roger Lala Andriamiarisoa (Antananarivo) and Emmanuël Sérusiaux (Liège) who accompanied us in the field. Without the skills of Roger Lala Andriamiarisoa, the fieldwork would not have been possible.

Chapter 11

New taxa of *Impatiens* (Balsaminaceae) from Madagascar VIII. *Impatiens max-huberi*, a new species from from Marojejy and Anjanaharibe-Sud.

This chapter has been published as:

Fischer, E.¹ & Rahelivololona, M.E.² (2016): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VIII. *Impatiens max-huberi*, a new species from from Marojejy and Anjanaharibe-Sud. *Phytotaxa* 244: 191-195.

¹ Institut für Integrierte Naturwissenschaften – Biologie, Universität Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany. efischer@uni-koblenz.de

² Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo, République de Madagascar.

Abstract

The new species *Impatiens max-huberi* is described from Mt. Marojejy. It resembles *Impatiens sambiranensis* from North-western Madagascar in the large pink-purple flowers with long spur, but differs in the alternate leaves and the curved spur.

Key words: taxonomy, endemism, Madagascar, Marojejy National Park

Introduction

The genus *Impatiens* Linnaeus (1753: 937) in Madagascar represent the most species-rich genus of plants, followed by *Diospyros* Linnaeus (1753: 1057) with nearly 250 species (P. Lowry personal communication) and *Bulbophyllum* Petit-Thouars (1822: tab. 3) with 203 species (Tropicos.org.Missouri Botanical Garden 10 Jun 2015). During

the revision of Balsaminaceae (Fischer & Rahelivololona 2000, 2004, 2007a, b, 2015, Fischer *et al.* 2003) it became apparent that we are far from a satisfactory knowledge of the diversity of *Impatiens* in Madagascar.

Perrier de la Bâthie (1934, 1948) and Humbert (1956) reported 105 species of *Impatiens* from Madagascar. However, while studying collections from P, TAN, MO, NEU and G numerous previously undescribed taxa were detected, raising the total number of species to more than 260. In this paper we describe a peculiar species from Mt. Marojejy where 47 species of *Impatiens* have been recorded.

The present study is based on the investigation of living and dried specimens. The type of *Impatiens max-huberi* was collected during an expedition to Marojejy National Park in October 2014. Herbarium specimens from the type locality and the adjacent Anjanaharibe Sud reserve were used to assess the variability of the new taxon. The type specimen of *Impatiens sambiranensis* H.Perrier (1934: 46; MADAGASCAR: base du massif de Manongarivo, versant du Sambirano, vers 500 m, *Perrier de la Bâthie 5811*, P holo!) and two further collections from the same area (Maromandia, 9 November 1922, *Decary 1264*, P!; Antsiranana, Réserve Spéciale de Manongarivo, à l'est d'Ankaramibe, Anatrotra, 100 m d'altitude au dessous du campement, 14°05'S 48°24'E, 12 January 1994, *Rakotomalala & Narison 126*, TAN!, MO!) were studied.

***Impatiens max-huberi* Eb.Fisch. & Rahelivololona, *sp. nov.* (Figs. 1, 2)**

Impatiens sambiranensis affinis sed foliis alternis, floribus rosei-purpureis sine maculis duo albis et calcare breviora incurvato valde differt.

TYPE— MADAGASCAR. Antsiranana, Marojejy National Park, path from Mandena to the summit of Marojejy, above Camp III, 1540 m, 14°26'23''S 49°44'28''E, 20 October 2014, *E. Fischer, Roger Lala, E. Sérusiaux, B. Goffinet & D. Ertz 221a* (holotype TAN!, isotype KOBL!).

Perennial herb, erect, glabrous. Stems succulent, green, up to 80–100 cm tall. Leaves alternate, dark green, shining, velvet-like above, purplish below, petiole 13–22 mm long, without extrafloral nectaries, lamina lanceolate-ovate to oblong-elliptic, widest in

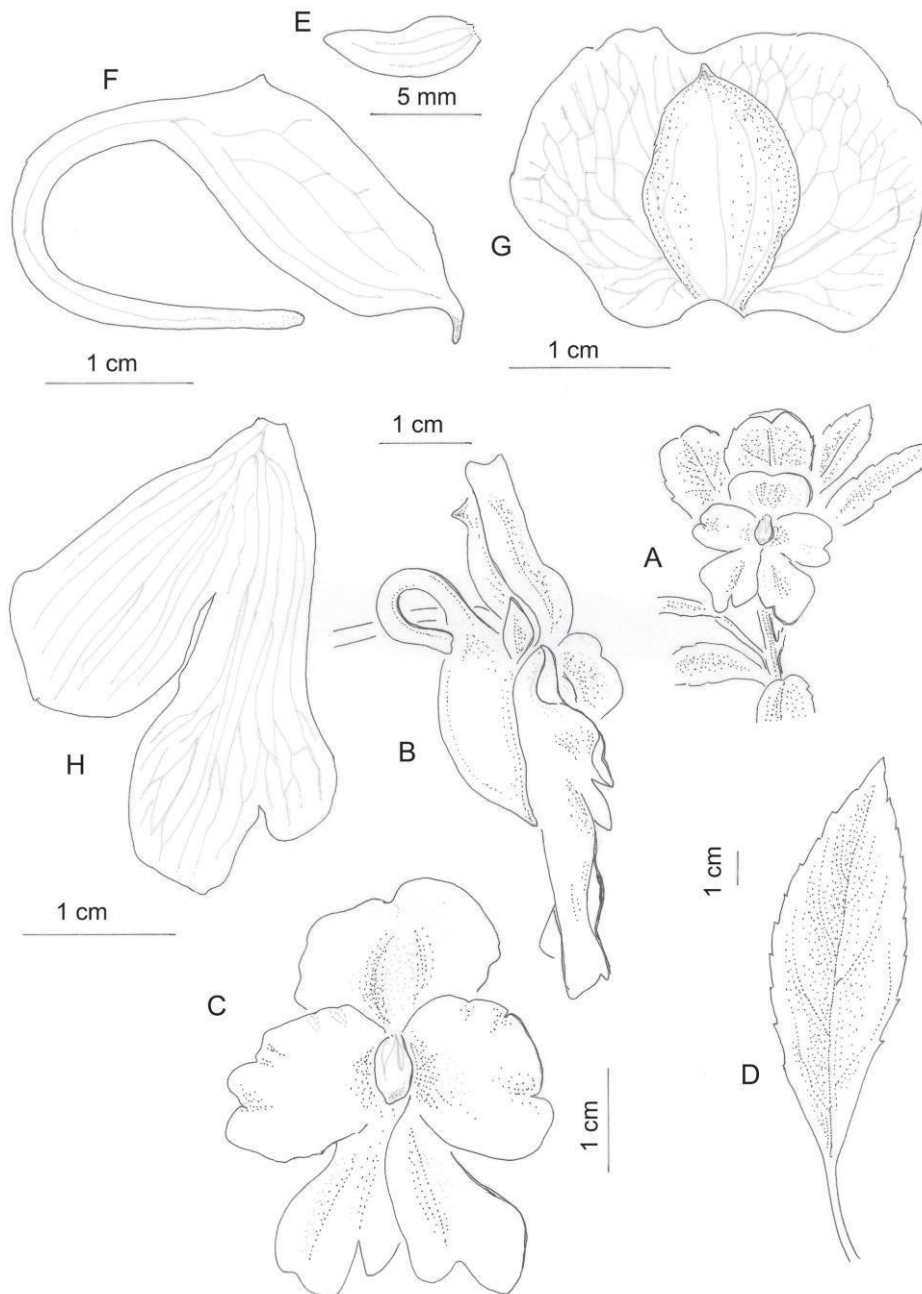


FIGURE 1. *Impatiens max-huberi*. **A**, habit, **B**, flower, lateral view, **C**, flower, frontal view, **D**, leaf, **E**, lateral sepal, **F**, lower sepal and spur, **G**, dorsal petal, **H**, lateral united petals. All drawn from *Fischer et al.* 221a by E. Fischer.

upper third, base attenuate, apex acuminate, 6.5–7.6 × 2.1–2.6 cm, with 4–6 pairs of secondary veins, margin dentate, with (6–) 8–10 (–13) pairs of teeth with gland-tipped appendages. Inflorescence axillary, with (1–) 2–6 flowers. Peduncle 1 mm long. Bracts linear-lanceolate, 3–4 × 1 mm. Pedicels 5.2–6.5 cm long, reddish. Flowers pinkish-purple, dorsal petal with greenish crest and apicule, lateral sepals greenish. Lateral

sepals lanceolate, curved, spreading in bud, 6×1.5 mm. Lower sepal navicular, $17-19 \times 8-10$ mm, with apicule at base $1.5-2$ mm long, 14 mm in diameter. Spur curved, slender, $28-45$ mm long and 2 mm wide. Dorsal petal \pm cucullate, emarginate at apex, $24 \times 18-19$ mm, dorsal crest distinct, $14-15 \times 6-8$ mm, apicule at apex 1 mm long, not visible from ventral side, dorsal crest seen from ventral forming a depression. Lateral united petals $30-35$ mm long, upper petal deeply emarginated at apex, 22×12 mm, lower petal deeply bilobed at apex, 30×15 mm, lower lobe $8-15 \times 7$ mm. Anthers $3-5$ mm long. Ovary $6-7$ mm long. Fruit elongate, fusiform, 15 mm long.

HABITAT— Upper montane forest to ericaceous shrub, $1330-1850$ m.

DISTRIBUTION— Madagascar, Mt. Marojejy and adjacent Anjanaharibe-Sud (Fig. 3).

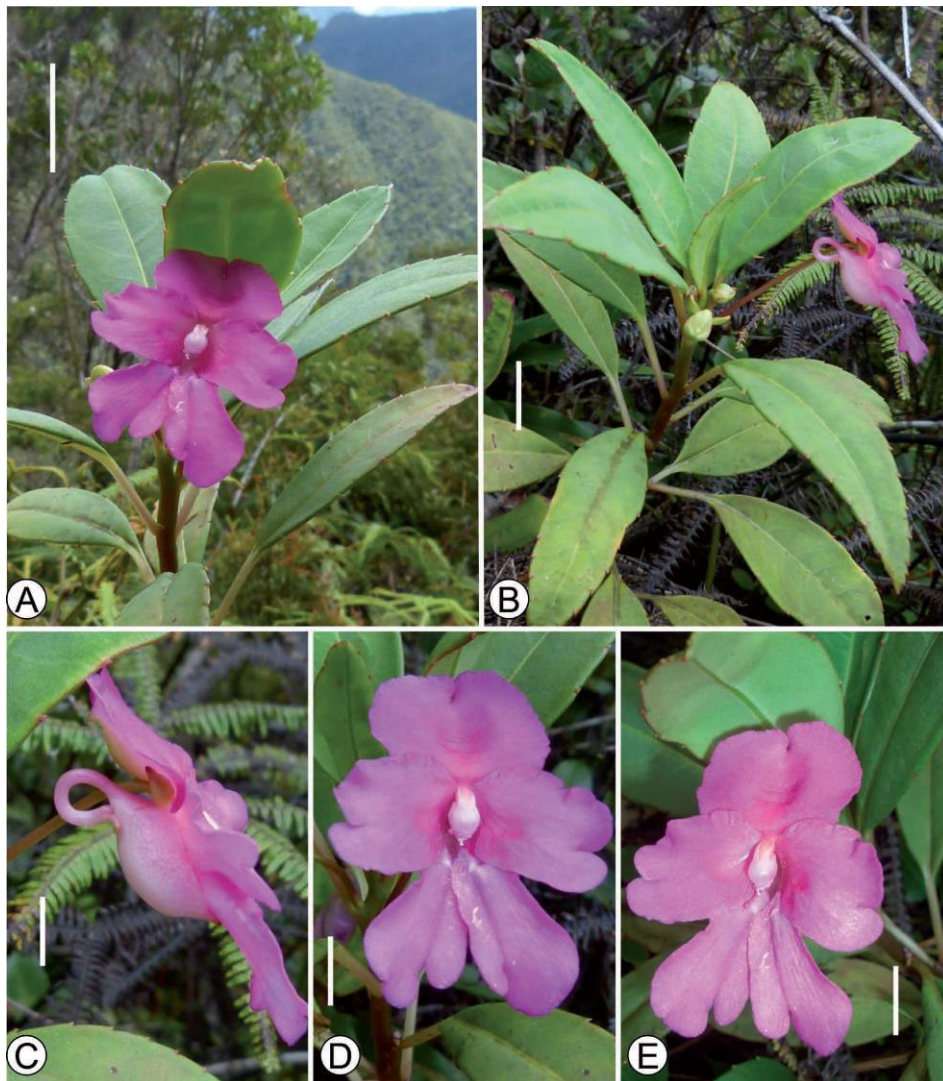


FIGURE 2. *Impatiens max-huberi*. A, B, habit with inflorescence. C, flower in lateral view. D–E, flower in frontal view. A–E photo. E. Fischer. Scale bar A–B: 2 cm, C–E: 1 cm.

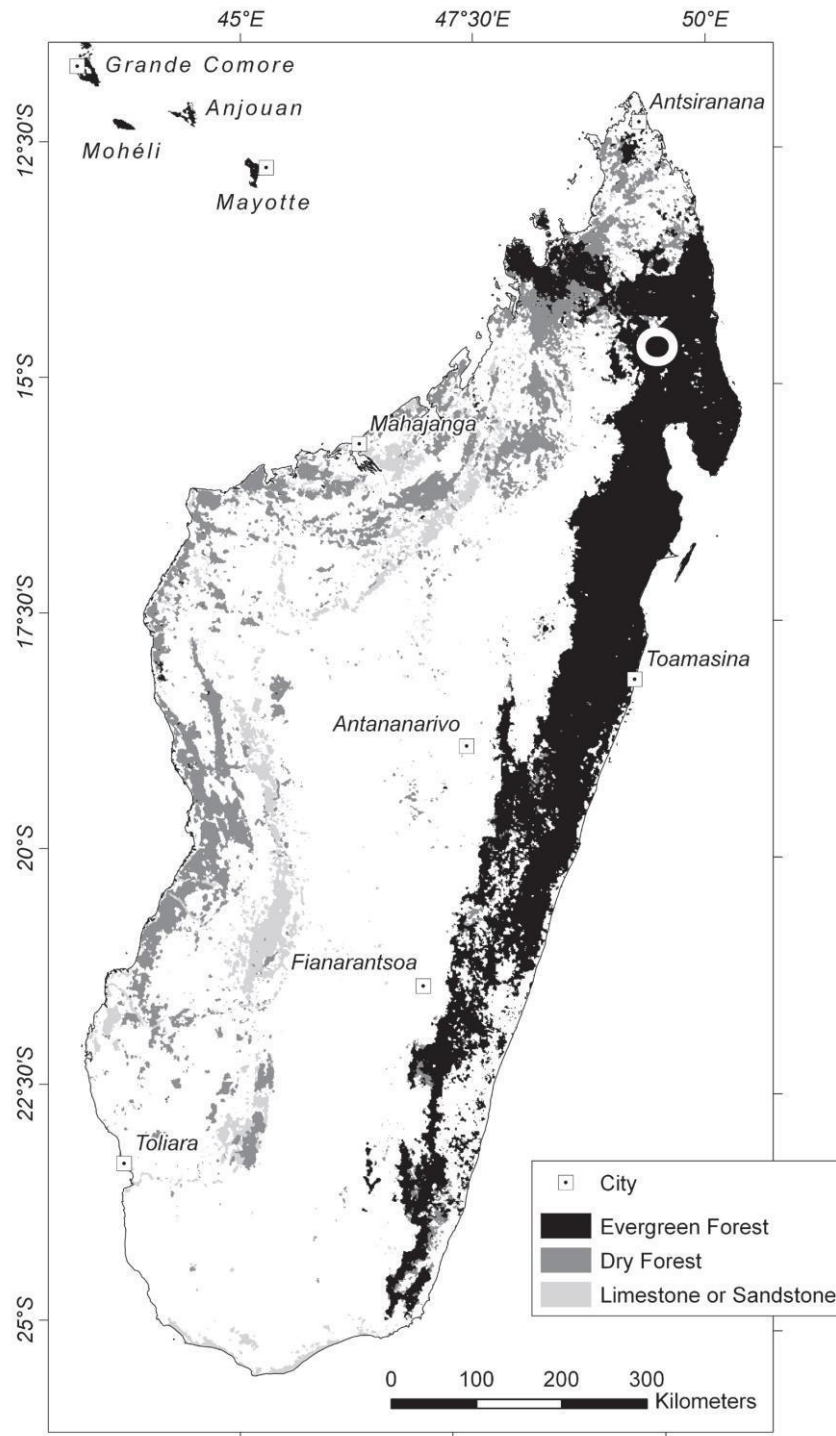


FIGURE 3. Distribution of *Impatiens max-huberi* in Madagascar (white circle).

ETYMOLOGY— Dedicated to Prof. Dr. Max Georg Huber, Professor of Theoretical Nuclear Physics, and Rector of the Rheinische Friedrich-Wilhelms-Universität Bonn from 1992 to 1997 for the generous support of taxonomic research and the Botanical Gardens.

ADDITIONAL SPECIMENS SEEN— MADAGASCAR.; Antsiranana, Marojejy Réserve Intégrale, 500–600 m above camp 3, montane lichens evergreen forest, 14°26'17"S 49°44'64"E, 1550 m, 28 November 1995, *Wohlhauser & Pfund 1046* (TAN!, NEU!); Antsiranana, Préfecture d'Antalaha, Sous-Préfecture d'Andapa, Commune rural de Bealampona, Sud-Ouest d'Andapa, Réserve Spéciale d'Anjanaharibe-Sud, village d'Andranotsarabe, suivant la route nationale Andapa—Bealanana de la piste vers l'ouest, Ambatomainty, camp 2, 14°44'42"S 49°27'42"E, 1185–1335 m, 3 November 1994, *Ravelonarivo & Rabesonina 522* (MO!, TAN!).

NOTES— *Impatiens max-huberi* is morphologically similar to *Impatiens sambiranensis* H.Perrier (1934: 46) which differs in the opposite to subverticillate leaves, the pink flowers with 2 white spots and the longer and almost straight to slightly curved spur (40–60 mm long). *Impatiens sambiranensis* is endemic to the Manongarivo Massif, where it grows in lowland rainforest up to 500 m, while *I. max-huberi* is found in the upper montane forest and the ericaceous shrub of Mt. Marojejy and the adjacent Anjanaharibe Massif.

CONSERVATION STATUS— *Impatiens max-huberi* has only been observed in Marojejy National Park and adjacent Anjanaharibe-Sud Special Reserve (Fig. 3). Both areas are protected but due to its restricted distribution area the species should be considered as endangered (EN).

Acknowledgements

We thank the Directors of the following herbaria for loan of specimens (acronyms according to Holmgren *et al.* 1990): BR, G, K, MO, NEU, TAN. We are indebted to the Missouri Botanical Garden, the Parc Botanique Zoologique Tsimbazaza and the Agence Nationale pour la Gestion des Aires Protégées (ANGAP) for research and collection permissions. The Akademie der Wissenschaften und Literatur Mainz kindly sponsored the field trip of the first author. Special thanks go to our colleagues Damien Ertz (Meise), Bernard Goffinet (Connecticut), Roger Lala Andriamiarisoa (Antananarivo) and Emmanuël Sérusiaux (Liège) who accompanied us in the field. Without the skills of Roger Lala Andriamiarisoa, the field work would have been impossible.

Chapter 12

New taxa of *Impatiens* (Balsaminaceae) from Madagascar IX. *Impatiens lutzii*, a new species from Montagne d'Ambre National Park.

This chapter has been published as:

Fischer, E.^{1*} & Rahelivololona, M. E.² (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar IX. *Impatiens lutzii*, a new species from Montagne d'Ambre National Park. *Phytotaxa* 239: 183-189.

¹ Institut für Integrierte Naturwissenschaften – Biologie, Universität Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany.

² Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo, République de Madagascar.

*Author for correspondence. E-mail: efischer@uni-koblenz.de

Abstract

Impatiens lutzii, a new species of *Impatiens* subg. *Trimorphopetalum*, is described from Montagne d'Ambre, Madagascar. It is morphologically similar to *Impatiens luisae-echterae*, *I. callmanderi* and *I. silviana* from Masoala, and to *I. decaryana* from central Madagascar, but differs from these species in the shape and ornamentation of the lower sepal, as well as the shape of the dorsal petal and the lateral united petals. A comparative table to distinguish *I. lutzii* from similar species of *Impatiens* is provided.

Key words: endemism, flies, flora, forest, myophily, pollination, taxonomy, *Trimorphopetalum*

Introduction

Madagascar harbours an unusual group of *Impatiens* (Linnaeus 1753: 937), which is characterized by the navicular lower sepal lacking a spur. It was originally described as a genus of its own, *Trimorphopetalum* Baker (1887: 454), but subsequently included by other authors (e.g., Warburg 1897; Perrier de la Bâthie 1934; Fischer & Rahelivololona 2002) in *Impatiens*. A first phylogeny of *Impatiens* (Yuan *et al.* 2004) showed that the spurless members of *Impatiens* from Madagascar are monophyletic, and ongoing molecular analyses (unpublished data) support this view. *Impatiens dorstenioides* (Baker 1887: 454) Warburg (1895: 391) was for a long time the only known species of this group until Perrier de la Bâthie (1934, 1948) published his revision of *Impatiens* and added 45 new species. During our revision of Balsaminaceae for the “Flore de Madagascar et des Comores” (Fischer & Rahelivololona 2000, 2004, 2007a, b; Fischer *et al.* 2003), several further taxa were described, and *Trimorphopetalum* was recognized as a subgenus (Fischer & Rahelivololona 2002).

In this paper we describe a peculiar new species of *Impatiens* subg. *Trimorphopetalum* from Montagne d’Ambre National Park. This part of Madagascar is covered by lowland to montane rainforest and harbours nine species of *Impatiens*, most of which are largely restricted to this area. The present study is based on the investigation of living and dried specimens. For the new species, *Impatiens lutzii*, three different collections have been available. A short history of the exploration of *Impatiens* in Madagascar as well as details on terminology and measurements are provided by Fischer & Rahelivololona (2002). Herbarium acronyms follow Holmgren *et al.* 1990.

Impatiens lutzii Eb.Fisch. & Raheliv., *sp. nov.* (Figs. 1–3)

Impatienti luisae-echterae, I. callmanderi, I. silvianae et I. decaryanae affinis sed forma et ornamentatione sepali inferiori, forma petali dorsali et forma et innervatione petalorum lateralium valde differt.

TYPE— Madagascar. Antsiranana, Parc National Montagne d’Ambre, montane rainforest near Camp des Roussettes, 12°02’33.7”S 49°09’23.3”E, 8 October 2014, 1222 m, Fischer & Andriamiarisoa 128 (holotype TA N!; isotype KOBL!).

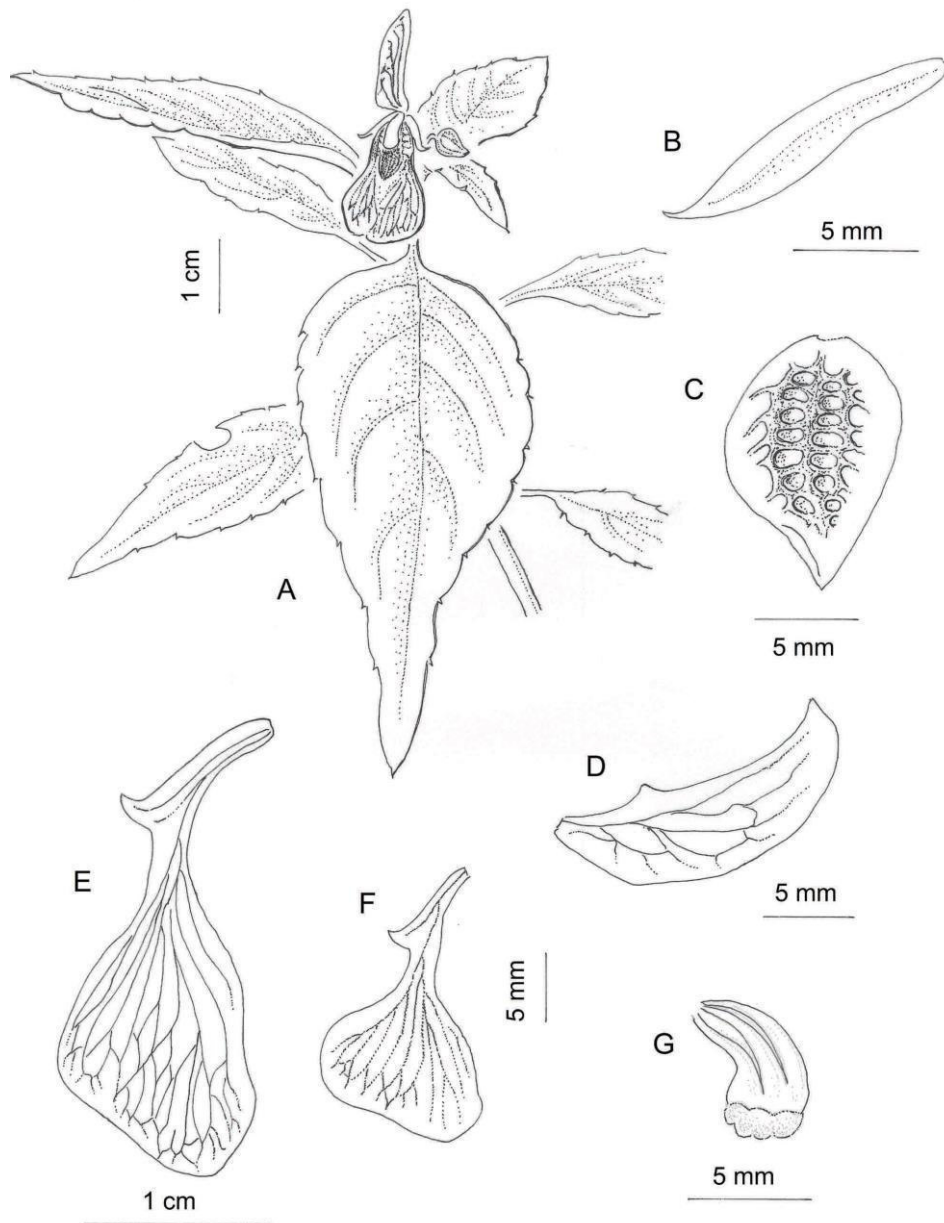


FIGURE 1. *Impatiens lutzii*. **A**, habit, **B**, lateral sepal, **C**, lower sepal, abaxial view, **D**, dorsal petal, **E–F**, lateral united petals, **G**, androecium. All drawn from the type, Fischer *et al.* 128. Artist: E. Fischer.

Erect herb, glabrous. Stems 150–350 mm tall. Leaves with petiole 18–20 mm long, lamina lanceolate to ovate, 50–80 × 24–28 mm, with acute apex, margin with 8–9 crenulations, each sinus with a filiform fimbria. Flowers yellow-green with dark purple venation, lower sepal almost entirely dark purple. Pedicels 30–40 mm long, glabrous. Lateral sepals two, 7–8 × (0.8–)1–1.2 mm, green. Lower sepal 13–15 × 8 mm, ovate with acute apex, nearly entirely dark purple, with 3 prominent veins, callus with central vein and net-like ornamentation with ca. 7 pits on each side. Dorsal petal helmet-like,

14–15 × 6 mm, transparent greenish yellow with purple venation, dorsal crest in lower third with a 1 mm long projection. Lateral united petals 28–30 mm long, upper petal greenish with purple veins, 7 × 1.5–2 mm, acute, lower petal 19–20 × 8–10 mm, rounded at apex, green-yellow with purple venation, sinus between upper and lower petal 1.5–2 mm wide. Anthers 5–6 mm long. Ovary 5 mm long. Fruit 10 × 5–5.5 mm.

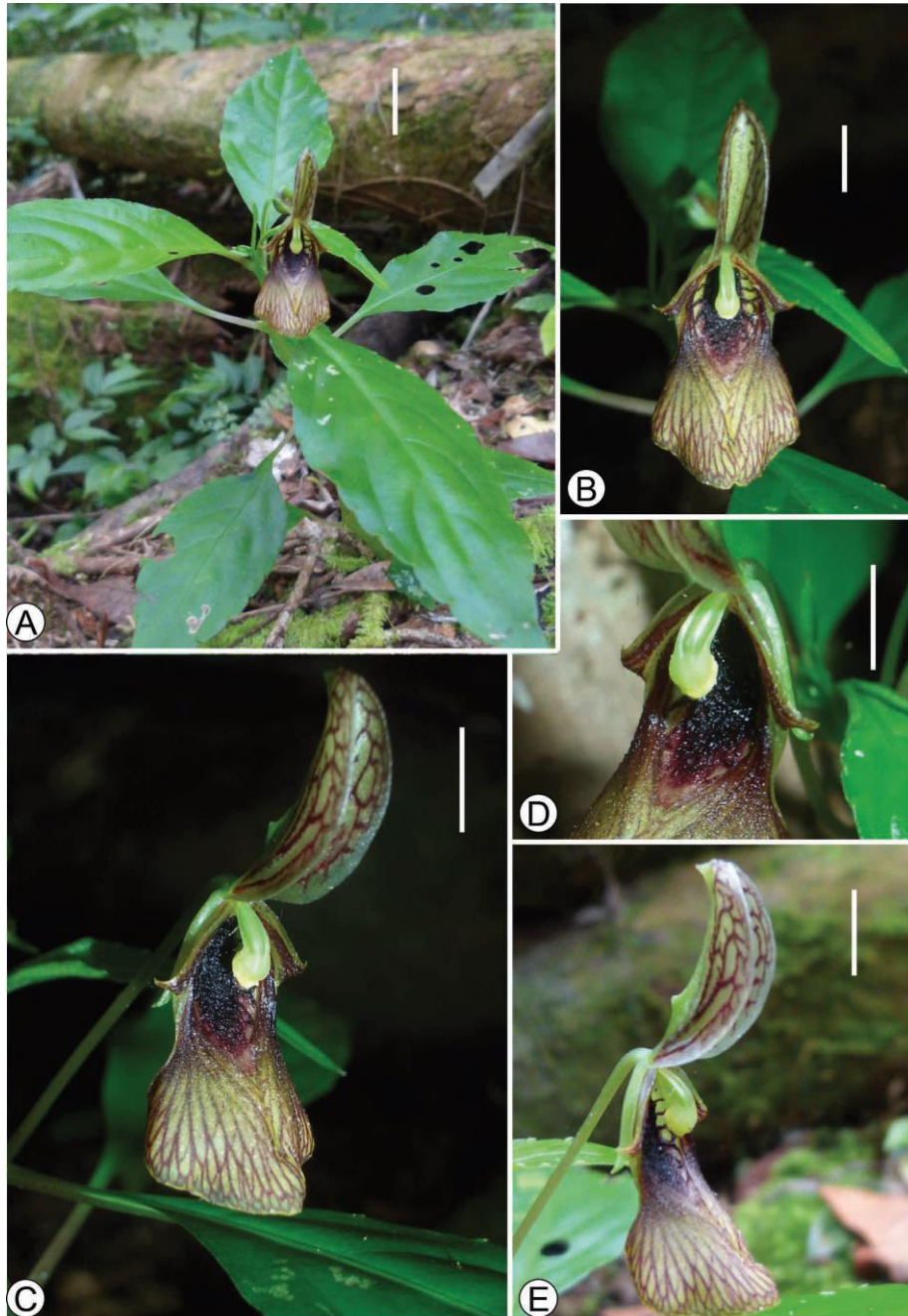


FIGURE 2. *Impatiens lutzii*. A, habit with inflorescence. B–C, E, flower, D, detail of flower with lateral sepals and androecium. Scale bar A: 20 mm, B–C, E: 10 mm, D: 5 mm. Photographs: E. Fischer, Montagne d' Ambre.

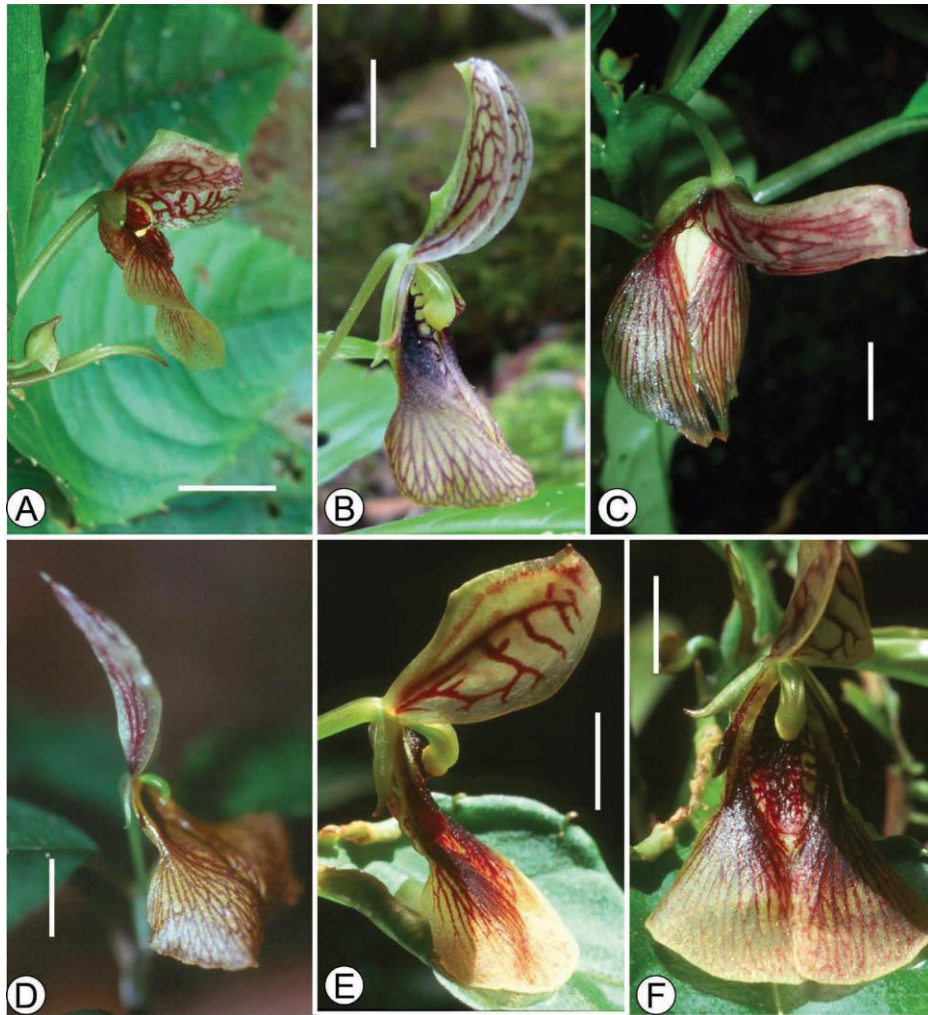


Figure 3. *Impatiens callmanderi*. **A**, flower. *I. lutzii*. **B**, flower. *I. silviana*. **C**, flower. *I. decaryana*. **D**, flower. *I. luisae-echterae*. **E–F**, flower. Scale bar A–F: 10 mm. Photographs: S. Wohlhauser, Masoala (A, E–F), E. Fischer (B–D).

HABITAT— Shadowed slope in montane moss evergreen rainforest, 932–1222 m a.s.l.

DISTRIBUTION— Madagascar, Montagne d’Ambre National Park, only known from the type locality (Fig. 4).

CONSERVATION STATUS— *Impatiens lutzii* has only been recorded from Montagne d’Ambre National Park. This area is protected but, due to its restricted range, the species should be considered as endangered.

EPONYMY— Dedicated to Dr. Reinhardt Lutz (born 1950), chancellor of the Rheinische Friedrich-Wilhelms-Universität Bonn, for his generous support of plant taxonomic research.

ADDITIONAL COLLECTIONS (PARATYPES)— Madagascar. Prov. de Diego-Suarez/Antsiranana, Montagne d'Ambre, versants ouest, 12°34'38"S 49°07'28"E, 20 January 2012, 932 m, *Randimbarison & Ramandimbiana 095* (TAN!; GI); environs de Diego-Suarez, forêt d'Ambre, 23 December 1959–18 January 1960, *Humbert 31991* (P!).

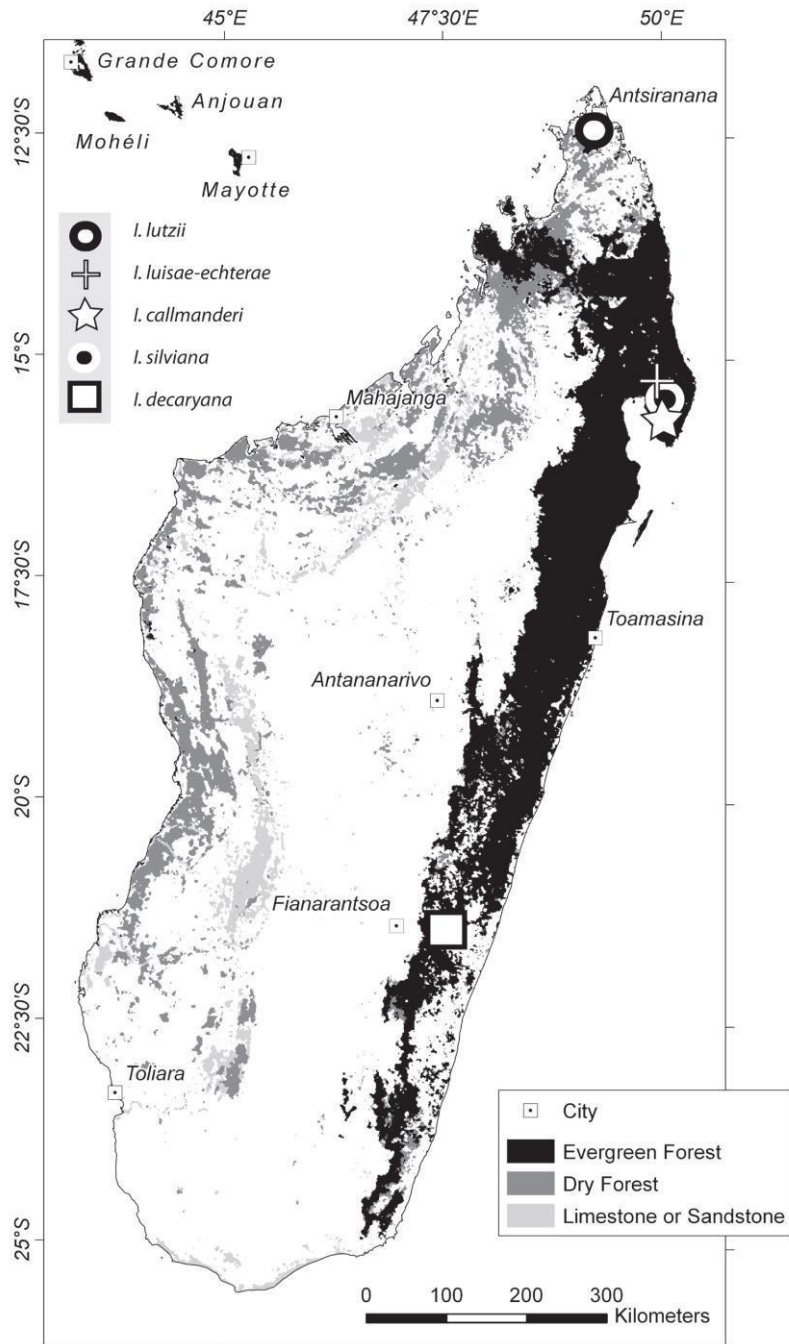


FIGURE 4. Map of Madagascar showing the known distribution of *Impatiens lutzii*, *I. luisae-echterae*, *I. callmanderi*, *I. silviana* and *I. decaryana*.

TABLE 1. Comparison of *Impatiens lutzii*, *I. luisae-echterae*, *I. callmanderi*, *I. silviana* and *I. decaryana*.

	<i>Impatiens lutzii</i>	<i>I. luisae-echterae</i>	<i>I. callmanderi</i>	<i>I. silviana</i>	<i>I. decaryana</i>
Leaf lamina	lanceolate-ovate, 50–80 × 24–28 mm	lanceolate-ovate, 75–110 × 28–40 mm	lanceolate-ovate, 110–130 × 40–50 mm	ovate-lanceolate, acuminate, 130-180 × 50-67 mm	oblong-lanceolate, 90–140 × 23–35 mm
Lateral sepals	linear-lanceolate, straight, 7–8 × (0.8–)1–1.2 mm	linear-lanceolate, straight, 4 × 1 mm	lanceolate-ovate, 7 × 2 mm	6 × 2.5 mm, falcate	linear-lanceolate, 7 × 1.5 mm
Lower sepal	entirely dark purple, 13–15 × 8 mm	greenish yellow with red-purple venation, 15 × 9–10 mm	yellowish with blackish spots, 12 × 7–8 mm	pale yellowish, with darker yellowish median callus and veins, 15 × 6 mm	pale green-yellow with reddish veins and reddish callus at base
Ornamentation of Lower Sepal	3 prominent veins, callus with central vein and net-like ornamentation with ca. 7 pits on each side	net-like ornamentation	veins with longitudinally arranged small pits	prominent median callus with riblike lateral veins	median to basal callus with anastomosing veins
Dorsal petal	14–15 × 6 mm, dorsal crest in lower third with 1 mm long projection	26 × 7–8 mm, dorsal crest in upper third with geniculation	15 × 10, crest in lower third with geniculation, apex with small recurved spur	17 × 6 mm, rounded projection just below spur like apex	17 × 4–5 mm, falcate with acuminate apex
Lateral petals length	28–30 mm	20 mm	19 mm	24 mm	15–20 mm
Upper petal	7 × 1.5–2 mm, apex acute	6–7 × 2 mm, apex acute	2 × 5 mm, apex obtuse	7 × 3 mm, curved, apex rounded	5–6 × 3–4 mm, dilated, triangular, apex acute
Lower petal	19–20 × 8–10 mm, rounded at apex	15 × 12 mm, rounded at apex	11–12 × 7–8 mm	17 × 10 mm, rounded at apex, small projection on inner margin	14–18 × 12–13 mm, rounded at apex
Distribution	Montagne d'Ambre	Masoala	Masoala	Masoala	Ikongo to Ifaniadina

NOTES— *Impatiens lutzii* belongs to the *Impatiens decaryana*-group and is similar to *I. luisae-echterae* Fischer *et al.* (2003: 24) (Fig. 3), *I. callmanderi* Fischer *et al.* (2003: 24) (Fig. 3) and *I. silviana* Fischer & Rahelivololona (2002: 279) (Fig. 3) from Masoala Peninsula, and to *I. decaryana* Perrier de la Bâthie (1934: 71) (Fig. 3) from Central Madagascar (Ikongo and Ifanadiana near Ranomafana, Fianarantsoa). However, it differs from these species in the shape of the dorsal petal, the ornamentation of the lower sepal and the shape and venation of the lateral united petals (Table 1). It also differs from *I. callmanderi* and *I. silviana* in the shape of the lateral sepals. The flowers of *Impatiens lutzii*, *I. luisae-echterae*, *I. callmanderi*, *I. silviana* and *I. decaryana* resemble each other and these species most probably share the same pollination syndrome, namely pollination by flies (myophily). The characters to distinguish among the species include the shape of the lateral sepals, the shape of the dorsal petal and the lateral united petals including the colour and pattern of venation, and the shape, ornamentation and colour of the lower sepal. Also, they are each restricted to a single small area and show a very narrow range (see Fig. 4), a feature that is typical for about 98% of the Madagascan members of *Impatiens*. Even *I. luisae-echterae*, *I. callmanderi* and *I. silviana*, which are restricted to the Masoala Peninsula, occur on different mountains or in valleys, and according to our observations are not growing sympatrically. Observations on living plants in the field, but also on herbarium specimens, show clear morphological discontinuities (see Fig. 3, Table 1), suggesting that we are not dealing with one variable species. Provisional molecular evidence (unpublished data) shows that these species are not closely related, except that they all belong to a large “*Trimorphopetalum*”-clade comprising all Madagascan spurless species of *Impatiens*. *Impatiens lutzii* is resolved in a clade together with an as yet undescribed species with very small greenish flowers (“*Impatiens elatostemoides*”-group) that is also endemic to the Montagne d’Ambre.

Acknowledgements

We thank the Directors of the following herbaria for the loan of specimens: BR, G, K, MO, NEU and TA N. We are indebted to the Missouri Botanical Garden, the Parc Botanique Zoologique Tsimbazaza and the Agence Nationale pour la Gestion des Aires Protégées (ANGAP) for research and collection permissions. The Akademie der Wissenschaften und Literatur Mainz kindly sponsored the field trip of the first author.

Chapter 12 — New taxa from Madagascar IX

Special thanks go to our colleagues Damien Ertz (Meise), Bernard Goffinet (Connecticut), Roger Lala Andriamiarisoa (Antanarivo) and Emmanuël Sérusiaux (Liège) who accompanied us in the field. Without the skills of Roger Lala Andriamiarisoa, the field work would not have been possible. We thank Sebastien Wohlhauser for kindly providing photographs of *Impatiens luisae-echterae* and *I. callmanderi*.

Chapter 13

***Impatiens galactica* (Balsaminaceae), a new spurless species of section *Trimorphopetalum* from Madagascar**

This chapter has been published as:

Fischer, E.,^{1*} Rahelivololona, M.E.² & Abrahamczyk, S.³ (2017): *Impatiens galactica* (Balsaminaceae), a new spurless species of section *Trimorphopetalum* from Madagascar. *Phytotaxa* 298 (3): 269-276.

¹Institute for Integrated Natural Sciences – Biology, University of Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany.

²Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo & Université de Mahajanga, République de Madagascar.

³Nees-Institute for Plant Biodiversity, University of Bonn, Meckenheimer Allee 170, 53115 Bonn, Germany.

*Author for correspondence. E-mail: efischer@uni-koblenz.de

Abstract

Impatiens galactica, a new species from lowland rainforest in Marojejy National Park, NE Madagascar, is described and illustrated. It belongs to *Impatiens* section *Trimorphopetalum* and is related to *I. messmerae*, also known from Mt. Marojejy. *Impatiens galactica* differs from the latter species in the shape of the lateral sepals, and in the dorsal petal and the lateral united petals being entirely glabrous and lacking small white scales. Furthermore, *I. galactica* has a distinct flower morphology with strongly reduced upper lobes of the lateral united petals. The lateral petals are thus resembling the lower case letter “b” or “d”, respectively. Additionally, it has unusually coloured yellowish white, semi-transparent flowers with an orange-yellow, shiny line

along the midrib of the lower sepal, all of which are lacking in *I. messmerae*.

Kew words: Balsaminaceae, *Impatiens galactica*, new spurless species, *Trimorphopetalum*, endemic, Marojejy, Madagascar, touch-me-not

Introduction

With more than 1000 species, *Impatiens* L. (Linnaeus 1753: 937) is one of the largest genera of the angiosperms (Janssens *et al.* 2009). A main centre of diversity for the group is the island of Madagascar, where more than 260 species are recognized (Abrahamczyk & Fischer 2015). Most of these species are narrow endemics and therefore have a high potential risk of extinction. Over the past about 15 years the number of *Impatiens* species known from Madagascar has drastically increased (Fischer & Rahelivololona 2002, 2004, 2007a, b, 2015a, b, c, 2016; Fischer *et al.* 2003). Especially the number of species in section *Trimorphopetalum* (Baker 1887: 454) Perrier de la Bâthie (1934: 64), representing now the largest section of Malagasy *Impatiens* species, has grown by about 46 species (Fischer & Rahelivololona 2007a, b, 2015a). Currently section *Trimorphopetalum* comprises 126 species and is characterized by relatively small, spurless flowers and the lack of extrafloral nectaries on the petioles (Fischer & Rahelivololona 2007a). All species of this section have a very unusual flower morphology and coloration. The flowers are often brownish or greenish and never white, pink or red. Additionally, several mainly cleistogamous species have been described (Perrier de la Bâthie 1934). Very little is known about the pollination ecology of these extraordinary species. In this paper we describe yet another new species in sect. *Trimorphopetalum*, thus bringing the total number of spurless species in Madagascar to 127.

Material and methods

We investigated living material in nature and in the Botanical Gardens Bonn, as well as dried specimen from the following herbaria: P, TAN, MO, G (acronyms after Holmgren *et al.* 1990). The standard terminology and measurement criteria for *Impatiens* were described in detail by Fischer & Rahelivololona (2002). For each morphological trait we measured ten representative objects using fresh material. After

critical point drying (CPD 020 Balzers Union), we studied the seeds using a scanning electron microscope (SEM, Cambridge S200).

Impatiens galactica Eb.Fisch., Raheliv. & Abrah. *sp. nov.* (Fig. 1, 2)

Impatiens messmerae affinis sed habitu minore glabro sine squamibus albis, sepalis lateralibus lanceolatis apice obtuse instructis, sepalo inferiore ovato apice abrupto et ornamentatione aurantiaco instructo, petalo dorsali triangulo dilatato submediano et petalis lateralibus sub formam litterae minore “d” cum parte superiore angusto et petalo superiore angusto apice brevissime instructo valde differt.

TYPE— MADAGASCAR. Antsiranana, Parc National Marojejy, small stream near Cascade d’Humbert, S 14°25’58.3” E 49°46’22.7”, *E. Fischer* 22, 18 October 2014 (holotype TAN!; isotypes P!, B!, MO!, BONNI!).

Decumbent to slightly ascending, perennial herb, up to 35 cm high. *Stems* reddish brown, succulent, branching and rooting at lower nodes. Plant entirely glabrous. *Leaves* alternate, spirally arranged, deep green above, pale green below; petioles reddish brown, 7–15 mm and continuously growing. Lamina 35–81 mm × 20–40 mm, leathery, elliptic to lanceolate, apex acute, base shortly attenuate; lateral veins (3)4 or 5 pairs; margin crenate; extrafloral nectaries 1–1.5 mm long, linear, 9 or 10 pairs, at the lamina margin between each pair of teeth, half erect, prominent especially at young leaves. *Inflorescence* 1- or 2-flowered. Flowers yellowish white, semi-transparent, with an orange-yellow, shiny, 2 mm wide line along the midrib of the lower sepal and a greenish crest on the dorsal petal. *Pedicels* 30–43 mm long, slender. *Lateral sepals* 2, 4–5(–6) mm × 1–1.5 mm, lanceolate, acute. *Lower sepal* (12–)14–16 mm × (6–)7–8 mm ovate-lanceolate, shallow naviculate, spurless, tapering to a 1–2 mm long tip. *Dorsal petal* 14–16 × (6–)7–8 mm, helmet-like, dorsally conspicuously crested, dilated to a triangle below the middle of the crest, tapering to a 1 long mm tip. *Lateral united petals* (18–)20–21(–23) mm long, with petals different in size and shape, connivent at the outer tip; upper petal (6–)7–8 mm × 2(–2.5) mm, rectangular; lower petal (18–)20–21(–23) mm × (8–)9–11 mm, shaped as the lower case letters “b” and “d”. *Anthers* 5.5–7 mm long. *Ovary* 5–6 mm long, curved downwards, grooved, glabrous. *Fruit* 18–24

mm × 5–6 mm, irregularly fusiform, grooved, glabrous, with 3–10 seeds. Seeds 2–3 mm × (1.0–) 1.5–2 mm, roundish-ovate, with trichomes, sticky when fresh (Fig. 3).

HABITAT— Lower rainforest belt, growing on granitic rocks along a small stream in dense lowland rainforest, 489 m (Fig. 4). On Mt. Marojejy this vegetation type is found below 800 m (Humbert 1955).

DISTRIBUTION— Madagascar, Marojejy National Park, small stream near Cascade d’Humbert (Fig. 5), only known from the type collection.

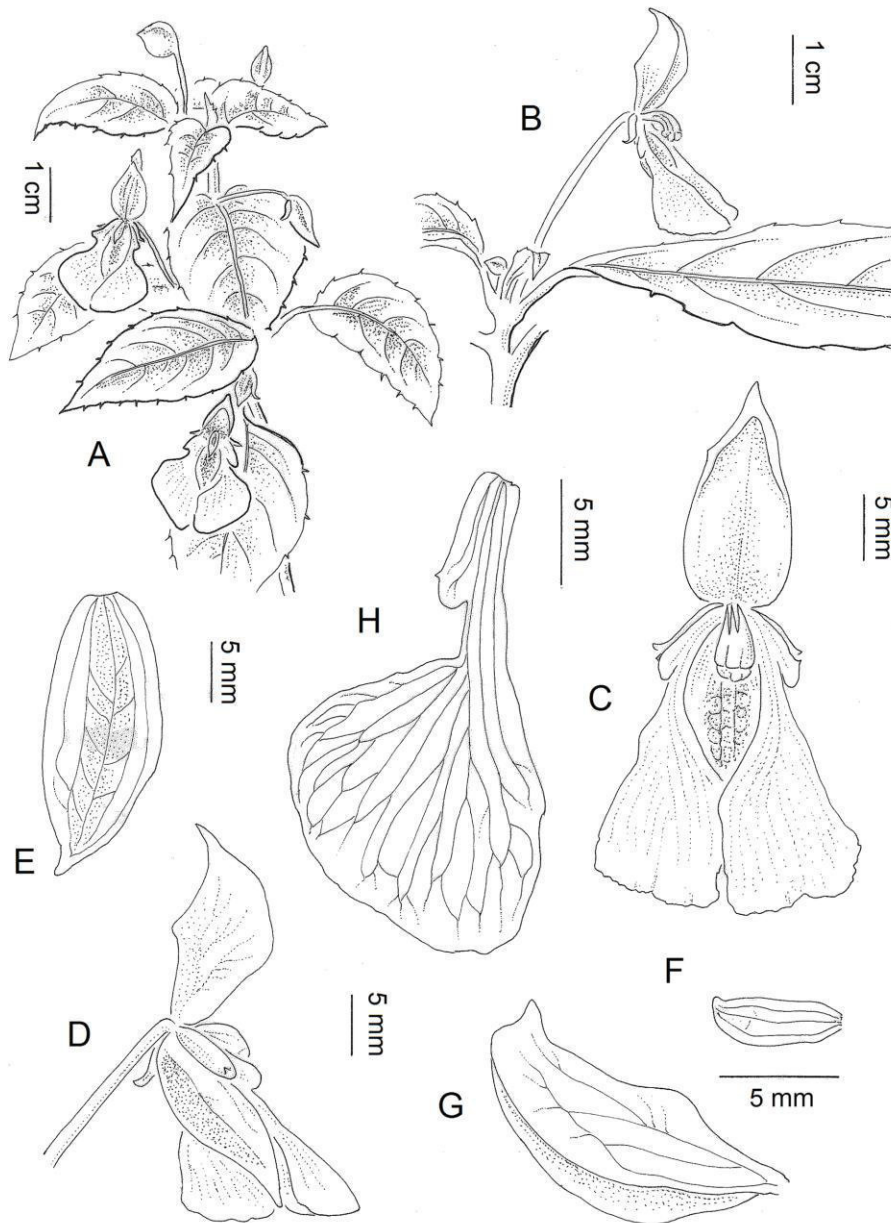


FIGURE 1. *Impatiens galactica*. **A, B**, habit; **C**, flower in abaxial view; **D**, flower in adaxial view; **E**, lower sepal; **F**, lateral sepal; **G**, dorsal petal; **H**, lateral united petals. All drawn from the type by E. Fischer.

PHENOLOGY— Collected in flower at the type locality in October. In cultivation at the Botanical Gardens of the University of Bonn, flowers have been noted almost every month.

ETYMOLOGY— From the Greek γαλαξίας (galaxias = the milky one), referring to the “milky look” of the yellowish white, semi-transparent flowers.

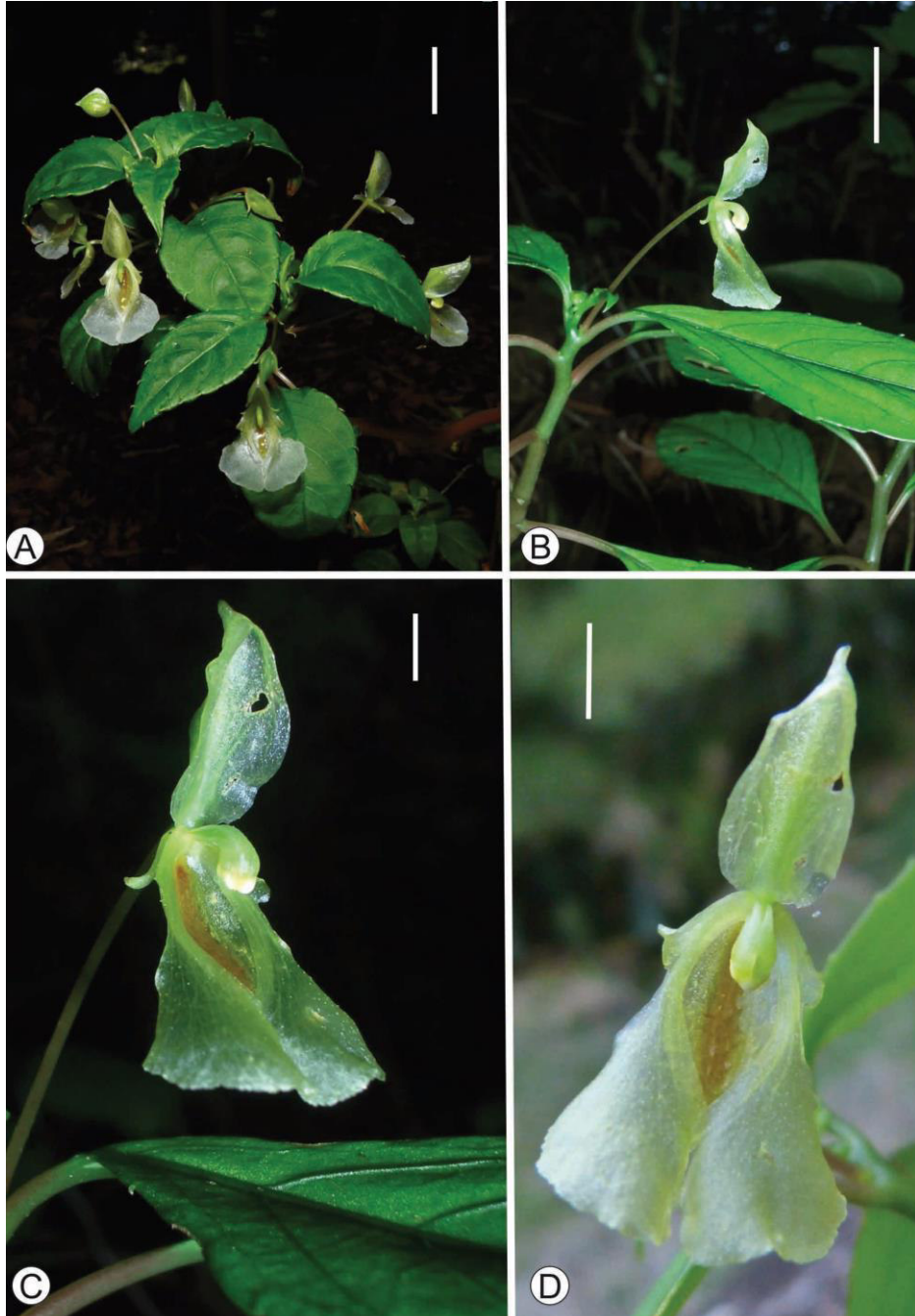


FIGURE 2. *Impatiens galactica*. **A**, habit; **B**, habit with inflorescence; **C & D**, flower. Photographs: S. Abrahamczyk (A), cultivated in Botanical Gardens University of Bonn; E. Fischer (B-D), Marojejy National Park, Madagascar. Scale bar = 2 cm (A & B), 5 mm (C & D).

CONSERVATION STATUS— With only a single collecting site, it is not possible to calculate an Extent of Occurrence (EEO). The area of occupancy (AOO) covers 9 km² and falls within the limits for the Critically Endangered status under sub-criterion B2 of the IUCN (2001). The species is currently only known from the type locality which is within a well-managed protected area (Marojejy National Park) and is considered as safe. However, despite its restricted range, no immediate threats to the species are expected and there is no evidence for a continuing decline. Hence, *I. galactica* does not qualify for any threatened category, and is assessed as Least Concern (LC).

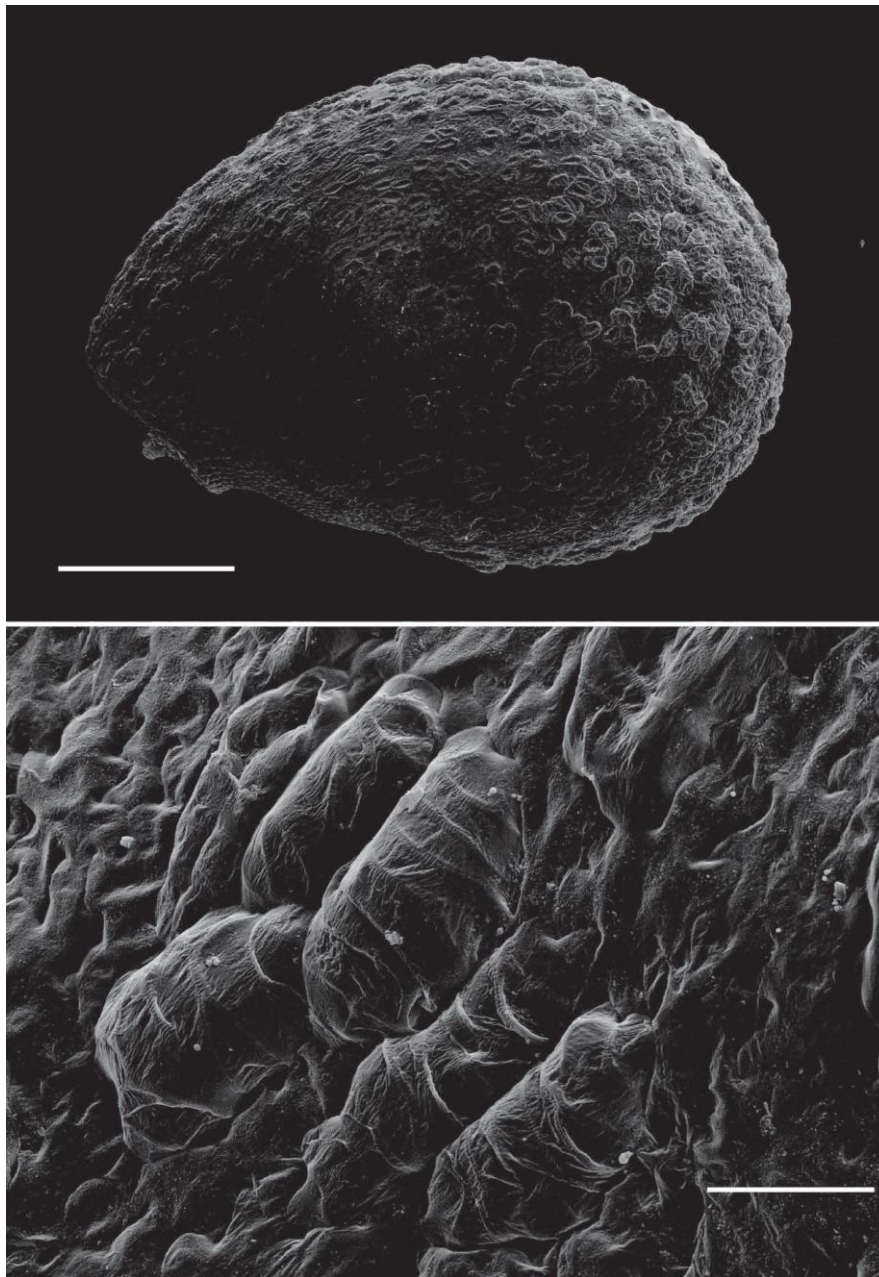


FIGURE 3. SEM micrograph of a seed of *Impatiens galactica* (A); note the flattened trichomes under a film of mucilage (B). Micrograph: H. Ensikat.



FIGURE 4. Habitat of *Impatiens galactica*, Marojejy National Park, Madagascar, Cascade Humbert. Photograph: E. Fischer.

NOTES— This new species of *Impatiens* is a member of section *Trimorphopetulum*, which is characterized by the lack of spurs in the flowers and extrafloral nectaries on the petioles (Fischer & Rahelivololona 2007a). It is probably closely related to the morphologically similar, but larger species, *I. messmerae* (Fischer & Rahelivololona 2007a: 296). The latter is also known from a similar habitat, a small stream on Mt. Marojejy but at higher elevation (750 m). However, *I. galactica* differs from *I. messmerae* in being a smaller plant (up to 35 cm vs. up to 60 cm high), being entirely

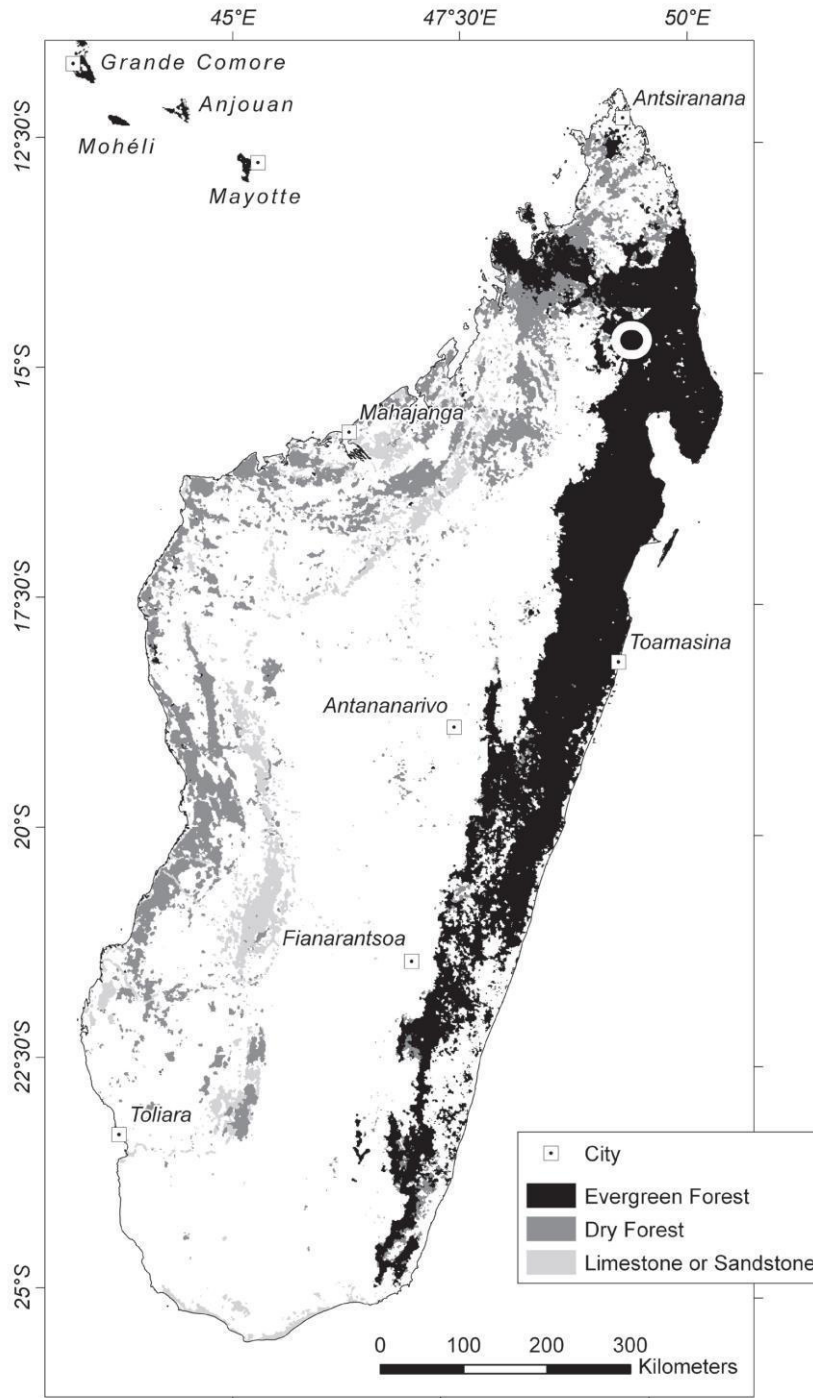


FIGURE 5. Known distribution of *Impatiens galactica* (black dot with white margin).

glabrous and lacking small white scales (vs. whitish scales present on stems and leaves). The lateral sepals in the new species are lanceolate with obtuse apex (vs. linear-filiform with acuminate apex), the lower sepal is ovate with a pronounced abruptly tapering short apex and a 2 mm wide orange line with slight ornamentation on midrib (vs. lanceolate and gradually tapering into an acuminate apex and completely

lacking any colour and ornamentation), the dorsal petal with dilated triangle placed slightly below middle towards base (vs. placed above middle towards apex in *I. messmerae*), and the lateral united petals shaped as the lower case letters “b” or “d”, which are very narrow in the upper part with upper petal narrow and bearing a very short tip (vs. upper petal much larger in comparison to lower petal, rectangular, obtuse, up to half the size of lower petal).

In cultivation we noted that *I. galactica* produces nectar mainly in the late afternoon and evening along the orange-yellow, shiny line on the lower sepal. Furthermore, the flowers exude a pleasant, fruity-sour scent that gets stronger during the late afternoon and evening. This, in combination with the flower colour, suggests pollination by nocturnal insects.

Acknowledgements

We thank the Directors of the following herbaria for the loan of specimens: BR, G, K, MO, NEU and TAN. We are indebted to the Missouri Botanical Garden, the Parc Botanique Zoologique Tsimbazaza and the Agence Nationale pour la Gestion des Aires Protégées (ANGAP) for research and collecting permission. The Akademie der Wissenschaften und Literatur Mainz kindly sponsored the field trip of the first author. Special thanks go to our colleagues Damien Ertz (Meise), Bernard Goffinet (Connecticut), Roger Lala Andriamiarisoa (Antananarivo) and Emmanuël Sérusiaux (Liège) who accompanied us in the field. Without the skills of Roger Lala Andriamiarisoa, the field work would have been impossible. We thank Norbert Holstein for comments, Hans-Jürgen Ensikat for SEM micrographs of the seeds, and the gardeners of the Botanical Gardens Bonn for the cultivation of *Impatiens galactica*.

Chapter 14

***Impatiens sielmannii* (Balsaminaceae), a new epiphytic species from Madagascar**

This chapter has been published as:

Fischer, E.^{1*}, Rahelivololona, M.E.² & Abrahamczyk, S.³ (2017): *Impatiens sielmannii* (Balsaminaceae), a new epiphytic species from Madagascar. Phytotaxa (accepted)

¹Institute for Integrated Natural Sciences – Biology, University of Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany; e-mail: efischer@uni-koblenz.de.

²Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo & Université de Mahajanga, République de Madagascar; e-mail: rmarielisette@yahoo.fr.

³Nees-Institute for Biodiversity of Plants, University of Bonn, Meckenheimer Allee 170, 53115 Bonn, Germany; e-mail: sabraham@uni-bonn.de.

*Author for correspondence. E-mail: efischer@uni-koblenz.de

Abstract

Impatiens sielmannii is described as a new epiphytic species from the montane rainforest of the Masoala peninsula in north-eastern Madagascar. It is closely related to *Impatiens druartii* but differs in the smaller habit, the more slender stem, the shorter and herbaceous elliptic lamina with shortly attenuate base, the distinctly visible reticulate venation on upper surface, the longer extrafloral nectaries on the leaf margin, the ovate and shorter lower sepal, and the shorter lateral united petals with reddish veins.

Key words: epiphyte, *Impatiens druartii*, montane rainforest, Masoala, Mt. Ambohitsitondroina.

Introduction

Epiphytism is quite rare in the genus *Impatiens* Linnaeus (1753: 937). Obligate epiphytes are mainly recorded from tropical Africa where 12 species are known: *Impatiens epiphytica* G.M.Schulze (1944: 459), *I. etindensis* Cheek & Eb.Fisch. (1999: 472), *I. frithii* Cheek & Csiba (2002: 669), *I. glandulisepala* Grey-Wilson (1979: 643), *I. grandisepala* Grey Wilson (1979: 643), *I. irangiensis* Eb.Fisch. (Fischer 1997: 64), *I. issembei* S.B.Janssens, Stévant & Eb.Fisch. (Janssens *et al.* 2010: 1513), *I. iteberoensis* R.Wilczek & G.M.Schulze (Wilczek & Schulze 1959: 186), *I. keillii* Gilg (1909: 106), *I. letouzeyi* Grey-Wilson (1979: 644), *I. paucidentata* De Wild. (De Wildeman 1922: 363), and *I. wilksiana* Stévant, S.B.Janssens & Eb.Fisch. (Janssens *et al.* 2010: 1513) (Grey-Wilson 1980). With more than 260 species Madagascar is one of the centres of diversity for this genus (Abrahamczyk & Fischer 2015). This is surprising since Madagascar has been colonized by *Impatiens* only once from eastern Africa during the Pliocene (Janssens *et al.* 2009). However, obligate epiphytes are rare and, due to the lack of field observations it is often difficult to distinguish between obligate and facultative epiphytes. *Impatiens truncicola* H.Perrier (1934: 45) is said to be an epiphyte but it is only known from the type collection. *Impatiens purroi* Eb.Fisch., Wohlh. & Raheliv. (Fischer *et al.* 2003: 18) is also reported as an epiphyte. *Impatiens stefan-vogeli* Eb.Fisch., Raheliv. & Abrah. (Fischer *et al.* submitted) was found as epiphyte on a fallen trunk but is also reported as growing on wet rocks. True obligate epiphytes of Madagascar are *Impatiens academiae-moguntinae* Eb.Fisch. & Raheliv. (Fischer & Rahelivololona 2007: 280) from Masoala Peninsula and *I. renae* Eb.Fisch. & Raheliv. (Fischer & Rahelivololona 2004: 38) from Mt. Marojejy.

Beside these spurred taxa have a comparatively large radiation (>125 species, mostly local endemics, all from the section *Trimorphopetalum*) and exist on Madagascar (Fischer *et al.* 2017). The relatively small, morphologically aberrant, spur-less flowers of these species show reddish- or yellowish-brown coloration patterns, often with semi-transparent parts and a three-dimensional sculpturing on the petal-like central sepal (Fischer & Rahelivololona 2002; Fischer *et al.* 2003). Within this highly diverse group, only *Impatiens druartii* Eb.Fisch. & Raheliv. (Fischer & Rahelivololona 2007: 306) is known as an obligate epiphyte. It occurs only in montane rainforests above 850 m on

Masoala Peninsula. Here we describe another obligate epiphytic species only known from ericaceous shrub on the crest of Masoala at Mt. Ambohitsitondroina.

Material and methods

Living plant material was investigated in nature as well as in Bonn University Botanical Gardens. Additionally, herbarium specimen from the following herbaria were studied: G, MO, NEU, P, TAN (acronyms after Holmgren *et al.* 1990). Standard terminology and measurement criteria for *Impatiens* were applied (Fischer & Rahelivololona 2002). Based on these criteria ten representative objects per morphometrical character were measured using fresh material.

Impatiens sielmannii Eb.Fisch., Raheliv. & Abrah. *sp. nov.* (Fig. 1, 2)

Impatiens druartii affinis sed habitu minore, caule angustiore et viride, lamina elliptica brevior et herbaceo basim breviter attenuato, nervibus reticulatis faciei superioris distincte visibilibus, nectariis extrafloralibus in lamina longioribus, sepalo inferiore ovato brevior cum apice distincti, et petalis lateralibus brevioribus et nervis rubris instructis petalis superioribus minoribus et angustioribus valde differt.

Impatiens sielmannii is closely related to *Impatiens druartii* but differs in the smaller habit, the more slender and green stem, the shorter and herbaceous elliptic lamina with shortly attenuate base, the distinctly visible reticulate venation on upper surface, the longer extrafloral nectaries on leaf margin, the ovate and shorter lower sepal with distinct apex, and the shorter lateral united petals with reddish veins and smaller and more narrow upper petal.

TYPE— Madagascar. Parc National Masoala, epiphytic on ericaceous shrub at summit of Mt. Ambohitsitondroina, 1097 m, 15°34'37.19" S 50°00'42.45" E (Fig. 3), *E. Fischer M.E. Rahelivololona, S. Abrahamczyk 1795*, 9 October 2015 (holotype TAN!; isotypes P!, MO!, BONN!).

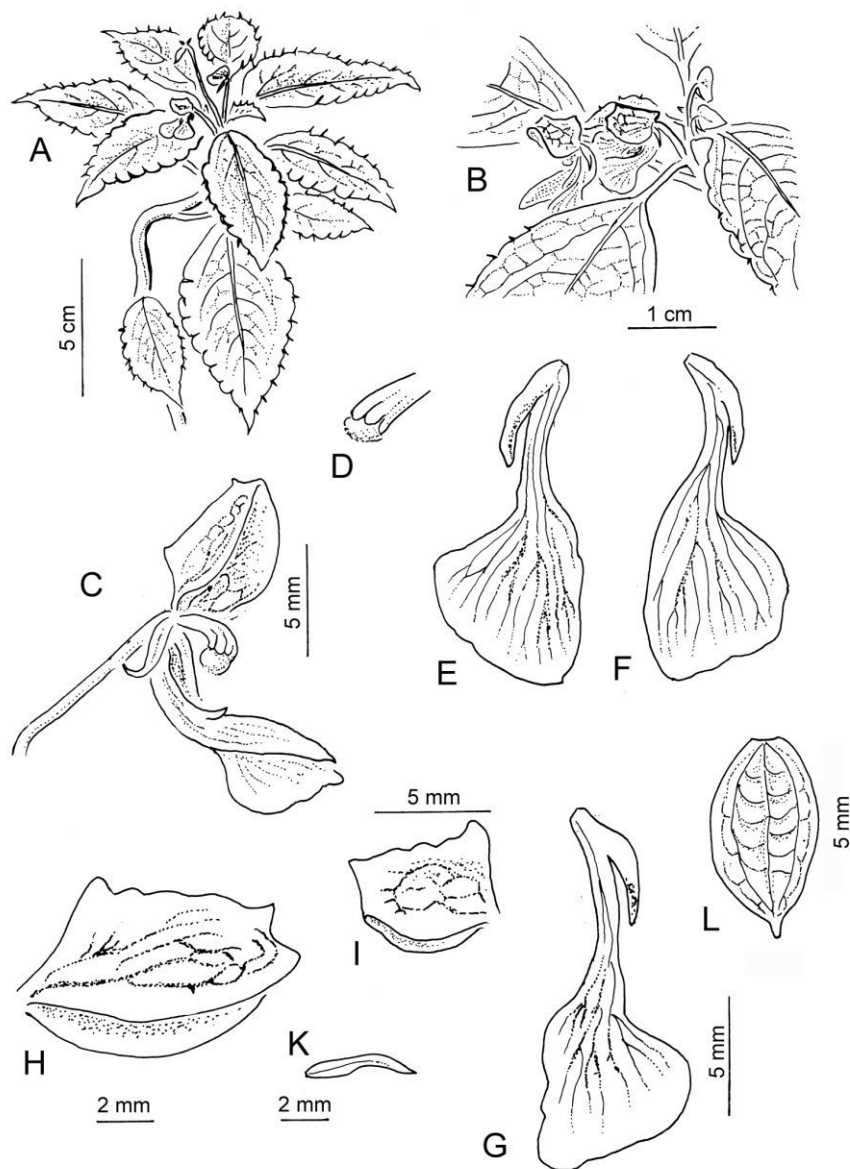


FIGURE 1. *Impatiens sielmannii*. **A.** Habit. **B.** View of inflorescence. **C.** Flower, lateral view. **D.** Anthers. **E - G.** Lateral united petals. **H - I.** Dorsal petal. **K.** Lateral sepal. **L.** Lower sepal. All drawn by E. Fischer from the type.

Ascending, perennial, epiphytic herb, up to 30 cm high. *Stems* up to 5 mm thick, greenish, succulent, branching and rooting at lower nodes and internodes. Plant entirely glabrous. *Leaves* alternate, spirally arranged, deep green above with light green veins, pale green below; petioles green, tinged with red, 13–24 mm long and continuously growing. Lamina 58–88 × 23–30 mm, elliptic to elliptic-lanceolate, apex acute, base shortly attenuate; lateral veins 4–7 pairs; margin crenate; extrafloral

nectaries 1.5–2 mm long, linear, 7–10 pairs, at the lamina margin between each pair of teeth, half erect, prominent especially at young leaves. Bracts 2–3 × 0.5 mm. Pedicel green tinged with red, 10–24 mm long. Inflorescence uniflorous, in the leaf-axills. Flower yellow with reddish veins on lateral petals, lower sepal yellow, dorsal petal with dark veins and green crest. Lateral sepals 2, 4–6 × 0.5 mm. Lower sepal ovate, 6–8 ×

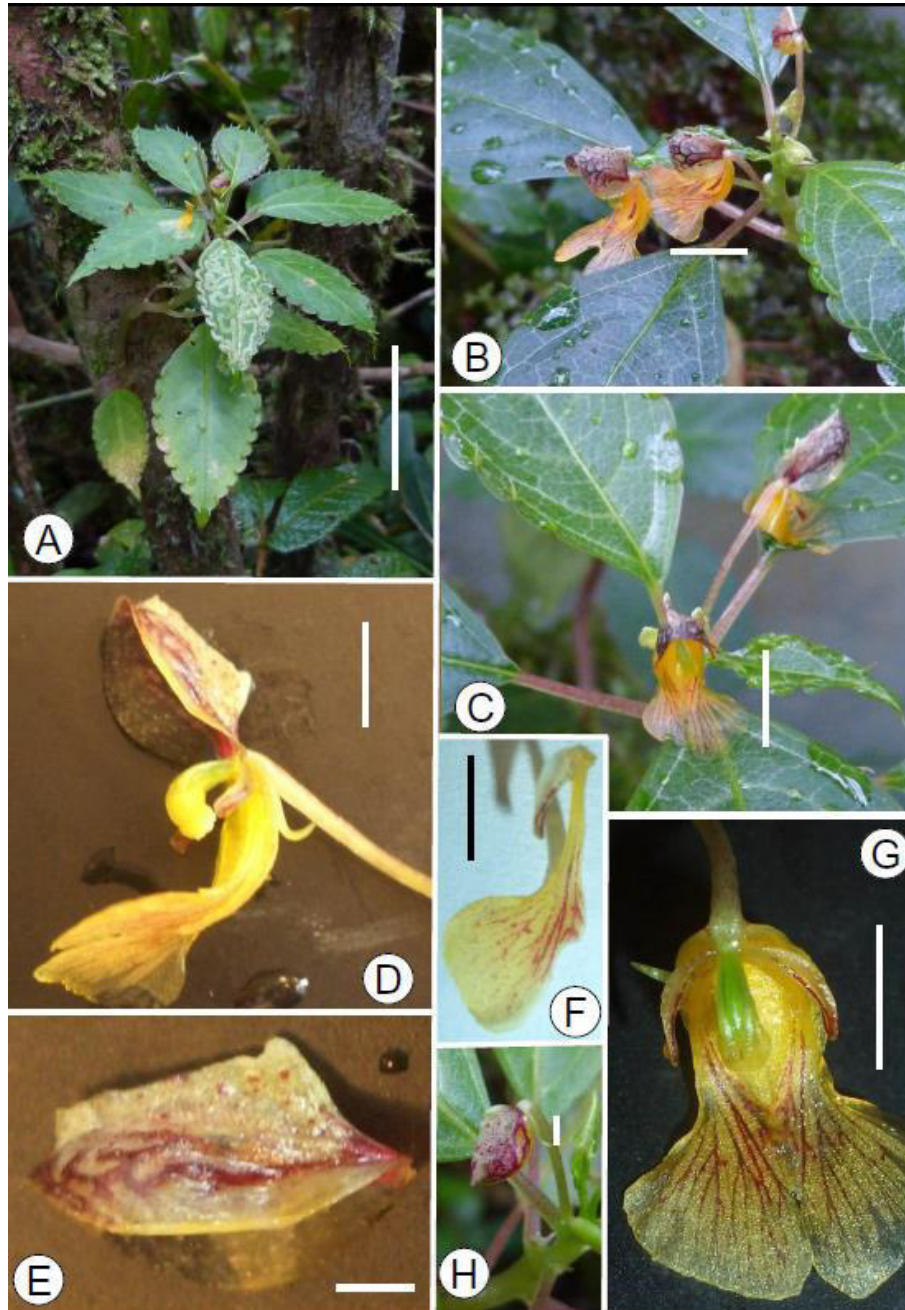


FIGURE 2. *Impatiens sielmannii*. A. Habit. B – C. View of inflorescence. D. Flower, lateral view. E. Dorsal petal. F. Lateral united petals. G. Flower with dorsal petal removed showing lateral sepals, lateral united petals and ovary with stamens. H. Flower bud. Phot. E. Fischer at the type locality (A) and at Bonn University Botanical Gardens (B – H). Scale bars: A 5cm, B–C 1 cm, D 5 mm, E 2 mm, F–G 5 mm, H 1 mm.



FIGURE 3. **A.** Habitat of *Impatiens sielmannii* on the summit of Mt. Ambohitsitondroina. The palm *Dypsis bonsai* is growing in the foreground. **B.** Habit of *I. sielmannii*. Phot. E. Fischer at the type locality.

3–4 mm, with reticulate pattern and distinct apex. Dorsal petal helmet-like, with apical crest bearing an apical acute spur and a distal obtuse spur of 1 mm length, 6–8 × (4) 5–6 mm, crest 1–1.5 mm high, with dark reddish-brownish reticulate venation. Lateral united petals (9) 11–12.5 mm long, upper petal lanceolate, obtuse, 3–4 × 0.8–1 mm,

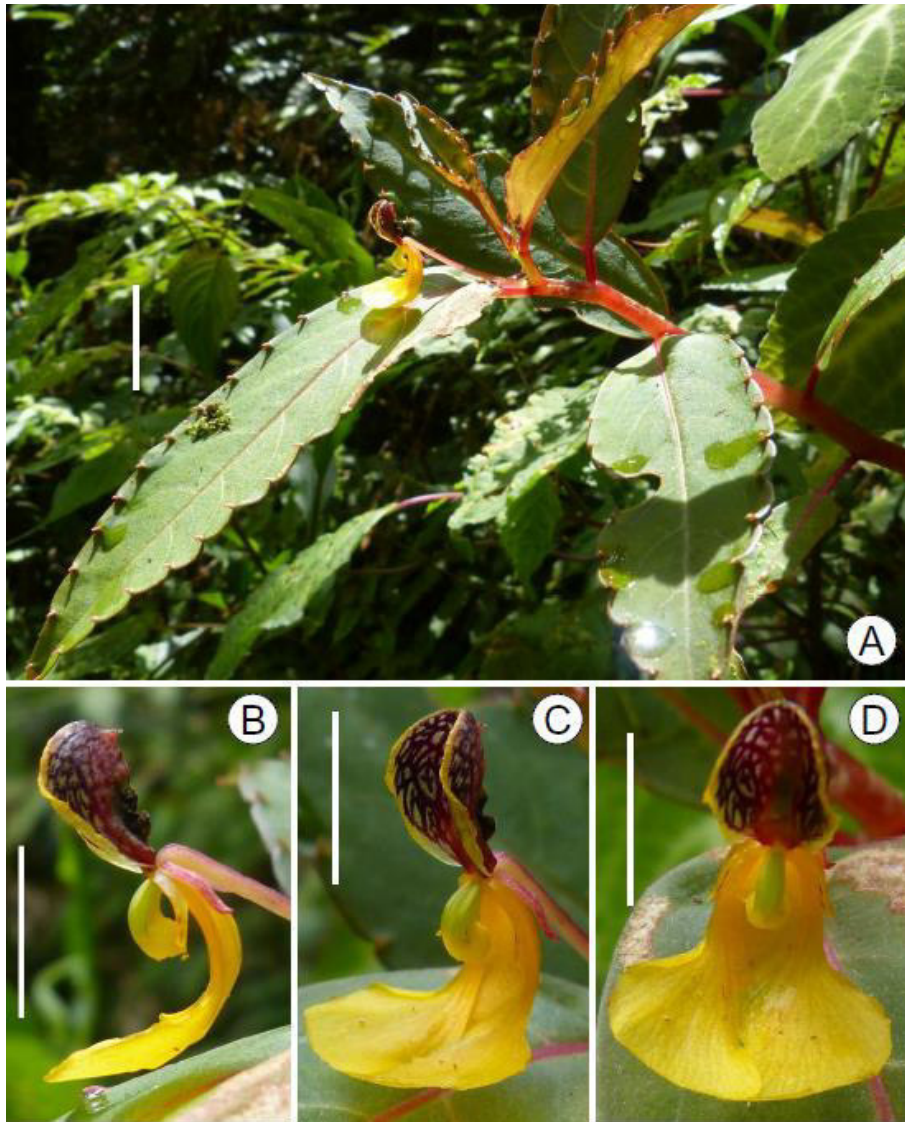


FIGURE 4. *Impatiens druartii*. A. Habit. B – D. Flowers. Phot. E. Fischer, Mt. Ambohitsitondroina. Scale bars: A 2 cm, B–D 1 cm.

lower petal (9) 11–12.5 × 3.5–4 mm, lower part rounded-triangular, with small spur at inner side, 5–6 mm wide. Stamens 3.5 mm long. Ovary 2.5–3 mm long. Fruit unknown.

HABITAT— Epiphytic at trunks of the ericaceous shrub near the top of Mt. Ambohitsitondroina, 1097 m a.s.l.

DISTRIBUTION— Madagascar, only known from the type locality.

ETYMOLOGY— Named in honour of the famous German wildlife cameraman and producer of TV documentations Heinz Sielmann (1917-2006), who elated many young people to campaign for nature. A stamp where he is shown in action with his camera was edited in 2017 on the occasion of his 100th birthday.

CONSERVATION STATUS— Endangered (EN) due to its extremely local distribution range on summit of Mt. Ambohitsitondroina, but protected within the Masoala National Park.

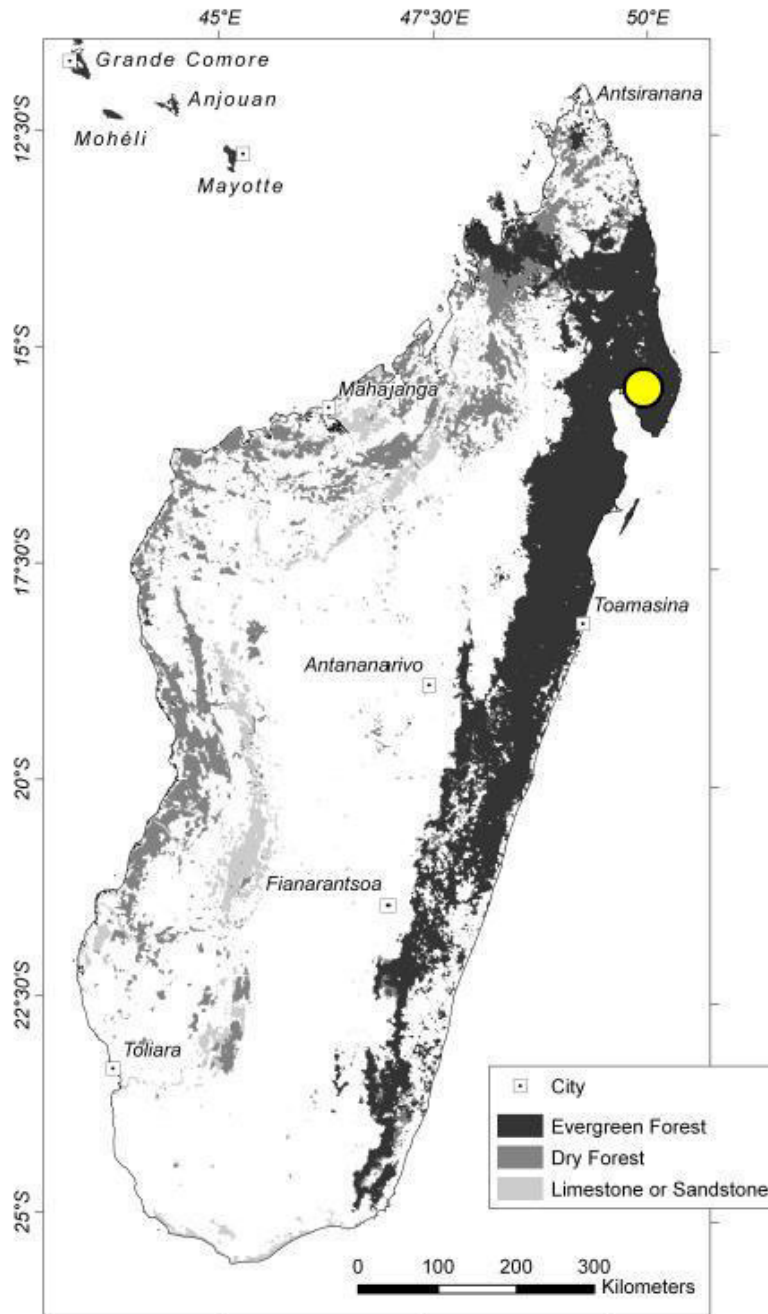


FIGURE 5. Distribution map of *Impatiens sielmannii*.

Chapter 14 — New epiphytic taxa from Madagascar

TABLE 1. Major differences between *Impatiens sielmannii* and *I. druartii*

	<i>Impatiens sielmannii</i>	<i>Impatiens druartii</i>
Stem diameter	up to 10 mm	up to 35 mm
Stem	green	green tinged with orange or red
Leaves	herbaceous, green	succulent, dark green above, light green on lower surface
Leaf venation	distinctly reticulate on upper lamina surface	only midvein and main lateral veins visible on upper lamina surface
Petiole	13 - 21 mm	20 mm
Lamina length	58 - 88 mm	80 - 120 mm
Lamina width	23 - 30 mm	24 - 30 mm
Extrafloral nectaries on leaf margin	1.5-2 mm	0.8-1 mm
Pedicel	10 - 24 mm	30 mm
Lateral sepal	4 - 6 mm x 0.5 mm	5 mm x 1 mm
Lower sepal	ovate, 6 - 8 x 3 - 4 mm	lanceolate, 12 mm x 3 mm
Dorsal petal	6 - 8 mm x 5 - 6 mm	9 mm x 6 mm
Lateral united petals length	(9) 11 - 12.5 mm	16 mm
Upper petal	3.5 - 4 mm x 1 mm	4.2 mm x 1 mm
Lower petal	(9) 11 - 12.5 mm x 3.5 - 5 mm	14 mm x 5 mm
Lateral united petals color	light yellow with darker reddish venation	dark yellow without visible venation
Stamens length	3.5 mm	2 - 3 mm
Ovary	2.5 - 3 mm	3 mm

DISCUSSION— *Impatiens sielmannii* is closely related to *Impatiens druartii* occurring in montane forests of the Masoala peninsula from 879 to 1000 m a.s.l. and thus almost sympatrically (Fischer & Rahelivololona 2007) because both species share flowers with yellow lower sepal and lateral united petals and the epiphytic habit. However, *Impatiens sielmannii* differs from *Impatiens druartii* in numerous characters, e.g. stems and leaves thinner, herbaceous and not succulent as in *I. druartii* (stems up to 10 mm thick), leaf and stem color green, leaf shape elliptic to elliptic-lanceolate, smaller than in *I. druartii*, extrafloral nectaries on leaf margin longer than in *I. druartii* (1.5-2 vs. 0.8-1 mm), lower sepal 6–8 mm × 3–4 mm, ovate, abruptly turned into acute apex, and the shape and length of the upper and lower lateral petal bearing reddish veins (Table 1).

NOTES – The ericaceous shrub near the top of Mt. Ambohitsitondroina bears another local endemic. The palm *Dypsis bonsai* Beentje (Dransfield & Beentje 1995: 252) was described from its summit. The species is only known from the type locality on Mt. Ambohitsitondroina and the summit region of Mt. Marojejy.

Acknowledgements

The first author would like to thank the Akademie der Wissenschaften und Literatur Mainz for funding support of the field trip to Madagascar. We thank the gardeners of Bonn University Botanical Gardens for cultivating *Impatiens sielmannii*. We are grateful to the Agence National pour la Gestion des Aires Protégées (ANGAP) at Antananarivo and Maroantsetra for research permits. We would like to thank the Direction des Eaux et Forêts, Antananarivo for export permits. Special thanks go to our colleagues from the Parc Botanique Zoologique de Tsimbazaza (PBZT), Antananarivo, for continuous support. We are indebted to J. Aridy from Maroantsetra who was a very experienced and knowledgeable guide and helped us a lot during the fieldwork in Masoala National Park.

Chapter 15

***Impatiens stefan-vogeli* (Balsaminaceae), a new species from Madagascar**

This chapter has been published as:

Fischer, E.^{1*}, Rahelivololona, M.E.² & Abrahamczyk, S.³ (2017): *Impatiens stefan-vogeli* (Balsaminaceae), a new epiphytic species from Madagascar. Phytotaxa (accepted)

¹Institute for Integrated Natural Sciences – Biology, University of Koblenz-Landau, Universitätsstraße 1, 56070 Koblenz, Germany.

²Parc Botanique et Zoologique de Tsimbazaza, BP 4096 Antananarivo & Université de Mahajanga, République de Madagascar

³Nees-Institute for Biodiversity of Plants, University of Bonn, Meckenheimer Allee 170, 53115 Bonn, Germany.

*Author for correspondence. E-mail: efischer@uni-koblenz.de

Abstract

Impatiens stefan-vogeli is described as a new species from the lowland rainforest of the Masoala peninsula in northeastern Madagascar. It is closely related to *Impatiens purroi* occurring in montane forests of Masoala but differs in having longer extrafloral nectaries on the lamina, longer pedicels, smaller flowers, a different-shaped lower, spur-carrying sepal and spur, emerging mid veins in the upper lateral petals bearing a distinct acumen at apex, different shapes of the lower and the dorsal petals, lower sepal and dorsal petal densely covered with white hairs, and a different flower coloration pattern.

Key words: epiphyte, *Impatiens purroi*, lowland rainforest, Masoala,

Introduction

Due to its diversity in flower architecture the genus *Impatiens* L. (Linnaeus 1753: 937) is known as the "dicots counterpart of orchids" (Yuan *et al.* 2004). The diversity of flower types has been interpreted as adaptations to a variety of pollinator groups ranging from different groups of bees and flies to butterflies, moths and birds (Abrahamczyk *et al.* 2017). With more than 260 species Madagascar is one of the centres of diversity for this genus (Abrahamczyk & Fischer 2015). This is surprising since Madagascar has been colonized by *Impatiens* only once from eastern Africa during the Pliocene (Janssens *et al.* 2009). Even more surprising is the high diversity of flower architectures on Madagascar (Fischer & Rahelivololona 2002, 2004, 2007a, b, 2015a, b, c, 2016; Fischer *et al.* 2003, 2017). In combination these data indicate a high mutation rate as well as a rapid morphological adaptation to changing pollinator groups.

In this publication we describe a new *Impatiens* species, closely related to *Impatiens purroi* Eb. Fisch., Wohlhauser & Rahelivololona (Fischer *et al.* 2003: 18). This group of species can be distinguished by a peculiar flower morphology with a characteristic spur shape. Additionally, it is one of the few epiphytic *Impatiens* taxa on Madagascar.

Material and methods

Living plant material was investigated in nature as well as in the Botanical Gardens Bonn. Additionally, herbarium specimen from the following herbaria were studied: G, MO, NEU, P, TAN (acronyms after Holmgren *et al.* 1990). Standard terminology and measurement criteria for *Impatiens* were applied (Fischer & Rahelivololona 2002). Based on these criteria ten representative objects per morphometrical character were measured using fresh material. Seeds were studied after critical point drying (CPD 020 Balzers Union) using a scanning electron microscope (SEM, Cambridge S200).

Impatiens stefan-vogeli Eb.Fisch., Raheliv. & Abrah. sp. nov. (Fig. 1, 2)

Impatiens purroi affinis sed nectariis extrafloralibus in lamina longioribus, pedicellis longioribus, lamina subtus sine nervibus reticulatis distinctis, floribus minoribus, forma sepali inferioris cum calcare, nervis mediis emergentibus petali lateralis superioris, petalis lateralibus superioribus apice distincte acuminate, forma petali inferioris et petali dorsalis, sepalo inferioris et petalo dorsalis dense albo-pilosa et coloratio floris valde differt.

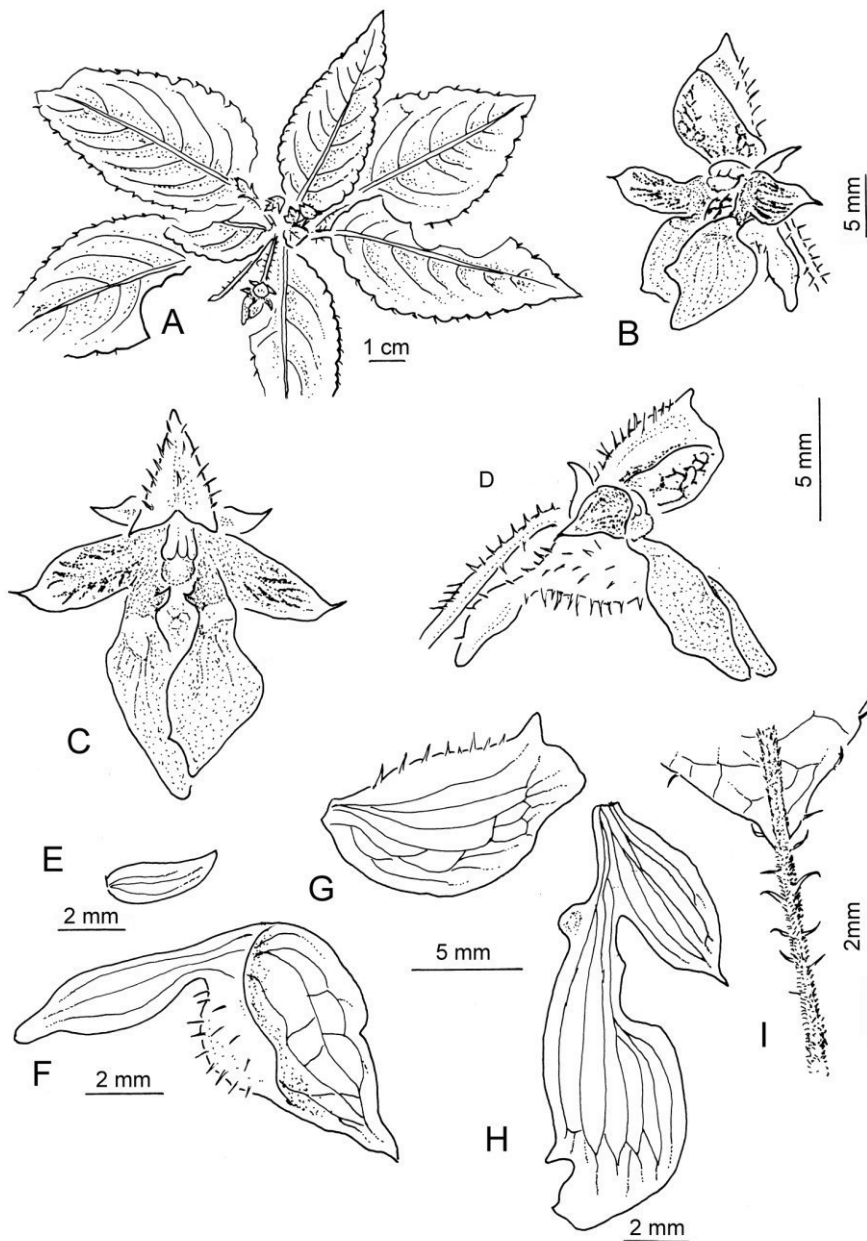


FIGURE 1. *Impatiens stefan-vogeli* A. Habit. B – C. Flower, frontal view. D. Flower, lateral view. E. Lateral sepal. F. Lower sepal with spur. G. Dorsal petal. H. Lateral united petals. I. Base of lamina with petiole showing extrafloral nectaries. All drawn by E. Fischer from the type.

Impatiens stefan-vogeli is closely related to *Impatiens purroi* occurring in montane forests of Masoala but differs in having longer extrafloral nectaries on the lamina, longer pedicels, the lack of a distinct reticulate venation on lower leaf surface, smaller flowers, a different-shaped lower sepal and spur, emerging mid veins in the upper lateral petals with distinct acumen at apex, different shapes of the lower and the dorsal petals, lower sepal and dorsal petal densely covered with white hairs, and a different flower coloration pattern.

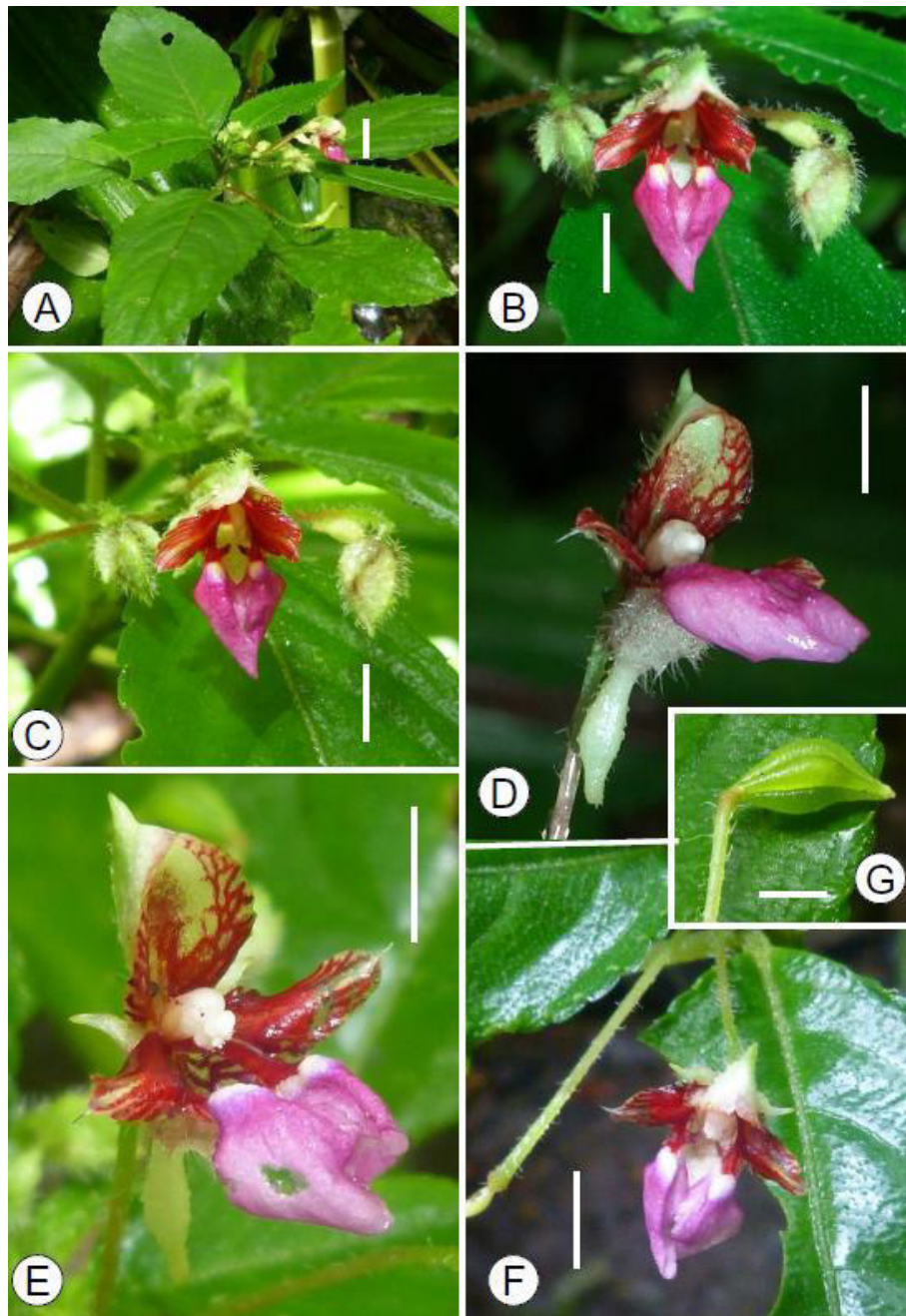


FIGURE 2. *Impatiens stefan-vogeli*. A. Habit. B–F. Flowers. G. Young capsule. Phot. E. Fischer at the type locality. Scale bars: A 1m, B–G 5 mm.

TYPE— Madagascar. Parc National Masoala, Centre de Recherche Andranobe, stream Andranobe, small tributary, S 15°40'45" E 49°57'37", 100 m (Fig. 3), *E. Fischer M.E. Rahelivololona, S. Abrahamczyk 1766*, 05 October 2015 (holotype TAN!; isotypes PI!, B!, MO!, BONN!).

Erect, epiphytic or rupicolous, perennial herb, up to 400 mm high. Stems rooting at nodes, reddish. Plant entirely pubescent with hairs of 0.3-0.5 mm length at stems and leaves. Leaves spirally arranged, deep green above, pale green below with distinct

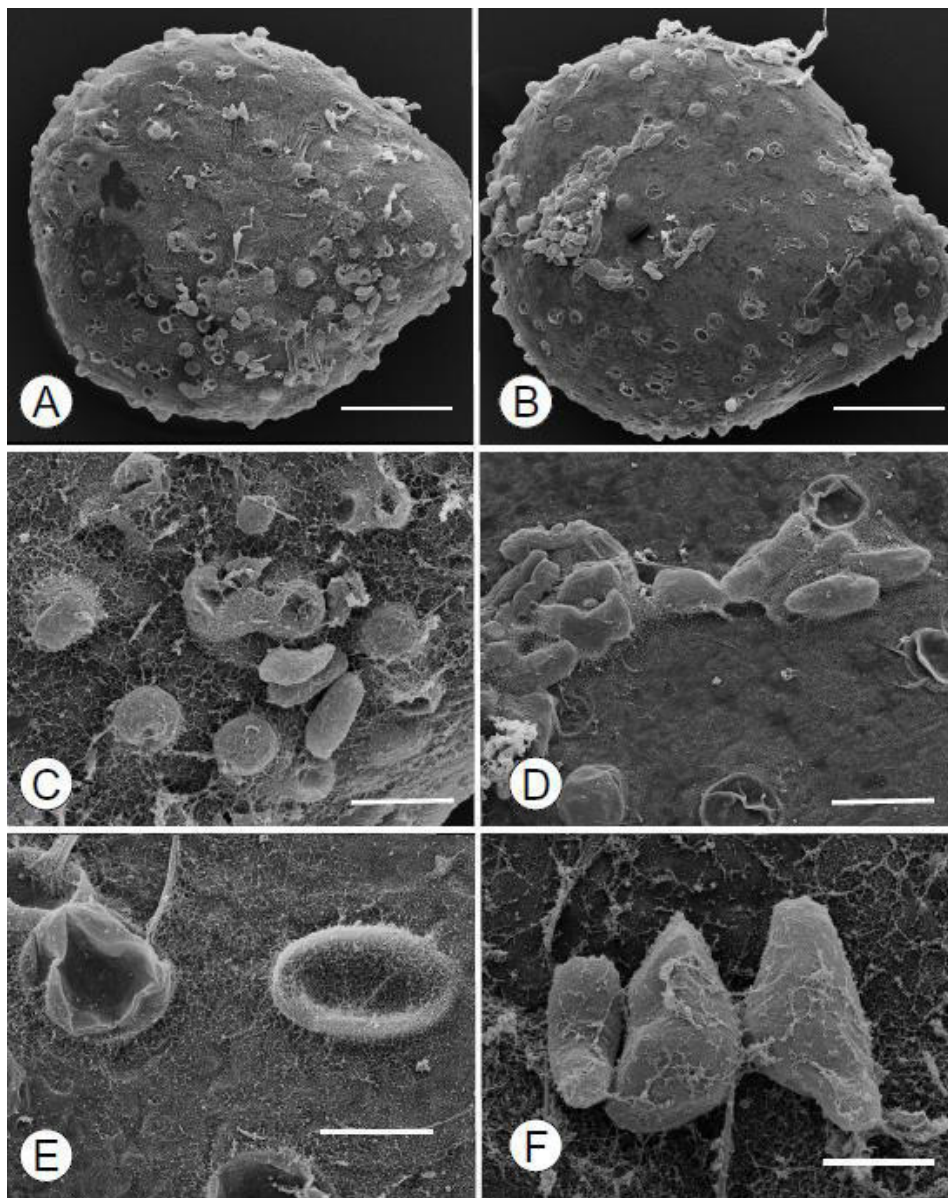


FIGURE 3. *Impatiens stefan-vogeli* A–F. Seed covered with mucilage excreting, dome-like trichomes. Photo by H.-J. Ensikat. A – B. Scale bar 300 µm. C – D. Scale bar 60 µm. E. Scale bar 30 µm. F. Scale bar 20 µm.

reticulate venation; the main veins and petioles reddish; the petiole 7–37 mm long, continuously growing. Lamina 47–98 mm x 25–42 mm, ovate-lanceolate, shiny, the apex acute, the basis shortly attenuate; lateral veins 5(–7) pairs; margin crenate to crenate-serrate; extrafloral nectaries at petiole and lower lamina 1.5–2 mm long, at rest of the lamina 1 mm long, linear at the lamina margin between each pair of teeth and at the tip of the apex, half erect, prominent especially at young leaves. Inflorescence 1-flowered. Flowers colourful; upper third of lower lateral petals, upper lateral petal and lateral parts of the dorsal petal dark red with light yellowish-green markings; mid third of lower lateral petal pink, turning gradually into pale pink in the lower third of lower lateral petal; whitish-yellow spot between upper and middle third; ovary-anther complex white. Pedicels (25–)31–39 mm long, slender, reddish-brown, with 0.8–1.2 mm long, white hairs. Lateral sepals 2, 4 mm x 1.5 mm, lanceolate, acute, greenish. Lower sepal 4 mm long, 8–9 mm deep, abruptly peaking into a 1 mm down facing tip, obliquely naviculate and abruptly constricted into a spur, densely covered with 0.8–1.2 mm long, white hairs, light yellowish-green, inside with dark red markings; spur 7 mm long, ± straight, bulgy, obtuse widest in the middle. Dorsal petal 7–8 mm x 4–5 mm, helmet-like, ovate, emarginated, yellowish-green, dorsally with prominent, greenish crest densely covered with 0.8–1.2 mm long, white hairs, peaking into a 1 mm long tip. Lateral united petals 12–14 mm long, with petals different in size and shape; upper petal 7–8 x 3 mm brought falcate with emerging, 1 mm long mid vein; lower petal 12–14 x 4 mm, spatulate with a 1 mm long, adaxial horn-like structure. Ovary 3–4 mm long, glabrous. Fruit 9–10 x 4 mm, glabrous with 2-3 seeds per fruit. Seeds 9(–11) x 3–4 mm, covered with mucilage excreted by dome-like trichomes (Fig. 3).

HABITAT— Lowland rainforest, growing epiphytic at tree trunks or rocks along a small streams in dense, swampy lowland rainforest, 100 m to 550 m (Fig. 4).

DISTRIBUTION— Only known from two lowland rainforest sites in Masoala National Park (Fig. 5).

PHENOLOGY— Collected in flower at the type locality in October. In cultivation at the Botanical Gardens of the University of Bonn, flowers have been noted almost every month.



FIGURE 4. **A–C.** Habitat of *Impatiens stefan-vogeli* in dense, swampy lowland rainforests. **A.** Overview. **B.** *Impatiens stefan-vogeli* on a fallen tree (arrow). **C.** Habit of *I. stefan-vogeli*. Phot. E. Fischer at the type locality.

ETYMOLOGY— Named after the famous German botanist and ecologist Prof. Dr. Stefan Vogel (1925-2015) who contributed massively to our understanding of flower ecology (Lack 2016).

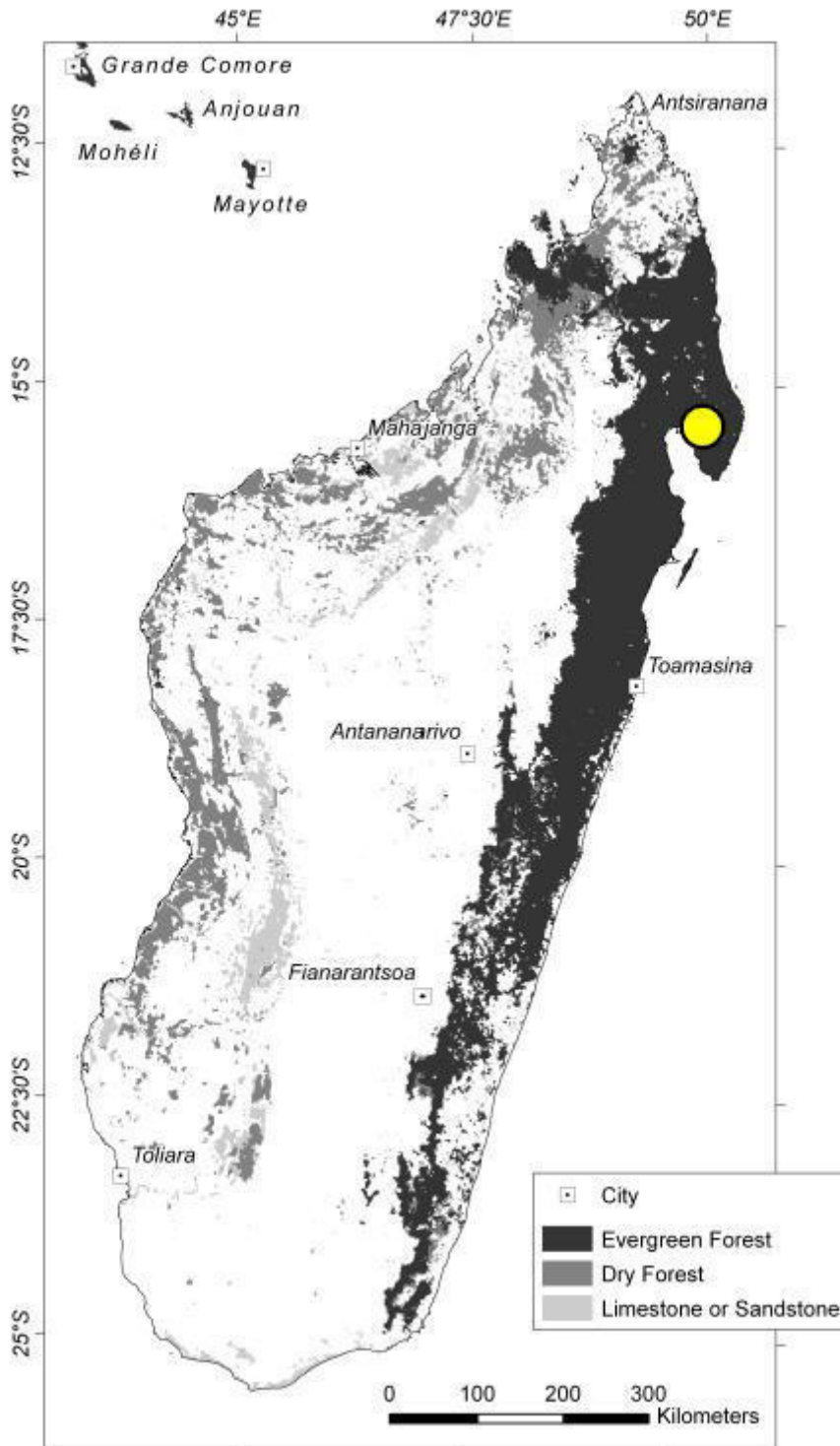


FIGURE 5. Distribution map of *Impatiens stefan-vogeli*.

CONSERVATION STATUS— This species is only known from two localities close to each other in the well managed Masoala National Park. Even though it has a small distribution range we neither expect an immediate threat to the species nor see

evidence for a continuing decline. Therefore, we suggest to categorize it as Least Concern (LC; IUCN 2001).

PARATYPE— Madagascar. Masoala Peninsula, Andranobe, S of Ambanizana, 15°41'S 049°58'E, 480 – 550 m, on rocks, *McPherson, Harimalala, Hoffmann & Robinson 17668*, 22 February 1999 (TAN, P).



FIGURE 6. Pollinator (halictid bee) of *Impatiens stefan-vogeli*. Phot. E. Fischer.

NOTES— *Impatiens stefan-vogeli* is closely related to *Impatiens purroi* occurring in montane forests of the Masoala peninsula at 720 m (Fischer *et al.* 2003) because both species share a unique flower morphology with bulgy spurs being widest in the middle as well as the epiphytic habit. However, *Impatiens stefan-vogeli* differs from *Impatiens purroi* in having longer extrafloral nectaries on the lamina, longer pedicels, the lack of a distinct reticulate venation on lower leaf surface, smaller flowers, a different-shaped lower, spur-carrying sepal and spur, emerging mid veins in the upper lateral petals, different shapes of the lower and the dorsal petals, lower sepal and dorsal petal densely covered with white hairs and a different flower coloration pattern. Additionally, *Impatiens stefan-vogeli* has horn-like structures at the adaxial side of the lower petals, restricting the entrance of the flower tube, which are much more prominent than in *Impatiens purroi*. At the type locality we observed legitimate flower visits by a halictid

bee (Fig. 6). The seeds are covered with mucilage excreting, dome-like trichomes, which might be an adaptation to the usually epiphytic growth of the species.

Acknowledgements

The first author would like to thank the Akademie der Wissenschaften und Literatur Mainz for funding support of the field trip to Madagascar. We thank the gardeners of the Botanical Gardens Bonn for cultivating *Impatiens stefan-vogeli* and Hans-Jürgen Ensikat for taking the REM photo of the seed. We are grateful to the Agence National pour la Gestion des Aires Protégées (ANGAP) at Antananarivo and Maroantsetra for research permits. We would like to thank the Direction des Eaux et Forêts, Antananarivo for export permits. Special thanks go to our colleagues from the Parc Botanique Zoologique de Tsimbazaza (PBZT), Antananarivo, for continuous support.

Chapter 16

Phylogeny and biogeography of Balsaminaceae inferred from ITS sequences

This chapter has been published as:

Yuan, Y.-M.^{1,5}, Song, Y.¹, Geuten, K.², Rahelivololona, E.³, Wohlhauser, S.¹, Fischer, E.⁴, Smets, E.² & Kuepfer, P.¹ (2004): Phylogeny and biogeography of Balsaminaceae inferred from ITS sequences. *Taxon* 53(2): 391-403.

¹ Institut de Botanique, Université de Neuchâtel, Emile-Argand 11, CH-2007 Neuchâtel, Switzerland. yongming.yuan@unine.ch (author for correspondence)

² Laboratory of Plant Systematics, K.U. Leuven, B-3001 Leuven, Belgium. koen.geuten@bio.kuleuven.ac.be

³ Parc Botanique et Zoologique de Tsimbazaza, B.P. 4096, Antananarivo, Madagascar. prota.madagascar@dts.mg

⁴ Institut für Biologie, Universität Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz, Germany. efischer@uni-koblenz.de

⁵ South China Institute of Botany, Chinese Academy of Sciences, Guangzhou, P. R. China. yongming.yuan@univie.ch

Abstract

Sequences of the internal transcribed spacers (ITS) of nuclear ribosomal DNA were acquired for 112 species of Balsaminaceae worldwide and five species of its closest relatives Marcgraviaceae and Tetrameristaceae. Phylogenetic analyses applying parsimony and distance estimates confirmed the monophyly of Balsaminaceae and suggest the monophyly of *Impatiens*. Within *Impatiens*, a few clades are recognized with strong support. Two of the most important clades are the spurless Madagascan endemic group, and the one comprising species with broadly fusiform fruits and the

basic chromosome number $x = 8$, that shows a Southeast Asia, southern India, Africa, and Madagascar connection. Despite recognition of several strongly supported small lineages, ITS data alone could not resolve relationships among most of the lineages with confident support values. ITS phylogenies are therefore of limited taxonomic value for *Impatiens*. However, ITS phylogenies do reveal that extant *Impatiens* species are of Southeast Asian origin, from where dispersals to boreal Eurasia and North America, to central Asia and eastern Europe via the Himalayas, and to India and Africa have occurred. The Madagascan *Impatiens* show an African origin. Molecular phylogenies suggest the ancestral basic chromosome number to be $x = 10$, and the spurred flowers and elongated linear fruits to be plesiomorphic states in *Impatiens*. A predominantly descending dysploid chromosome evolution, following dispersal of the clade with broadly fusiform fruits from Southeast Asia to India, Africa, and Madagascar, is also suggested.

Keywords: Balsaminaceae, biogeography, chromosome evolution, ITS, phylogeny.

Introduction

Balsaminaceae are a medium-sized family with two genera, *Hydrocera* and *Impatiens*. Other generic names published for Balsaminaceae, such as *Petalonema* Peter, *Semeiocardium* Zoll. and *Impatientella* H. Perrier, are confirmed to be synonyms of *Impatiens* (Grey-Wilson, 1989a; Rao & al., 1986). *Hydrocera* has only one species, *H. triflora*, a semi-aquatic herb native to the Indo-Malesian countries. Morphologically, it can be easily distinguished from *Impatiens* by its five free petals and the indehiscent berry-like fruit. *Impatiens* is a highly diversified genus with over 900 species distributed primarily in the highlands and mountains of the Old World tropics and subtropics with five conspicuous diversity hotspots: tropical Africa, (ca. 109 spp.; Grey-Wilson, 1980b), Madagascar (ca. 120 spp.; Fischer & Rahelivololona, 2002), southern India and Sri Lanka (ca. 150 spp.), the eastern Himalayas (ca. 120 spp.), and Southeast Asia in its broad sense (including Burma, Thailand, southwest China, Indochina peninsula, and the Thailand, southwest China, the Indochina peninsula, and the Malesian archipelagos, ca. 250 spp.). Many new species are still being described from these regions (e.g., Chen, 2000; Shimizu, 2000; Fischer & Rahelivololona, 2002; Fischer & al., 2003; Huang & al., 2003). High proportions of local endemism are associated with

these hotspots, for example, as many as 91% of the southern Indian species are endemic (Rao & al., 1986), and almost all the native species of Madagascar are endemic. Contrary to paleotropical areas, only a few *Impatiens* species are found in temperate areas of the northern hemisphere. There are no native species in South America or Australia. Some *Impatiens* species are of horticultural importance, e.g., the popularly grown flowers, the “Balsam”, *I. balsamina*, the “Busy Lizzie”, *I. walleriana*, and the “New Guinea Hybrid *Impatiens*”, *I. hawkeri*.

Impatiens is a well-known example of a taxonomically difficult group (Hooker & Thompson, 1859; Grey-Wilson, 1980b). The delicate yet hypervariable structure and fragile nature of its flowers (Fig. 1) make it almost impossible to determine a species when specimens are pressed conventionally without detailed descriptions or drawings of its floral morphology (Grey-Wilson, 1980c). Many early publications based on herbarium specimens are therefore incomplete or misleading. The only global infrageneric classification of *Impatiens* was the early work of Warburg & Reiche (1895), which recognized 14 sections. However, this classification was considered neither natural nor practical (Grey-Wilson, 1980b). Thus a reliable infrageneric classification is still missing. Although aggregates of closely allied species can be recognized, it is hard to unravel the phylogenetic relationships among the species aggregates on the basis of gross morphology. These difficulties have necessarily limited most studies on *Impatiens* so far to be regional and purely descriptive taxonomic treatments (e.g., Perrier de la Bathie, 1934, 1948; Humbert, 1956; Chen, 1978; Grey-Wilson, 1980a, 1985, 1989a; Akiyama & al., 1992a, 1995, 1996; Akiyama & Ohba, 2000; Fischer & Rahelivololona, 2002).

Impatiens shows a wide range of chromosome number variation of $2n = 6, 8, 10, 12, 14, 15, 16, 17, 18, 19, 20, 24, 26, 28, 30, 32, 34, 36, 40, 44, 48, 50, 54,$ and 66 (Song & al., 2003). The most frequent numbers are $2n = 14, 16, 18,$ and 20, that take the major part (78%) of the species observed. Different hypotheses have been proposed regarding the evolution of the basic numbers through dysploidy in conjunction with polyploidy in *Impatiens*. Jones & Smith (1966) and Akiyama & al. (1992b) suggested $x = 7$ to be the ancestral type, from which the other numbers were derived mainly by ascending dysploidy, whereas Rao & al. (1986) suggested evolution of $x = 7, 9$ and 10 from the basic number $x = 8$ through both descending and ascending dysploidy.

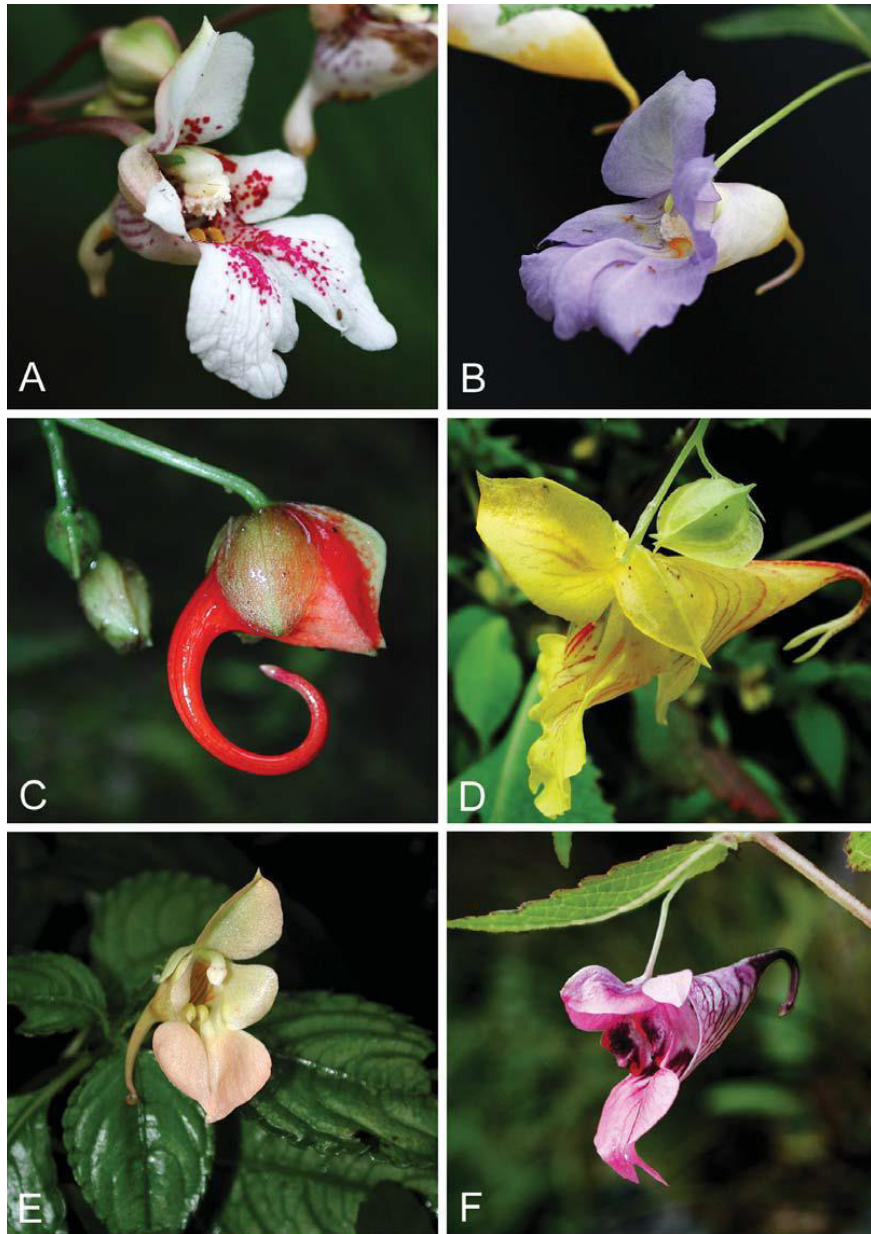


FIGURE. 1. *Impatiens* shows tremendous diversity in floral colour and morphology, and can be considered as the “dicots counterpart of orchid”. Its flower is zygomorphic and resupinate through twisting of the pedicel. Each flower has three sepals, two of which are reduced lateral sepals and one petal-like lower sepal that is modified into a nectary-tipped spur that exhibits a wide range of variation in form and size, from shallowly navicular to bucciniform or deeply saccate, short or long filiform, straight, twisted or curved. Each flower has five petals. One upper dorsal petal is usually hoodlike. The other four lower petals are united into two lateral pairs, yet each retains two unequal lobes. The united lateral petals are also extremely variable in shape and size, associated with different pollinators as they provide a suitable landing platform and entrance guide for pollinators to the spur and nectar. The five stamens are united by the upper part of the filaments and completely cap the gynoecium, which has five fused carpels. Shown here are examples of flowers of *Impatiens* of different colours. **A**, *I. campanulata*; *I. arguta*; **C**, *I. yingjiangensis*; **D**, *I. soulieana*; **E**, *I. mengtseana*; **F**, *I. delavayi*.

Phylogenetic studies may offer independent test on the evolution of the basic chromosome numbers. Balsaminaceae show an interesting distributional pattern. While *Hydrocera* is an Indo-Malesian genus, *Impatiens* basically exhibits prominent African-Malagasy/Indo-Himalayan-Southeast Asian phytogeographic connection, since its diversity centers are all located along this chain. Whereas the species in northern temperate regions probably represent recent radiations from Southeastern Asia and the adjacent Sino-Himalayan areas, it is still questionable whether the disjunctive distribution of the main diversity centers across the paleotropical regions represents ancient vicariant events resulting from the fragmentation of Gondwana, or more recent dispersals. Jones & Smith (1966) suggested that *Impatiens* originated in the Himalayan region and dispersed to other areas based on species diversity and karyological data. On the contrary, Grey-Wilson (1980b) formulated an hypothesis suggesting that Balsaminaceae originated in western Gondwana in the Paleogene ca. 50 million years ago (Ma), and subsequently spread to Southeast Asia through Madagascar and India at the time of or after the Indian plate collided with Laurasia (ca. 45 Ma). He rejected the possibility of an overland migration between Africa and India. These conclusions were based on the pronounced similarity of species among Africa, Madagascar, and southern India, as well as on the assumed sister relationship between Balsaminaceae and Tropaeolaceae. The distributional patterns of extant Balsaminaceae, however, suggest that the diversification of the family probably started in South or Southeast Asia instead of Africa, as *Hydrocera* occurs only in these regions. Assuming a Southeast Asian origin of *Impatiens* and a subsequent radiation to Africa and Madagascar through India can equally result in the pronounced similarity of species among India, Africa, and Madagascar that was correctly recognized by Grey-Wilson (1980b). Obviously, the competing biogeographic hypotheses can be tested by using the phylogenies of the species from the main diversification centers.

Despite the conspicuous diversity and the interesting distributional patterns shown by Balsaminaceae, few molecular phylogenetic studies have been made on this family. Several studies aimed at addressing phylogenetic relationships at the family level or above have included limited representative species (not more than five) of Balsaminaceae. These studies have confirmed Balsaminaceae as a member of the order Ericales at the base of the asterids (Morton & al., 1996, 1997; Soltis & al., 2000; Albach & al., 2001; Anderberg & al., 2002; Bremer & al., 2002; Geuten & al., 2004),

instead of the order Geraniales of former Rosidae as traditionally considered (Cronquist, 1981). Recently, 25 species from the eastern Himalayan area have been subjected to a molecular phylogenetic study using chloroplast *rbcL* and *trnLF* sequences (Fujihashi & al., 2002). Besides its inappropriate analysis (e.g., too distant outgroups from rosids were used), this study is sketchy due to its limited sampling, and the resulted phylogenies are incapable of addressing the questions about overall phylogeny and biogeography of the whole family as mentioned above. Global phylogenetic relationships within the family remain unknown, and the more general problems such as diversification patterns of floral and vegetative morphology and historical biogeography of the family need to be addressed through more comprehensive global studies of the entire family. Here we conducted a comprehensive molecular phylogenetic study on Balsaminaceae by using nucleotide sequence data of internal transcribed spacer regions of nuclear ribosomal DNA. Through the molecular phylogenies we intended to further examine the morphological and karyological evolution, as well as the historical biogeography, of the family.

Materials and methods

INGROUP SAMPLING AND OUTGROUP CHOICE.— We sampled both genera of Balsaminaceae, *Hydrocera* and *Impatiens*. As far as possible, samples were selected to maximize representation of the whole distribution range and the diversity of *Impatiens*. Representatives from all the hot-spots of species diversity of the genus were sampled. Representatives of the closely related families, Marcgraviaceae and Tetrameristaceae sensu APG (2003), were sampled as outgroups, following the results revealed by the recent molecular phylogenetic studies on large scope (Soltis & al., 2000; Albach & al., 2001; Anderberg & al., 2002; Geuten & al., 2004). The species, origin of samples, voucher information, and GenBank sequence accessions are listed in the Appendix (see online version of *Taxon*). Our data matrix includes 117 taxa in total, of which five taxa of Tetrameristaceae and Marcgraviaceae were used as outgroups. A reduced analysis limited to Balsaminaceae (112 taxa in total) was also conducted, to reveal possible consequences caused by high divergence among the three families. In the latter case, *Hydrocera triflora* was considered as an outgroup.

DNA EXTRACTION, PCR AMPLIFICATION AND SEQUENCING.— Total DNA was extracted from fresh, silica-gel dried, or herbarium leaves with the CTAB method of Doyle & Doyle (1987) or the DNeasy Plant Mini Kit (QIAGEN AG, Basel). The ITS fragment was amplified via standard PCR in 25 µl reaction volume as described in Yuan & al. (2003). Successfully amplified DNA fragments were purified prior to sequencing using the QIAquick™ PCR purification kit (QIAGEN AG, Basel) following the manufacturer's protocol. Cycle sequencing reactions were performed using the dye-terminator chemistry as implemented in the ABI PRISM® BigDye™ Terminator Cycle Sequencing Ready Reaction Kit (Applied Biosystems) in a Biometra thermal cycler. The sequencing products were cleaned using the Ethanol/Sodium Acetate precipitation method and then analyzed on an ABI310 automated sequencer (Applied Biosystems). Automation-generated base-calls were edited manually against the electropherograms using the software Sequence Navigator (Applied Biosystems, Foster City, U.S.A.). Alternatively, some sequences were obtained via the methods described in Geuten & al. (2004).

SEQUENCE ALIGNMENT.— The obtained ITS sequences were initially aligned with Clustal X applying the default parameters (Thompson & al., 1997) and then manually adjusted for indels otherwise not properly recognized by Clustal. Careful manual adjustment was necessary, and three regions that seem to correspond to loops in secondary rRNA structure (Denduangboripant & Cronk, 2001) involve high alignment ambiguity. These regions (103 sites in the aligned data matrix) were then excluded from subsequent phylogenetic analyses. The gaps of aligned ITS sequences were considered as missing data.

MAXIMUM PARSIMONY (MP) ANALYSIS.— For MP analysis, the dataset was analyzed with heuristic searches by using PAUP* v4.0b10 (Swofford, 2000). Characters were equally weighted and unordered. Branch collapse option was set to collapse if minimum length was zero. Heuristic searches were conducted in three steps. First search was made to obtain an empirical tree length. Subsequently, heuristic searches were conducted for 1000 replicates of random addition of sequences, with TBR branch swapping, ACCTRAN, MULTREES option on, STEEPEST DESCENT option off, and from each replicate a maximum of 100 trees saved. Finally, a TBR branch swapping was conducted on all the best trees found in the previous step to save a maximum of 100,000 trees. The optimal trees kept by this

swapping were then filtered out and a consensus was calculated. Relative clade support was evaluated by bootstrap analyses (Felsenstein, 1985). Bootstrap values were calculated by using 500 replicates of heuristic searches, with random sequence addition, TBR branch swapping, MULTREES options on, the STEEPEST DESCENT option off, and a maximum of 1000 trees saved for each replicate.

NEIGHBOR-JOINING (NJ) ANALYSIS.— As a comparison to MP analysis, a distance analysis applying NJ optimality criteria (Saitou & Nei, 1987) was also conducted on both complete and reduced data matrices by using PAUP* v4.0b10 (Swofford, 2000). The NJ analyses applied maximum likelihood distance estimates based on the model and parameters suggested by Modeltest (3.06) using an arbitrarily chosen MP tree and the Akaike information criterion (Akaike, 1974; Posada & Crandall, 1998). Bootstrap values were obtained from 1000 replicate NJ analyses.

CHARACTER-STATE OPTIMIZATION AND BIOGEOGRAPHIC ANALYSES.— Selected characters, such as presence of flower spur, shape of fruit, and the basic chromosomal numbers, have been considered as unordered binary or multi-state characters and were optimized onto the molecular phylogeny to examine their evolution by using MacClade version 3.08 (Maddison & Maddison, 1992). The geographic distribution was also examined in the same way to trace the historical biogeography of Balsaminaceae. The NJ tree based on the reduced data set was used for the tracing. Arbitrarily chosen MP trees were also compared for the tracing. Chromosomal data were based on Song & al. (2003), and for species that have no chromosome number report the basic number was considered as missing. Seven areas of endemism

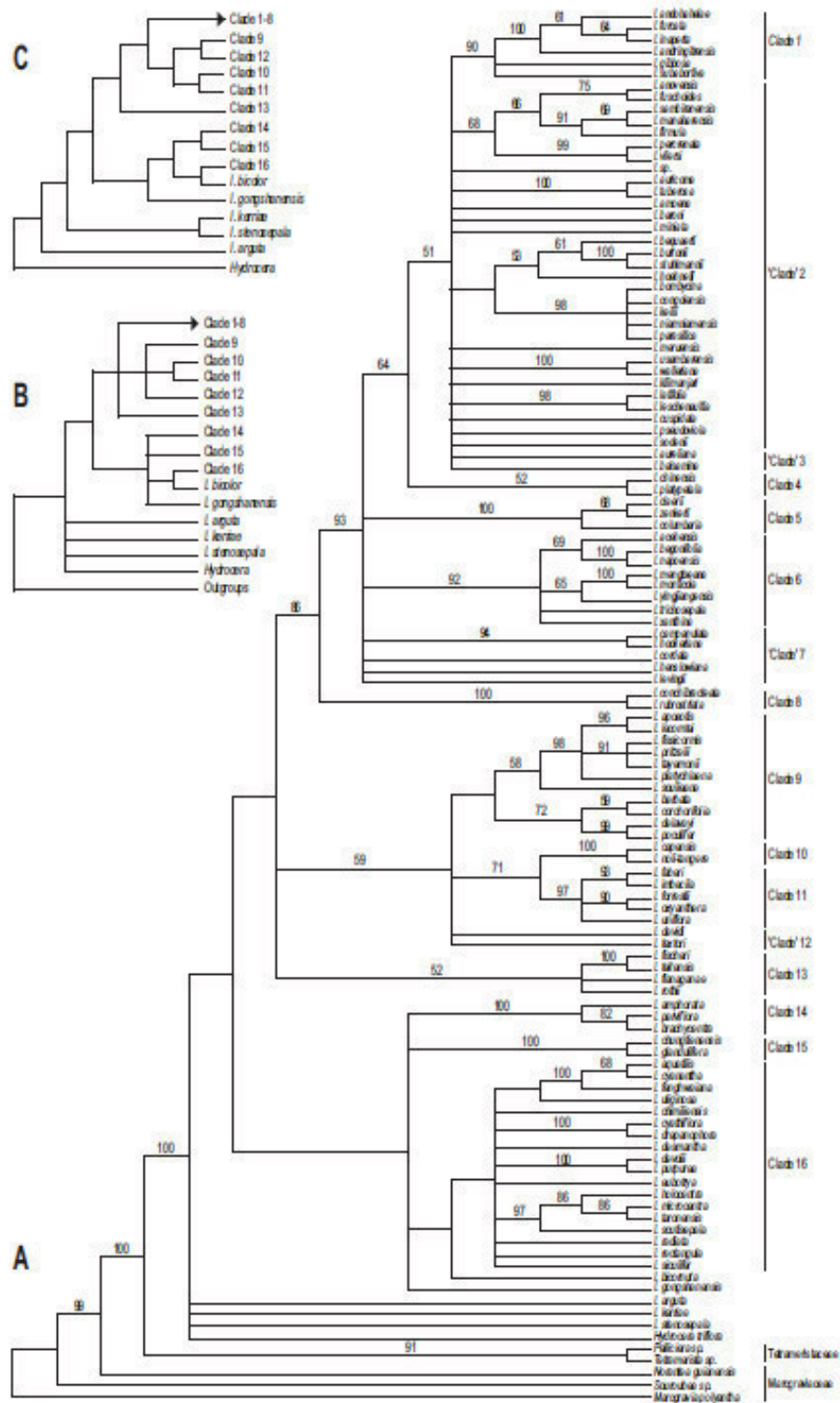


FIGURE. 2. Parsimony analyses. **A**, the strict consensus of the most parsimonious trees retained from MP analyses on the complete ITS data set (length = 2928, CI = 0.34 including autapomorphies, CI = 0.30 excluding autapomorphies, RI = 0.66). Numbers above the branches are bootstrap values supporting the corresponding branch when greater than 50%. **B**, a simplified dendrogram of the strict consensus shown in A. **C**, a simplified dendrogram of the strict consensus of the most parsimonious trees retained from MP analyses on the reduced ITS dataset where the divergent outgroups were removed.

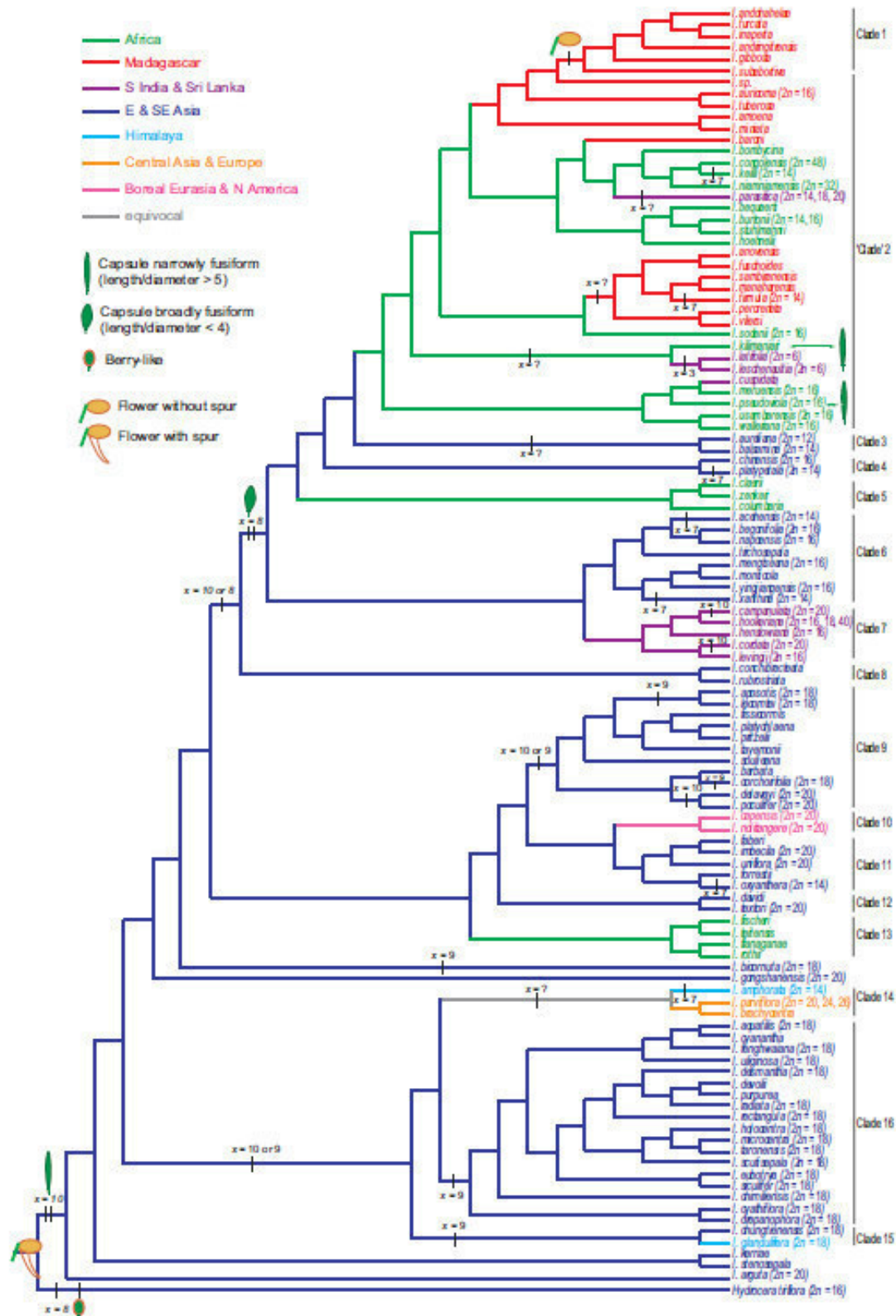


FIGURE. 4. Parsimonious optimization of the distribution centers of endemism, basic chromosome numbers, and selected morphological characters onto the NJ tree generated from the reduced ITS dataset. Vertical bars indicate positions of character state changes. Chromosome numbers when available are shown after the species names.

were designated on the basis of species diversity: (1) Africa, (2) Madagascar, (3) South India and Sri Lanka, (4) the Himalayas, (5) East and Southeast Asia, comprising Japan, Taiwan and the other Southeast Asian islands, the mainland Southeast Asian countries, and the area of the southern and southwestern China, (6) Central Asia and Europe, and (7) boreal Eurasia and North America. Wide distributions over more than two areas of endemism were counted as polymorphisms.

Results

SEQUENCE CHARACTERISTICS.— All the sequences are newly acquired and have been submitted to GenBank (Appendix). No evidence of paralogous ITS sequences was found, because all PCR products were resolved as a single band and no double peaks were encountered in sequencing. The length of the complete unaligned ITS fragments of the ingroup taxa ranged from 579 to 655 base pairs.

The full ITS dataset including ingroup and outgroup taxa consisted of 783 characters, of which 103 (13.2%) involved alignment ambiguity and were excluded from phylogenetic analyses, 180 (23.0%) are constant, 121 (15.4%) are variable but uninformative, and 379 (48.4%) are potentially informative. This dataset resulted in pairwise maximum likelihood distance estimate ranging from 0 (*I. bombycina* vs. *I. congolensis*, *I. bombycina* vs. *I. niamniamensis*, *I. congolensis* vs. *I. niamniamensis*) to 0.840 (*I. platychlaena* vs. *Pelliciera* sp.) among all taxa, and 0 to 0.542 (*I. kerriae* vs. *Hydrocera triflora*) among the ingroup taxa. The alignments were submitted to TreeBASE and are also available from the corresponding author.

ITS PHYLOGENY.— MP analysis of the ITS dataset including all outgroup and ingroup taxa resulted in an unknown number of equally parsimonious trees (61,443 trees kept) of 2928 steps, consistency index (CI) = 0.34 including autapomorphies, CI = 0.30 excluding autapomorphies, and retention index (RI) = 0.66. The strict consensus of the optimal trees kept by heuristic searches and the bootstrap clade support (when greater than 50%) are shown in Fig. 2A. The MP strict consensus tree was moderately resolved. Despite the relative high sequence divergence, the resolution among the main lineages is poor or receives less significant support, while some lineages of closely related taxa are better resolved with strong supports. The internal branches connecting the main lineages are conspicuously shorter in comparison to the long

terminal branches, suggesting a high proportion of autapomorphic variations of the sequences. The monophyly of Balsaminaceae is highly supported (bootstrap value 100%). The genus *Hydrocera* fell in a basal polytomy with the main *Impatiens* clade and several other *Impatiens* species, viz., *I. arguta*, *I. kerriae*, and *I. stenosepala*.

We assigned numbers (clades 1 through 16) to the resolved lineages of *Impatiens* (Fig. 2A). In addition, a group of closely related non-monophyletic taxa were also referred as a clade, e.g., “clade 2”, for convenience of illustration and discussion. Noticeably, the spurless Madagascan endemic taxa were resolved as a highly supported (90%) monophyletic clade (clade 1). Together with a few species from Southeast Asia (clades 3, 4 and 6), most of the sampled African, Madagascan, and southern Indian species formed a strongly supported clade (93%), consisting of the clades 1 through 7, whereas only four African species, *I. fischeri*, *I. flanaganae*, *I. teitensis*, *I. rothii*, and the Indian *I. repens* grouped together as a weakly supported clade (52%, clade 13) that nested out of the other African species but grouped with Southeast Asian clades. The North American species, *I. capensis*, showed close affinity with the boreal temperate species, *I. nolitangere* (100%, clade 10), and both together grouped with some Southeast Asian clades (9, 11, and 12). The eastern European species, *I. parviflora*, and the central Asian species, *I. brachycentra*, grouped together with the western Himalayan species, *I. amphorata*, as a strongly supported clade (100%, clade 14), and these three species together showed affinity to some Southeast Asian and Himalayan clades (Fig. 2A).

The general-time-reversible model with invariable sites and rate heterogeneity (i.e., GTR+I+ Γ model) was suggested to best fit the ITS data based on an arbitrarily chosen MP tree (data not shown). NJ tree was reconstructed using maximum likelihood distance estimates applying the inferred model and its parameters. The topology of the neighbor-joining tree (Fig. 3A) highly resembles that of the strict consensus of the MP analyses. The monotypic genus *Hydrocera* was resolved as sister to the monophyletic *Impatiens* with moderate bootstrap support (76%). The main lineages, e.g., the clades 1 through 16 of *Impatiens*, remained almost the same as revealed by MP analyses with similar clade supports. The minor differences between NJ and MP analysis results involve different positions (Figs. 2A and 3A) of *I. bicornuta*, *I. gonshanensis*, *I. stenosepala*, clade 10 (consisting of *I. capensis* and *I. nolitangere*), and clade 15 (consisting of *I. chungtienensis* and *I. glandulifera*). However, these different resolutions did not receive significant bootstrap support in either analysis.

To determine if the relatively divergent outgroups had any potential influence on results of the phylogenetic analysis, we conducted both MP and NJ analyses on a reduced dataset that included only Balsaminaceae. The topology of the trees based on the reduced datasets strongly resembles that of trees generated from the complete datasets, as shown in the simplified dendrograms (Figs. 2C, 3C). While the main topology of the trees remained the same, the positions of *I. arguta*, *I. bicornuta*, *I. gongshanensis*, *I. kerriae*, *I. stenosepala*, and clade 12 consisting of *I. davidi* and *I. textori* were slightly altered. However, none of these different resolutions receives significant support.

CHARACTER-STATE MAPPING.— Two morphological characters, occurrence of flower spur and shape of fruit, and the basic chromosome numbers were optimized onto the ITS tree generated from NJ analyses on the reduced dataset (Fig. 4). Parsimonious optimization suggests that linear-fusiform capsule, spurred flower, and basic chromosome number $x = 10$ represent the plesiomorphic states within *Impatiens*. Despite that the relationships among basal clades of the NJ tree were poorly supported, it is noteworthy that the important characterstate changes suggested by the optimization correspond well to a few strongly supported nodes. For example, the broad-fusiform fruit was suggested as having evolved from linear-fusiform only once, which corresponds to the transition of basic chromosome number from $x = 10$ to $x = 8$, and the node of these transitions were highly supported by both MP and NJ analyses (bootstrap value 85–93%). The spurless flower was also suggested as a unique synapomorphic character-state for the Madagascan endemic clade 1 which received strong MP and NJ supports (90–96%). Optimization using arbitrarily chosen MP trees did not reveal any deviation of the above conclusions.

BIOGEOGRAPHIC ANALYSIS.— Fitch parsimony optimization of centers of endemism as a multi-state character infers Southeast Asia as the ancestral area for extant Balsaminaceae (Fig. 4). *Impatiens* species in other areas are inferred to have dispersed from Southeast Asia. Two to three dispersals from Southeast Asia to Africa are suggested: one dispersal resulted in clade 13 consisting of *I. fischeri*, *I. teitensis*, etc., and another one or two dispersals involved divergence of other African species. The Madagascan *Impatiens* are inferred as having dispersed from Africa, whereas the *Impatiens* species from southern India and Sri Lanka seem to have had two origins: some were dispersed from Southeast Asia (clade 7), and others from Africa (within the

assemblage “clade” 2). The central Asian and European *Impatiens* were dispersed from Southeast Asia via the Himalayas, whereas the boreal Eurasian and North American *Impatiens* are resolved as being dispersed from Southeast Asia. Optimization using the NJ tree or arbitrarily chosen MP trees revealed the same pattern.

Discussion

PHYLOGENY OF BALSAMINACEAE.— Recent studies, using cpDNA markers to address phylogenetic relationships at family level or above, have revealed the monophyly of Balsaminaceae and its inclusion in the order Ericales of the basal asterids (Morton & al., 1996, 1997; Soltis & al., 2000; Albach & al., 2001; Anderberg & al., 2002; Bremer & al., 2002; Geuten & al., 2004). Our present results based on nuclear ITS data are highly in agreement with these studies in concluding the monophyly of Balsaminaceae (bootstrap value 100% in both MP and NJ analyses).

At first glance, *Hydrocera triflora*, the only species of the genus, looks very much like an *Impatiens* species, in particular *I. balsamina* (Grey-Wilson, 1980d). Due to its unique floral (five free petals) and fruit (indehiscent and berry-like) morphology, *Hydrocera* is almost always considered as a genus distinct from *Impatiens* in modern botanical publications (e.g., Grey-Wilson, 1985, 1980d; Chen, 2001), despite that in some classic works such as Linnaeus' *Species Plantarum* it was considered as a species of *Impatiens*. Nevertheless, its phylogenetic relationships with the different lineages of *Impatiens* have never been explicitly studied. Since the floral morphology of *Impatiens* is highly diversified, the unique floral morphology of *H. triflora* does not necessarily ensure it as a distinct genus rather than a specialized ingroup of *Impatiens*. Our present results, however, allow the recognition of *Hydrocera* as a distinct genus sister to *Impatiens*. In the strict consensus of the MP trees, *H. triflora* falls into a basal polytomy consisting of *I. arguta*, *I. kerriae*, and *I. stenosepala*, and the clade comprising all the other *Impatiens* species (Fig. 2A), but in the NJ tree all *Impatiens* species are shown to be monophyletic with moderate support (76%) and sister to *Hydrocera* (Fig. 3A).

IMPLICATIONS OF THE MOLECULAR PHYLOGENIES ON INFRAGENERIC CLASSIFICATION OF IMPATIENS.— *Impatiens* is taxonomically considered as one of the most difficult genera of angiosperms, primarily due to the delicate yet

hypervariable structure and fragile nature of its flowers that are extremely difficult to examine in dried specimens if prepared conventionally (Grey-Wilson, 1980b, c). There is so far no comprehensive infrageneric classification available for the genus. The only global attempt was the early work of Warburg & Reiche (1895), in which 14 sections were recognized. However, this classification was considered neither natural nor practical (Grey-Wilson, 1980b), and was thus not followed by later authors. The only modern general treatment for the genus is the important revision of the African taxa by Grey-Wilson (1980b), which recognized six informal infrageneric groups for the African species for practical diagnosis only. Perrier de la Bathie (1934) proposed three sections for the Madagascan *Impatiens* based on floral morphology: sect. *Preimpatiens* (= sect. *Impatiens*) (flowers with conspicuous spur), sect. *Trimorphopetalum* (flowers without spur, anthers dehiscent apically), and the monotypic sect. *Impatientella* (flowers without spur, anthers dehiscent laterally), the latter two being endemic to Madagascar. Fischer & Rahelivololona (2002) recently elevated sect. *Trimorphopetalum* to subgeneric level. The monotypic sect. *Impatientella* contains only the spurless and entirely cleistogamous species, *I. inaperta*. Our results support monophyly of the Madagascan endemic spurless species (Figs 2A and 3A: clade 1), and show that the cleistogamous *I. inaperta* is closely related to *I. furcata* of sect. *Trimorphopetalum* (or subgen. *Sensu* Fischer & Rahelivololona, 2002). However, our molecular phylogenies show that this monophyletic clade is the most derived within *Impatiens*, and recognizing it as a distinct taxonomic identity makes the rest of the genus (taxonomically defined as section or subgenus *Impatiens*) paraphyletic. Apart from the highly supported spurless clade, molecular phylogenies also revealed a highly supported clade comprising clades 1 through 7 as shown in Figs. 2A and 3A. This clade is supported by several non-molecular characters as well, e.g., broad fusiform fruit and basic chromosome number principally $x = 8$, which have taxonomic importance.

Despite recognition of the clades mentioned above and several strongly supported small lineages (e.g., clades 5–6, 8, 10–11, 13–15), our molecular phylogenies do not resolve relationships among the lineages with confidence, and therefore offer limited taxonomic implications. Nevertheless, despite the low bootstrap support (52–64%), the African clade 13 (Figs. 2A and 3A), which nested apart from other African species, corresponds well to a species aggregate recognized by Grey-Wilson (1980b). Further

phylogenetic studies, e.g., with additional molecular data from cpDNA or single-copy nuclear DNA, may improve the resolution and clade supports of the molecular phylogenies.

As pointed out by Grey-Wilson (1980b), clusters or aggregates of species are more or less clearly defined by gross morphology and geographic distribution, but the relationships among these distinguishable aggregates of species cannot be defined with confidence. Molecular phylogenies seem to show a similar pattern: small clades are recognized with strong support, but relationships among those clades are unresolved or resolved without significant support. The wide distribution of the genus, and the high morphological diversity associated with localized endemism (linked to distinguishable aggregates of species) suggest that active diversification and rapid radiation have been prevalent in the evolution of *Impatiens*. Molecular data reveal evidence of such rapid evolution, by the relatively high sequence divergence, the noticeable difficulties in sequence alignment of certain regions, the high proportion of autapomorphic variations, and the conspicuous short internal branches connecting the main branches.

BIOGEOGRAPHIC IMPLICATIONS OF THE MOLECULAR PHYLOGENY.—Balsaminaceae show an interesting mainly paleotropical distributional pattern, with several diversity hotspots disjunctively located in tropical Africa, Madagascar, southern India and Sri Lanka, the eastern Himalayas, and Southeast Asia. While Jones & Smith (1966) suggested that *Impatiens* originated in the Himalayan region, Grey-Wilson (1980b) formulated an hypothesis suggesting that Balsaminaceae originated in western Gondwana and spread to Southeast Asia through Madagascar and India. From Southeast Asia and the adjacent Sino-Himalayan area, *Impatiens* diversified secondarily into two lineages: one lineage radiating to the temperate Eurasian areas and North America, and the other radiating to tropical and subtropical areas of Southeast Asian islands. Meanwhile, Grey-Wilson (1980b) rejected the possibility of an overland migration between Africa and India.

Parsimonious optimization of the centers of endemism (Africa, Madagascar, southern India and Sri Lanka, the Himalayas, Central Asia and Europe, Southeast Asia, and Boreal Eurasia and North America) onto the molecular phylogenies reveal Southeast Asia as the ancestral area of extant *Impatiens* (Fig. 4). The boreal species *I. nolitangere* and North American species *I. capensis* are suggested as having

dispersed from Southeast Asia. The central Asian and European species, such as *I. brachycentra* and *I. parviflora*, may have been dispersed from Southeast Asia through the Himalayas. Africa seems to have been colonized at least twice from Southeast Asia: once by a colonizer with elongated linear-fusiform fruits that led to the small clade 13, and at another time by a colonizer with broad fusiform fruits that gave rise to the others (Fig. 4). As our sampling of Indian species is still insufficient, it is not known if the colonization of Africa might have been achieved via India as stepping-stones. Nevertheless, as far as the species we sampled from India and Sri Lanka are concerned, some species (such as those of clade 7) showed Southeast Asian connection and some showed African connections (e.g., *I. cuspidata*, *I. latifolia*, *I. leschensultia*, and *I. parasitica*). Madagascan *Impatiens* shows clearly an African origin.

The historical biogeography of *Impatiens* suggested by molecular phylogenies is, in fact, in concordance with the conspicuous species similarity among Africa, Madagascar, southern India, and Southeast Asia noticed by Grey-Wilson (1980b). This similarity is shown mainly by the species with broad fusiform fruits and the basic chromosome number of $x = 8$ (clades 1 through 7 in Fig. 4). However, our present results suggest a Southeast Asian origin of *Impatiens* and dispersals to Africa and Madagascar, whereas on the contrary, Grey-Wilson (1980b) suggested an opposite direction of dispersal from an assumed west Gondwanan (African) origin. It is worth mentioning that the present biogeographic pattern largely depends on a few nodes with strong bootstrap supports. These include the node comprising all Balsaminaceae (bootstrap 100%), the node comprising clades 1 through 8 (bootstrap 82–86%), and the node comprising clades 1 through 7 (bootstrap 85–97%) (Figs. 2A and 3A).

MORPHOLOGICAL AND CHROMOSOMAL EVOLUTION.— The fascinating floral diversity of *Impatiens* makes it an ideal subject for studying floral evolution. The greatest variation of floral morphology is seen in the lower sepal, its spur, and the lateral united petals, which seem related to different pollinators and breeding systems. Grey-Wilson (1980b) has proposed hypothetic schemes for floral evolution, e.g., loss of the upper pair of lateral sepals resulted in the evolution of a flower type with three sepals from flower types with five sepals, elaboration of the lower sepal into a nectary-tipped spur of various shapes and colors, fusion of the two lateral petals into a united pair, with reduction in size of the upper petal, and elaboration of the lower petal. Our

results do not yet offer comprehensive inferences on floral evolution, due to poor resolution and weak support for many internal branches. Our ongoing studies seek more insights on these questions by acquiring more molecular data from different loci. Nevertheless, our phylogenies do bring insight on evolution of some floral traits. For example, the loss of a floral spur seen in some Madagascan endemics appears to have occurred only once (Fig. 4). Floral characters related to cleistogamy shown by *I. inaperta* have been used to diagnose section *Impatientella* (Perrier de la Bathie, 1934). Recent studies show that facultative cleistogamy is also regularly observed in the North American *I. capensis* (Antlfinger, 1986; Paoletti & Holsinger, 1999; Lu, 2002). In our molecular trees, these two species are far isolated from each other, which suggests that the same cleistogamous breeding system originated independently.

The characters of fruits have been considered of phylogenetic importance in Balsaminaceae, particularly the shape of capsules in *Impatiens* (Grey-Wilson, 1980b). When traced with our molecular phylogenies, the elongated linear or narrowly fusiform fruit was shown to be plesiomorphic, and the globose or broadly fusiform fruit was shown to be derived from the linear type, while a few reversals also occurred (Fig. 4). The elongated linear type of fruit occurs mostly in Southeast Asian, Himalayan, and North-temperate species, whereas the broadly fusiform type of fruit is more characteristic of African, Madagascan and southern Indian species.

Impatiens shows a wide range of chromosome number variation, but the most frequent numbers are $2n = 14, 16, 18,$ and 20 (Song & al., 2003). Thus the major part of species show the basic chromosome numbers $x = 7, 8, 9,$ and 10 . This series of basic chromosome numbers suggests a typical dysploid evolutionary relationship among them. Different hypotheses have been proposed to interpret the evolution of the basic numbers. Jones & Smith (1966) and Akiyama & al. (1992b) suggested $x = 7$ to be the ancestral type, from which the other numbers were derived by ascending dysploidy, whereas Rao & al. (1986) suggested evolution of $x = 7, 9$ and 10 from the basic number $x = 8$ through both descending and ascending dysploidy. Interestingly, preliminary optimization of the incomplete chromosomal data (data are missing for most Madagascan species) onto the molecular phylogenies reveals $x = 10$ to be the most likely ancestral base number in *Impatiens*, with other base numbers being derived mainly through descending dysploidy (Fig. 4). Consistent with the transition of elongated linear to broadly fusiform fruits, the optimization suggested a transition of

base chromosome number from $x = 10$ to $x = 8$ for the same clade. Considering geographic distribution, there was probably a predominantly descending dysploidy following dispersal of the clade with broadly fusiform fruits to India, Africa, and Madagascar. As an extreme case, the lowest basic chromosome number, $x = 3$, was found in two Indian species, *I. latifolia* and *I. leschenaultii*. Interestingly, these two species are confirmed to have African affinity.

Our present paper has presented the first detailed phylogenetic study on Balsaminaceae with a worldwide sampling, and it has given insight on the evolution and biogeography of the family. Despite poor resolution or weak support among main lineages of *Impatiens*, we have established evolutionary patterns of some important morphological traits, basic chromosome numbers, and geographical origins. The evolutionary history of *Impatiens* apparently involved rapid diversification and extensive range expansion particularly in the Old World tropics and subtropics.

Acknowledgements

We are very much indebted to the following persons or institutes for supplying us plant material or help in plant collections: Dr. Martin Callmander, Dr. Philippe Chassot, Andrien Favre, Dr. Xue-Jun Ge, Dr. Jason Grant, Dr. Gang Hao, Dr. Eisuke Hayasaka, Dr. Zhen-Yu Jiang, Ray Morgan, Odile Phaehler, Michael Ronikier, Magali Schnell, Dr. Lena Struwe, Mali Wang, the National Botanic Garden of Belgium, Nationaal Herbarium Nederland, Leiden, Berlin-Dahlem Botanic Garden, Royal Botanical Garden, Edinburgh, and Royal Botanic Gardens, Kew, and the staff in Neuchâtel Botanical Garden. We thank also Dr. Dan Potter for sharing an unpublished sequence. The study was financially supported by the Swiss National Science Foundation (FN 3100AO-102165), and the Hundreds Talents Project of Chinese Academy of Sciences granted to Y.-M. Yuan, and by research grants of the K. U. Leuven OT/01/25 and the Fund for Scientific Research - Flanders (Belgium; G.0104.01; 1.5.069.02; 1.5.061.03) granted to E. Smets. Thanks to Anja Vandepierre (K. U. Leuven) for technical assistance, Dr. Jason Grant for critical reading of the manuscript, and two anonymous reviewers for critical comments.

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

Appendix. Origin of plant material, voucher, and GenBank accession number of the species sampled.

Taxon	Origin	Voucher	GenBank acc.	Clade
<i>I. acehensis</i> C. Grey-Wilson	Sumatra, Indonesia	<i>Favre</i> s.n. (NEU)	AY348739	Clade 6
<i>I. amoena</i> H. Perrier	Antsatrotro, Madagascar	<i>Wohlhauser, Callmander & Rakotomamonjy</i> SW 61422 (PBZT)	AY348795	“Clade” 2
<i>I. amphorata</i> Edgew.	W Himalaya	<i>B. de Retz</i> 5566 (BR)	AY348740	Clade14
<i>I. andohahelae</i> Eb. Fisch. & Rahelivololona	Andohahela, Madagascar	<i>Rahelivololona, Druard, Jerome & Fiadana And6</i> (PBZT)	AY348741	Clade 1
<i>I. andringitrensis</i> H. Perrier	Ambatofitorahana, Madagascar	<i>Rahelivololona Ambatofitorahana-2</i> (PBZT)	AY348742	Clade 1
<i>I. anovenssis</i> H. Perrier	Ambanizana, Madagascar	<i>Rahelivololona, Saola & Scenario Ambanizana-11</i> (PBZT)	AY348743	“Clade” 2
<i>I. aposotis</i> Hook. f.	Sichuan, China	<i>Yuan CN2k2-159</i> (NEU)	AY348744	Clade 9
<i>I. aquatilis</i> Hook. f.	Yunnan, China	<i>Song CNY017</i> (NEU)	AY348745	Clade16
<i>I. arguta</i> Hook. f. & Thoms.	Yunnan, China	<i>Yuan CN2k-74</i> (NEU)	AY348746	
<i>I. aureliana</i> Hook. f.	Yunnan, China	<i>Yuan CN2k1-56</i> (NEU)	AY348747	Clade 3

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. auricoma</i> Baill.	Comores origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE1</i> (NEU)	AY348748	“Clade” 2
<i>I. balsamina</i> L.	cult. Guanzhou, China	<i>Yuan CN2k1-06</i> (NEU)	AY348749	Clade 3
<i>I. barbata</i> Comber	Yunnan, China	<i>Yuan CN2k2-178</i> (NEU)	AY348750	Clade 9
<i>I. baroni</i> Baker	Ranomafana, Madagascar	<i>Rahelivololona,</i> <i>Jacky & Remi</i> <i>RNM-4 (PBZT)</i>	AY348751	“Clade” 2
<i>I. begoniifolia</i> S. Akiyama & H. Ohba	Yunnan, China	<i>Yuan CN2k1-51</i> (NEU)	AY348752	Clade 6
<i>I. bequaerti</i> De Wild.	Congo origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE2</i> (NEU)	AY348753	“Clade” 2
<i>I. bicornuta</i> Wall.	Yunnan, China	<i>Yuan CN2k-55</i> (NEU)	AY348754	
<i>I. bombycina</i> W. Lobin & E. Fischer	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE3</i> (NEU)	AY348755	“Clade” 2
<i>I. brachycentra</i> Kar. & Kir.	central Asia	<i>Burt 3834 (E)</i>	AY348756	Clade14
<i>I. burtonii</i> Hook. f.	Kenya origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE4</i> (NEU)	AY348757	“Clade” 2
<i>I. campanulata</i> Wight	South India origin, cult. by Ray Morgan, UK	<i>Ray Morgan s. n.</i> (NEU)	AY348758	Clade17
<i>I. capensis</i> Meerb.	Quebec, Canada	<i>Küpfer s. n. (NEU)</i>	AY348759	Clade10

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. chimiliensis</i> Comber	Yunnan, China	<i>Yuan CN2k-51</i> (NEU)	AY348760	Clade16
<i>I. chinensis</i> L.	Yunnan, China	<i>Yuan CN2k1-49</i> (NEU)	AY348761	Clade 4
<i>I. chungtienensis</i> Y. L. Chen	Yunnan, China	<i>Yuan CN2k2-204</i> (NEU)	AY348762	Clade15
<i>I. claeri</i> N. Halle	Gabon origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE5</i> (NEU)	AY348763	Clade 5
<i>I. columbaria</i> J. J. Bos	Gabon origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE6</i> (NEU)	AY348764	Clade 5
<i>I. conchibracteata</i> Y. L. Chen & Y. Q. Lu	Sichuan, China	<i>Hao 427</i> (NEU)	AY348765	Clade 8
<i>I. congolensis</i> G. M. Schulze & R. Wilczek	Congo origin, Africa, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE7</i> (NEU)	AY348766	“Clade” 2
<i>I. corchorifolia</i> Franch.	Yunnan, China	<i>Chassot & Yuan</i> <i>99-173</i> (NEU)	AY348767	Clade 9
<i>I. cordata</i> Wight	South India origin, cult. by Ray Morgan, UK	<i>Ray Morgan s. n.</i> (NEU)	AY348768	Clade 7
<i>I. cuspidata</i> Wight & Arn.	South India origin, cult. by Ray Morgan, UK	<i>Ray Morgan s. n.</i> (NEU)	AY348769	“Clade” 2
<i>I. cyanantha</i> Hook. f.	Yunnan, China	<i>Yuan CN2k1-84</i> (NEU)	AY348770	Clade16
<i>I. cyathiflora</i> Hook. f.	Yunnan, China	<i>Chassot & Yuan</i> <i>99-29</i> (NEU)	AY348771	Clade16

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. davidi</i> Franch.	Fujian, China	<i>Yuan CN2k-09</i> (NEU)	AY348772	Clade12
<i>I. delavayi</i> Franch.	Yunnan, China	<i>Chassot & Yuan</i> <i>99-154</i> (NEU)	AY348773	Clade 9
<i>I. desmantha</i> Hook. f.	Yunnan, China	<i>Yuan CN2k2-30</i> (NEU)	AY348774	Clade16
<i>I. devolii</i> T. C. Huang	Taiwan, China	<i>Jiang s. n.</i>	AY348775	Clade16
<i>I. drepanophora</i> Hook. f.	Yunnan, China	<i>Yuan CN2k1-41</i> (NEU)	AY348776	Clade16
<i>I. eubotrya</i> Miq.	Sumatra, Indonesia	<i>Favre s.n.</i> (NEU)	AY348777	Clade16
<i>I. faberi</i> Hook. f.	Sichuan, China	<i>Song S007</i> (NEU)	AY348778	Clade11
<i>I. fenghwaiana</i> Y. L. Chen	Guangxi, China	<i>Yuan CN2k1-78</i> (NEU)	AY348779	Clade16
<i>I. firmula</i> Baker	Ranomafana, Madagascar	<i>Rahelivololona,</i> <i>Jacky & Remi</i> <i>RNM 4</i> (PBZT)	AY348780	“Clade” 2
<i>I. fischeri</i> Warb.	Kenya <i>Odile</i>	<i>Phaehler & Magali</i> <i>Schnell I-01</i> (NEU)	AY348781	Clade13
<i>I. fissicornis</i> Maxim.	Shaanxi, China	<i>Wang SH-003</i> (NEU)	AY348782	Clade 9
<i>I. flanaganae</i> Hemsl.	Africa	RBG Edinburgh 19860179 (E)	AY348783	Clade13
<i>I. forrestii</i> Hook. f. ex W. W. Smith	Yunnan, China	<i>Yuan CN2k-79</i> (NEU)	AY348784	Clade11
<i>I. fuchsioides</i> H. Perrier	Tsaratanana, Madagascar	<i>Rahelivololona</i> <i>ROR 395</i> (PBZT)	AY348785	“Clade” 2

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. furcata</i> H.Perrier	African origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE8</i> (NEU)	AY348786	Clade 1
<i>I. gibbosa</i> H. Perrier	Tsaratanana, Madagascar	<i>Rahelivololona,</i> <i>Wohlhauser &</i> <i>Callamander T11</i> (PBZT)	AY348787	Clade 1
<i>I. glandulifera</i> Arn.	Western Himalaya origin, cult. Bot. Gard. Neuchâtel	<i>Yuan JBE1</i> (NEU)	AY348788	Clade15
<i>I. gongshanensis</i> Y. L. Chen	Yunnan, China	<i>Yuan CN2k1-27</i> (NEU)	AY348789	
<i>I. henslowiana</i> Arn.	Sri Lanka origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE10</i> (NEU)	AY348790	Clade 7
<i>I. hoehnelii</i> T. C. E. Fries	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE9</i> (NEU)	AY348792	"Clade" 2
<i>I. holocentra</i> Hand.-Mazz.	Yunnan, China	<i>Yuan CN2k-54</i> (NEU)	AY348793	Clade16
<i>I. hookeriana</i> Arn.	Sri Lanka origin, cult. Bot. Gard. UC, Davis	<i>Bot. Gard. UC</i> <i>Davis 75.0276</i>	AY348794	Clade 7
<i>I. imbecilla</i> Hook. f.	Sichuan, China	<i>Hao 426</i> (NEU)	AY348796	Clade11
<i>I. inaperta</i> H.Perrier	Madagascar origin, cult. Bot. Gard. Neuchâtel	<i>Yuan JBE2</i> (NEU)	AY348797	Clade 1
<i>I. keilii</i> Gilg.	African origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE11</i> (NEU)	AY348798	"Clade" 2

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. kerriae</i> Craib	Qingmai, Thailand	<i>Chassot 99-238</i> (NEU)	AY348799	
<i>I. kilimanjari</i> Oliver	Africa	<i>JMG 94613</i> (BR)	AY348800	“Clade” 2
<i>I. latifolia</i> L.	Inida origin, cult. by Ray Morgen, U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348801	“Clade” 2
<i>I. lecomtei</i> Hook. f.	Yunnan, China	<i>Yuan CN2k2-202</i> (NEU)	AY348802	Clade 9
<i>I. leschenaultii</i> Wall.	India Origin, cult. by Ray Morgen, U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348803	“Clade” 2
<i>I. levingei</i> Gamble ex Hook. f.	India Origin, cult. U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348804	Clade 7
<i>I. manaharensis</i> Baill.	Madagascar	<i>Wohlhauser & al.</i> <i>WCL 1</i> (PBZT)	AY348805	“Clade” 2
<i>I. mengtseana</i> Hook. f.	Yunnan, China	<i>Yuan CN2k1-38</i> (NEU) AY348806 Clade 6	AY348806	Clade 6
<i>I. meruensis</i> Gilg.	Tanzania origin, cult. by Ray Morgen, U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348807	“Clade” 2
<i>I. microcentra</i> Hand.-Mazz.	Yunnan, China	<i>Yuan CN2k-50</i> (NEU)	AY348808	Clade16
<i>I. miniata</i> Grey- Wilson	Tsaratanana, Madagascar	<i>Rahelivololona,</i> <i>Wohlhauser &</i> <i>Callmander T1</i> (PBZT)	AY348809	“Clade” 2
<i>I. monticola</i> Hook. f.	Sichuan, China	<i>Hao 425</i> (NEU)	AY348810	Clade 6

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. napoensis</i> Y. L. Chen	Yunnan, China	<i>Yuan CN2k1-61</i> (NEU)	AY348811	Clade 6
<i>I. niamniamensis</i> Gilg.	Africa origin, cult. Bot. Gard. Koblenz Univ	<i>Fischer NE13</i> (NEU)	AY348812	“Clade” 2
<i>I. noli-tangere</i> L.	Jilin, China	<i>Yuan CN2k1-86</i> (NEU)	AY348813	Clade10
<i>I. oxyanthera</i> Hook. f.	Sichuan, China	<i>Song S008</i> (NEU)	AY348814	Clade11
<i>I. parasitica</i> Bedd.	India origin, cult. by Ray Morgen, U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348815	“Clade” 2
<i>I. parviflora</i> DC:	Poland	<i>Ronikier s.n.</i>	AY348816	Clade14
<i>I. percrenata</i> H. Perrier	Andohahela, Madagascar	<i>Rahelivololona,</i> <i>Druard, Jerome &</i> <i>Fiadana And 3</i> (PBZT)	AY348817	“Clade” 2
<i>I. platychlaena</i> Hook.f.	Sichuan, China	<i>Song S009</i> (NEU)	AY348818	Clade 9
<i>I. platypetala</i> Lindl.	Bali, Indonesia origin, cult. by Ray Morgen, U.K.	<i>Ray Morgan s.n.</i> (NEU)	AY348819	Clade 4
<i>I. poculifer</i> Hook. f.	Yunnan, China	<i>Yuan CN2k2-209</i> (NEU)	AY348820	Clade 9
<i>I. pritzelii</i> Hook.f.	Sichuan, China	<i>Song jf011</i> (NEU)	AY348821	Clade 9
<i>I. pseudoviola</i> Gilg.	central Africa	RBG Edinburgh 19680124 (E)	AY348822	“Clade” 2
<i>I. purpurea</i> Hand.-Mazz.	Yunnan, China	<i>Song Y007</i> (NEU)	AY348823	Clade16

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. radiata</i> Hook. f.	Yunnan, China	<i>Yuan CN2k-77</i> (NEU)	AY348824	Clade16
<i>I. rectangula</i> Hand.-Mazz.	Yunnan, China	<i>Yuan CN2k1-26</i> (NEU)	AY348825	Clade16
<i>I. rothii</i> Hook. f.	Ethiopia	<i>Pierre Binggeli s.</i> <i>n.</i> (NEU)	AY348827	Clade13
<i>I. rubrostriata</i> Hook. f.	Yunnan, China	<i>Yuan CN2k1-44</i> (NEU)	AY348828	Clade 8
<i>I. sambiranensis</i> H. Perrier	Tsaratanana, Madagascar	<i>Rahelivololona,</i> <i>Wohlhauser &</i> <i>Callamander T4</i> (PBZT)	AY348829	“Clade” 2
<i>I. scutisepala</i> Hook. f.	Yunnan, China	<i>Yuan CN2k-56</i> (NEU)	AY348830	Clade16
<i>I. siculifer</i> Hook. f.	Yunnan, China	<i>Yuan CN2k-80</i> (NEU)	AY348831	Clade16
<i>I. sodenii</i> Engl. & Warb. ex Engl.	Kenya origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE15</i> (NEU)	AY348832	“Clade” 2
<i>I. soulieana</i> Hook. f.	Sichuan, China	<i>Yuan CN2k2-163</i> (NEU)	AY348833	Clade 9
<i>I. stenosepala</i> Pritz. ex Diels	Shaanxi, China	<i>Wang Sh001</i> (NEU)	AY348835	
<i>I. stuhlmannii</i> Warb.	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE17</i> (NEU)	AY348836	“Clade” 2
<i>I. subabortiva</i> H. Perrier	Tsaratanana, Madagascar	<i>Rahelivololona,</i> <i>Wohlhauser &</i> <i>Callmander T6</i> (PBZT)	AY348837	Clade 1

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. taronensis</i> Hand.-Mazz.	Yunnan, China	<i>Yuan CN2k-57</i> (NEU)	AY348838	Clade16
<i>I. tayemonii</i> Hayata	Taiwan, China	<i>Zhengyu Jiang T2</i> (NEU)	AY348839	Clade 9
<i>I. teitensis</i> Grey- Wilson	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE18</i> (NEU)	AY348840	Clade13
<i>I. textori</i> Miq.	Japan	<i>Kanno & al. 1114</i> (TUS)	AY348841	Clade12
<i>I. trichosepala</i> Y. L. Chen	Yunnan, China	<i>Yuan CN2k1-68</i> (NEU)	AY348843	Clade 6
<i>I. tuberosa</i> H.Perrier	Madagascar origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE19</i> (NEU)	AY348844	“Clade” 2
<i>I. uliginosa</i> Franch.	Yunnan, China	<i>Yuan CN2k2-173</i> (NEU)	AY348845	Clade16
<i>I. uniflora</i> Hayata	Taiwan, China	<i>Zhengyu Jiang T1</i>	AY348846	Clade11
<i>I. usambarensis</i> Grey-Wilson	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE20</i> (NEU)	AY348847	“Clade” 2
<i>I. vilersi</i> Costantin & Poisson	Andohahela, Madagascar	<i>Rahelivololona, Druard, Jerome & Fiadana And 2</i> (PBZT)	AY348848	“Clade” 2
<i>I. walleriana</i> Hook.f.	Kenya	<i>Odile Phaehler & Magali Schnell 108</i> (NEU)	AY348849	“Clade” 2
<i>I. xanthina</i> Comber	Yunnan, China	<i>Yuan CN2k1-15</i> (NEU)	AY348850	Clade 6

Chapter 16 — Phylogeny and biogeography of Balsaminaceae

<i>I. yingjiangensis</i> S.Akiyama & H. Ohba	Yunnan, China	<i>Yuan CN2k1-55</i> (NEU)	AY348851	Clade 6
<i>I. zenkeri</i> Warb.	African origin, cult. Bot. Gard. Koblenz Univ.	<i>Fischer NE21</i> (NEU)	AY348852	Clade 5
<i>I. sp.</i>	Tsaratanana, Madagascar	<i>Rolland</i> <i>Ranaivojaona, &</i> <i>Roll Tsaratanana</i> <i>1 (PBZT)</i>	AY348834	“Clade” 2
<i>Hydrocera triflora</i> Wight & Arn.	Sri Lanka	<i>Robyns 7260,</i> <i>0249369 (L)</i>	AY348853	
<i>Marcgravia</i> <i>polyantha</i> Delp.	sample from botanical Garden, origin unknown	Jard. Bot. Nat. Belgique FB/S3781 (BR)	AY348854	
<i>Norantea</i> <i>guianensis</i> Aubl.	sample from botanical Garden, origin unknown	Jard. Bot. Nat. Belgique FB/S3779 (BR)	AY348855	
<i>Pelliciera</i> sp.	Costa Rica	<i>Pennington & al.</i> <i>586 (K)</i>	AY348856	
<i>Souroubea</i> sp.	Peru	BG Univ. Utrecht 76GR00102 (U)	AY348857	
<i>Tetramerista</i> sp.	Brunei Darussalam	<i>Coode s.n. (K)</i>	AY348858	

Chapter 17

Phylogeny, infrageneric classification and species delimitation in the Malagasy *Impatiens* (Balsaminaceae)

This chapter has been published as:

Rahelivololona, E.M.¹, Fischer, E.², Janssens, S.B.³ & Razafimandimbison, S.G.⁴ (2018): Phylogeny, infrageneric classification and species delimitation in the Malagasy *Impatiens* (Balsaminaceae). *Phytokeys* 110: 51 – 67.

1 Parc Botanique et Zoologique de Tsimbazaza, BP 4096, Antananarivo 101, Madagascar and Université de Mahajanga, Mahajanga I 401, Madagascar

2 Institute for Integrated Sciences, Department of Biology, University of Koblenz-Landau, Universitätsstr. 1, D-56070 Koblenz, Germany

3 Meise Botanical Garden, Nieuwelaan 38, BE-1860 Meise, Belgium

4 Swedish Museum of Natural History, Department of Botany, Box 50007, SE-10405 Stockholm, Sweden

Abstract

The species-rich genus *Impatiens* (Balsaminaceae) is represented in Madagascar by no less than 260 species. We conducted molecular phylogenetic analyses of the Malagasy *Impatiens* based on nuclear and plastid data and 52 accessions (representing 33 species) to: 1) reassess the monophyly of the Malagasy *Impatiens*; 2) assess the monophyly of the sections *Preimpatiens* (*Humblotianae* and *Vulgare* groups) with spurs and *Trimorphopetalum* without spurs as delimited by Perrier de la Bâthie, as well as that of the subgenera *Impatiens* and *Trimorphopetalum* as defined by Fischer and Rahelivololona; 3) infer the current status of some morphologically variable species; and 4) test whether the species of *Impatiens* from the Marojejy National Park form a monophyletic group. The Malagasy *Impatiens* are further

confirmed to be paraphyletic with respect of the Comorian *I. auricoma*. The present sectional and subgeneric classifications of the Malagasy *Impatiens* are partly supported, with strong support for the monophyly of the sect. or subgen. *Trimorphopetalum*. Section *Preimpatiens* was not supported as monophyletic and neither the *Humblotianae* group nor the *Vulgare* group is monophyletic. *Impatiens elatostemmoides*, *I. "hammarbyoides"*, *I. inaperta*, *I. lyallii* and *I. manaharensis* are either para- or polyphyletic and may represent morpho-species. The *Impatiens* species from the Marojejy National Park do not form a monophyletic group and therefore are suggested to be derived from numerous independent colonisation events from all over Madagascar followed by subsequent diversifications.

Keywords Balsaminaceae, infrageneric classification, *Impatiens*, Madagascar, monophyly, species delimitation, systematics, taxonomy

Introduction

The genus *Impatiens* L. (Balsaminaceae) is a monophyletic and diverse genus with more than 1000 species (e.g. Yuan et al. 2004, Janssens et al. 2009) and is represented by at least 260 endemic species in Madagascar (e.g. Fischer and Rahelivololona 2002, 2004a, b, 2015a, b, c, 2016, Fischer et al. 2003, 2017). This continental island is one of the centres of species diversity for the genus, which is the largest flowering plant genus on the island (Perrier de la Bâthie 1934, 1948, Humbert 1955, 1956, Fischer and Rahelivololona 2002, 2004a, b, 2007a, b, 2015a, b, c, 2016, Fischer et al. 2003, 2017) (Figs 1, 2). Fischer and Rahelivololona (e.g. 2002, 2004a, b) initiated the taxonomic studies of the Malagasy and Comorian members of *Impatiens* in an attempt to produce an updated Flora of the family Balsaminaceae for Madagascar and the Comoros. Since then, 75 new species have been described and at least another 75 new species will be published in the near future (E. Rahelivololona and E. Fischer, unpubl. data). The majority of the Malagasy *Impatiens* occurs in the montane regions of northern and eastern Madagascar (e.g. Tsaratanana National Park with 36 species, Marojejy National Park with 48 species, Masoala National Park with 59 species) (Figs 1, 2).

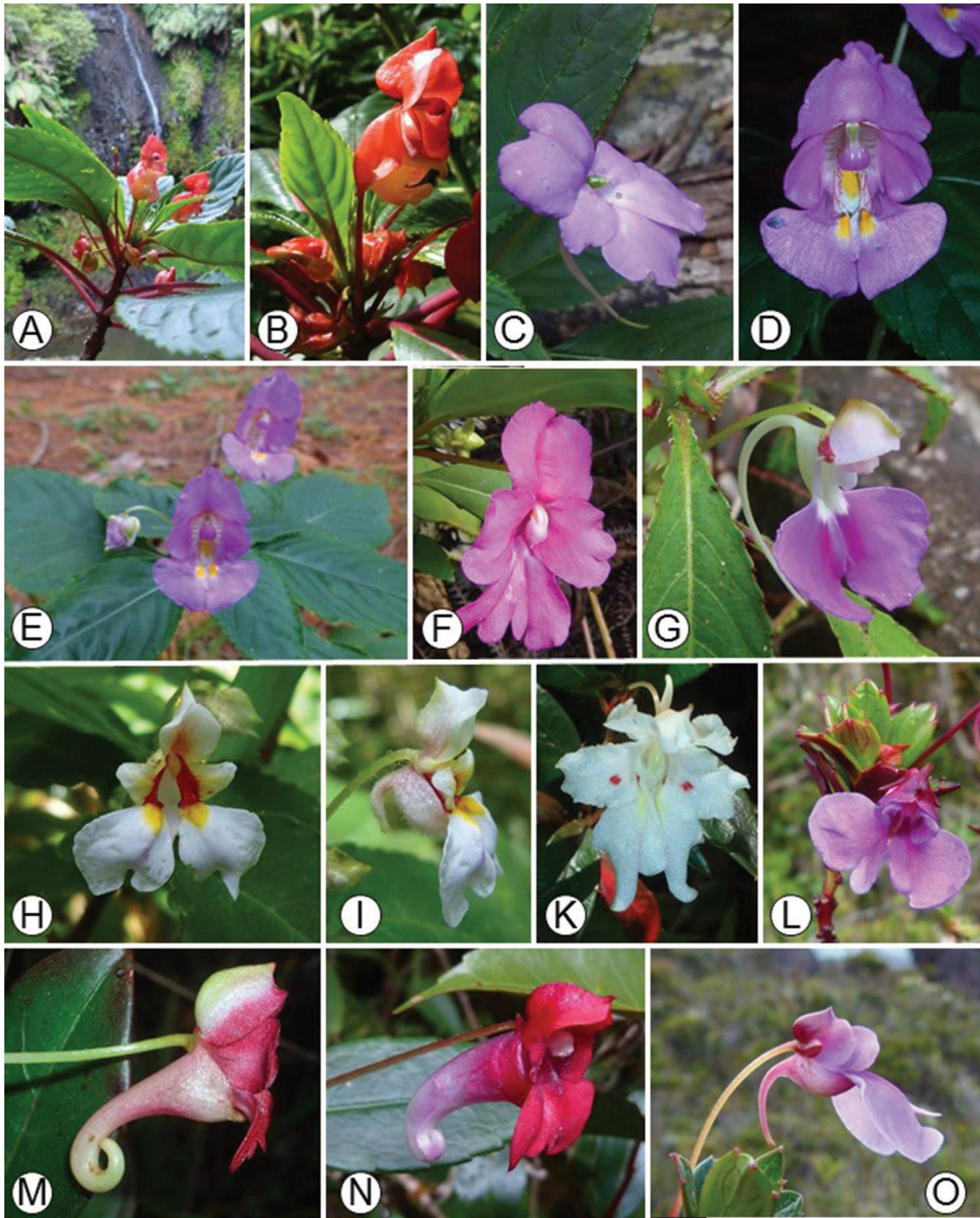


FIGURE 1. Representatives of *Impatiens* subgen. *Impatiens*. **A, B** *Impatiens bicaudata*, Montagne d'Ambre **C** *I. lyallii*, Montagne d'Ambre **D, E** *I. bisaccata*, Montagne d'Ambre **F** *I. max-huberi*, Marojejy **G** *I. nomenyae*, Marojejy **H, I** *I. masoalensis*, Marojejy **K** *I. cf. manaharensis*, Marojejy **L, O** *I. marojejyensis*, Marojejy **M** *I. susan-nathansoniae*, Marojejy **N** *I. hendrikii*, Marojejy. Photos: E. Fischer.

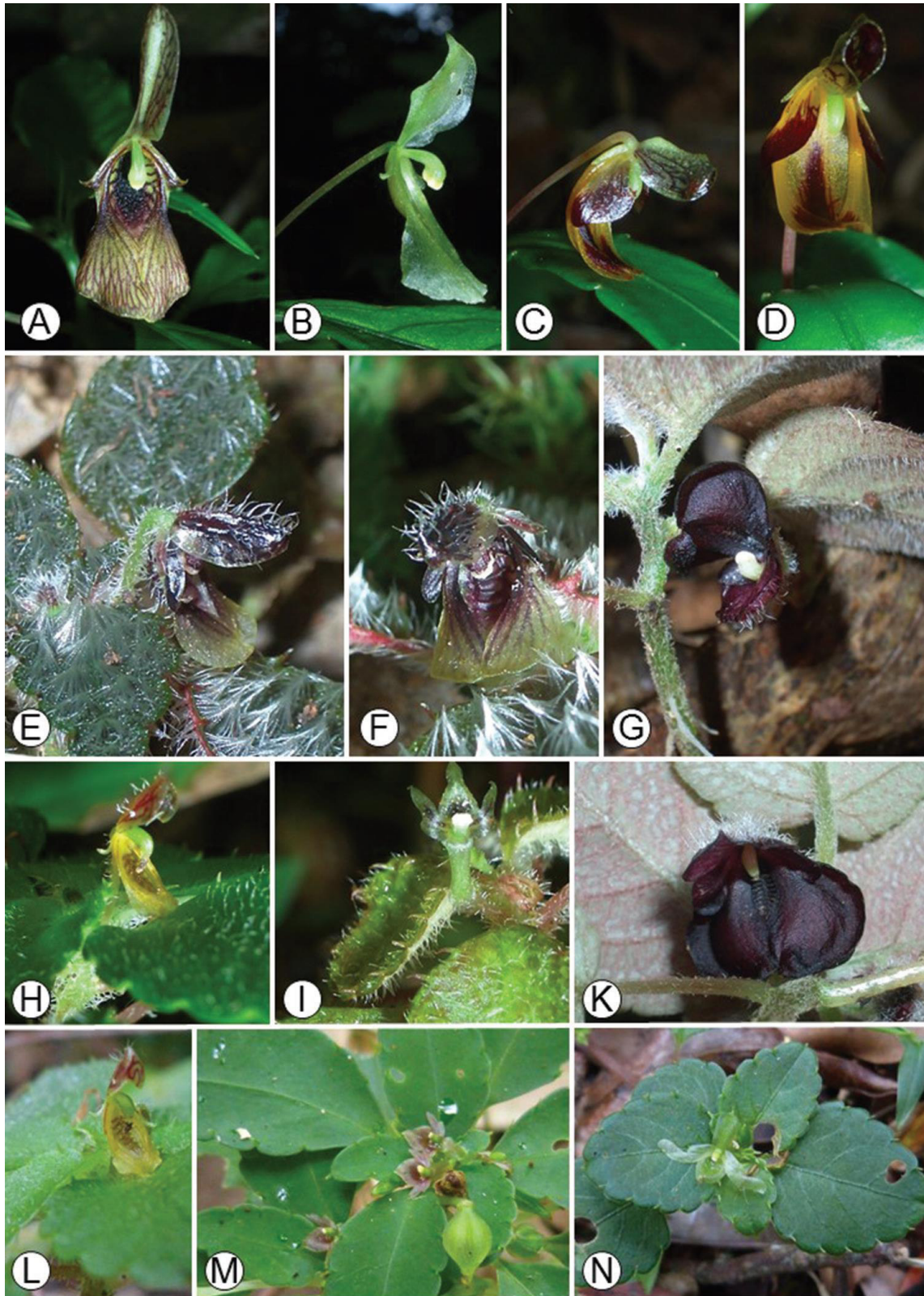


FIGURE 2. Representatives of *Impatiens* subgen. *Trimorphopetalum*. **A** *Impatiens lutzii*, Montagne d'Ambre **B** *I. galactica*, Marojejy **C, D** *I. "capuronii"*, Marojejy **E, F** *I. furcata*, Marojejy **G, K** *I. navicula*, Marojejy **H, L** *I. "humillima"*, Marojejy **I** *I. "hammarbyoides"*, Marojejy **M** *I. elatostemmoides*, Marojejy **N** *I. sp. nov. aff. elatostemmoides* 3, Montagne d'Ambre. Photos: E. Fischer.



FIGURE 3. **A, B** Lowland rainforest of the Marojejy National park **A** ca. 400 m **B** ca. 490 m **C** Moist montane rainforest of the Marojejy National park at ca. 1100 m. Photo: E. Fischer.

Warburg and Reiche (1895) provided the first global infrageneric classification for *Impatiens* based solely on morphological data. Since then, a number of infrageneric classifications of the genus have been proposed for some tropical regions (including Madagascar). Perrier de la Bâthie (1934) established the first sectional classifications for the Malagasy and Comorian *Impatiens*, placing the species with obvious spurs and

anthers with apical dehiscence in his section *Preimpatiens*. The author subdivided sect. *Preimpatiens* into two groups: the *Vulgare* group with pink, purple, white or orange flowers with shorter and slender spurs and the *Humblotianae* group with red, yellow or orange flowers with larger and broader spurs. Furthermore, Perrier de la Bâthie (1934) classified the Malagasy *Impatiens* species with anthers dehiscing apically but without spurs on the low sepals into two sections: the monotypic sect. *Impatientella* with deltoid and sharp anthers and sect. *Trimorphopetalum* with obtuse or truncate anthers (Fig. 2), both endemic to Madagascar. Fischer and Rahelivololona (2002) recognised Perrier de la Bâthie's sect. *Impatiens* with spurs (Fig. 1) and sect. *Trimorphopetalum* without spurs (Fig. 4) at subgeneric level. They formally subsumed sect. *Impatientella* into subgen. *Trimorphopetalum*.

The category of species is widely accepted as the basic or working unit of biological classification (Rosell et al. 2010, Hohenegger 2014). From a phylogenetic point of view, a species of traditional taxonomy is often viewed as a species hypothesis tested by recovering either monophyletic or non-monophyletic units. Most species concepts (e.g. Baum and Shaw 1995) consider monophyly to be congruent with species hypotheses, while almost all species concepts view polyphyly as a rejection of species hypotheses (e.g. Rosell et al. 2010). Previous and contemporary workers (e.g. Perrier de la Bâthie 1934, Fischer and Rahelivololona 2002, Fischer et al. 2003, 2017), dealing with species circumscription in the Malagasy *Impatiens*, have encountered difficulties in deciding whether a taxon represents a “real” species or a morpho-species. Several species (e.g. *I. elatostemmoides* H.Perrier, *I. “hammarbyoides”* Eb.Fisch. & Raheliv. (nomen provisorium, not yet published), *I. inaperta* (H.Perrier.) H.Perrier, *I. lyallii* H.Perrier and *I. manaharensis* Baill.) are known to be morphologically variable and this raises doubts as to whether these species deserve specific status. Molecular trees (phylogenetic hypotheses) can identify mono-, para- or polyphyletic taxa and can therefore be an important tool for assessing species delimitation. In addition, phylogenetic trees can also be used for assessing the various infrageneric classifications of the Malagasy *Impatiens*.

The first molecular phylogenetic study of the family Balsaminaceae by Yuan et al. (2004), based on nuclear ribosomal ITS (nrITS) sequence data and including 18 Malagasy *Impatiens* species (six species from subgen. *Trimorphopetalum* and 12 species from subgen. *Impatiens*), indicated that the Malagasy *Impatiens* species were

polyphyletic, as they were resolved into three groups: a *Humblotianae-Vulgare-Trimorphopetalum* clade, a lineage with *I. baroni* Baker of sect. *Impatiens* and a *Humblotianae-Vulgare* clade consisting of seven Malagasy species of sect. *Impatiens* (*I. anovensis* H.Perrier to *I. vilersii* Costantin & Poiss.). The authors also showed the monophyly of the Malagasy sect. *Trimorphopetalum* only if sect. *Impatientella*, containing the spurless and entirely cleistogamous species *I. inaperta*, is included. Their results suggested a Malagasy origin of the Comorian species. In addition, each of the Malagasy *Impatiens* clades was nested within an African *Impatiens* lineage, suggesting multiple African origins of the Malagasy *Impatiens*. Moreover, subgen. *Impatiens* was not monophyletic. In contrast to Yuan et al. (2004), Janssens et al. (2006, 2007, 2009), who included representatives of subgen. *Impatiens* and *Trimorphopetalum*, strongly supported the monophyly of the Malagasy *Impatiens* (including the Comorian *I. auricoma*). These last three studies also confirmed a single African origin of the Malagasy representatives. However, all of the above-mentioned molecular studies (Yuan et al. 2004 with 17 species; Janssens et al. 2006, 2007 and 2009 with six species) used a very limited sampling of the Malagasy *Impatiens* and, therefore, the monophyly of subgen. *Trimorphopetalum* was in need of being tested with a much larger sampling effort. More recently, based on both morphological and molecular evidence, Yu et al. (2015) divided the genus *Impatiens* into two subgenera, subgen. *Clavicarpa* and subgen. *Impatiens*. Moreover, the authors delineated seven sections in subgenus *Impatiens*: sect. *Semeiocardium*, sect. *Tuberosae*, sect. *Racemosae*, sect. *Impatiens*, sect. *Scorpioidae*, sect. *Fasciculatae* and sect. *Uniflorae*. Of these, the latter is characterised by short fusiform capsules and includes all Malagasy species of *Impatiens*, as well as several African and Asian species.

The Marojejy National Park is located in north-eastern Madagascar within the SAVA Region. With its tallest peak rising to 2137 m, the area is home to a diverse flora of upland species. The wide range of elevations and rugged topography of Marojejy create diverse habitats, which transition quickly with changes in altitude. There are four types of forests within the park: lowland rainforest below 800 m (Fig. 3); moist montane rainforest between 800 and 1400 m (Fig. 3); sclerophyllous montane cloud forest between 1400 and 1800 m; and ericoid shrub above 1800 m (Fig. 4) (Humbert 1955). The higher summits are covered by subalpine grassland with small ericaceous shrubs (Fig. 4), and are home to numerous local endemic species of *Impatiens* and of other



FIGURE 4. **A** Sclerophyllous montane cloud forest of the Marojejy National park; 1500 m **B** Subalpine grassland, Marojejy at ca. 2100 m. Photo: E. Fischer.

large genera, such as *Streptocarpus* (Gesneriaceae) and *Helichrysum* (Asteraceae). The park has been recognised as a marked centre of plant endemism. For example, 32 palm species found in the Marojejy area are endemic to Madagascar and seven of them are restricted to the park. Of the 18 species of tree ferns, inventoried in the rainforests of Marojejy, seven are endemic to the area (Madagascar Catalogue 2017).

Whether the endemic species of *Impatiens* from the Marojejy form a monophyletic group or are the result of a mixture of colonisation events from other regions through time have yet to be assessed.

The main objective of this study was to reconstruct a new and larger phylogeny of the Malagasy *Impatiens*, with a particular emphasis on taxa collected from Marojejy, using two nuclear *AP3/DEF* homologues (*ImpDEF1* and *ImpDEF2*) and the plastid *atpB-rbcL* spacer. The resulting phylogeny was subsequently used to (i) reassess the monophyly of the Malagasy *Impatiens* as stated by Janssens et al. (2006, 2007, 2009); (ii) assess the monophyly of the sections *Preimpatiens* (*Humblotianae* and *Vulgare* groups) and *Trimorphopetalum* as delimited by Perrier de la Bâthie (1934), as well as that of the subgenera *Impatiens* and *Trimorphopetalum* (including sect. *Impatientella*) as defined by Fischer and Rahelivololona (2002); (iii) assess the current species status of the morphologically variable species *I. elatostemmoides*, *I. "hammarbyoides"*, *I. inaperta* and *I. manaharensis*, using monophyly as the primary criterion (Backlund and Bremer 1998); and iv) test whether the species of *Impatiens* from the Marojejy National Park form a monophyletic group. The sectional classification proposed by Yu et al. (2015) could not be assessed, as our sampling was solely addressing the Malagasy and Comorian *Impatiens* species.

Methods

TAXON SAMPLING— The taxon sampling for this study was focused on the Malagasy representatives of the genus *Impatiens*. We expanded the previous dataset of Yuan et al. (2004) and Janssens et al. (2009) with 29 new accessions (Table 1). In total, 52 accessions were included in our analyses, representing 48 Malagasy specimens (representing about 31–33 species), two Comorian accessions (representing one species) and two African species (Table 1). This sampling represented the three major groups defined by Perrier de la Bâthie (1934) as occurring in Madagascar and the Comoros: 31 accessions from sect. *Preimpatiens* (Perrier de la Bâthie, 1934) or subgen. *Impatiens* (Fischer & Rahelivololona, 2002) (10 accessions representing six species of the *Humblotianae* group; 21 accessions representing 11 or 12 species of the *Vulgare* group); and 22 accessions representing about 14 species from sect. *Trimorphopetalum* (Perrier de la Bâthie, 1934) or subgen. *Trimorphopetalum* (Fischer

& Rahelivololona, 2002). The species showing some morphological variation were represented by more than one individual and, thus, were the subject of a test for monophyly. Twenty-seven accessions, represented by at least 17 species, were from the Marojejy National Park. *Impatiens ceciliai* and *I. hydrogetonoides*, both from Africa, were used as outgroup based on Janssens et al. (2006, 2009).

TABLE 1. List of taxa studied, voucher information and accession numbers of the selected markers. ‘–’ refers to a missing sequence.

Taxa	Voucher information	nrITS	atpB– rbcL	ImpDEF1	ImpDEF2
<i>Impatiens andringitrensis</i> H.Perrier	Bot. Gard. Bonn 36655 (BONN), Madagascar	–	MH157104	MH157123	–
<i>Impatiens auricoma</i> Baill. 1	Bot. Gard. Bonn 34154 (BONN), Comores	–	DQ147815	EF133562	EF133615
<i>Impatiens auricoma</i> Baill. 2	E. Fischer 1270 (Bot. Gard. Zürich, E.Fischer s.n.) (BONN), Comores	MH881113	MH881068	–	–
<i>Impatiens bicaudata</i> H.Perrier 1	E. Fischer 1340 (Bot. Gard. Bonn 36586) (BONN), Madagascar	MH881114	MH881069	–	MH881160
<i>Impatiens bicaudata</i> H.Perrier 2	E. Fischer 1437 (BONN), Madagascar	MH881115	MH881070	MH881199	MH881161

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens bicaudata</i> H.Perrier 3	Bot. Gard. Zürich, E.Fischer s.n. (BONN), Madagascar	–	–	MH881198	–
<i>Impatiens bisaccata</i> H.Perrier 1	E. Fischer 1271 (Bot. Gard. Bonn 36496) (BONN), Madagascar	MH157152	MH881071	–	–
<i>Impatiens bisaccata</i> H.Perrier 2	E. Fischer 1435 (BONN), Madagascar	MH881117	MH881072	MH881200	–
<i>Impatiens “capuronii”</i> Humb. ex Eb.Fisch. & Raheliv. ined.	E. Fischer 1432 (Bot. Gard. Bonn 36427) (BONN), Madagascar	MH157171	MH157106	MH157127	MH157135
<i>Impatiens catati</i> H.Perrier 1	E. Fischer 1347 (Bot. Gard. Bonn 35920) (BONN), Madagascar	MH881120	MH881074	–	–
<i>Impatiens catati</i> H.Perrier 2	E. Fischer 1278 (Bot. Gard. Bonn 28424) (BONN), Madagascar	MH157142	FJ826634	FJ826686	–

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens cecili</i> N.E.Br.	Knox 4353 (LV), Zimbabwe	–	FJ826635	FJ826687	FJ826741
<i>Impatiens</i> cf. <i>manaharensis</i> Baill.2	E. Fischer 1427 (BONN), Madagascar	MH881123	MH881078	MH881204	MH881166
<i>Impatiens</i> cf. <i>manaharensis</i> Baill. 3	E. Fischer 1348 (Bot. Gard. Bonn 36384)(BONN), Madagascar	MH881139	–	–	MH881182
<i>Impatiens</i> <i>elatostemmoides</i> H.Perrier 1	E. Fischer 1284 (Bot. Gard. Bonn 26821) (BONN), Madagascar	MH157156	MF567403	–	MF567460
<i>Impatiens</i> <i>elatostemmoides</i> H.Perrier 2	E. Fischer 1420 (BONN), Madagascar	MH881124	MH881080	MH881205	–
<i>Impatiens</i> sp. nov. aff. <i>elatostemmoides</i> H.Perrier 3	E. Fischer 1439 (BONN), Madagascar	MH881110	MH881065	MH881194	MH881156
<i>Impatiens</i> <i>elatostemmoides</i> H.Perrier 4	E. Fischer 1429 (BONN), Madagascar	MH881121	MH881076	–	–
<i>Impatiens</i> <i>eliana</i> S.Abrahamczyk & Eb.Fisch	E. Fischer 1326 (Bot. Gard. Bonn 36144) (BONN), Madagascar	MH157157	MF567404	–	MF567461

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens eriosperma</i> H.Perrier	E.Fischer 1342 (Bot. Gard. Bonn 35921) (BONN), Madagascar	MH157158	MF567414	–	MF567466
<i>Impatiens furcata</i> H.Perrier	E. Fischer 1441 (BONN), Madagascar	MH881127	MH881083	MH881206	MH881170
<i>Impatiens galactica</i> Eb.Fisch., Raheliv. & S.Abrahamczyk 1	E. Fischer 1319 (Bot. Gard. Bonn 36393) (BONN), Madagascar	MH881153	MH881107	–	–
<i>Impatiens galactica</i> Eb.Fisch., Raheliv. & S.Abrahamczyk 2	E. Fischer 1426 (BONN), Madagascar	MH881128	MH881108	MH881225	MH881192
<i>Impatiens „hammarbyoides“</i> Eb.Fisch. & Raheliv. 1 ined.	E. Fischer 1430 (BONN), Madagascar	MH157165	MF567417	MF567445	MF567469
<i>Impatiens “hammarbyoides”</i> Eb.Fisch. & Raheliv.2 ined.	E. Fischer 1447 (Bot. Gard. Bonn 37437) (BONN), Madagascar	MH157144	MH157099	MH157121	–
<i>Impatiens hendrikii</i> Eb.Fisch. &Raheliv. 1	E. Fischer 1445 (BONN), Madagascar	MH881130	MH881086	MH881209	MH881173

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens hendrikii</i> Eb.Fisch. &Raheliv. 2	E. Fischer 1440 (BONN), Madagascar	MH881129	MH881085	MH881208	MH881172
<i>Impatiens "humillima"</i> Humb. Eb.F isch. & Raheliv. ined.	E. Fischer 1431 (BONN), Madagascar	MH881131	MH881087	MH881210	MH881174
<i>Impatiens hydrogetonoides</i> Launert	Dessein 719 (BR), Zambia	–	FJ826648	FJ826699	FJ826755
<i>Impatiens inaperta</i> (H-Perr.) H.Perrier 1	E. Fischer 1346 (Bot. Gard. Bonn 27467) (BONN), Madagascar	–	MH157109	–	–
<i>Impatiens inaperta</i> (H-Perr.) H.Perrier 2	E. Fischer 1357 (BONN), Madagascar	MH881132	MH881089	–	–
<i>Impatiens inaperta</i> (H-Perr.) H.Perrier 3	E. Fischer 1448 (BONN), Madagascar	MH881133	MH881090	MH881213	MH881177
<i>Impatiens laurentii</i> Eb.Fisch. & Raheliv.	E. Fischer 1293 (Bot. Gard. Bonn 36132) (BONN), Madagascar	MH157159	–	MH157120	–
<i>Impatiens lutzii</i> Eb.Fisch. & Raheliv. 1	E. Fischer 1318 (Bot. Gard. Bonn 36381)	MH881135	MH881092	–	MH881179

Chapter 17 — Phylogeny, infrageneric classification and species

	(BONN), Madagascar				
<i>Impatiens lutzii</i> Eb.Fisch. & Raheliv. 2	E. Fischer 1438 (BONN), Madagascar	MH881136	MH881093	MH881214	MH881180
<i>Impatiens lyallii</i> H.Perrier 1	E. Fischer 1294 (Bot. Gard. Bonn 152a) (BONN), Madagascar	MH157169	MF567420	MF567448	MF567471
<i>Impatiens lyallii</i> H.Perrier 2	E. Fischer 1341 (Bot. Gard. Bonn 152b)(BONN), Madagascar	MH881138	MH881094	–	–
<i>Impatiens manaharensis</i> Baill. 1	E. Fischer 1434 (Bot. Gard. Bonn 36384) (BONN), Madagascar	MH881139	MH881077	MH881203	MH881182
<i>Impatiens mandrakae</i> Eb.Fisch. & Raheliv.	E. Fischer 1345 (Bot. Gard. Bonn 26822) (BONN), Madagascar	MH157166	MF567421	–	MF567472
<i>Impatiens marojejyensis</i> Humbert & H.Perrier	E. Fischer 1444 (BONN), Madagascar	MH881141	MH881096	MH881215	MH881184

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens masoalensis</i> H.Perrier 1	E. Fischer 1443 (BONN), Madagascar	MH881143	–	MH881216	–
<i>Impatiens masoalensis</i> H.Perrier 2	E. Fischer 1424 (Bot. Gard. Bonn 36386) (BONN), Madagascar	MH157161	MF567422	MF567449	MF567473
<i>Impatiens masoalensis</i> H.Perrier 3	E. Fischer 1424 (BONN), Madagascar	MH881144	–	MH881217	MH881186
<i>Impatiens max- huberi</i> Eb.Fisch. &Raheliv.	E. Fischer 1421 (Bot. Gard. Bonn 36428) (BONN), Madagascar	MH157147	MH157110	MH157116	MH157137
<i>Impatiens navicula</i> Eb.Fisch. & Raheliv. 1	E. Fischer 1422 (BONN), Madagascar	MH881147	MH881101	MH881220	MH881189
<i>Impatiens navicula</i> Eb.Fisch. & Raheliv. 2	E. Fischer 1446 (BONN), Madagascar	MH881146	MH881100	MH881219	MH881188
<i>Impatiens nomenyae</i> Eb.Fisch. & Raheliv.	E. Fischer 1425 (BONN), Madagascar	MH881148	MH881102	MH881221	–
<i>Impatiens renae</i> Eb.Fisch. & Raheliv.	E. Fischer 1442 (BONN), Madagascar	MH881149	MH881103	MH881222	–

Chapter 17 — Phylogeny, infrageneric classification and species

<i>Impatiens rutenbergii</i> O.Hoffm	E. Fischer 1310 (Bot. Gard. Bonn 37463) (BONN), Madagascar	MH881150	MH881104	–	MH881190
<i>Impatiens scripta</i> H.Perrier	E. Fischer 1423 (BONN), Madagascar	MH881151	MH881105	MH881223	MH881191
<i>Impatiens</i> sp. nov. aff. <i>lyallii</i>	E. Fischer 1428 (BONN), Madagascar	MH881152	MH881106	MH881224	–
<i>Impatiens susan-nathansoniae</i> Eb.Fisch. & Raheliv.	E. Fischer 1433 (BONN), Madagascar	MH881155	MH881109	MH881226	MH881193

MOLECULAR PROTOCOLS— Total genomic DNA was isolated from silica-dried leaf material using a modified CTAB protocol (Doyle and Doyle 1987), which was optimised for *Impatiens* by Janssens et al. (2006, 2009). The two nuclear *AP3/DEF* homologues (*ImpDEF1* and *ImpDEF2*) and the plastid *atpB-rbcL* intergenic spacer were amplified following Janssens et al. (2007) and Janssens et al. (2006). PCR reactions for all three gene markers investigated in this study consisted of 2 min initial denaturation at 94 °C and 30 cycles of 30 s denaturation at 94 °C, 30 s primer annealing at primer specific temperature and 1 min extension at 72 °C. Primer annealing for *ImpDEF1*, *ImpDEF2* and *atpB-rbcL* were at 57 °C, 55.5 °C and 51 °C, respectively. Amplification reactions were carried out on a Gene Amp PCR system 9700 (Applied Biosystems). Purified amplification products were sent to Macrogen, Inc. (Seoul, South Korea) for sequencing. Sequences obtained in this study will be deposited at GenBank (Table 1).

DATA ANALYSES— Contiguous sequences were assembled using Geneious v7.0.6 (Biomatters, New Zealand). Automatic alignment of the datasets was carried out with MAFFT (Kato et al. 2002) under an E-INS-i algorithm, a 100PAM/k=2 scoring matrix, a gap open penalty of 1.3 and an offset value of 0.123. Subsequent manual fine-tuning

of the aligned dataset was done in Geneious v7.0.6. Congruency between the nuclear and chloroplast datasets was inferred by a partition homogeneity test as implemented in PAUP*4.0b10a (Swofford 2000). The best-fit nucleotide substitution model for each plastid and nuclear dataset was determined using jModel Test 2.1.4 (Posada 2008) under the Akaike information criterion (AIC). The GTR+I+G model was found as best fit for *ImpDEF1*, whereas the GTR+G model was calculated as best substitution model for *ImpDEF2* and *atpB-rbcL*. A mixed-model approach was used in which the combined dataset was partitioned in order to apply a different model of evolution on each DNA region (Ronquist and Huelsenbeck 2003). Bayesian Inference (BI) analyses were conducted with MrBayes v3.1 (Huelsenbeck and Ronquist 2001) on three individual data partitions and a combined data matrix. Each analysis ran two times for 10 million generations. Trees were sampled every 2500 generations. Inspection of chain convergence and ESS parameters was done with TRACER v1.4 (Rambaut and Drummond 2007). Bayesian posterior probability (BPP) values between 0.50 and 0.95 were considered to be weakly supported, whereas BPP values above or equal to 0.95 were taken into consideration to indicate well-supported branches (Suzuki et al. 2002, Alfaro et al. 2003). Maximum Likelihood analyses were carried out on the CIPRES web portal using RAxML v7.2.8 (Stamatakis et al. 2008) under the GTRGAMMA model. Non-parametric ML bootstrapping analysis was calculated with 1000 bootstrap replicates.

Results

The aligned *atpB-rbcL* and *ImpDEF1/ImpDEF2* matrices contained 924 bp and 812 bp, respectively. The phylogenetic tree, based on the combined data, is shown in Figure 5. The monophyly of the Malagasy *Impatiens* was not supported by our analyses, as the Comorian species *I. auricoma* was deeply nested within the Malagasy *Impatiens* Clade I (BS: 99; BPP: 1). Therefore, the Malagasy *Impatiens* are paraphyletic, unless the Comorian *Impatiens* species are included. The sect. *Preimpatiens* sensu Perrier de la Bâthie (1934)/subgen. *Impatiens* sensu Fischer and Rahelivololona (2002) was not resolved as a monophyletic group. Neither the *Humbotianae* group nor the *Vulgare* group was supported as monophyletic (Fig. 5). However, sect. *Trimorphopetalum* sensu Perrier de la Bâthie (1934)/subgen. *Trimorphopetalum* sensu Fischer and Rahelivololona (2002) was strongly supported as a monophyletic group (BS: 92; BPP:

1). The earliest diversified lineages in the Malagasy *Impatiens* clade fell into a large polytomy containing five groups (Fig. 5): *I. marojejensis* Humbert & H.Perrier (member of the *Vulgare* group), *Impatiens* Clade I (formed by the representatives of the *Humblotianae* and *Vulgare* groups) (BS: 99; BPP: 1), *Impatiens* Clade II (also formed by the representatives of the *Humblotianae* and *Vulgare* groups) (BS: 59; BPP: 0.87), *I. nomenyae* Ed.Fisch. & Raheliv. and a strongly supported Clade III (BS: 92; BPP: 1) (formed by the representatives of the *Trimorphopetalum*). The phylogenetic relationships amongst these major lineages were unresolved. Within the *Impatiens* Clade II, the morphologically variable *I. manaharensis* was not supported as monophyletic. Within the *Impatiens* Clade III, the morphologically variable species *I. elatostemmoides* appeared polyphyletic, while *I. "hammarbyoides"*, *I. lyallii* and *I. inaperta*, also variable, seemed paraphyletic. Finally, the sampled species of *Impatiens* from the Marojejy National Park did not form a monophyletic group, as they were scattered across the tree (Fig. 5).

Discussion

The present analyses confirm the paraphyly of the Malagasy *Impatiens* with respect to the Comorian *I. auricoma*. This is consistent with Janssens et al. (2006, 2007, and 2009) but inconsistent with the polyphyly of the Malagasy *Impatiens* as shown by Yuan et al. (2004). The monophyly of sect. *Trimorphopetalum* (*I. inaperta* included) suggested by Yuan et al. (2004) is further strongly supported (BS: 92; BPP: 100) by the present study. In other words, subgen. *Trimorphopetalum*, as delimited by Fischer and Rahelivololona (2002), is supported. Spurless, greenish, brown to blackish or yellowish (never white, pink or purple) flowers with boat-shaped lower sepals, obtuse or truncate and apically dehiscent anthers and the lack of extrafloral nectaries on leaf lamina and petioles are the synapomorphic characters for this lineage, which seems to have evolved from a common ancestor with spurs (Fig. 5). In Yuan et al. (2004), the *Trimorphopetalum* clade was resolved as the most derived within *Impatiens*. The authors argued that this spurless lineage could not be recognised at sectional or subgeneric level, as proposed by Perrier de la Bâthie (1934) and Fischer and Rahelivololona (2002), respectively, because this taxonomic decision seems to make sect. *Preimpiens* sensu Perrier de la Bâthie (1934) or *I.* subgen. *Impatiens* sensu Fischer and Rahelivololona (2002) paraphyletic. Our results do not support or reject

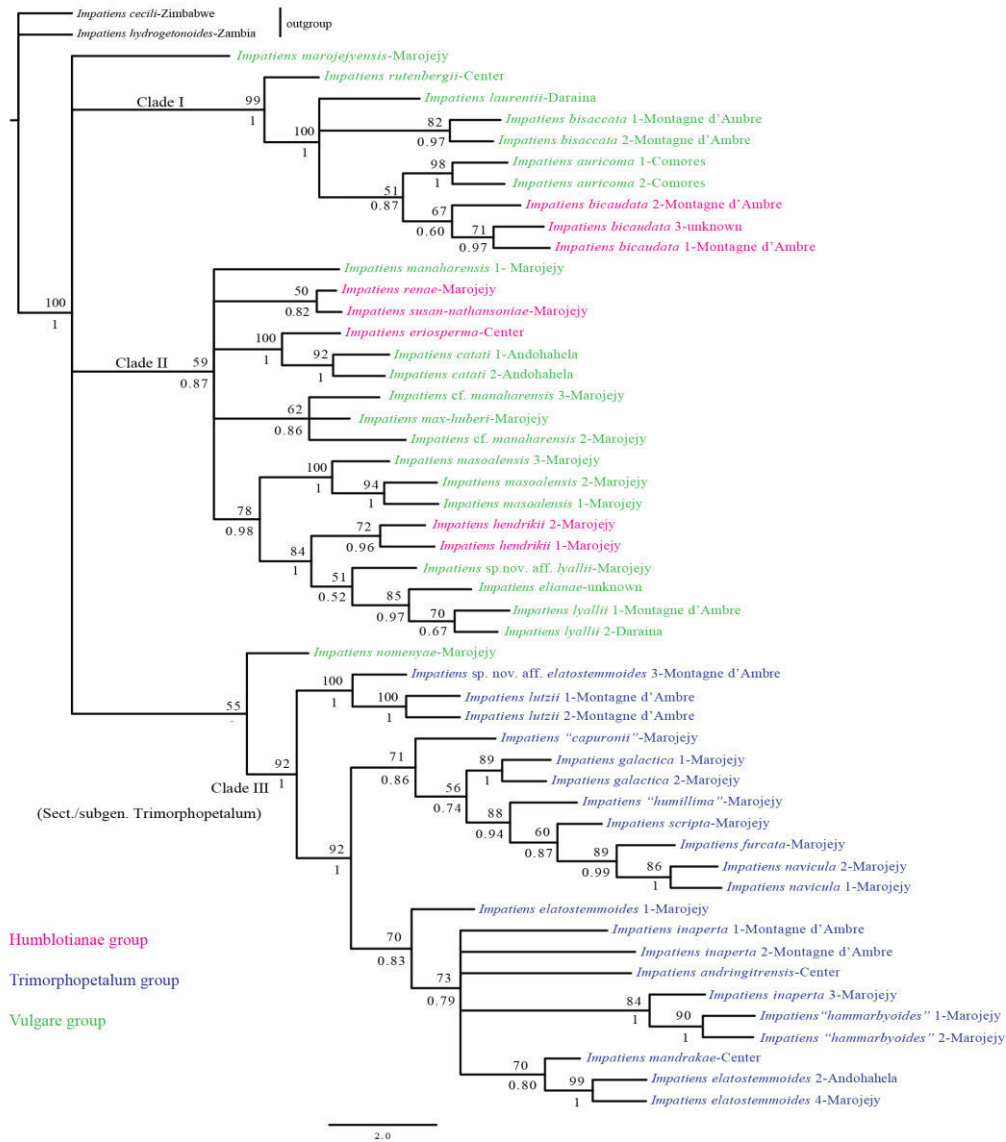


FIGURE 5. Maximum likelihood tree based on the combined nuclear-plastid data. Bootstrap support values and Bayesian posterior probabilities are above and below nodes, respectively.

Yuan et al. (2004)'s claims, as the Malagasy *Impatiens* clade (including the Comorian *I. auricomma*) is largely unresolved (Fig. 5). Neither the sampled species from the *Vulgare* group nor those from the *Humblotianae* group form a monophyletic group, a result consistent with Yuan et al. (2004). Therefore, our results provide no support for the *Vulgare* group characterised by shorter and slender spurs or for the *Humblotianae* group defined by larger and broader spurs, as delimited by Perrier de la Bâthie (1934). Furthermore, our analyses do not support or reject the monophyly of sect. *Preimpatiens* sensu Perrier de la Bâthie (1934) or subgen. *Impatiens* sensu Fischer and Rahelivololona (2002). To summarise, this study partly supports the sectional and

subgeneric classifications of the Malagasy *Impatiens* proposed by Perrier de la Bâthie (1934) and Fischer and Rahelivololona (2002). More molecular data are needed to further assess the monophyly of sect. *Preimpatiens* or subgen. *Impatiens*.

In addition, results of this molecular phylogenetic study further highlight the difficulties that the *Impatiens* taxonomists have faced when dealing with the species delimitation of the Malagasy *Impatiens* (e.g. Perrier de la Bâthie 1934; Humbert 1956; Fischer and Rahelivololona 2002, 2004a, 2007, 2015a, b, c). *Impatiens manaharensis* seems polyphyletic and this supports our suspicion in the field that at least two taxa with very different morphology could be distinguished within this variable species. *Impatiens elatostemmoides* seems polyphyletic, while *I. inaperta*, *I. "hammarbyoides"* and *I. lyallii* (Fig. 5) appear paraphyletic. Therefore, these morphologically variable species may well represent morpho-species, meaning that they represent a group of several different species or are parts of a species complex. As a consequence, this study indicates that the current species delimitation of these para- or polyphyletic species is in need of revision.

Finally, the *Impatiens* taxa from the Marojejy National Park do not form a monophyletic group, as they are spread across the tree (Fig. 5). This suggests that they are the result of numerous independent colonisation events from elsewhere in Madagascar, followed by subsequent diversifications. In other words, they seem to have had multiple origins.

Conclusions

The Malagasy *Impatiens* are paraphyletic with respect of the Comorian *I. auricoma*. The present subgeneric and sectional classifications of the Malagasy *Impatiens* are partly supported, with strong support for the monophyly of subgen. *Trimorphopetalum*. Neither the *Humblotianae* group nor the *Vulgare* group forms a monophyletic group. *Impatiens elatostemmoides*, *I. "hammarbyoides"*, *I. inaperta* and *I. manaharensis* are either para- or polyphyletic and may represent morpho-species. The *Impatiens* species from Marojejy do not form a natural group. A further study based on a much larger molecular data set and sampling from the entire geographic ranges of *Impatiens* in Madagascar is needed to produce a well-resolved phylogeny. This will hopefully allow for a retest of the monophyly of sect. *Preimpatiens* sensu Perrier de la Bâthie (1934)

or subgen. *Impatiens* sensu Fischer and Rahelivololona (2002), as well as molecular dating and biogeographic analyses of the Malagasy *Impatiens*.

Acknowledgments

The first author (EMR) thanks the colleagues from Institute for Integrated Sciences, Department of Biology, University of Koblenz-Landau for training and funding, the Laboratory of Plant Systematics, Institute of Botany and Microbiology, Leuven for technical and financial support of the molecular laboratory work, P. Küpfer, Y.-M. Yuan, S. Wohlhauser, M. Callmander and P. Druart (all formerly University of Neuchâtel) for introducing her to molecular phylogenetics, technical training on molecular biology and financial support at the beginning of her studies; the DGF (Direction Générale des Forêts) and the MNP (Madagascar National Parks) in Madagascar for issuing collecting and exportation permits to EMR and EF; the Parc Botanique et Zoologique de Tsimbazaza (PBZT), Antananarivo, Madagascar, for allowing her to conduct the research on *Impatiens*; and the two anonymous reviewers and the Associate Editor (Hanno Schaefer) for their comments on an early version of the paper. The second author (EF) is indebted to the Missouri Botanical Garden and the Parc Botanique et Zoologique de Tsimbazaza for arranging our research and collecting permits. The Akademie der Wissenschaften und Literatur Mainz kindly sponsored the field trip of EF. Special thanks go to our colleagues Damien Ertz (Meise), Bernard Goffinet (Connecticut), Roger Lala Andriamiarisoa (Antananarivo) and Emmanuël Sérusiaux (Liège) who accompanied us in the field. Without the skills of Roger Lala Andriamiarisoa, the fieldwork would have been impossible.

Chapter 18

Conclusions

In this thesis, I present the results of my studies on taxonomy, systematics, and biogeography of *Impatiens* (Balsaminaceae) in Madagascar and the Comoro islands.

In Chapter 1 I reviewed the literature on taxonomy and classification of Balsaminaceae, on habitat, world distribution, morphology, molecular phylogenetics and infrageneric classification of the genus *Impatiens*. **In Chapters 2-15** (Fischer & Rahelivololona 2002, 2003, 2004, 2007, 2015a, 2015b, 2015c, 2016, Fischer et al. 2004, 2017, 2018a, b submitted, Rahelivololona et al. 2003) I presented the first results of a revision of Balsaminaceae of Madagascar and the Comoro islands including the description of 78 new species. **In Chapter 16** (Yuan et al. 2004) we worked on the phylogeny and biogeography of Balsaminaceae inferred from ITS sequences using combined results from molecular phylogenetic and morphological analyses. **In Chapter 17** (Rahelivololona et al. 2018) we conducted a phylogeny and assessment of the infrageneric classification of species in the Malagasy *Impatiens* (Balsaminaceae) with a particular emphasis on taxa collected from Marojejy.

Below I summarise the most important findings of each chapter and provide an outlook for future studies.

How many species of *Impatiens* occur in Madagascar and the Comoro islands?

To provide additional information on the taxonomic revision of *Impatiens* in Madagascar and the Comoro islands, the identification of already described species as well as the description of new species was conducted. Based on herbarium specimens from BR, G, K, NEU, P, TAN and on living plants collected during several

field trips, 78 new species and 6 nomina nova have been published and another 70 new taxa are already identified. Actually more than 260 species occur in Madagascar and the Comoro islands and all of them are endemic. For each species, a description of the morphology, phenology, ecology and known distribution range was provided. Apart from new taxa, the delimitation of already described species like *Impatiens firmula* Baker and *Impatiens hildebrandtii* Baill. could be clarified by studying the types and by observing the variability in the field.

Are the groups of *Impatiens* in Madagascar monophyletic, and what is the systematic position of *Trimorphopetalum*?

Yuan & al. (2004) conducted a molecular phylogenetic study to examine the morphological and karyological evolution, and the historical biogeography of the Balsaminaceae family by using nucleotide sequence data of internal transcribed spacer regions of nuclear ribosomal DNA. The results support the monophyly of the Malagasy endemic section *Trimorphopetalum* and show that the cleistogamous *Impatiens inaperta* should be included in the sect. *Trimorphopetalum* which is the most derived within *Impatiens*. Therefore, the section *Preimpatiens* proposed by Perrier de la Bâthie (1934) is paraphyletic.

Rahelivololona & al. (2018) provided a phylogenetic study focused on three subdivisions (based on macromorphological characters) proposed by Perrier de la Bâthie (1934). The analysis was done using two nuclear *AP3/DEF* homologues (*ImpDEF1* and *ImpDEF2*) and the plastid *atpB-rbcL* spacer to reassess or assess the monophyly of the Malagasy *Impatiens*, of the sections *Preimpatiens* (*Humblotianae* and *Vulgare* groups) and *Trimorphopetalum*. A focus was on the species of *Impatiens* from the Marojejy National Park and of the morphologically variable species *I. elatostemmoides*, *I. "hammarbyoides"*, *I. inaperta* and *I. manaharensis*, using monophyly as the primary criterion.

As results the Malagasy *Impatiens* are paraphyletic and the section *Preimpatiens* sensu Perrier de la Bâthie (1934) (= subgen. *Impatiens* sensu Fischer & Rahelivololona 2002) was not resolved as a monophyletic group. The section *Trimorphopetalum* sensu Perrier de la Bâthie (1934) (= subgen. *Trimorphopetalum* sensu Fischer & Rahelivololona 2002), however, was strongly confirmed as a monophyletic lineage

(BS: 92; BPP: 1). Neither the *Humblotianae* group nor the *Vulgare* group was supported as monophyletic. None of the morphologically variable species appeared to be monophyletic and the sampled species of *Impatiens* from the Marojejy National Park do also not form a monophyletic group.

What are the biogeographical position and the distribution patterns of Impatiens in Madagascar and the Comoro islands?

Investigation of the geographical affinities and species distribution of section *Impatiens* (including *Humblotianae* group and *Vulgare* group) and section *Trimorphopetalum* were conducted and the origin and evolution as well as species richness and endemism were discussed.

The isolation, the climate and the complex topography of Madagascar have generated the microhabitats and ecological niches favourable to the diversification of *Impatiens* species. *Impatiens* of Madagascar with 260 endemic species is actually the largest genus in Madagascar. Therefore, Madagascar and the Comoro islands are among the most species-rich regions in the world for *Impatiens*.

Future studies

In *Impatiens* on Madagascar, there remain numerous unresolved questions that need to be addressed:

- A further study based on a much larger molecular data set and sampling from the entire geographic ranges of *Impatiens* in Madagascar is needed to retest the monophyly of the different subgenera and sections, as well as a molecular dating of the Malagasy *Impatiens*.
- The study of pollinators as a key for understanding the radiation and species richness is required: Within *Impatiens* the different shapes of spur are related to pollinators (bees, birds, butterflies and moths). Therefore pollinator observation of specific species need to be done to understand the radiation of species by adaptation and coevolution with these pollinators. A pollination study with a large number of species within section *Trimorphopetalum* will help to

understand the mechanism of complete disappearance of the spur, the shift of pollinators and the evolution of species richness.

- The destruction of the natural habitats of *Impatiens* and the subsequent reduction of humidity in logged area constitute a severe threat for the survival of many species. The conservation and reforestation of vulnerable areas such as Ankaratra, Daraina, Mandraka and Col des Tapia near Antsirabe is required.
- In terms of conservation and to mitigate the threat on the genus, a study on the ex-situ-conservation of Malagasy *Impatiens* species is very important as long as some species are suitable for horticultural purposes (e.g. *Impatiens mayae-valeriae*, *Impatiens emiliae* and species with broad red spur).
- Finally, the publication of the revision of *Impatiens* of Madagascar and the Comoro islands will help other botanists to identify the species and will thus increase our knowledge on the group.

Chapter 19

Zusammenfassung

In dieser Arbeit werden die Ergebnisse meiner Studien zu Taxonomie, Systematik und Biogeographie von *Impatiens* (Balsaminaceae) auf Madagaskar und den Komoren präsentiert.

In Kapitel 1 wurde die Literatur zur Taxonomie und der Klassifizierung von Balsaminaceae-Arten, zum Lebensraum, zur weltweiten Verbreitung, der Morphologie, der molekularen Phylogenetik und der infragenerischen Klassifizierung der Gattung *Impatiens* zusammengestellt. In den Kapiteln 2-15 (Fischer & Rahelivololona 2002, 2003, 2004, 2007, Fischer et al. 2003, 2015a, 2015b, 2015c, 2016, 2017, 2018a, b eingereicht, Rahelivololona et al. 2003) präsentiere ich die ersten Ergebnisse einer Revision der Balsaminaceae von Madagaskar und den Komoren, einschließlich der Beschreibung von 78 neuen Arten. In Kapitel 16 (Yuan et al. 2004) arbeiteten wir an der Phylogenie und Biogeographie von Balsaminaceae, die aus ITS-Sequenzen abgeleitet wurden, unter Verwendung kombinierter Ergebnisse aus molekularphylogenetischen und morphologischen Analysen. In Kapitel 17 (Rahelivololona et al. 2018) führten wir eine phylogenetische Analyse und Bewertung der infragenerischen Klassifizierung von Arten in den madagassischen *Impatiens* Taxa (Balsaminaceae) durch, wobei der Schwerpunkt auf in Marojejy gesammelten Taxa lag. Kapitel 18 (Rahelivololona et al. eingereicht) stellt eine Studie über die Biogeographie der Gattung *Impatiens* L. auf Madagaskar und den Komoren dar.

Im Folgenden fasse ich die wichtigsten Ergebnisse der einzelnen Kapitel zusammen und gebe einen Ausblick auf zukünftige Studien.

Wie viele Arten von *Impatiens* kommen auf Madagaskar und auf den Komoren vor?

Um zusätzliche Informationen zur taxonomischen Revision von *Impatiens* auf Madagaskar und den Komoren bereitzustellen, wurde die Identifizierung bereits beschriebener Arten sowie die Beschreibung neuer Arten durchgeführt. Basierend auf Herbarbelegen aus BR, G, K, NEU, P, TAN und auf lebenden Pflanzen, die auf mehreren Exkursionen gesammelt wurden, haben wir 78 neue Arten und 6 Nomina Nova veröffentlicht und bereits weitere 70 neue Taxa identifiziert. Aktuell kommen mehr als 260 Arten auf Madagaskar und den Komoren vor, die alle endemisch sind. Für jede Art wurde eine Beschreibung der Morphologie, der Phänologie, der Ökologie und des bekannten Verbreitungsareals erstellt. Abgesehen von neuen Taxa, konnte die Abgrenzung bereits beschriebener Arten wie *Impatiens formula* Baker und *Impatiens hildebrandtii* Baill. durch Untersuchungen der Typusbelege und durch die Beobachtung der Variabilität im Feld geklärt werden.

Sind die Gruppen innerhalb der Gattung *Impatiens* auf Madagaskar monophyletisch und wie ist die systematische Stellung von *Trimorphopetalum*?

Yuan & al. (2004) führten eine molekular-phylogenetische Studie zur Untersuchung der morphologischen und karyologischen Evolution sowie der historischen Biogeographie der Balsaminaceae durch, unter Verwendung von Nukleotidsequenzdaten interner transkribierter Spacer-Regionen der ribosomalen Kern-DNA. Die Ergebnisse stützen die Monophylie der madagassischen, endemischen Sektion *Trimorphopetalum* und zeigen, dass die kleistogame Art *Impatiens inaperta* in die Sektion aufgenommen werden sollte. *Trimorphopetalum* ist die Sektion, die innerhalb der Gattung *Impatiens*, die am meisten abgeleitete Gruppe darstellt. Die von Perrier de la Bâthie (1934) vorgeschlagene Sektion *Preimpatiens* ist paraphyletisch.

Rahelivololona & al. (2018) lieferten eine phylogenetische Studie, die sich auf die drei Unterteilungen konzentriert (basierend auf makromorphologischen Merkmalen), die von Perrier de la Bâthie (1934) vorgeschlagen wurden. Die Analyse wurde mit zwei

AP3 / DEF-Homologen (ImpDEF1 und ImpDEF2) und dem Chloroplasten atpB-rbcL-Spacer durchgeführt, um die Monophylie der madagassischen *Impatiens* der Sektionen *Preimpatiens* (*Humblotianae* und *Vulgare*) und *Trimorphopetalum* zu bestätigen oder neu zu bewerten. Ein Schwerpunkt lag auf den *Impatiens* Arten aus dem Marojejy-Nationalpark und den morphologisch variablen Arten *I. elatostemmoides*, *I. „Hammarbyoides“*, *I. inaperta* und *I. manaharensis*, wobei als Hauptkriterium die angenommene Monophylie verwendet wurde.

Als Ergebnis sind die madagassischen *Impatiens* Arten paraphyletisch und die Sektion *Preimpatiens* sensu Perrier de la Bâthie (1934) (= Subgen. *Impatiens* sensu Fischer & Rahelivololona 2002) wurde nicht als monophyletische Gruppe aufgelöst. Die Sektion *Trimorphopetalum* sensu Perrier de la Bâthie (1934) (= Subgen. *Trimorphopetalum* sensu Fischer & Rahelivololona 2002) wurde jedoch als monophyletische Linie (BS: 92; BPP: 1) bestätigt. Weder die *Humblotianae*-Gruppe noch die *Vulgare*-Gruppe wurden als monophyletisch unterstützt. Keine der morphologisch variablen Arten scheint monophyletisch zu sein, und die untersuchten *Impatiens* Arten aus dem Nationalpark Marojejy bilden ebenfalls keine monophyletische Gruppe.

Wie ist die biogeographische Stellung und welche Verbreitungsmuster von *Impatiens* finden sich auf Madagaskar und den Komoren?

Untersucht wurden die geographischen Ähnlichkeiten und die Artenverteilung der Sektion *Impatiens* (einschließlich der *Humblotianae*-Gruppe und der *Vulgare*-Gruppe) sowie der Sektion *Trimorphopetalum*. Dabei wurden Ursprung und Entwicklung sowie Artenreichtum und Endemismus diskutiert.

Die Isolation, das Klima und die komplexe Topografie Madagaskars haben die für die Diversifizierung der *Impatiens*-Arten günstigen Mikrohabitate und ökologischen Nischen geschaffen. Mit 260 endemischen Arten ist *Impatiens* die artenreichste Gattung Madagaskars. Daher gehören Madagaskar und die Komoren zu den für *Impatiens* artenreichsten Regionen der Welt.

Zukünftige Studien

In *Impatiens* auf Madagaskar gibt es noch zahlreiche ungelöste Fragen, die angesprochen werden müssen:

- Eine weitere Studie, die auf einem viel größeren molekularen Datensatz und Stichproben aus den gesamten geografischen Bereichen von *Impatiens* auf Madagaskar basiert, ist erforderlich, um die Monophylie der verschiedenen Untergattungen und Sektionen sowie eine molekulare Datierung der madagassischen *Impatiens* erneut zu testen.
- Die Untersuchung von Bestäubern als Schlüssel zum Verständnis der Radiation und Artenvielfalt ist erforderlich: In *Impatiens* hängen die verschiedenen Formen der Sporne eng mit Bestäubern (Bienen, Vögeln, Schmetterlingen und Nachtfalter) zusammen. Daher müssen Bestäuberbeobachtungen spezifischer Arten durchgeführt werden, um die Radiation der Arten durch Anpassung und Koevolution mit diesen Bestäubern zu verstehen. Eine Bestäubungsstudie mit einer großen Anzahl von Arten innerhalb der Sektion *Trimorphopetalum* wird dazu beitragen, den Mechanismus der vollständigen Reduktion des Sporns, den „shift“ von Bestäubern und die Entwicklung des Artenreichtums zu verstehen.
- Die Zerstörung der natürlichen Lebensräume von *Impatiens* und die anschließende Verringerung der Luftfeuchtigkeit in abgeholzten Habitaten stellen eine ernsthafte Bedrohung für das Überleben vieler Arten dar. Die Erhaltung und Wiederaufforstung gefährdeter Gebiete wie Ankaratra, Daraina, Mandraka und Col des Tapia in der Nähe von Antsirabe sind erforderlich.
- Im Hinblick auf die Erhaltung und zur Minderung der Bedrohung der Gattung ist eine Studie zur ex-situ-Erhaltung von madagassischen *Impatiens*-Arten von großer Bedeutung, da einige Arten für gärtnerische Zwecke geeignet sind (z. B. *Impatiens mayae-valeriae*, *Impatiens emiliae* und Arten mit breitem rotem Sporn).
- Schließlich wird die Veröffentlichung der Revision von *Impatiens* auf Madagaskar und den Komoren anderen Botanikern helfen, die Arten zu identifizieren, und so unser Wissen über die Gruppe zu erweitern.

Acknowledgements

First of all, I would like to thank Prof. Dr. Eberhard Fischer (Department of Biology, University of Koblenz-Landau) for accepting me as a PhD student and giving me the opportunity to investigate the Balsaminaceae of Madagascar. I am very grateful for the many fruitful discussions and joint field trips in various regions of Madagascar, his kind advice and continuous support, and the friendly working environment he provided during my stays at Koblenz.

Prof. Dr. Wilhelm Barthlott (Nees Institute for Biodiversity of Plants, University of Bonn) kindly agreed to officiate as second referee. He has been to Madagascar several times, and my work benefitted extensively from his vast experience.

During my stays at Koblenz, I very much benefitted from the hospitality and friendship of Brigitte Nilow-Lange and her family. My sincere thanks go to Prof. Dr. Ulrich Sinsch from the Department of Biology, University Koblenz-Landau for his continuous support. My special thanks go to all the friends and colleagues from the Botany working group at Koblenz, including Dr. Dorothee Killmann, Dr. Markus Ackermann, Dr. Katja Rembold (now Botanical Garden Zürich, Switzerland) and to Siegmar Seidel from the Rwanda Centre and office for African contributions.

I am indebted to the colleagues from the Botanical Gardens of the University of Bonn for their help and advice: Prof. Dr. Maximilian Weigend, Dr. Wolfram Lobin, Hans-Jürgen Ensikat and Dr. Stefan Abrahamczyk.

Dr. Steven Janssens (Botanical Garden Meise, Belgium) always supported my work and spent much time in discussions on molecular phylogeny. I am grateful to the following colleagues for advice and support: Dr. Thomas Haevermans and Dr. Hull Sovanmoly (Museum National d'Histoire Naturelle, Paris). My heartfelt thanks and recognitions go to Dr. Sylvain Razafimandimbison, Stockholm, for his kind help, support and patience all along my study.

I am grateful and indebted to Prof. Phillipe Küpfer, Sebastien Wohlhauser, Dr. Martin Callmander, Dr. Y.M. Yuan (Neuchatel University, Swiss) for their advices to work on Impatiens, their support and valuable help at the begining of my research and all those

Acknowledgements

who helped me to achieve all field work and laboratory studies especially. From 1999 to 2003, field work was conducted in Tsaratanana Montagne, Ambanizana-Masoala, Mandraka, Ranomafana, Marojejy, Andohahela and Nanatonana-Maosala in collaboration of Parc Botanique et Zoologique de Tsimbazaza (PBZT) and the University of Neuchatel. In 2004 the field work in Ranomafana and Tsitola was conducted in collaboration with PBZT and the University of Koblenz–Landau. In 2008 and 2009 the study was conducted in collaboration with the Sud Expert Plant/IRD project in Betampona, Ranomafana and Ambanizana-Masoala. Finally the herbaria of TAN, P, G, K, NEU and MO are thanked for their collaboration. Laboratory work on herbarium material between 2000 and 2002 was supported by University of Neuchatel and between 2004-2010 by University of Koblenz–Landau & DAAD as well as the Museum National d’Histoire Naturelle de Paris (2007).

In Madagascar I wish to thank my colleagues from the Parc Zoologique Botanique de Tsimbazaza (PBZT) especially Mrs Ramanantenasoa Claudette and Dr. Rapanarivo Solo Hery and at the University of Mahajanga Prof. Hery Lys Ranarijaona and Prof. Rajaonarison Francois.

Additional acknowledgements are given in the respective chapters

References

- Abrahamczyk, S., Lozada Gobilard, S., Ackermann, M., Fischer E., Krieger V., Redling A. & Weigend M. (2017): A question of data quality – testing pollination syndromes in Balsaminaceae. *PLoS One* 12: e0186125.
- Abrahamczyk, S. & Fischer, E. (2015) *Impatiens elianae* (Balsaminaceae), a new species from central Madagascar, with notes on the taxonomic relationship of *I. lyallii* and *I. trichoceras*. *Phytotaxa* 226: 83–91. <http://dx.doi.org/10.11646/phytotaxa.226.1.8>
- Akaike, H. 1974. A new look at the statistical model identification. *IEEE Trans Automatic Contributions* 19: 716–723.
- Akiyama, S. & Ohba, H. 2000. Inflorescences of the Himalayan species of *Impatiens* (Balsaminaceae). *Journal of Japanese Botany* 75: 226–240.
- Akiyama, S., Ohba, H. & Suzuki, M. 1992a. Notes on east Himalayan species of *Impatiens*, I. *Journal of Japanese Botany* 67: 187–193.
- Akiyama, S., Ohba, H. & Wu, S.-K. 1996. Further notes of *Impatiens* (Balsaminaceae) from Yunnan, China. *Bulletin of the National Science Museum, B (Tokyo)* 22: 135–144.
- Akiyama, S., Ohba, H., Sugawara, T., Yang, Y.-P. & Murata, J. 1995. Notes on *Impatiens* (Balsaminaceae) from southwestern Yunnan, China. *Journal of Japanese Botany* 70: 95–106.
- Akiyama, S., Wakabayashi, M. & Ohba, H. 1992b. Chromosome evolution in Himalayan *Impatiens* (Balsaminaceae). *Botanical Journal of the Linnean Society* 109: 247–257.
- Albach, D. C., Soltis, P. S., Soltis, D. E. & Olmstead, R. G. 2001. Phylogenetic analysis of a sterids based on sequences of four genes. *Annals of the Missouri Botanical Garden* 88: 163–212.
- Alfaro ME, Zoller S, Lutzoni F (2003) Bayes or Bootstrap? A simulation study comparing Performance of Bayesian Markov Chain Monte Carlo sampling and

References

- Bootstrapping in assessing Phylogenetic confidence. *Molecular Biology and Evolution* 20(2): 255–266. <https://doi.org/10.1093/molbev/msg028>
- Almeda F. 2003– Melastomataceae, Princess Flowers: 375-379, in Goodman, S.M. & Benstead, J.P. (eds), *The Natural History of Madagascar*. The University of Chicago Press.
- Anderberg, A. A., Rydin, C. & Källersjö, M. 2002. Phylogenetic relationships in the order Ericales s. l.: analyses of molecular data from five genes from the plastid and mitochondrial genomes. *American Journal of Botany* 89: 677–687.
- Antlfinger, A. E. 1986. Field germination and seedling growth of chasmogamous and cleistogamous progeny of *Impatiens capensis* (Balsaminaceae). *American Journal of Botany* 73: 1267–1273.
- APG. 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* 141: 399–436.
- Arisumi, T. 1980. Chromosome numbers and comparative breeding behavior of certain *Impatiens* from Africa, India, and New Guinea. *Journal of the American Society for Horticultural Science* 105: 99-102
- Backlund, A., & Bremer, K. (1998): To be or not to be: Principles of classification and monotypic plant families. *Taxon* 47(2): 391–400. <https://doi.org/10.2307/1223768>
- Baillon, M.H. (1881) Sur une Balsamine de Madagascar. *Bulletin Mensuel de la Société Linnéenne de Paris* 1: 286.
- Baillon, M. (1886) Liste des plantes de Madagascar (suite). *Bulletin Mensuel de la Société Linnéenne de Paris* 1: 594–595.
- Baker, J.G. (1883) Contributions to the Flora of Madagascar. Part I. Polypetalae. *Journal of the Linnean Society of London, Botany* 20:87–158.
- Baker, J.G. (1887) Further Contributions to the Flora of Madagascar. *Journal of the Linnean Society of London, Botany* 22: 441–472.
- Bardot-Vaucoulon, M. 1997. Observations sur le milieu et la végétation du Massif de l'Ankarana (Nord de Madagascar) et description de trois nouvelles espèces de *Chlorophytum* (Liliaceae), *Tacca* (Taccaceae) et *Adenia* (Passifloraceae). *Adansonia*, sér. 3, 19: 139-163.

References

- Baum, D. & Shaw, K.L. (1995): Genealogical perspectives on the species problem. In: Hoch, P.C. & Stephenson, A.G. (Eds): *Experimental and Molecular Approaches to Plant Biosystematics*. Missouri Botanical Garden Press, St. Louis: 289–303.
- Bhaskar, V. (1975) *Studies in Balsaminaceae*. Ph.D. Thesis, University of Mysore, Mysore (Manasagangotri), Mysore, India.
- Bhaskar, V. & Razi B.A. (1981): Peninsula Indian *Impatiens* (Balsaminaceae). *Bulletin of the Botanical Survey of India* 23 (3-4): 191-196.
- Bhaskar, V. (1981): The genus *Impatiens* L. in South India: endemism and affinities. *The Indian Forester* 107(6): 368-376.
- Bhaskar, V. (2012): Taxonomic Monograph on *Impatiens* Linn. (Balsaminaceae) of Western Ghats; India- The key genus for endemism. Centre for Plant Taxonomy Studies. Bangalore India. 710p.
- Bos J.J. (1991): Novitates gabonenses 4. Another new species of *Impatiens* (Balsaminaceae) from Gabon. *Bulletin du Muséum National d'Histoire Naturelle, Paris, B, Adansonia* 12: 239-242.
- Bosser, J., Cadet, T. & Marais, W. (eds.) (1979): Balsaminaceae (64) à Burseraceae (68). Flore des Mascareignes (Réunion-Maurice-Rodrigues).
- Bremer, B., Bremer, K., Heidari, N., Erixon, P., Olmstead, R. G., Anderberg, A. A., Källersjö, M. & Barkhordarian, E. (2002): Phylogenetics of asterids based on 3 coding and 3 non-coding chloroplast DNA markers and the utility of non-coding DNA at higher taxonomic levels. *Molecular Phylogeny and Evolution* 24: 274–301.
- Callmander, M.W. & Laivao, M.O. (2003): Pandanaceae, *Pandanus*: 460-467, in Goodman, S.M. & Benstead, J.P. (eds), *The Natural History of Madagascar*. The University of Chicago Press.
- Cheek, M. & Csiba, L. (2002): A new epiphytic species of *Impatiens* (Balsaminaceae) from Western Cameroon. *Kew Bulletin* 57: 669–674.
- Cheek, M. & Fischer, E. (1999) A tuberous and epiphytic new species of *Impatiens* (Balsaminaceae) from southwest Cameroon. *Kew Bulletin* 54: 471–475.
- Chen, Y.-L. (1978): Notulae de genere *Impatiens* L. florum sinicae. *Acta Phytotaxonomica Sinica* 16: 36–55.

References

- Chen, Y.-L. (2000): Three new species of *Impatiens* L. from China. *Acta Phytotaxonomica Sinica* 38: 557–562.
- Chen, Y.-L. (2001): Balsaminaceae, *Flora Reipublicae Popularis Sinicae*, Tomus 47 (2). Science Press, Beijing.
- Cronquist, A. (1981): *An Integrated System of Classification of Flowering Plants*. Columbia Univ. Press, New York.
- Dahlgren, R. (1989): An updated angiosperm classification. *Botanical Journal of the Linnean Society* 100(3): 197–203. <https://doi.org/10.1111/j.1095-8339-1989.tb01717.x>
- Day, P.D., Pellicer, J. & Kynast, R.G. (2012): Orange balsam (*Impatiens capensis* Meerb., Balsaminaceae): a re-evaluation by chromosome number and genome size. *The Journal of the Torrey Botanical Society* 139: 26–33.
- De Wildeman, E. (1922): *Plantae Bequaertianae III. Balsaminaceae*. 351–367.
- Denduangboripant, J. & Cronk, Q. C. B. (2001): Evolution and alignment of the hypervariable *arm1* of *Aeschynanthus* (Gesneriaceae) ITS2 nuclear ribosomal DNA. *Molecular Phylogeny and Evolution* 20: 163–172.
- Dorr, L.J. (1997): *Plant collectors in Madagascar and the Comoro Islands*. Royal Botanic Gardens, Kew VII–XLV, pp. 1–524.
- Doyle, J.J. & Doyle, J.L. (1987): A rapid DNA isolation method for small quantities of fresh tissues. *Phytochemistry Bulletin* 19: 11–15.
- Drake, E. del Castillo (1896): *Impatiens catati*. In: Grandidier, A. (Ed.) *Histoire physique, naturelle et politique de Madagascar, Atlas 2*: t. 170A.
- Dransfield, J. & Beentje, H. (1995): *The Palms of Madagascar*. Royal Botanic Gardens Kew.
- Felsenstein, J. (1985): Confidence limits on phylogenies: an approach using the bootstrap. *Evolution* 39: 783–791. and The International Palm Society. VII–XII, 1–475.
- Fischer, E. (1997): Contributions to the Flora of Central Africa V: Two new species of *Impatiens* (Balsaminaceae) from Eastern Zaïre. *Bulletin du Jardin Botanique National de Belgique* 66: 63–71.

References

- Fischer, E. (2004): Balsaminaceae. In Kubitzki, K. (Ed.), Families and Genera of Vascular Plants, vol. 6. Springer-Verlag, Berlin, Heidelberg, pp. 20–25.
- Fischer E.; Dhetchuvi J.-P. & Ntaganda C. (2003): A new species of *Impatiens* (Balsaminaceae) from Nyungwe Forest, Rwanda. *Systematics and Geography of Plants* 73: 91-101.
- Fischer, E. & Rahelivololona, M.E. (2002): New taxa of *Impatiens* (Balsaminaceae) from Madagascar I. *Adansonia*, sér. 3 (24): 271-294. <http://sciencepress.mnhn.fr/sites/default/files/articles/pdf/a2002n2a15.pdf>
- Fischer, E. & Rahelivololona M. E. (2004a): New taxa of *Impatiens* (Balsaminaceae) from Madagascar. III. *Adansonia* 26: 37–52. <http://sciencepress.mnhn.fr/sites/default/files/articles/pdf/a2004n1a2.pdf>
- Fischer, E. & Rahelivololona M. E. (2004b): A new epiphytic species of *Impatiens* (Balsaminaceae) from the Comoro Islands. *Adansonia* 26: 93-95.
- Fischer, E. Rahelivololona MÉ. (2007a): New taxa of *Impatiens* (Balsaminaceae) from Madagascar. IV. *Adansonia*, sér. 329 (2): 269–315.
- Fischer, E. & Rahelivololona, E. (2007b): New taxa of *Impatiens* from Madagascar V. New species of *Impatiens* from Masoala Peninsula. *Adansonia* sér. 3; 29: 317-332.
- Fischer, E. & Rahelivololona E. (2015a): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VI. *Impatiens otto-eleonora*, a new species from Masoala Peninsula, and notes on the taxonomic relationships of *Impatiens formula* and *I. hildebrandtii*. *Phytotaxa*. 217: 155-163. <http://dx.doi.org/10.11646/phytotaxa.217.2.5>
- Fischer, E. & Rahelivololona E. (2015b): New taxa of *Impatiens* (Balsaminaceae) from Madagascar IX. *Impatiens lutzii*, a new species from Montagne d'Ambre National Park. *Phytotaxa* 239: 183-189. <http://dx.doi.org/10.11646/phytotaxa.239.2.7>
- Fischer, E. & Rahelivololona E. (2015c): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VII. Two new species of *Impatiens* from Mt. Marojejy, Madagascar. *Phytotaxa* 239: 213–222. <http://dx.doi.org/10.11646/phytotaxa.239.3.2>
- Fischer, E. & Rahelivololona E. (2016): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VIII. *Impatiens max-huberi*, a new species from Marojejy and Anjanaharibe-Sud. *Phytotaxa* 244 (2): 191–195. <https://doi.org/10.11646/phytotaxa.244.2.7>

References

- Fischer, E., Rahelivololona, M.E. & Abrahamczyk, S. (2017): *Impatiens galactica* (Balsaminaceae), a new spurless species of section *Trimorphopetalum* from Madagascar. *Phytotaxa* 298 (3): 269-276. <https://doi.org/10.11646/phytotaxa.298.3.6>
- Fischer, E., Wohlhauser, S. & Rahelivololona, E. (2003): New taxa of *Impatiens* (Balsaminaceae) from Madagascar II. A collection from Masoala Peninsula. *Adansonia*, sér. 3; 25: 17-31.
- Frimodt-Møller C. & Grey-Wilson C. (1999): Two new taxa of *Impatiens* (Balsaminaceae) from the Udzungwa Mountains, Tanzania. *Kew Bulletin* 54: 179-184.
- Fuchs, H.P. (1963): Nomenklatorische Ergänzungen zu der Arbeit Nicolaas Meerburg und die drei von ihm verfassten botanischen Tafelwerke. *Acta Botanica Neerlandica* 12: 12–16.
- Fujihashi, H., Akiyama, S. & Ohba, H. 2002. Origin and relationships of the Sino-Himalayan *Impatiens* (Balsaminaceae) based on molecular phylogenetic analysis, chromosome numbers and gross morphology. *Journal of Japanese Botany* 77: 284–295.
- Ganzhorn, J.U., Lowry, P.P.II, Schatz, G. & Sommer, S. (2001): The biodiversity of Madagascar: one of the world's hottest hotspots on its way out. *Oryx* 35: 346-348.
- Gautier, L. (1999): Inventaire floristique de la Réserve Spéciale de Manongarivo (Nord-Ouest de Madagascar). Dicotyledoneae. Documents de travail 6. Geneva: Projet Ecologie Politique et Biodiversité.
- Geuten, K., Smets, E., Schols, P., Yuan, Y.-M., Janssens, S., Küpfer, P. & Pyck, N. (2004): Conflicting phylogenies of balsaminoid families and the polytomy in Ericales: combining data in a Bayesian framework. *Molecular Phylogeny and Evolution* 31: 711–729.
- Gilg, E. (1909): Balsaminaceae Africae. *Botanische Jahrbücher für Systematik und Pflanzengeographie* 43: 97–128.
- Green, G.M. & Sussman R. (1990): Deforestation history of Eastern rainforest of Madagascar from satellite images. *Sciences* vol. 248 No 4952: 212-215.
- Grey-Wilson, C. (1979) New taxa in African *Impatiens*. *Kew Bulletin* 33: 641–649.

References

- Grey-Wilson, C. (1980a) *Impatiens* in Papuasia, Studies in Balsaminaceae: I. *Kew Bulletin* 34: 661–688.
- Grey-Wilson, C. (1980b): *Impatiens of Africa*. A.A.Balkema Rotterdam. 235 pp.
- Grey-Wilson, C. (1980c): *Hydrocera triflora*, its floral morphology and relationships with *Impatiens* Studies in Balsaminaceae V. *Kew Bulletin* 35(1): 213–219.
- Grey-Wilson, C. (1980d): Notes on collecting *Impatiens* (Balsaminaceae). *Flora Malesiana Bulletin* 33: 3435–3436.
- Grey-Wilson, C. (1985): Balsaminaceae. Pp. 76–120 in: Dassanayake, M. D. & Fosberg, F. R. (eds.), *A Revised Handbook to the Flora of Ceylon*. Amerind Publ. Co., Pvt. Ltd., New Delhi.
- Grey-Wilson, C. (1989a): A revision of Sumatran *Impatiens*. Studies in Balsaminaceae: VIII. *Kew Bulletin* 44: 67–105.
- Grey-Wilson, C. (1989b): *Semeiocardium* Zoll.; is it a good genus? Studies in Balsaminaceae: IX. *Kew Bulletin* 44:107–113.
- Haevermans, T. (2003): *Euphorbia*: 385-391, in Goodman, S.M. & Benstead, J.P. (eds), *The Natural History of Madagascar*. The University of Chicago Press.
- Hallé N. & Louis A.M. (1989): Un nouvel *Impatiens* (Balsaminaceae) du Gabon. *Bulletin du Muséum National d'Histoire Naturelle, B, Adansonia* 11: 11-15.
- Heckel, E. (1910) Les plantes utiles de Madagascar. *Annales du Musée Colonial de Marseille, Série 2, 8*: 1-372.
- Hoffmann, O. (1882): Reliquiae Rutenbergianae V (Botanik, Fortsetzung) Geraniaceen, Tribus Balsamineen. *Abhandlungen des Naturwissenschaftlichen Vereins zu Bremen* 7: 335–336.
- Hohenegger, J (2014): Species as the basic units in evolution and biodiversity: recognition of species in the recent and geological past as exemplified by larger foraminifera. *Gondwana Research* 25: 707–728. <https://doi.org/10.1016/j.gr.2013.09.009>
- Holmgren, P.K., Holmgren, N.H. & Barnett, L.C. (1990) *Index Herbariorum*. Part I: *The Herbaria of the World*. New York Botanical Garden, New York, 704 pp.

References

- Hooker, J.D. (1874-75): Geraniaceae-Balsamineae. In: Flora of British India 1: 440-483.
- Hooker, J.D. (1904): An epitome of the British Indian species of *Impatiens*. *Records of the Botanical Survey of India* 4: 1-10.
- Hooker, J.D. (1905): An epitome of the British Indian species of *Impatiens*. *Records of the Botanical Survey of India* 4: 11-35.
- Hooker, J.D. (1906): An epitome of the British Indian species of *Impatiens*. *Records of the Botanical Survey of India* 4: 37-58.
- Hooker, J. D. & Thompson, T. (1859): Praecursores ad floram Indicam. Balsaminaceae. *Botanical Journal of the Linnean Society* 4: 106–157.
- Huang, S.-H., Shui, Y.-M. & Chen, W.-H. (2003): New taxa of *Impatiens* from Yunnan. *Acta Botanica Yunnanica* 25: 261–280.
- Huelsenbeck, J.P. & Ronquist, F. (2001): MrBayes: Bayesian inference of phylogeny. *Bioinformatics* 17(8): 754–755. <https://doi.org/10.1093/bioinformatics/17.8.754>
- Humbert, H. (1955): Une merveille de la nature à Madagascar. Première exploration botanique du Massif du Marojejy et ses satellites. *Mémoire de l'Institut Scientifique de Madagascar* 6: 1–205.
- Humbert, H. (1956): Contributions à l'étude de la flore de Madagascar et des Comores (fascicule 5). *Notulae Systematicae* 15: 113–134.
- Huynh, K.L. (1968) Morphologie du pollen des Tropaeolacées et des Balsaminacées - II. *Grana Palynologica* 8: 277-516.
- Huynh, K.L. (1974) Emploi des données de la morphologie du pollen actuel à l'appui de la théorie de la dérive des continents. Réflexion méthodologiques. Les genres *Impatiens* et *Anemone*. *Bulletin de la Science Géologique* 27: 185-193.
- IUCN (2001) *IUCN red list categories and criteria*: Version 3.1. IUCN Species Survival Commission, Gland, Switzerland and Cambridge UK, iv + 32 pp.
- Janssens, S. (2008): Evolutionary studies in Balsaminaceae: Integration of evidence from molecular and morphological data. Ph. D. Thesis, Katholieke Universiteit Leuven; 257p

References

- Janssens, S., Geuten, K., Viane, T., Yuan, Y.-M., Song, Y. & Smets, E. (2007): Phylogenetic utility of the *AP3/DEF* K-domain and its molecular evolution in *Impatiens* (Balsaminaceae). *Molecular Phylogenetics and Evolution* 43: 225–239. <https://doi.org/10.1016/j.ympev.2006.11.016>
- Janssens, S., Geuten, K., Yuan, Y.-M., Song, Y., Küpfer, P. & Smets, E. (2006): Phylogenetics of *Impatiens* and *Hydrocera* (Balsaminaceae) using chloroplast *atpB-rbcL* spacer sequences. *Systematic Botany* 31: 171–180. <https://doi.org/10.1600/036364406775971796>
- Janssens, S.B., Fischer, E. & Stévant, T. (2010): New insights on the origin of epiphytic *Impatiens* species (Balsaminaceae) from West Central Africa based on molecular phylogenetic analyses. *Taxon* 59(5): 1508–1518.
- Janssens, S.B., Knox, E.B., Huysmans, S., Smets, E.F., & Merckx, V.S. (2009): Rapid radiation of *Impatiens* (Balsaminaceae) during Pliocene and Pleistocene: result of a global climate change. *Molecular Phylogenetics and Evolution* 52: 806–824. <https://doi.org/10.1016/j.ympev.2009.04.013>
- Jones, K. & Smith, J. B. (1966): The cytogeography of *Impatiens* L. (Balsaminaceae). *Kew Bulletin* 20: 63–72.
- Katoh, K., Misawa K., Keiichi Kuma, K., Miyata, T., 2002. MAFFT: a novel method for rapid multiple sequence alignment based on fast Fourier transform. *Nucleic Acids Research* 30 (14): 3059–3066. <https://doi.org/10.1093/nar/gkf436>
- Koechlin J., Guillaumet J.-L. & Morat, P. (1974). Flore et végétation de Madagascar. *Flora et Vegetatio Mundi*; 5. Vaduz: J. Cramer, 701 pp.
- Lack, H.W. (2016): Stefan Vogel (1925–2015). *Willdenowia* 46: 283–286.
- Linnaeus, C. (1753): *Species plantarum*. L. Salvius, Stockholm, 1200 pp.
- Lozada-Gobilard, S., Weigend, M., Fischer, E., Janssens, S.B., Ackermann, M. & Abrahamczyk, S. (2018): Breeding systems in Balsaminaceae in relation to pollen/ovule ratio, pollination syndromes, life history and climate zone. *Plant Biology* doi:10.1111/plb.12905
- Lu, Y.-Q. (2002): Why is cleistogamy a selected reproductive strategy in *Impatiens capensis* (Balsaminaceae)? *Biological Journal of the Linnean Society* 75: 543–553

References

- Madagascar Catalogue (2017): *Catalogue of the vascular plants of Madagascar*. Missouri Botanical Garden, St. Louis, USA & Antananarivo, Madagascar [http://www.efloras.org/Madagascar. Accessed: March 2017].
- Maddison, W. P. & Maddison, D. R. (1992): *MacClade: Analysis of Phylogeny and Character Evolution, version 3.0*. Sinauer, Sunderland, Massachusetts
- Meerburgh, N. (1775): *Impatiens capensis* Meerburgh. *Afbeeldingen van Zeldzaame Gewassen* 1: t. 10.
- Morton, C. M., Chase, M. W., Kron, K. A. & Swensen, S. M. (1996): A molecular evaluation of the monophyly of the order Ebenales based upon *rbcL* sequence data. *Systematic Botany* 21: 567–586.
- Morton, C. M., Mori, S. A., Prance, G. T., Karol, K. G. & Chase, M. W. (1997): Phylogenetic relationships of Lecythidaceae: a cladistic analysis using *rbcL* sequence and morphological data. *American Journal of Botany* 84: 530–540.
- Paoletti, C. & Holsinger, K. E. (1999): Spatial patterns of polygenic variation in *Impatiens capensis*, a species with an environmentally controlled mixed mating system. *J. Evol. Biol.* 12: 689–696.
- Pernet, R. (1957) Les plantes medicinales malgaches. Catalogue de nos connaissances chimiques et pharmacologiques, Mémoires de l'Institut Scientifique de Madagascar VIII, serie B.
- Perrier de la Bâthie, H. (1927): *Impatientella* gen. nov. *Bulletin de l'Académie malgache*, Nouvelle Série 10:21-24.
- Perrier de la Bâthie, H. (1934): Les *Impatiens* de Madagascar. *Archives de Botanique* 7 (1933), *Mémoire* 1: 1–124.
- Perrier de la Bâthie, H. (1948): Révision des *Impatiens* de Madagascar et des Comores. *Memoires de l'Academie des Sciences* 67: 1–16.
- Petit-Thouars, A.A. (1822): *Histoire particulière des plantes orchidées recueillies sur les trois îles australes d'Afrique, de France, de Bourbon et de Madagascar*. Paris, 110 pp.
- Posada, D. (2008): Modeltest: Phylogenetic model Averaging. *Molecular Biology and Evolution* 25: 1253-1256. <https://doi.org/10.1093/molbev/msn083>

References

- Posada, D. & Crandall, K. A. (1998): Modeltest: testing the model of DNA substitution. *Bioinformatics* 14, 817–818.
- Rambaut, A. & Drummond, J. (2007): BEAST: Bayesian evolutionary analysis by sampling tree. *BMC Evolutionary Biology* 7: 214. <https://doi.org/10.1186/1471-2148-7-214>
- Rao, R. V. S., Ayyangar, K. R. & Sampathkumar, R. (1986): On the karyological characteristics of some members of Balsaminaceae. *Cytologia* 51: 251–260.
- Ronquist, F. & Huelsenbeck, J.P. (2003): Mr. Bayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* 19: 1572–1574. <https://doi.org/10.1093/bioinformatics/btg180>
- Rosell, J.A., Olson, M.E., Beeks, A., De-Nova, J.A., Lemos, R.M., Camacho, J.P., Feria, T.P., Gomez-Bermejo, R. & Montero, J.C. (2010): Diversification in species complexes: tests of species origin and delimitation in the *Bursera simaruba* clade of tropical trees (Burseraceae). *Molecular Phylogenetics and Evolution* 57: 798–811. <https://doi.org/10.1016/j.ympev.2010.08.004>
- Ruchisansakun, S. Suksathan, P., van der Niet, T., Smets, E. F., Saw-Lwin & Janssens, S.B. (in press): Balsaminaceae of Myanmar. *Blumea*.
- Saitou, N. & Nei, M. (1987): The neighbor-joining methods: a new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution* 4: 406–425.
- Schulze, G.M. (1944): Beiträge zur Kenntnis der afrikanischen Balsaminaceen. *Botanische Jahrbücher für Systematik und Pflanzengeographie* 73: 453–466.
- Shimizu, T. (2000): New species of the Thai *Impatiens* (Balsaminaceae): 2. *Bull. National Science Museum, B (Tokyo)* 26: 35–42.
- Soltis, D. E., Soltis, P. S., Chase, M. W., Mort, M. E., Albach, D. C., Zanis, M., Savolainen, V., Hahn, W. H., Hoot, S. B., Fay, M. F., Axtell, M., Swensen, S. M., Prince, L. M., Kress, W. J., Nixon, K. C. & Farris, J. S. (2000): Angiosperm phylogeny inferred from 18S rDNA, *rbcL*, and *atpB* sequences. *Botanical Journal of the Linnean Society* 133: 381–461.
- Song, Y. (2006) Evolution and biogeography of Balsaminaceae: insights from molecular phylogeny. Ph.D. thesis, University of Neuchâtel-Faculty of Science-Evolutionary Botany Laboratory, Neuchâtel-Switzerland.

References

- Song, Y., Yuan, Y.-M. & Küpfer, P. (2003): Chromosomal evolution in Balsaminaceae, with cytological observations on 45 species from Southeast Asia. *Caryologia* 56: 463–481.
- Stamatakis, A., Hoover, P. & Rougemont, J. (2008): A rapid bootstrap algorithm for RAxML Web servers. *Systematic Biology* 57(5): 758–771. <https://doi.org/10.1080/10635150802429642>
- Suzuki, Y., Glasko, G.V. & Nei, M. (2002): Overcredibility of molecular phylogenies obtained by Bayesian phylogenetics. *Proceeding of the National Academy of Sciences of the United State of America* 99: 16138–16143. <https://doi.org/10.1073/pnas.212646199>
- Swofford, D.L. (2000): PAUP* Phylogenetic Analysis Using Parsimony (*and Other Methods).Version 4. Sinauer Associates, Sunderland, Massachusetts.
- Takhtajan, A. (1980): Outline of the classification of flowering plants (Magnoliophyta). *The Botanical Review* 46: 225–359.
- Takhtajan, A. (1997): *Diversity and Classification of flowering plants*. New York, Columbia University Press:pp. 1 - 643.
- Thompson, J. D., Gibson, T. J., Plewniak, F., Jeanmougin, F. & Higgins, D. G. (1997): The Clustal X windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Research* 24:4876–4882.
- Thorne, R.F. (2000): The classification and geography of the flowering plants: dicotyledons of the class Angiospermae. *Botanical Review* 66 (4): 441–647. <http://dx.doi.org/10.1007/BF02869011>
- Thunberg, C.P. (1794): *Prodromus plantarum Capensium quas in Promontorio Bonae Spei Africis, annis 1772-1775, collegit Carol. Pet. Thunberg*. Pars Prior: I–XXIX, pp. 1–83.
- Warburg, O. & Reiche, K. (1895): Balsaminaceae. Pp. 383–392 in: Engler, H. G. A. & Prantl, K. A. E. (eds.), *Die Natürlichen Pflanzenfamilien*, Teil 3, Abteil. 5. Wilhelm Engelmann, Leipzig
- Warburg, O. (1897): Balsaminaceae Africanæ. *Botanische Jahrbücher für Systematik* 22: 46–53.

References

- Wilczek, R. & Schulze, G.M. (1959) Novitates Africanae V, Balsaminaceae-Impatiens. *Bulletin du Jardin Botanique de l'État à Bruxelles* 29: 185–192.
- Yu, S.X., Janssens, S., Zhu, X.Y., Liden, M., Gao, T.G. & Wang, W. (2015): Phylogeny of *Impatiens* (Balsaminaceae): integrating molecular and morphological evidence into a new classification. *Cladistics* (2015) 1–19. <https://doi.org/10.1111/cla.12119>
- Yuan, Y.-M., Song, Y., Geuten, K., Rahelivololona, E., Wohlhauser, S., Fischer, E., Smets, E. & Küpfer, P. (2004): Phylogeny and biogeography of Balsaminaceae inferred from ITS sequences. *Taxon* 53: 391–403. <https://doi.org/10.2307/4135617>
- Yuan, Y.-M., Wohlhauser, S., Möller, M., Chassot, P., Mansion, G., Grant, J., Küpfer, P. & Klackenberg, J. (2003): Monophyly and relationships of the tribe Exaceae (Gentianaceae) inferred from nuclear ribosomal and chloroplast DNA sequences. *Molecular Phylogeny and Evolution* 28: 500–517.
- Zinov'Eva-Stahevitch, A. E. & Grant, W. F. (1985): Chromosomal Differentiation in *Impatiens* L. (Balsaminaceae). *Caryologia* 38: 139-145.

Declaration on the authors own contribution to the submitted
papers:

Fischer, E. & Rahelivololona, E. (2002): New taxa of *Impatiens* (Balsaminaceae) from Madagascar. I. Adansonia sér. 3, **24**: 271-291.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E., Wohlhauser, S. & Rahelivololona, E. (2003): New taxa of *Impatiens* (Balsaminaceae) from Madagascar II. A collection from Masoala Peninsula. Adansonia sér. 3, **25**: 17-31.

Own contribution (50%) comprises measurements, analysis of material and discussion.

Rahelivololona, E., Fischer, E. & Wohlhauser, S. (2003): Balsaminaceae. In: Goodman, S.M. & Benstead, J.P. (eds.): The Natural History of Madagascar. The University of Chicago Press: 402-409.

Own contribution (80%) comprises establishment of check-list, analysis and discussion.

Fischer, E. & Rahelivololona, E. (2004): New taxa of *Impatiens* (Balsaminaceae) from Madagascar III. Adansonia sér. 3, **26**: 37-52.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E. & Rahelivololona, E. (2004): A new epiphytic species of *Impatiens* (Balsaminaceae) from the Comoro Islands. Adansonia sér. 3, **26**: 93-95.

Own contribution (50%) comprises measurements, analysis and discussion.

Fischer, E. & Rahelivololona, E. (2007): New taxa of *Impatiens* from Madagascar IV. Adansonia **29**: 613-616.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Declaration own contribution

Fischer, E. & Rahelivololona, E. (2007): New taxa of *Impatiens* from Madagascar V. *Adansonia* 29: 317-332.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E. & Rahelivololona, E. (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VI. *Impatiens otto-eleonorae*, a new species from Masoala Peninsula, and notes on the taxonomic relationships of *Impatiens firmula* and *I. hildebrandtii*. *Phytotaxa* **217**: 155-163.

Own contribution (50%) comprises measurements, analysis and discussion.

Fischer, E. & Rahelivololona, M.E. (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VII. Two new species of *Impatiens* from Mt. Marojejy, Madagascar. *Phytotaxa* **239**: 213-222.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E. & Rahelivololona, M.E. (2016): New taxa of *Impatiens* (Balsaminaceae) from Madagascar VIII. *Impatiens max-huberi*, a new species from Marojejy and Anjanaharibe-Sud. *Phytotaxa* **244**: 191-195.

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E. & Rahelivololona, M.E. (2015): New taxa of *Impatiens* (Balsaminaceae) from Madagascar IX. *Impatiens lutzii*, a new species from Montagne d'Ambre National Park. *Phytotaxa* **239**: 183-189.

Own contribution (50%) comprises measurements, analysis and discussion.

Fischer, E., Rahelivololona, M.E. & Abrahamczyk, S. (2017): *Impatiens galactica* (Balsaminaceae), a new spurless species of section *Trimorphopetalum* from Madagascar. *Phytotaxa* 298 (3): 269-276.

Own contribution (50%) comprises measurements, analysis and discussion.

Fischer, E., Rahelivololona, M.E. & Abrahamczyk, S. (2017): *Impatiens sielmannii* (Balsaminaceae), a new epiphytic species from Madagascar

Declaration own contribution

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Fischer, E., Rahelivololona, M.E. & Abrahamczyk, S. (2017): *Impatiens stefan-vogeli* (Balsaminaceae), a new epiphytic species from Madagascar

Own contribution (50%) comprises collection of material, measurements, analysis and discussion.

Yuan, Y.-M, Song, Y., Geuten, K., Rahelivololona, E., Wohlhauser, S., Fischer, E., Smets, E. & Kuepfer, P. (2004): Phylogeny and biogeography of Balsaminaceae inferred from ITS sequences. *Taxon* **53(2)**: 391-403.

Own contribution (30%) comprises collection of material, contributions to analysis of Malagasy species and discussion.

Rahelivololona, E.M., Fischer, E., Janssens, S.B. & Razafimandimbison, S.G. (2018): Phylogeny, infrageneric classification and species delimitation in the Malagasy *Impatiens* (Balsaminaceae). *Phytokeys* 110: 51 – 67.

Own contribution (70%) comprises conception of paper, collection of material, contributions to analysis and discussion.

Curriculum vitae

Curriculum vitae

For reasons of data protection, the curriculum vitae is not included in the online version (pages 314-319)

Declaration

Erklärung

Hiermit erkläre ich,

- dass ich die eingereichte Dissertation selbstständig verfasst habe und alle von mir für die Arbeit genutzten Hilfsmittel in der Arbeit angegeben sowie die Anteile etwaig beteiligter Mitarbeiter sowie anderer Autoren klar gekennzeichnet sind;
- dass ich die Dissertation oder Teile hiervon nicht als Prüfungsarbeit für eine Staatliche oder andere wissenschaftliche Prüfung eingereicht habe;
- dass ich die gleiche oder eine andere Abhandlung nicht in einem anderen Fachbereich oder einer anderen wissenschaftlichen Hochschule als Dissertation eingereicht habe.

Eliseth

Rachelvobene
Marie Eliseth