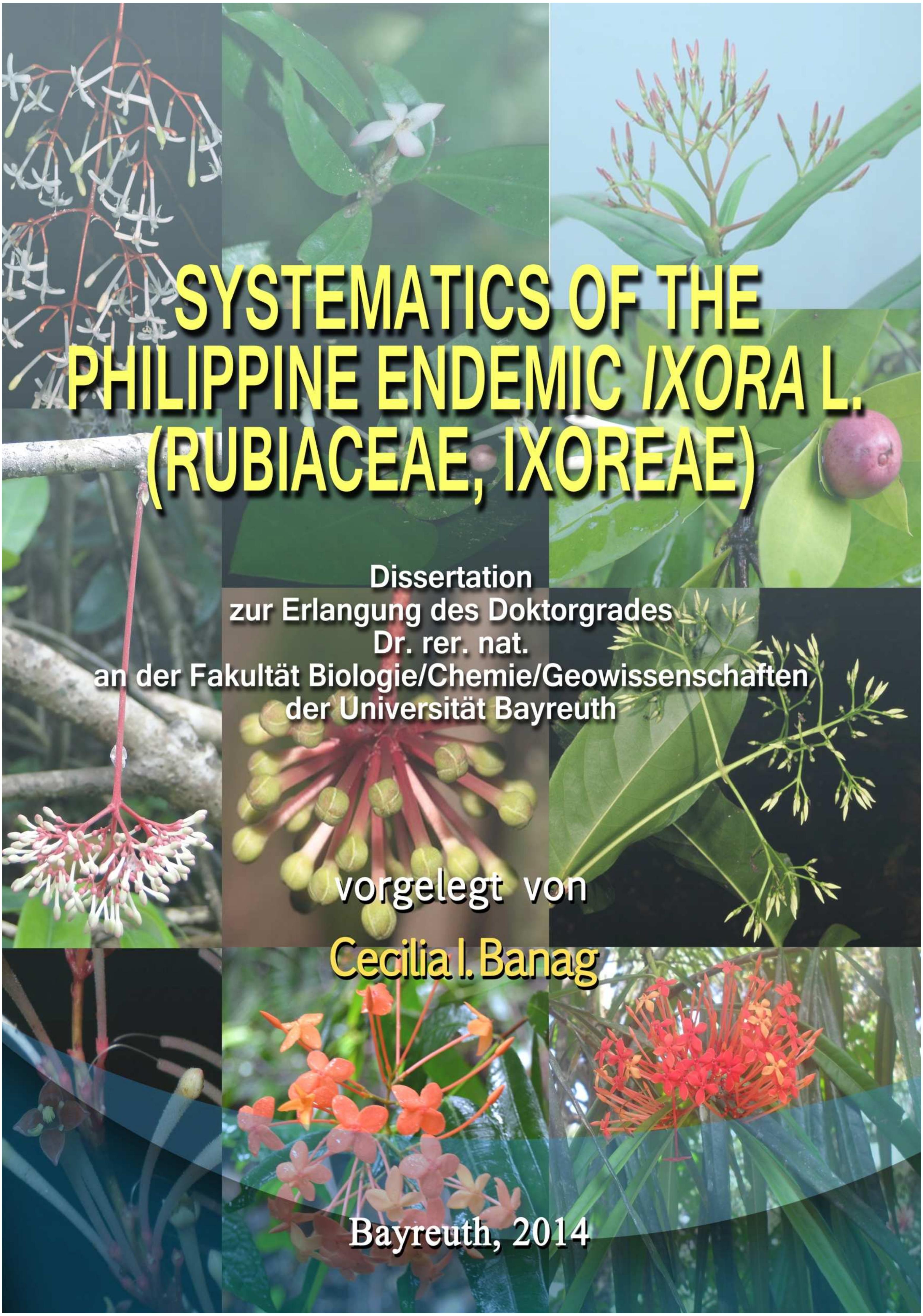

SYSTEMATICS OF THE PHILIPPINE ENDEMIC *IXORA* L. (RUBIACEAE, IXOREAE)

Dissertation
zur Erlangung des Doktorgrades
Dr. rer. nat.
an der Fakultät Biologie/Chemie/Geowissenschaften
der Universität Bayreuth

vorgelegt von

Cecilia I. Banag

Bayreuth, 2014

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Bayreuth, 2014

Die vorliegende Arbeit wurde in der Zeit von Juli 2012 bis September 2014 in Bayreuth am Lehrstuhl Pflanzensystematik unter Betreuung von Frau Prof. Dr. Sigrid Liede-Schumann und Herrn PD Dr. Ulrich Meve angefertigt.

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Prof. Dr. Sigrid Liede-Schumann (Erstgutachter)
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Prof. Dr. Gerhard Gebauer (Vorsitz)
Prof. Dr. Carl Beierkuhnlein

This dissertation is submitted as a 'Cumulative Thesis' that includes four publications: three submitted articles and one article in preparation for submission.

List of Publications

Submitted (under review):

1) Banag C.I., Mouly A., Alejandro G.J.D., Meve U. & Liede-Schumann S.: Molecular phylogeny and biogeography of Philippine *Ixora* L. (Rubiaceae). Submitted to *Taxon*, TAXON-D-14-00139.

2) Banag C.I., Thrippleton T., Alejandro G.J.D., Reineking B. & Liede-Schumann S.: Bioclimatic niches of endemic *Ixora* species on the Philippines: potential threats by climate change. Submitted to *Plant Ecology*, VEGE-D-14-00279.

3) Banag C.I., Tandang D., Meve U. & Liede-Schumann S.: Two new species of *Ixora* (Ixoroideae, Rubiaceae) endemic to the Philippines. Submitted to *Phytotaxa*, 4646.

In preparation for submission to Phytotaxa:

4) Banag C.I., De Block, P., Alejandro, G.J.D., Liede-Schumann S. & Meve U.: The Philippine species of *Ixora* (Rubiaceae).

Publications not included into this thesis:

5) Banag C.I., Manalastas N.M.B. & Alejandro, G.J.D. 2014.: Synonymy of Philippine *Ixora* (Ixoreae, Rubiaceae) and *Ixora silagoensis sp. nov.* Nordic Journal of Botany doi: 10.1111/njb.00411.

6) Banag C.I. & Tandang D.: Taxonomic notes on three widespread endemic *Ixora* (Rubiaceae) in the Philippines. Submitted to National Museum of the Philippines Journal of Natural History (under review).

Declaration of contribution to publications

This thesis contains four research articles for which most of the work presented was carried out by myself. Molecular and most of the analytical work was done at the University of Bayreuth with the assistance and support of Prof. Dr. Sigrid Liede-Schumann, PD Dr. Ulrich Meve and Prof. Dr. Grecebio Jonathan Alejandro. Sample collections were conducted in the Philippines from 2010 to 2013 with the help of the Thomasian Angiosperm Phylogeny and Barcoding group from the University of Santo Tomas (UST), Manila, Philippines and Mr. Danilo Tandang and Dr. Arvin Diesmos from the National Museum of the Philippines (NMP). I prepared all manuscripts with considerations to the suggestions and comments of all co-authors.

1st Publication

Banag C.I., Mouly A., Alejandro G.J.D., Meve U. & Liede-Schumann S.: **Molecular phylogeny and biogeography of Philippine *Ixora* L. (Rubiaceae).** Submitted to *Taxon*, TAXON-D-14-00139.

Fieldwork was done by myself with the help of students and researchers from the University of Santo Tomas and National Museum of the Philippines. I did the molecular work alone with assistance of Mrs. Angelika Täuber at the Department of Plant Systematics, University of Bayreuth. Data analysis was done by myself with guidance from Prof. Dr. Sigrid Liede Schumann and Prof. Dr. Arnaud Mouly. I have written the manuscript with considerations to the comments of all co-authors.

2nd Publication

Banag C.I., Thrippleton T., Alejandro G.J.D., Reineking B. & Liede-Schumann S.: **Bioclimatic niches of endemic *Ixora* species on the Philippines: potential threats by climate change.** Submitted to *Plant Ecology*, VEGE-D-14-00279.

Georeferencing of all localities found in the herbarium specimens of *Ixora* was done by myself. Mr. Timothy Thrippleton (ETH, Zurich) helped me run the modelling in MAXENT using the R script prepared by Prof. Dr. Björn Reineking. Data analysis was done by myself with the assistance of Mr. Thrippleton and Prof. Dr. Sigrid Liede-Schumann who had the idea for this research. I have written the manuscript with considerations to the comments from all co-authors.

3rd Publication

Banag C.I., Tandang D., Meve U. & Liede-Schumann S.: **Two new species of *Ixora* (Ixoroideae, Rubiaceae) endemic to the Philippines.** Submitted to *Phytotaxa*, 4646.

Fieldwork in Samar was done by myself for the collection of *I. reynaldoi* and the fieldwork in Palawan was done by D. Tandang (NMP, Philippines) and Prof. Grecebio Jonathan D. Alejandro (UST, Philippines) for the collection of *I. alejandroi*. Morphological analysis of the two new species was done by myself. Botanical illustrations were drawn by Arianne Zacarias (UST) and Nemesio B. Diego, Jr. (NMP). I prepared the manuscript with considerations to the comments from all co-authors.

4th Publication

Banag C.I., Alejandro, De Block, P., G.J.D., Liede-Schumann S. & Meve U.: **The Philippine species of *Ixora* (Rubiaceae)**. In preparation for submission to Phytotaxa.

Fieldwork in the Philippines was done by myself with the help of students and researchers from the University of Santo Tomas and National Museum of the Philippines. All herbarium specimens of *Ixora* from A, C, L, NY, and US was sent on loan to UBT (curator: PD Dr. Ulrich Meve). Research visits to BK, BR, C, CAHUP, K, P, PNH, PPC, SAN and morphological analysis of all herbarium specimens was done by myself. Botanical illustrations were drawn by Arianne Zacarias (UST), Joseph Capino (UST) and Nemesio B. Diego, Jr. (NMP). I prepared the manuscript with considerations to the comments from all co-authors.

CONTENTS

Summary

Ixora L. belonging to the tribe Ixoreae (Rubiaceae, subfamily Ixoroideae), is a large pantropical rain forest genus of shrubs and small trees. It comprises ca. 530 species that is presently subject to intensive investigations leading to far-reaching systematic changes. Recently, based on molecular evidence, *Ixora* was further enlarge to accommodate several genera (*Captaincookia* N.Hallé, *Doricera* Verdc., *Hitoa* Nadeaud, *Myonima* Comm. ex Juss., *Thouarsiora* Homolle ex Arénes and *Versteegia* Valeton). In consequence, tribe Ixoreae has become monogeneric. Although there have been a number of revisions focusing on specific geographical regions, e.g. in Africa, Madagascar, Marquesas Islands and Australia, the continental Asian taxa have never been fully revised and no clear picture of their diversity is available. In the Philippines, the only available account of *Ixora* is an enumeration by Merrill published in 1923 which is more than 85 years old and outdated due to numerous classification changes in the family Rubiaceae. To date, species diversity of *Ixora* in the Philippines remains poorly known and basic information on species distribution and ecology, taxonomic keys and diagnostic illustrations are limited. With this work, I want to fill a gap in our knowledge of the genus by assessing the phylogenetic relationships of Philippine representatives of *Ixora*: 1) using morphological and molecular data, 2) derive information on environmental requirements of *Ixora* species endemic to the Philippines using Maxent, and 3) publish a comprehensive taxonomic revision of the Philippine *Ixora* including nomenclatural treatments (lectotypifications) and new records, full illustrations, distribution maps and keys of the recognized taxa.

An important first result of the present research was the finding that Philippine *Ixora* is polyphyletic, with representatives from at least three independent lineages. In both the parsimony and Bayesian analyses of the combined chloroplast markers (*rps16* and *trnT–F*) and nuclear markers (ITS and ETS), two main lineages of *Ixora* were recovered, an Asian-Pacific lineage and an Asian-African-Malagasy-Mascarene-Neotropical lineage. Also, the results of the Statistical Dispersal-Vicariance Analysis (S-DIVA) revealed a complex biogeographical history for *Ixora* with several dispersal and vicariance events that have led to its current distribution. Furthermore, Philippines are shown to constitute an overlay zone into which species from both major lineages of *Ixora*, the Pacific and the African-Asian one, have immigrated and subsequently radiated.

The results presented also revealed for the first time the bioclimatic relationships of endemic Philippine *Ixora* and showed that the species preferred areas with lower amount of annual rainfall and regions with higher annual precipitation variance (standard deviation). This may indicate the species' potential to adapt to the changing climate or an adaptation of the species to monsoon seasons in the Philippines. This is of particular importance as it was reported that Philippines will experience a substantial difference in terms of seasonal rainfall change in most parts of the country due to climate change. Ecological niche modelling was carried out for the two species with most occurrence records, *I. bartlingii* and *I. auriculata,* using Maxent. Model results suggested that these two *Ixora* species will shift their geographic distributions under predicted levels of climate change. These models can be used to assist in designing conservation strategies for the species as it identified localities and areas with the potential to withstand climate change until at least 2080.

Lastly, a taxonomic revision of the Philippine species of *Ixora* was done following the methods of classical herbarium taxonomy. A total of 31 species is recognized from the previously described 41 species; the remaining 10 species are recognized as synonyms of other well-defined species. *Ixora mearnsii, I. pilosa* and *I. propinqua* are considered as doubtful species, and are to be excluded. Additionally, three new species (*I. alejandroi, I. reynaldoi,* and *I. silagoensis*) are reported. Three more flowering specimens which may well represent additional new species but are not formally named because they are too imperfectly known are also included. A detailed morphological, anatomical and biological documentation of the recognized Philippine species of *Ixora* is given. All species are extensively described, native species illustrated and a taxonomic key to native and cultivated species is provided. Distribution maps with full citations of all specimens seen are supplied for each taxon.

Zusammenfassung

Ixora L. is ein große, pantropische Gattung der Tribus Ixoreae (Rubiaceae, Unterfam. Ixoroideae), die mit Sträuchern und kleinen Bäumen vorzugsweise in Regenwäldern anzutreffen ist. *Ixora* umfaßt ca. 530 Arten, die gegenwärtig Gegenstand intensiver Untersuchungen sind, die zu weit reichenden systematisch-taxonomischen Veränderungen führen werden. Basierend auf molekularen Befunden wurde *Ixora* erst kürzlich im Umfang vergrößert, indem die Gattungen *Captaincookia* N.Hallé, *Doricera* Verdc., *Hitoa* Nadeaud, *Myonima* Comm. ex Juss., *Thouarsiora* Homolle ex Arénes und *Versteegia* Valeton eingezogen wurden und damit die Tribus Ixoreae nunmehr monogenerisch ist. Obwohl eine ganze Reihe von geographisch begrenzten Teil-Revisionen der Gattung vorliegen, z.B. für Afrika, Madagaskar, die Marquesas Inseln und Australien, fehlt die Bearbeitung der kontinental-asiatischen Taxa, und es ist kein klares Bild über die Diversität dort verfügbar. Für *Ixora* auf den Philippinen ist die vorliegende Literatur beschränkt auf die Aufzählung der Taxa („Enumeration“) durch Merrill. Diese Publikation stammt von 1923, ist somit über 85 Jahre alt und entsprechend veraltet aufgrund der erheblichen klassifikatorischen Veränderungen in der Famile der Rubiaceae seither. Bis heute ist die Artenvielfalt von *Ixora* auf den Philippinen nur ungenügend bekannt, so daß grundlegende Informationen zu Ökologie und Verbreitung der Arten fehlen und Bestimmungsschlüssel oder diagnostisch brauchbare Illustrationen nur begrenzt vorhanden sind. Mit dieser Arbeit möchte ich die Lücken in der Kenntnis über die Gattung füllen: 1) durch die Untersuchung der phylogenetischen Verwandtschaft der philippinischenVertreter von *Ixora* auf der Basis morphologischer und molekularer Daten, 2) durch die Ableitung von Umweltansprüchen der endemischen philippinischen *Ixora*-Arten unter Verwendung von MAXENT, und 3) durch eine umfangreiche taxonomische Revision von *Ixora* für die Philippinen unter Einschluß nomenklatorischer Arbeiten (Lectotypifizierungen), sowie neuen Aufsammlungen, umfangreichen Abbildungen, Verbreitungskarten und Bestimmungsschlüsseln für die anerkannten Taxa.

Ein wichtiges Ergebnis der vorliegenden Arbeit ist die Erkenntnis, daß die philippinischen *Ixora*-Arten polyphyletisch sind und aus wenigstens drei unabhängigen Abstammungslinien hervorgegangen sind. Parsimonie- sowie Bayesian-Analysen der kombinierten Sequenzdaten der Chloroplasten-Marker (*rps16* und *trnT–F*) und Kern-DNA-Marker (ITS und ETS) offenbaren für *Ixora* zwei Haupt-Abstammungslinien, eine asiatisch-pazifische und eine asiatisch-afrikanisch-madegassisch-maskarenisch-neotropische Linie. Die

Ergebnisse der "Statistical-Dispersal Vicariance Analysis" (S-DIVA) enthüllen außerdem eine komplexe biogeographische Geschichte der Gattung *Ixora* mit mehreren Ausbreitungs- und Vikarianz-Ereignissen, die für die gegenwärtige Verbreitung verantwortlich sind. Darüber hinaus konnte demonstriert werden, daß die Philippinen eine Überlappungszone sowohl der pazifischen als auch der afrikanisch-asiatischen Hauptverwandtschaftlinie darstellen, in die *Ixora*-Arten eingewandert sind und eine anschließenden Radiation erfahren haben.

Die hier präsentierten Resultate enthüllen erstmalig die ähnlichen bioklimatischen Ansprüche der auf den Philippinen endemischen *Ixora*-Arten. Es konnte gezeigt werden, daß die Pflanzen einerseits Gebiete mit eher geringen jährlichen Niederschlagsmengen bevorzugen, die andererseits aber durch höhere jährliche Schwankungen (Standardabweichung) gekennzeichnet sind. Dies ist ein deutlicher Hinweis auf das große Potential der Arten, sich verändernden Klimaten bzw. den wechselhaften Monsun-Regenzeiten der Philippinen anzupassen. Dieser Umstand ist aktuell von besonderer Bedeutung auf den Philippinen, da erhebliche Schwankungen bei den jährlichen Niederschlagsmengen aufgrund des Klimawandels aus den meisten Teilen des Landes gemeldet werden. „Ecological niche modelling" (unter Verwendung von MAXENT) wurde für die beiden Arten durchgeführt, von denen die meisten Verbreitungsdaten vorliegen; *I. bartlingii* und *I. auriculata*. Die Modell-Berechnungen postulieren eine deutliche geographische Verschiebung der Verbreitungsgebiete der beiden *Ixora*-Arten, sollten die Klimaveränderungen so eintreten wie derzeit prognostiziert. Solche Modelle können außerdem die Entwicklung von Artenschutzstrategien unterstützen, da sie auch Gebiete identifizieren, die das Potential haben, dem Klimawechsel bis wenigstens 2080 zu widerstehen.

Abschließend wurde eine taxonomische Revision der philippinischen Taxa von *Ixora* auf der Basis klassischer Herbarium-Taxonomie durchgeführt. Insgesamt werden 31 der vormals 41 beschriebenen Arten akzeptiert; die verbleibenden 10 Arten wurden als Synonyme gut definierter Arten erkannt. *Ixora mearnsii, I. pilosa* und *I. propinqua* sind als unzureichend dokumentierte Arten auszuschließen. Zusätzlich werden drei neue Arten (*I. alejandroi, I. reynaldoi,* and *I. silagoensis*) beschrieben. Drei weitere Elemente könnten neue Arten repäsentieren, aber das Material ist nicht ausreichend für die Errichtung neuer Taxa. Es wird eine detaillierte morphologische, anatomische und biologische Dokumentation der für die Philippinen anerkannten *Ixora*-Arten vorgelegt, die ausführliche Beschreibungen und Illustrationen für alle einheimischen Taxa, sowie einen Bestimmungsschlüssel für alle einheimischen und kultivierten Arten liefert. Darüber hinaus werden Verbreitungskarten für alle Arten unter voller Zitierung sämtlicher untersuchter Herbarbelege vorgelegt.

1. General Introduction

Rubiaceae (or coffee family) is the fourth largest angiosperm family comprising ca. 611 genera with approximately 13,143 species (Davis *et al.* 2009). This family is mainly tropical in distribution, and often dominates the understorey of forests (Robbrecht 1988). There are several opposing taxonomic views (Verdcourt 1958; Bremekamp 1966; Schumann 1981; Robbrecht 1988, 1993) regarding the classification of Rubiaceae and despite numerous phylogenetic studies (e.g. Bremer *et al.* 1995; Bremer 1996; Bremer & Thulin 1998; Andreasen & Bremer 2000; Bremer & Manen 2000; Razafimandimbison & Bremer 2002), several members of Rubiaceae are still incompletely known and undertreated up to this time. Many Rubiaceae genera need revision and the complexity of subfamilial and tribal classification remains unsettled (Robbrecht 1988; Bremer 1996; Alejandro & Liede 2003).

Merrill (1923) recognized 63 genera of Philippine Rubiaceae in the "Enumeration of Philippine Flowering Plants", but the most recent account was of Alejandro and Liede (2003) with about 80 recorded genera including a list of new taxa and name changes in Philippine Rubiaceae species. Bremekamp (1934, 1939, 1940a-d, 1947a, b) initialized generic revisions involving Philippine Rubiaceae with publications using extensive Latin descriptions. But most of the revisions on Philippine Rubiaceae species were carried out by Ridsdale (1978a-c, 1979, 1982, 1985, 1989, 1996). His works include revisions of genera like *Mitragyna* Korth., *Uncaria* Schreb., *Adina* Salisb., *Nauclea* L., *Neonauclea* Merr., *Badusa* A. Gray and *Sulitia* Merr.. Alejandro and Liede's (2003) work adopted the latest accepted classification of Robbrecht (1988, 1993) and incorporated molecular studies involving the Philippine Rubiaceae genera. All new taxonomical classification and name changes in Philippine Rubiaceae species since Merrill (1923) are listed in Table 1 of Alejandro and Liede (2003). They also suggested reinvestigation and revision of several Philippine Rubiaceae genera including the pantropical genus *Ixora* L.

Ixora (Ixoreae; Andreasen & Bremer 2000) is considered as the third largest genus of Rubiaceae and comprises ca. 530 species of shrubs and small trees mostly found in moist and wet forests (Davis *et al.* 2009). Although pantropical, the genus is centered in Asia, with the highest species number occurring in Southeast Asia (ca. 66 species in Malaysia) (De Block 1998). Most species have white, pink, orange or red flowers, contorted corolla lobe aestivation, bilocular ovaries, with a single ovule in each locule, with red or purple drupaceous fruits (Lorence *et al.* 2007). Since Linnaeus' (1753) descriptions and until the start of the 20th century the genera *Pavetta* L. and *Ixora* were treated as a single genus (Schumann 1891; Bremekamp 1934, 1937). However, *Ixora* can easily be distinguished from *Pavetta* mainly by salveform bifid stigmas, and combination of these characters: articulate petioles, hermaphroditic flowers, hypocrateriform corollas, two-carpellate ovaries with solitary ovule in each locule of the carpel and drupaceous fruits (De Block 1998; Lorence *et al.* 2007; Mouly *et al.* 2009a). *Ixora* has always been recognized as a well circumscribed genus based on morphology with the following diagnostic features (adapted from De Block 2014b): petioles articulate, inflorescences terminal; inflorescence branching trichotomous; flowers narrowly tubular, 4-merous; aestivation contorted; stigma with 2, 3, or 4 lobes; ovary bi-, tri- or tetralocular with a single ovule per locule; fruits drupaceous; seeds with a large adaxial excavation. However identification is much more difficult at the species level, with the species distinguished on the basis of minor and often continuous characters, usually involving features of the inflorescences and flowers, e.g. corolla tube/lobe ratio and pubescence of the inflorescence (De Block 1998; Tosh *et al.* 2013).

Some phylogenetic studies have been carried out focusing on the tribal placement and circumscription of the genus (Andreasen & Bremer 1996, 2000; Mouly *et al.* 2009a,b). A detailed molecular study by Mouly *et al.* (2009a) on *Ixora*, placed *Captaincookia* N.Hallé, *Doricera* Verdc., *Hitoa* Nadeaud, *Myonima* Comm. ex Juss., *Thouarsiora* Homolle ex Arénes and *Versteegia* Valeton in synonymy with *Ixora,* resulting in a boader circumscription of the genus which in consequence became the sole member of tribe Ixoreae. In another study of Mouly *et al.* (2009b), all *Ixora* species sampled were resolved in two large lineages, an Asian-Pacific and an Afro-Malagasy-Neotropical-Mascarene one. Tosh *et al.* (2013) recently investigated the evolutionary history of Afro-Madagascan *Ixora* and recovered two separate lineages of Madagascan taxa. None of these phylogenetic studies, however, included representatives of Philippine *Ixora*.

Members of the genus *Ixora* are of particular interest because of their ornamental value as garden plants and their potential in producing a wide variety of pharmaceuticals due to their secondary metabolites such as iridoids (Inouye *et al*. 1988). About ten species are already cultivated for their large inflorescences and nicely coloured flowers (e.g. *Ixora coccinea*). According to Merrill (1923), the genus is represented in the Philippines by 42 species and 2 subspecies. Alejandro (2007) provided an update listing 41 species, of which 30 were identified as endemic.

The taxonomic history of Philippine *Ixora* began as early as 1830 when De Candolle described *I. macrophylla* D.C. based on collections made by Haenke in Manila. But it was only during the arrival of A.D.E. Elmer in the Philippines in 1904 that considerable work on Philippine *Ixora* begun. From 1906 to 1934, Elmer published a total of 13 species of Philippine *Ixora* in the Leaflets of Philippine Botany (Merrill 1923). Another American botanist, E. D. Merrill, along with Elmer, stands apart from other botanists in his contributions to Philippine botany (Sohmer & Davis 2007). Merrill published seven articles in the Philippine Journal of Science (Merrill 1923) in which 22 new species of Philippine *Ixora* were described. Towards the end of Merrill's tenure in the Philippines, he published three volumes of his work entitled An Enumeration of Philippine Flowering Plants. In this publication, he listed the then known species of *Ixora* (Merrill 1923), including synonyms.

To date, the species diversity of *Ixora* in the Philippines remains poorly known and the phylogeny of species in this group has not been studied. The only available data is an enumeration by Merrill (1923), more than 85 years old and outdated due to the classification changes in the family Rubiaceae (e.g. Robbrecht & Manen 2006; Alejandro & Liede 2003; Andreasen & Bremer 2000). Moreover, the generic and species descriptions are inadequate for both the vegetative and reproductive parts which are important in understanding the genus and its species. Basic information on species distribution and ecology, taxonomic keys and diagnostic illustrations are limited to non-existent.

Since the Philippine species of *Ixora* were not included in past phylogenetic studies of the genus due to the unavailability of genetic samples and a lack of revisionary work on the genus, this study aims to fill in the large gaps of knowledge in order to understand the genus further.

Presently, the Philippines (Fig. 1) is recognized as both a global “hotspot” and a “megadiverse” country (Myers *et al.* 2000). However, the enormity of both diversity and endemism in the Philippines is significantly underappreciated and underestimated. This first detailed study and revision of the Philippine *Ixora* is an additional contribution to the understanding of the country’s plant biodiversity as information on the species diversity of *Ixora* in the Philippines will be updated and completely known. This study will also lead to the enhancement of scientific understanding of *Ixora* and its species by providing detailed description and information on its distribution in the Philippines. To date, there has been no study on Philippine *Ixora,* a fact that renders this study a worthwhile contribution to the

Philippine Flora and an additional contribution to the continuing project on Philippine Rubiaceae (Alejandro & Liede 2003).

Figure 1. Map of the Philippines. *(Source: www.nationsonline.org)*

2. Aims of research

The present study aims at the understanding of one of the genera of Philippine Rubiaceae under several aspects. Specifically, the study has the following objectives:

1) to investigate the phylogenetic relationships of Philippine *Ixora* species using molecular sequence data from two chloroplast regions (*rps16* and *trnT–F*) and two nuclear regions, the ribosomal external transcribed spacer (ETS) and internal transcribed spacer (ITS),

2) to make inferences on the biogeographical origin of *Ixora,* using Statistical Dispersal-Vicariance Analysis (S-DIVA),

3) to test the hypothesis that endemic Philippine *Ixora* species will shift their geographic distributions and habitat suitability under conditions of climate change, and

4) to publish a comprehensive taxonomic revision of the Philippine *Ixora* including nomenclatural treatments of missing types, new records, full illustrations, distribution maps and keys of the recognized species.

3. Synopsis

3.1 Materials and Methods

Study Taxa

Ixora is a genus of shrubs and small trees widely distributed in the Philippines growing in lowland evergreen dipterocarp forests or more rarely in semi-deciduous forests. In the Philippines *Ixora* is represented by ca. 41 species, of which 30 are considered as endemics (Alejandro 2007). Species of *Ixora* have either showy or inconspicuous inflorescences, hypocrateriform and contorted flowers and anthers inserted on the inner perianth (Di Maio & Peixoto 2012).

Philippine *Ixora* (Fig. 2) can be easily recognized by the following characters: articulate petioles; trichotomously branched, terminal inflorescences that are erect or pendulous (with the exception of *I. macrophylla* DC. with cauliflorous inflorescences); 4-merous flowers with long, cylindrical corolla tubes; free stigmatic lobes; uni-ovulate locules; drupaceous fruits; drupes with two seeds having large adaxial excavation. The number of flowers per inflorescence is also variable, some species have solitary flowers (e.g. *I. bibracteata* Elmer), several others are pauciflorous (*I. philippinensis* Merr.) but most species have inflorescences with numerous flowers (e.g. *I. magnifica* Elmer*; I. silagoensis* Manalastas *et al.*). Despite these morphological characters, several *Ixora* species are difficult to distinguish as in the case for African and Madagascan *Ixora* (De Block 1998 2014a,b).

In this work, mainly Philippines species of *Ixora* were investigated but comparison with other species of the genus were carried out whenever appropriate.

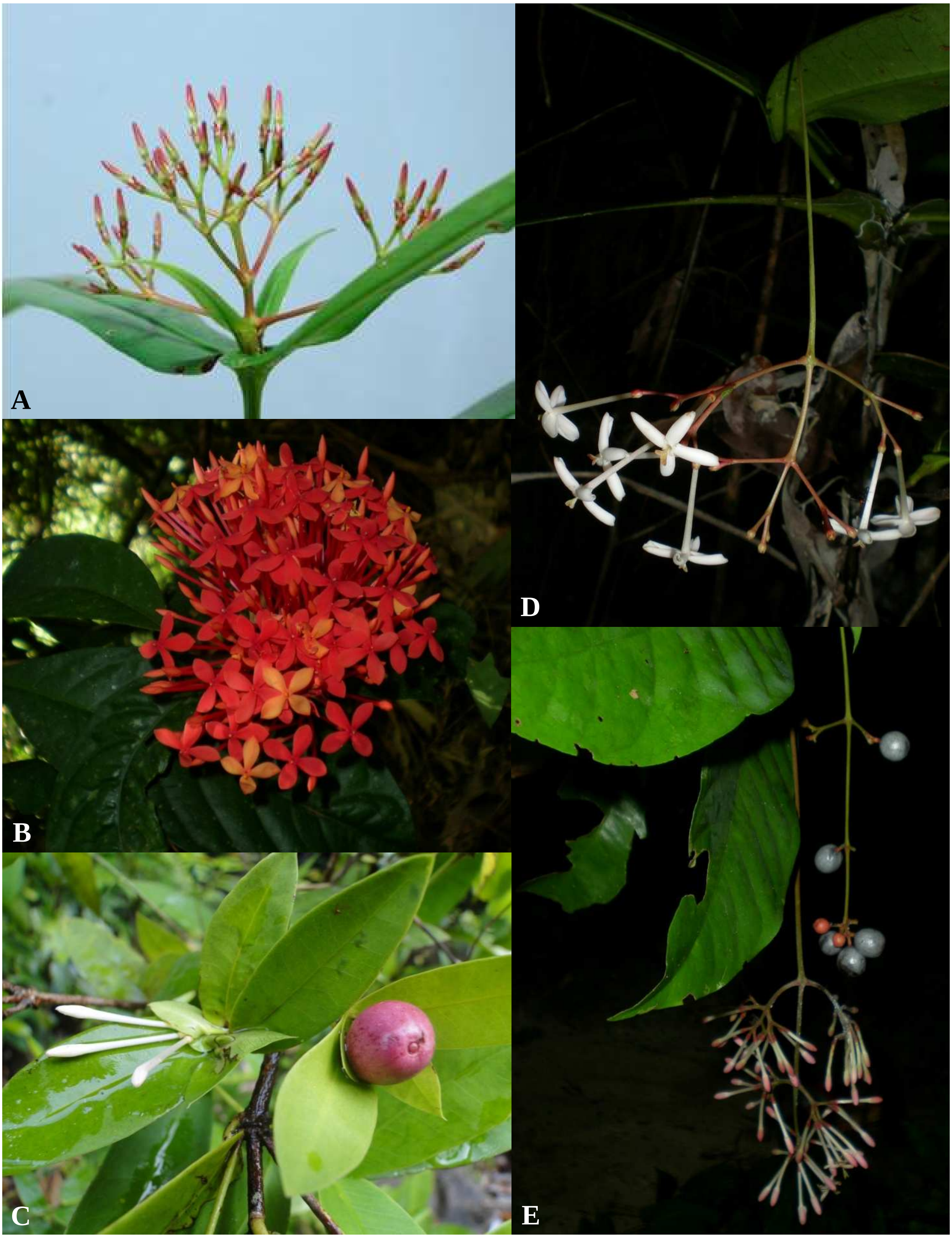

Figure 2. Selected species of Philippine *Ixora*. A–*I. silagoensis*; B–*I. magnifica*; C–*I. philippinensis*; D–*I. auriculata*; E–*I. bartlingii*. Photos taken by: C.I. Banag and D. Tandang.

Molecular Methods (Publication 1)

A total of 72 *Ixora* accessions, representing approximately 60 species were included in the molecular analyses. Following Mouly *et al*. (2009b), three suitable outgroup taxa from the tribes Aleisanthieae (*Greeniopsis multiflora* Merr. and *Aleisanthiopsis distantiflora* (Merr.) Tange) and Greeneeae (*Greenea corymbosa* K.Schum.) were chosen to root the trees. All sequences of non-Philippine *Ixora* and the outgroup taxa that were used in this study were downloaded at the European Molecular Biology Laboratory (EMBL) Nucleotide Sequence Database website.

Total DNA was extracted from dried material preserved in silica gel (Chase & Hills 1991) following the protocols of DNeasy Plant Mini Kit (Qiagen, Germany). Primers that were used for the amplification of nuclear and chloroplast DNA regions are based from Mouly *et al.* (2009b). PCR amplifications were run on a BIOMETRA thermocycler. All amplification products were cleaned using Qia-Quick PCR purification kit (Qiagen, Germany) and sent to LGC Genomics (Germany) for sequencing.

Phylogenetic analyses (Publication 1)

The *rps16*, *trnT–F*, ITS and ETS sequences were edited and pre-aligned using CodonCode Aligner version 4.0.4 and subsequently adjusted manually. Sequences were aligned with SeaView version 4.0. All variable nucleotide positions were verified against the original electropherograms.

Separate and combined analyses of the *rps16*, *trnT–F*, ITS and ETS matrices were performed using Bayesian Markov chain Monte Carlo (MCMC) inference (Yang & Rannala 1997) as implemented in the program MrBayes version 3.1 (Huelsenbeck & Ronquist 2001). The model of DNA substitution for each region was determined using Modeltest v. 2.0 (Nylander 2004) under the Akaike information criterion (Akaike 1974). Groups characterized by a posterior probability (PP) of more than 0.95 were regarded as strongly supported.

For partitioned data sets, maximum parsimony (MP) analyses were performed with PAUP* v.4.0b10 (Swofford 2002). Clades receiving a bootstrap support of 50–69% were regarded as weakly supported, 70–85% as moderately supported, and 86–100% as strongly supported.

Biogeographical Analysis (Publication 1)

Statistical Dispersal-Vicariance Analysis (S-DIVA; Yu *et al.* 2010) implemented in RASP v. 2.1. (Reconstruct Ancestral State in Phylogenies; Yu *et al.* 2011) was used to reconstruct the possible ancestral ranges of the genus *Ixora* on the phylogenetic trees. The frequencies of an ancestral range at a node in ancestral reconstructions were averaged over all trees (Yu *et al.* 2010).

Georeferencing (Publication 2)

Locality data of the naturally occurring Philippine *Ixora* were derived from herbarium specimens, online databases and the authors' own field surveys during 2008 to 2012. In all, 492 locality records were collated. Records lacking coordinates were georeferenced using World Gazetteer (http://worldgazetteer.com) and Geonames (http://www.geonames.org/export/web-services.html). All coordinates were carefully checked for plausibility and/or error-corrected using Google Earth (version 7; Google 2013).

Distribution modelling (Publication 2)

For analyzing species' distributions, 19 bioclimatic variables were considered. These bioclimatic variables were retrieved from the WorldClim database at 2.5′ resolution (approx. 3.5 km in the Philippine archipelago) for the period 1950-2000 (http://www.worldclim.org; see also Hijmans et al. 2005).

For future climate projections, two scenarios (A2 and B1) for the year 2080 from the GCM data portal (http://www.ccafs-climate.org) were chosen to represent the maximum range between lowest and highest expected climate change.

Raster data sets were processed using R (R Development Core Team 2012) with the packages *raster*, *sp* and *rgdal*.

Models were developed for *I. bartlingii* and *I. auriculata* using Maxent version 3.3.3k (http://www.cs.princeton.edu/~schapire/maxent/). Maxent (Phillips *et al.* 2006; Phillips & Dudik 2008; Elith *et al.* 2011) is an evolutionary-computing method based on the maximum entropy algorithm. It thereby provides an estimate of the species realized niche, and projects it into geographic space (Phillips *et al.* 2006). Maxent is among the most frequently used methods for modelling and has been shown to often perform better than many other presence-only models (Phillips *et al.* 2006; Fischer *et al.* 2011). A detailed description of Maxent is given in Phillips *et al.* (2006) and Phillips and Dudik (2008).

Maxent has been found to be robust to changes in sample size and can still have good predictive ability at low sample sizes making it the ideal model for the prediction of distributions for rare species (Hernandez *et al.* 2006; Wisz *et al.* 2008; Garcia *et al.* 2013). However, since our models only include environmental conditions, important aspects such as dispersal barriers and biotic interactions are not considered; model results therefore have to be interpreted with care, taking these restrictions into account. Model settings were kept at default values and model outputs were generated using logistic output. Variable selection followed Morueta-Holme *et al.* (2010).

Performance of the Maxent model was assessed using the Area Under the receiver operating characteristics Curve (AUC, Hanley & McNeil 1982). The AUC provides a measure of the model's discriminatory ability between suitable and unsuitable areas for a species and is a well-established approach for model evaluation (Reineking & Schröder 2006).

Morphological Analysis (Publication 3 and 4)

The revision is based mainly on the analysis of herbarium specimens deposited in the following herbaria: A, BK, BR, C, CAHUP, K, L, NY, P, PNH, PPC, SAN and US (Thiers 2013). This information is supplemented by fieldwork (C.I. Banag) and by literature review. All herbarium label data are stored in an electronic database using Microsoft Office Access 2007. For species descriptions and keys, all measurements are based on dried herbarium specimens. Some features such as shapes were documented based on alcohol-preserved flowers and fruits, all colors are those reported by collectors for living material or digital photos when possible unless explicitly stated otherwise. Measurements are presented in the following descriptions: length × width, followed by the units of measurement (mm or cm). Specimens are cited per province, alphabetically by collector. All species cited in this paper have been seen from herbarium specimens or in their natural habitat by the authors. Comparisons with other representatives of the genus are made whenever appropriate.

Taxonomy of *Ixora* (Publication 3 and 4)

A genus description comprising general characteristics of all *Ixora* species is presented in this study. The implicit character attributes of the genus are not repeated in the individual description of the species. A practical key that puts emphasis on the most obvious character states of the species is presented using a combination of both vegetative and reproductive morphological characters. Detailed description and full illustration of new species are also provided.

Nomenclatural treatment (Publication 4)

Most of the type specimens of Philippine flowering plants deposited at the Philippine National Herbarium (PNH) were unfortunately lost during the World War II. In most cases, however, isotypes are housed in one or several of the herbaria mentioned in the section on morphological analysis. In such instances, a lectotype was chosen among the available herbarium material. If isotypes are not also available, a neotype was chosen to represent the species.

3.2 Results and Discussion

Molecular phylogeny and biogeography of Philippine *Ixora* L. (Rubiaceae) (Publication 1)

The 132 new sequences generated in this study were combined with sequences previously generated and used by Mouly *et al.* (2009b) and Tosh *et al.* (2013) resulting in a total of 264 sequences, representing approximately 60 *Ixora* spp. Phylogenetic analyses of the combined chloroplast (*rps16* and *trnT–F*) and nuclear (ITS and ETS) DNA showed that Philippine *Ixora* is polyphyletic as the 35 samples of Philippine *Ixora* included in our study are recovered in at least three, possibly five different clades.

In the phylogenetic tree of the combined cp– and nrDNA data sets, the ingroup taxa are resolved in two large lineages: the Asian-Pacific clade and Asian-Afro-Malagasy-Neotropical-Mascarene clade. The main clades of Mouly *et al.* (2009b), namely the African-Malagasy-Neotropical and the Pacific clades are also retrieved in our study. However, in contrast to Mouly *et al.* (2009b), Asian species are retrieved in several parts of the tree. Most likely, this effect is due to the much reduced sampling of Asian, in particular Philippine material in Mouly *et al.* (2009b). The fact that Asian *Ixora* might not be monophyletic is indicated in Mouly *et al.* (2009b), but the level of polyphyly observed in this study is entirely unexpected.

Our results show that many species considered widespread are in fact polyphyletic, including *I. salicifolia* DC. and *I. philippinensis* Merr., thus necessitating a re-evaluation of the species concept in *Ixora*. Moreover, in our study some species thought to be closely related based on morphological characters were not retrieved in the same clade in the phylogenetic trees including *I. macrophylla* DC., *I. bartlingii* Elmer and *I. longistipula* Merr. pointing at a high level of morphological homoplasy.

With the results of the Statistical Dispersal-Vicariance Analysis we were able to disentangle the biogeographical patterns and diversification history of Philippine *Ixora* and the genus as a whole. Mouly *et al.* (2009a) have shown that *Ixora s.l.* is sister to the South-East Asian Greeneeae and both to the Indo-Malayan Aleisanthieae. Thus, an origin of *Ixora* in Asia is most likely and also indicated by S-DIVA. Furthermore, it indicates a complex biogeographical history for *Ixora* with several dispersal and vicariance events that have led to its current distribution. Philippines are shown to constitute an overlay zone into which species from both major lineages of *Ixora*, the Pacific and the African-Asian one, have immigrated and subsequently radiated.

Bioclimatic niches of endemic *Ixora* species on the Philippines: potential threats by climate change (Publication 2)

The pantropical genus *Ixora* is highly diverse, with several species endemic to the Philippines. Owing to their endemic nature, many of these species are endangered and little is known about their basic biology. Our results reveal for the first time the bioclimatic relationships of endemic Philippine *Ixora.* Analysis of the endemic species relationships with the bioclimatic variables suggest that species are differentiated with respect to mean annual temperature, mean annual precipitation and particularly seasonality variables. The bioclimatic preference of *Ixora* species as revealed in our study showed a constant pattern with respect to mean annual temperature and the amount of temperature variation over the year, but exhibited a stronger differentiation regarding the amount of precipitation and precipitation seasonality. The species' preference towards areas with lower amount of annual rainfall and regions with higher annual precipitation variance (standard deviation) may indicate the species' potential to adapt to changing climates or maybe the result to adaptation of the species to monsoon seasons in the Philippines. This is of particular importance as it was reported that Philippines will experience a substantial difference in terms of seasonal rainfall change in most parts of the country, and that climate change will probably lead to an active southwest monsoon in Luzon and Visayas. Ecological niche modelling was carried out for the two species with most occurrence records, *I. bartlingii* and *I. auriculata,* using Maxent. These two species of *Ixora* have a wider distribution and have been recorded in several provinces across the country as compared to other endemic species of *Ixora* which are found only in a single province or locality in the Philippines. Maxent predicted gains in suitable habitat for *I. bartlingii* in Mindanao, particularly in the provinces of Misamis Occidental, Zamboanga del Sur, and Zamboanga del Norte, but loss of habitat in northern Luzon, in the Cordillera Administrative Region (CAR), and Pampanga, Bulacan, and Bataan provinces. *Ixora auriculata* also showed loss of potential area in northern parts of Luzon, in Cagayan, Isabela, and Nueva Vizcaya provinces. Models anticipated greater risk of distributional loss for *I. auriculata* than for *I. bartlingii.* Furthermore, the model results suggest that these two *Ixora* species will shift their geographic distributions under predicted levels of climate change. The scope, sequence and effects of climate change cannot be predicted with absolute certainty. Under these conditions, detailed knowledge considering the adaptive capacity of a species such as its ability to disperse to and colonize new habitats (Davis & Shaw 2001; Carvahlo *et al.* 2010) becomes an essential asset for its conservation as it faces a climate-defined future.

Two new endemic species of *Ixora* (Ixoroideae, Rubiaceae) from the Philippines (Publication 3)

Two new species of *Ixora* are described from the provinces of Palawan and Samar, Philippines: *I. alejandroi* Banag & Tandang and *I. reynaldoi* Banag. The two new species are compared with other species of the genus. *Ixora alejandroi* is characterized by its elongated cyme with congested secondary axes, stigmatic lobes shortly cleft in the middle, rounded at the top. Stigmatic lobes of *Ixora* consist of elongate branches and recurving at maturity. *Ixora alejandroi* is most closely related to *I. tenelliflora*, a non–endemic species also found in Palawan, because of the pendulous or drooping inflorescences with clusters of flowers along the central axis but differing from it by the stigmatic lobes, shortly cleft in the middle, rounded at the top (vs. stigmatic lobes elongated) the length of the central first order axis 1–2 cm long (vs. 9–12 cm long), lateral order axes ≤ 0.5 cm long (vs. 3–5 cm long) and first order bracts with stipular parts absent (vs. stipular parts fused to an ovate blade with central awn). Florally, however, *I. tenelliflora* is easily distinguishable from *I. alejandroi* by its white corolla, much longer corolla tube and long and narrowly elliptic corolla. Based on the IUCN Red List Category (2001), *I. alejandroi* is considered as Critically Endagered (CR; B2a; B2b (i-iii)). Tourism is identified as a major threat for the suitable habitat of *I. alejandroi* on Mt. St. Paul, Sabang Palawan followed by threats from activities such as forest clearing and agriculture. Rarity of the species is suspected by the authors based on the number of mature individuals after careful exploration of the area and several field surveys conducted in Palawan. This species is named after Prof. Dr. Grecebio Jonathan D. Alejandro, who has made significant contributions to the knowledge of Philippine Rubiaceae.

Ixora reynaldoi differs from the other species of the genus by its shortly petiolate or subsessile leaves, a pseudanthium type of inflorescence and very long bracteoles and calyx lobes (up to 10 mm). In Philippine *Ixora*, calyces are small and not exceeding 5 mm in length. Only *I. leytensis* Elmer has calyx lobes that reach 5 mm, all other species have calyx lobes in the range of 2–3.5 mm. Calyces less than 2 mm long are very rare and occur in e.g. *I. myriantha* Merr. (up to 1.2 mm) and *I. philippinensis* Merr. (up to 1.5 mm). *Ixora reynaldoi* has very long bracteoles and calyx lobes, a very rare feature in Philippine *Ixora* and the genus as a whole, only known in *I. amplexicaulis* Gillespie from Fiji (bracteoles about 9 mm long, calyx lobes narrowly triangular, 7–8 mm long). Based on the IUCN Red List Category (2001), *I. reynaldoi* is considered as Critically Endagered (CR; B2a; B2b (i-iii)). The suitable habitat for *I. reynaldoi* on Maydolong, Eastern Samar is indicated as an endangered environment, threatened by human activity (deforestation, agricultural expansion), reducing the extent of forest, and the geographic location of Eastern Samar being one of the provinces in the Philippines frequently hit by typhoons. Rarity of the species is suspected by the authors based on the low number of mature individuals found after careful exploration of the area and several field surveys conducted in Samar. This species is named after Reynaldo J. Banag, the late father of Cecilia Banag.

The Philippine species of *Ixora* (Rubiaceae) (Publication 4)

A revision of the Philippine species of *Ixora* was carried out following the methods of classical herbarium taxonomy. A total of 31 species are recognized from the previously described 41 species, 10 species are merged with other well-defined species of the genus, as no reasons were found to keep them separate. Three species, *I. mearnsii* Merr., *I. pilosa* Merr. and *I. propinqua* Merr. were considered as doubtful species, because the materials on which the descriptions of these species were based are destroyed in PNH and no duplicates of the original collections could be traced for this revision. The relatively vague descriptions in the protologue of these two species do not permit to relate them with sufficient certainty to other species. Additionally, three new species (*I. alejandroi*, *I. reynaldoi*, and *I. silagoensis*) are reported. Four more flowering specimens which may well represent additional new species but are not formally named because they are too imperfectly known are also included. A detailed morphological, anatomical and biological documentation of the recognized Philippine species of *Ixora* is given. All species were extensively described, native species illustrated and taxonomic key to native and cultivated species are provided. Distribution maps with full citations of all specimens seen are supplied for each taxon.

3.3 Conclusion and Perspectives

This study is a contribution to the recent advances in our understanding of the systematics and biogeography of the large Angiosperm family Rubiaceae and attempts to provide a more in-depth analysis of the Philippine Rubiaceae with emphasis on the genus *Ixora.*

First, the phylogenetic study on Philippine *Ixora* has shed some light on the understanding of the relationships among the species and has proven the usefulness of combining several molecular markers in obtaining more robust and better resolved topologies for large genera like *Ixora.* Although our focus is on the phylogenetic diversity of Philippine *Ixora,* our results have provided clear evidence that a broader phylogenetic study of the genus *Ixora* is needed to accurately estimate the species-level diversity as low support was observed for several internodes among Asian species including the Philippine samples. Moreover, the S-DIVA analysis has shown that Philippines constitute an overlay zone into which species from both major lineages of *Ixora*, the Pacific and the African-Asian one, have immigrated and subsequently radiated. However, a more detailed study on some parts of the genus, focusing on Asian material, is still needed to understand the complex biogeographical patterns in *Ixora* inside the Malesian Region. Future studies should also include more populations especially of species with wider distributions – be it on several islands or a presumed disjunction between the island archipelagoes and mainland Asia - in order to more finely resolve the phylogeography of Philippine *Ixora* species.

Philippine endemic *Ixora* species included in the bioclimatic niche modelling showed similar niches in respect to mean annual temperature and temperature seasonality, but some degree of differentiation in precipitation amount and seasonality. The different niches with respect to seasonality can lead to differentiated response under conditions of climate change, as shown in the example of *I. bartlingii* and *I. auriculata*. Despite the general global warming, climate change is likely to decrease the areas with optimum habitat suitability and shift distribution ranges towards the western and southern regions of the country. However, the present study did not consider the impact of population density, land use and habitat fragmentation, so in face of a strongly increasing landuse and population in the future, the actual fraction of suitable areas is likely to be substantially lower. The improvement of the data situation, in particular with respect to species occurrence and human landuse changes, are recommended to test the implications from the present study and to draw more general conclusions on the ecology of endemic *Ixora* species in the Philippines. At the same time it is hoped that the assessments emerging from this study may be useful in future modelling studies and development of conservation strategies particularly for the endemic *Ixora* species in the Philippines. Our models can also assist the design of conservation strategies for the species, as they identify areas predicted to have potential to withstand climate change until at least 2080, representing assessment priorities for *in situ* conservation of the Philippine endemic *Ixora.*

Finally, the species level revision of the genus using morphological and molecular data is laying the base for future studies in the genus, allowing it to safely assign additional information to a well circumscribed species. Thus, it can be used to select species with possible medicinal value, or species that may be used in breeding projects for ornamentals, or species that may be significant for phylogenetic studies. This study has also contributed to the understanding of the evolution of taxonomically useful characters that could lead to identifying or uncovering hidden/cryptic species of *Ixora* which should be investigated in more detail and which may have important implications on the biodiversity and conservation in the country. The full species accounts for Philippine *Ixora* can contribute to a future publication of a comprehensive book that will provide distribution maps, descriptions, keys and illustrations of the species of *Ixora* that may be used to further facilitate identification of Philippine *Ixora* species.

3.4 References

Akaike, H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716–723.

Alejandro, G. J. D. 2007. The Current Status of the Philippine Rubiaceae. *Philippine Journal of Systematic Biology* 1 (1): 47–60.

Alejandro, G. J. D. & Liede-Schumann, S. 2003. The Philippine Rubiaceae genera. Updated synopsis in INTKEY databases of the DELTA system. *Blumea* 48: 261–277.

Andreasen, K. & Bremer, B. 1996. Phylogeny of the subfamily Ixoroideae (Rubiaceae). *Opera Bot. Belg.* 7: 119–138.

Andreasen, K. & Bremer, B. 2000. Combined phylogeneteic analysis in the Rubiaceae-Ixoroideae: morphology, nuclear and chloroplast DNA data. *Amer. J. Bot.* 87: 1731–1748.

Bremekamp, C. E. B. 1934. A monograph of the genus *Pavetta* L. Feddes *Repert. Spec. Nov. Regni Veg*. 37: 1–208.

Bremekamp, C. E. B. 1937. The Malesian species of the genus *Ixora* (Rub.). *Bulletin de Jordan Botanique de Buitenzorg*, serie 3,14: 197–367.

Bremekamp, C. E. B. 1939. A monograph of the genus *Pavetta* L.: additions and emendations. Feddes Repert. Spcec. *Nov. Regni Veg.* 47: 12–28,81–98.

Bremekamp, C. E. B. 1940a. *Antherostele* genus novum Rubiacearum Urophyllo affine. *J. Arnold Arbor.* 21: 25–31.

Bremekamp, C. E. B. 1940b. A preliminary account of the Philippine species of *Urophyllum* Wall., *Pleiocarpidia* K. Schum., and *Praravinia* Korth. (Rubiaceae). *J. Arnold Arbor.* 21:32-47.

Bremekamp, C. E. B. 1940c. On *Urophyllum* Wall. (Rubiaceae) and its nearest allies. *Recueil Trav. Bot. Neerl.* 37: 171–197.

Bremekamp, C. E. B. 1940d. A monograph of the genus *Pleiocarpidia* K. Sch. (Rubiaceae). *J. Arnold Arbor.* 28: 261–308.

Bremekamp, C. E. B. 1947a. A monograph of the genus *Acranthera* Arn. ex Meisn. *J. Arnold Arbor.* 28: 261–308.

Bremekamp, C. E. B. 1947b. A monograph of the genus *Streblosa* Korth. (Rubiaceae). *J. Arnold Arbor.* 28: 145–185.

Bremekamp, C. E. B. 1966. Remarks on the position, the delimitation and the subdivision of the Rubiaceae. *Acta Botanica Neerlandica*, 15: 1–33.

Bremer, B. 1996. Phylogenetic studies within Rubiaceae and relationships to other families based on molecular data. *Opera Bot. Belg.* 7: 33–50.

Bremer, B. & Manen, J.-F. 2000. Phylogeny and classification of the subfamily Rubioideae (Rubiaceae). *Pl. Syst. Evol.*, 225: 43–72.

Bremer, B. & Thulin, M. 1998. Collapse of Isertieae, re-establishment of Mussaendeae, and a new genus of Sabiceeae (Rubiaceae); phylogenetic relationships based on *rbcL* data. *Pl. Syst. Evol.* 211: 71–92.

Bremer, B., Andreasen, K. & Olson, D. 1995. Subfamilial and Tribal Relationships in the Rubiaceae based on rbcL sequence data. *Ann. Missouri Bot. Gard.* 82: 383–397.

Chase, M. W. & Hills, H. H. 1991. Silica gel: An ideal material for preservation of leaf samples for DNA studies. *Taxon* 40: 215–220.

Carvalho, S. B., Brito, J. C., Crespo, E. J. & Possingham, H. P. 2010. From climate change predictions to actions – conserving vulnerable animal groups in hotspots at a regional scale. *Global Change Biology* 16: 3257–3270.

Davis, M. B. & Shaw, R. G. 2001. Range shifts and adaptive responses to quaternary climate change. *Science* 292: 673–679.

Davis, A. P., Govaerts, R., Bridson, D. M., Ruhsam, M. & Moat, J. 2009. A global assessment of distribution, diversity, endemism, and taxonomic effort in the Rubiaceae. *Ann. Missouri Bot. Gard.* 96: 68–78.

De Block, P. 1998. The African species of *Ixora* (Rubiaceae – Pavetteae). *Opera Bot. Belg.* 9: 1–218.

De Block, P. 2013. The Malagasy species of *Ixora* (Rubiaceae–Pavetteae). *Opera Bot. Belg.* 16: in press.

De Block, P. 2014a. A synopsis of the of the multilocular species of *Ixora* (Rubiaceae) from Madagascar. *Phytotaxa* 162 (3): 121–133.

De Block, P. 2014b. Eight new species of *Ixora* (Ixoreae-Rubiaceae) from Madagascar. *Plant Ecology and Evolution* 147(2): 237–255.

Di Maio, F. R. & Peixoto, A. L. 2012. Four new species of *Ixora* (Rubiaceae, Ixoreae) from Brazil. *Brittonia* 64(4): 413–420.

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E. & Yates, C. J. 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* 17:43–57.

Fischer, D., Thomas, S. M., Niemitz, F., Reineking, B. & Beierkuhnlein. C. 2011. Projection of climatic suitability for *Aedes albopictus* Skuse (Culicidae) in Europe under climate change conditions. *Global and Planetary Change* 78: 54–64.

Garcia, K., Lasco, R., Ines, A., Lyon, B. & Pulhin, F. 2013. Predicting geographic distribution and habitat suitability due to climate change of selected threatened forest tree species in the Philippines. *Appl. Geogr.* 44:12–22.

Hanley, J. A. & McNeil, B. J. 1982. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 143: 29–36.

Hernandez, P. A., Graham, C. H., Master, L. L. & Albert, D. L. 2006. The effect of sample size and species characteristics on performance of different species distribution modelling methods. *Ecography* 29: 773–785.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P.G. & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* 25:1965–1978.

Huelsenbeck, J. P. & Ronquist, F. 2001. MrBayes: Bayesian inference of phylogenetic trees. *Bioinformatics*17: 754–755.

Inouye, H., Takeda, Y., Nishimura, H., Kanomi, A., Okuda, T. & Puff, C. 1988. Chemotaxonomic studies of Rubiaceous plants containing iridoid glycosides. *Phytochemistry* 27: 2591–2598.

International Union for Conservation of Nature. 2001. *IUCN Red List Categories: Version 3.1*. IUCN Species Survival Commission, IUCN, Gland, Switzerland and Cambridge, U.K., ii + 30 pp.

Linnaeus, C. 1753. Species Plantarum. Stockholm p. 110.

Lorence, D., Wagner, W. L., Mouly, A. & Florence, J. 2007. Revision of *Ixora* (Rubiaceae) in the Marquesas Islands (French Polynesia). *Bot. J. Linn. Soc.* 155:581-597.

Merrill, E. D. 1923. An Enumeration of Philippine Flowering Plants. Manila Bureau of Printing. 2: 492–576.

Morueta-Holme, N., Fløjgaard, C. & Svenning, J. C. 2010. Climate Change Risks and Conservation Implications for a Threatened Small-Range Mammal Species. *PLoS ONE* 5(4): e10360.

Mouly, A. 2008. Systématique de la tribu des Ixoreae A. Gray (Rubiaceae): phylogénie, biogéographie et taxinomie. *Acta Botanica Gallica* 155 (3): 457–464.

Mouly, A., Razafimandimbison, S. G., Khodabandeh, A. & Bremer B. 2009a. Phylogeny and classification of the giant pantropical showy genus Ixora (Rubiaceae - Ixoreae) with indications of geographical monophyletic units and hybrids. *Am. J. Bot.* 96: 686–706.

Mouly, A., Razafimandimbison, S. G., Florence, J., Jérémie, J. & Bremer B. 2009b. Paraphyly of Ixora and new tribal delimitation of Ixoreae (Rubiaceae): inference from combined chloroplast (rps16, rbcL, and trnT-F) sequence data. *Ann. Missouri Bot. Gard.* 96: 146-160.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Nylander, J.A.A. 2004. MrModeltest 2.0. Program distributed by the author. Evolutionary Biology Centre, Uppsala University, Uppsala, Sweden.

Phillips, S. J. & Dudík, M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31:161–175.

Phillips, S. J., Anderson, R. P. & Schapire, R. E. 2006. Maximum entropy modeling of species geographic distributions. *Ecol. Model.* 190:231–259.

R Development Core Team. 2012. *R: A language and environment for statistical computing.* Vienna, Austria.

Razafimandimbison, S. G., & Bremer, B. 2002. Phylogeny and classification of Naucleae s.l. (Rubiaceae) inferred from molecular (ITS, *rbcL,* and *trnT-F*) and morphological data. *Am. J. Bot.* 89: 1027–1041.

Reineking, B. & Schröder, B. 2006. Constrain to perform: Regularization of habitat models. *Ecol. Model.* 193:675–690.

Ridsdale, C. E. 1978a. A revision of *Mitragyna* and *Uncaria. Blumea* 24:43-100.

Ridsdale, C. E. 1978b. A revision of *Neonauclea (*Rubiaceae). *Blumea* 34:177-275.

Ridsdale, C. E. 1978c. A revision of the tribe Naucleeae s.s. (Rubiaceae). *Blumea* 24:307-366.

Ridsdale, C. E. 1979. The taxonomic position of *Sulitia* (Rubiaceae). *Blumea* 25:301-303.

Ridsdale, C. E. 1982. A revision of the genus *Badusa* (Rubiaceae, Condamineeae, Porlandiinae). *Blumea* 28:145-150.

Ridsdale, C. E. 1985. The genus *Fagerlindia* (Rubiaceae) in the Philippines. *Blumea* 25:301-303.

Ridsdale, C. E. 1989. A revision of *Neonauclea* (Rubiaceae). *Blumea* 34:177-275.

Ridsdale, C. E. 1996. A review of *Aidia* s.l. (Rubiaceae) in Southest Asia and Malesia. *Blumea* 41:135-179.

Robbrecht, E. 1988. Tropical Woody Rubiaceae. *Opera Bot. Belg*. 1: 1–271.

Robbrecht, E. 1993. Supplement to the 1988 outline of the classification of the Rubiaceae index to genera. *Opera Bot. Belg.* 6: 173–196.

Robbrecht, E. & Manen, J. F. 2006. The major evolutionary lineages of the coffee family (Rubiaceae, angiosperms). Combined analysis (nDNA and cpDNA) to infer the position of *Coptosapelta* and *Luculia*, and supertree construction based on *rbcL*, *rps16*, *trnL-trnF* and *atpB-rbcL* data. A new classification in two subfamilies, Cinchonoideae and Rubioideae. *Syst. Geogr. Pl.* 76: 85-146.

Schumann, K. 1891. Rubiaceae. Engler, A. & Prantl, K. (eds.), Die natürlichen Pflanzenfamilien, part 4: 1-156. W. Engelmann, Leipzig.

Sohmer, S. H. & Davis, A. P. 2007. The genus *Psychotria* (Rubiaceae) in the Philippine Archipelago. Sida, Botanical Miscellany, No. 27. Texas, USA.

Swofford, D. L. 2002. PAUP*: Phylogenetic analysis using parsimony (* and other methods), version 4.0b. Sinauer Associates, Sunderland, Massachusetts, USA.

Thiers, B. 2013. *Index Herbarorium: A global directory of public herbaria and associated staff.* New York Botanical Garden's Virtual Herbarium. Available from http://sweetgum.nybg.org/ih/ (Accessed 8 January 2014).

Tosh, J., Dessein, S., Buerki, S., Groeninckx, I., Mouly, A., Bremer, B., Smets, E. F. & De Block, P. 2013. Evolutionary history of the Afro-Madagascan *Ixora* species (Rubiaceae): species diversification and distribution of key morphological traits inferred from dated molecular phylogenetic trees. *Ann. Bot.*112(9): 1723–1742.

Verdcourt, B. 1958. Remarks on the classification of the Rubiaceae. *Bull. Jard. Bot. État. Bruxelles*, 28: 209–290.

Wisz, M. S., Hijmans, R. J., Li, J., Peterson, A. T., Graham, C. H. & Guisan, A. 2008. Predicting species distributions working group. Effects of sample size on the performance of species distribution models. *Diversity and Distributions* 14:763–773.

Yang, Z. & Rannala, B. 1997. Bayesian phylogenetic inference using DNA sequences: A Markov chain Monte Carlo method. *Molec. Biol. Evol.*14 : 717–724 .

Yu, Y., Downie, S. R., He, X-J., Deng, X-L. & Yan, L. 2011. Phylogeny and biogeography of Chinese Heracleum (Apiaceae tribe Tordylieae) with comments on their fruit morphology. *Pl. Syst. Evol.* 296(3–4): 179–203

Yu, Y., Harris, A. J. & He X-J. 2010. S-DIVA (Statistical Dispersal-Vicariance Analysis): a tool for inferring biogeographic histories. *Molec. Phylog. Evol.*. 56: 848–850.

PUBLICATION 1

MOLECULAR PHYLOGENY AND BIOGEOGRAPHY OF PHILIPPINE *IXORA* L. (RUBIACEAE)

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TAXON (under Review)

Molecular phylogeny and biogeography of Philippine *Ixora* L. (Rubiaceae)

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Abstract The Philippine archipelago has emerged as one of the globally important model island archipelagoes for studying evolutionary processes of diversification. However, previous molecular studies on the pantropical genus *Ixora* have failed to include representative species from the Philippines due to lack of available genetic samples. Hence, the first molecular study on Philippine *Ixora* is here presented. Two chloroplast markers (*rps16* and *trnT–F*) and two nuclear markers (ITS and ETS) were used, totalling in 4309 base pairs. The Philippine *Ixora* was found to be polyphyletic, with representatives from at least three independent lineages. In both the parsimony and Bayesian analyses, two main lineages of *Ixora* were recovered, an Asian-Pacific lineage and an Asian-African-Malagasy-Neotropical-Mascarene lineage. The results of the Statistical Dispersal-Vicariance Analysis indicates a complex biogeographical history for *Ixora* with several dispersal and vicariance events that have led to its current distribution. Furthermore, Philippines are shown to constitute an overlay zone into which species from both major lineages of *Ixora,* the Pacific and the African-Asian one, have immigrated and subsequently radiated.

Keywords biogeography, Huxley's line, *Ixora*, molecular systematics, Philippines, phylogeny, S-DIVA, Wallace's line

INTRODUCTION

The pantropical genus *Ixora* L. (Ixoreae; Andreasen & Bremer, 2000) is the third largest genus in the family Rubiaceae, with approximately 530 species (Davis & al., 2009). Although pantropical, the highest species numbers are recorded in Southeast Asia (De Block, 1998). Approximately 280 or up to 300 species exist in continental Asia-Malesia (Mouly, 2008), with 66 species in Borneo alone as recognized by Bremekamp (1937), in contrast to only 37 species in continental Africa (De Block, 1998), but ca. 40 species in Madagascar (De Block, 2013); and ± 35 species in tropical America (De Block, 1998). Although there have been a number of revisions focusing on specific geographical regions, e.g. in Africa (De Block, 1998), Madagascar (De Block, 2013), Marquesas Islands (Lorence & al., 2007) and Australia (Reynolds & Forster, 2006), the continental Asian taxa have never been fully revised and no clear picture of their diversity is available (Mouly, 2008). Some phylogenetic studies have been carried out focusing on the tribal placement and circumscription of the genus (Andreasen & Bremer 1996, 2000; Mouly & al., 2009a,b). In the study of Mouly & al. (2009b), all *Ixora* species sampled are resolved in two large lineages, an Asian-Pacific and an Afro-Malagasy-Neotropical-Mascarene one. Tosh & al. (2013) recently investigated the evolutionary history of Afro-Madagascan *Ixora* and recovered two separate lineages of Madagascan taxa. Both molecular studies, however, failed to include representative species restricted to the Philippines.

In the Philippines, Rubiaceae is the family with the largest number of indigenous species, 443 (83%) of the 535 species found in the country are endemics (Davis & al., 2009). The genus *Ixora* provides an exemplary case, with a particularly high number of endemic species known in the country (30 out of 41 species; Alejandro, 2007). To date, the genus and species descriptions for both the vegetative and reproductive parts which are important in understanding the genus and its species are limited. The only available account is an enumeration by Merrill (1923), more than 85 years old and outdated due to numerous classification changes in the family Rubiaceae (e.g. Andreasen & Bremer, 2000; Alejandro & Liede-Schumann, 2003; Robbrecht & Manen, 2006). Preliminary investigation of herbarium specimens including types showed that species of *Ixora* in the Philippines can be distinguished on the basis of minor and often continuous characters, usually involving features of the inflorescences, e.g. corolla tube/lobe ratio, pubescence of the inflorescence, which was also observed by De Block (1998) for African representatives of the genus. Moreover, the species diversity of *Ixora* in the Philippines remains poorly known and the phylogeny and biogeography of species in this group has not been studied.

Philippines has played an important role in the development of early biogeographical thoughts in the field of biogeography (Wallace, 1869). The complex geological history of the more than 7,000 islands that comprise the archipelago has rendered it more difficult to understand the diversification of the rich floral and faunal biodiversity in the country (Hall, 2002). This has drawn the attention of biogeographers, population geneticists, conservation biologists and phylogeneticists to investigate the archipelago and its diverse, endemic species as a model system for addressing a variety of conceptual questions that is related to evolutionary history (Brown & al., 2013). Thus, the Philippine archipelago has emerged as one of the globally important model island archipelagoes for studying evolutionary processes of diversification (Brown & al., 2013). Studies utilizing robust and well-sampled phylogenetic analyses toward understanding complex biogeographical histories have advanced in the last two decades, however, such studies are very limited for plants and are far behind the investigations concerning animals (Heaney, 2007; Brown & Diesmos, 2009; Esselstyn & al., 2011; Siler & al., 2011). Biogeographical studies including Philippine plants were conducted only for a few genera such as *Cyrtandra* J.R.Forst. & G.Forst. (Gesneriaceae; Atkins & al.,2001), *Rhododendron* L. (Ericaceae; Brown & al., 2006) and *Begonia* L. (Begoniaceae; Thomas & al., 2012). In Philippine Rubiaceae, such biogeographical studies are also scarce due to unavailability of genetic samples especially for species-rich genera like *Ixora.* Considering the recent molecular evidence showing that Asian *Ixora* is not monophyletic (Mouly & al., 2009b) and a dated phylogenetic tree indicating that the Miocene (14–15 Mya) was a key period for the onset of the diversification of *Ixora* in Asia and the Pacific (Mouly, 2008; Tosh & al., 2013), the phylogenetic relationships of Philippine *Ixora*, its position in the phylogenetic tree of tribe Ixoreae and its biogeographical origin require further investigation.

Since no representatives of native Philippine *Ixora* were included in the past phylogenetic studies on *Ixora* and tribe Ixoreae due to the unavailability of genetic samples and a lack of revisionary work on Philippine *Ixora*, this first molecular study provides a better understanding of *Ixora* in the Philippines and a good reference for morphological interspecies relationships for the preparation of the much needed taxonomic revision of Philippine *Ixora* and a contribution to the understanding of the genus as a whole. Therefore, the present study aims to investigate the phylogenetic relationships of Philippine *Ixora* species using molecular sequence data from two chloroplast regions (*rps16* and *trnT–F*) and nuclear ribosomal external transcribed spacer (ETS) and internal transcribed spacer (ITS). The resulting phylogenies will then be used to: (1) assess the monophyly of Philippine *Ixora*, (2) explore the phylogenetic relationships within Philippine *Ixora* lineages and (3) infer the biogeographical origin of Philippine *Ixora* using S-DIVA.

MATERIALS AND METHODS

Taxon sampling

Fieldwork was conducted in the Philippine islands from 2010 to 2013 in order to collect herbarium, alcohol and DNA material of Philippine *Ixora* spp. We included 72 *Ixora* accessions (see Appendix), representing approximately 60 species of which about 24 species are sampled from the Philippines including five samples which were not identified to species level but are candidates for new species awaiting description.

Following Mouly & al. (2009b), three suitable outgroup taxa from the tribes Aleisanthieae (*Greeniopsis multiflora* Merr. and *Aleisanthiopsis distantiflora* (Merr.) Tange) and Greeneeae (*Greenea corymbosa* K.Schum.) were chosen to root the trees.

DNA extraction, amplification, sequencing and alignment

Total DNA was extracted from dried material preserved in silica gel (Chase &Hills, 1991) following the protocols of DNeasy Plant Mini Kit (Qiagen, Germany). PCR mixes for chloroplast regions were made up to 25 µl and contained 1.0 µl $MgCl_2$, 2.5 µl 10 × PCR buffer, 2.0 µl dNTP, 1.0 µl of 10 µM forward primer, 1.0 µl of 10 µM reverse primer, 0.35 1.0 µl Taq DNA polymerase and 1 µl of total genomic DNA. Amplification of *rps16* and *trnT–F* used the following PCR settings: initial melting phase of 2 min at 95°C; followed by 35 cycles of 30 s at 95°C, 1 min at 50–55°C, and 2 min at 72°C; and ended with a final extension phase of 7 min at 72°C.

PCR mixes for the nuclear regions were the same as for the chloroplast regions, except that 1 µl each of dimethylsulfoxide (DMSO) and bovine serum albumin (BSA) was added per 25 µl. The ETS amplification profile was: initial melting phase of 1 min at 97°C; followed by 40 cycles of 10 s at 97°C, 30 s at 55°C, 30 s at 72°C; and ended with a final extension phase of 7 min at 72°C. The ITS amplification profile was: initial melting phase of 3 min at 94°C; followed by 30 cycles of 1 min at 94°C, 1 min at 52°C, 1 min at 72°C; and ended with a final extension of 7 min at 72°C.

Primers used for the amplification of nuclear and chloroplast DNA regions are listed in Table 1. PCR amplifications were run on a BIOMETRA thermocycler. All amplification products were cleaned using Qia-Quick PCR purification kit (Qiagen, Germany) and sent to LGC Genomics (Germany) for sequencing.

The *rps16*, *trnT–F*, ITS and ETS sequences were edited and pre-aligned using CodonCode Aligner version 4.0.4 and subsequently adjusted manually. Alignment of sequences was conducted using SeaView version 4.0. All variable nucleotide positions were verified against the original electropherograms.

Table 1. Amplification primers for nuclear and chloroplast regions

Region	Primer	Primer Sequence	Reference
ETS	18S-E	GCAGGATCAACCAGGTAGCA	Baldwin & Markos, 1998; Razafimandimbison & al.,
	ETS-HL	GATCACAGCCTGAGCGGTG	2009
ITS	ITS1	GTCCACTGAACCTTATCATTTAG	Urbatsch & al., 2000; White & al., 1990
	ITS4	TCCTCCGCTTATTGATATGC	
rps16	rpsF	GTGGTAGAAAGCAACGTGCGACTT	Oxelman & al., 1997
	rpsR2	TCGGGATCGAACATCAATTGCAAC	
trnT-F	A1	ACAAATGCGATGCTCTAACC	Taberlet & al., 1991; Bremer & al., 2002; Lantz &
	I	CCAACTCCATTTGTTAGAAC	Bremer, 2004
	C	CGAAATCGGTAGACGCTACG	
	F	ATTTGAACTGGTGACACGAG	

Phylogenetic analyses

Separate and combined analyses of the *rps16*, *trnT–F*, ITS and ETS matrices were performed using Bayesian Markov chain Monte Carlo (MCMC) inference (Yang & Rannala, 1997) as implemented in the program MrBayes version 3.1 (Huelsenbeck & Ronquist, 2001). The model of DNA substitution for each region was determined using Modeltest v. 2.0 (Nylander, 2004) under the Akaike information criterion (Akaike, 1974). The selected models were general time reversible (GTR) with among-site substitution rate heterogeneity described by a gamma distribution (Yang, 1994) for ITS and *rps16* (GTR+G), GTR with a fraction of invariant site constraint and gamma distribution for ribosomal ETS and *trnT–L* segment (GTR+I+G), and GTR with a fraction of invariant site constraint for the *trnL–F* (GTR+I). All analyses were performed with four independent Markov chains run for 3×10^6 generations, and burn-in after 500 sampled trees. The analyses were run three times using different random starting trees to evaluate the convergence of the likelihood values and probabilities of posterior clades (Huelsenbeck & al., 2002). Saved trees from the three independent runs were pooled to build the consensus tree. Groups characterized by a posterior probability (PP) of more than 0.95 were regarded as strongly supported.

For partitioned data sets, maximum parsimony (MP) analyses were performed with PAUP* v.4.0b10 (Swofford, 2002). We conducted equal weighted parsimony heuristic searches on: (a) combined nuclear data set; (b) combined chloroplast data set; and (c) combined nuclear-chloroplast data. Each analysis consisted of 10,000 random sequence addition replicates, MULTREES option off, and tree-bisection reconnection (TBR) branch swapping. In all analyses, characters were given equal weight and gaps were treated as missing data. The consistency index (CI; Kluge & Farris, 1969) and retention index (RI; Farris, 1989) were calculated to estimate homoplasy. Bootstrap (BS; Felsenstein, 1985) values using 10,000 replicates, MULTREES option off and TBR branch swapping; five random addition sequences were performed to assess relative support for the identified clades. Clades receiving a bootstrap support of 50–69% were regarded as weakly supported, 70–85% as moderately supported, and 86–100% as strongly supported.

Biogeographical Analysis

The distribution range of *Ixora* including the three outgroup taxa was divided into five areas. These areas are: A (Philippines), B (Asia excluding the Philippines), C (Africa), D (Neotropics), and E (Pacific).The distribution range of the cultivated species is coded with area B as representing their area of origin and not their current distribution (including cultivation and individuals naturalized from culture).

Statistical Dispersal-Vicariance Analysis (S-DIVA; Yu& al., 2010) implemented in RASP v. 2.1. (Reconstruct Ancestral State in Phylogenies; Yu & al., 2011) was used to reconstruct the possible ancestral ranges of the genus *Ixora* on the phylogenetic trees. The frequencies of an ancestral range at a node in ancestral reconstructions were averaged over all trees (Yu & al., 2010). To account for the uncertainties in phylogeny, we used 7003 trees from the MCMC output and ran S-DIVA on all of them with the number of maximum areas kept as five.

RESULTS

Sequence characteristics

The 132 new sequences generated in this study were combined with sequences previously generated and used by Mouly & al. (2009b) and Tosh & al. (2013) resulting in a total of 264 sequences, representing approximately 60 *Ixora* spp. Ambiguously aligned sites were excluded from the data sets before analyses (Table 2). Levels of genetic variation between species were generally low for all regions investigated. The total number of parsimony informative characters (PICs) ranged from 51 in *rps16* to 140 in the ETS. In terms of percentage variability, the ETS region has the highest number of PICs (31.18%). The lowest percentage of variability was observed in *trnT–F* (3.97%). The number of parsimony informative characters was very low within the combined data set (377 bp), representing about 9% of the aligned sequences.

Table 2. Information for phylogenetic analyses (*rps16, trnT–F*, ITS and ETS).

	rps16	*trnT-F*	ITS	ETS	Combined
No. of sequences investigated	74	75	53	62	75
No. of new sequences	35	35	35	27	132
Range of sequence length (bp)	593-876	767-1744	552-791	282-436	1507-3850
Length of aligned matrices (bp)	956	2040	864	449	4309
Number of PIC	51 (5.33%)	81 (3.97%)	105 (12.15%)	140 (31.18%)	377 (8.75%)
Number of ambiguous sites excluded	260 (27.19%)	327 (16.03%)	243 (28.13%)	36 (8.02%)	866 (20.09%)
Length of MP trees	171	262	302	423	1171
Consistency Index	0.81	0.92	0.72	0.66	0.72
Retention Index	0.87	0.94	0.84	0.79	0.80
Number of trees saved	8180	3340	7340	7515	1980

Separate nuclear and chloroplast analyses

Phylogenetic analyses of individual data sets generated largely unresolved and poorly supported phylogenetic trees (data not shown). The characteristics of the individual chloroplast and nuclear regions are listed in Table2. The nuclear and chloroplast trees (Fig. 1A and1B) both resolved that the Philippine *Ixora* species are not monophyletic but that the species are placed in at least three different clades. Topological incongruence in the phylogenetic placement of several non-Philippine taxa between the nuclear and chloroplast DNA data sets was also observed, e.g. *Ixora valetoniana* from New Guinea, *I. finlaysoniana* and *I. brunonis* from Asia (Fig.1A, 1B).

Combined nuclear and chloroplast analyses

Of all data sets analyzed, the combined data set (Fig. 2) shows the highest resolution and, in general, better support for clades retrieved in the separate cpDNA and nrDNA analysis. Monophyly of the tropical Asian clade is not supported in all phylogenetic analyses of the combined and separate cpDNA and nrDNA datasets. In both the MP and Bayesian analyses (Fig. 2), two main lineages were recovered, an Asian-Pacific lineage (clade A) and an Asian-African-Malagasy-Neotropical-Mascarene lineage (clade B). However, both lineages are weakly supported in the parsimony analyses (BS= <50) but moderately supported in the model-based analyses (PP=0.87).

In clade A, two subclades were formed: a subclade consisting of endemic Philippine *Ixora* species (PP=100, BS=1.00) and another subclade composed of species from the wider Pacific area (with exception of the Indian *I. calycina*) (PP=100, BS=1.00). Clade B consists of the other Asian *Ixora* spp. including the remaining Philippine *Ixora* species (PP=0.76, BS=<50) and is sister to an African-Malagasy-Neotropical-Mascarene clade (PP=0.94, BS=0.59).

The 35 Philippine *Ixora* samples excluding *I. finlaysoniana* 2, fall into five clades, here labelled with A1, B1, B2, B3 and B4 (Fig. 2). Clade A1 (PP=1.00, BS=100) includes eight Philippine *Ixora* samples, consisting of the pair *I. silagoensis* and *I. reynaldoi* (PP=1.00, BS=97), *I. angustilimba* and *I. bibracteata* (PP=0.82, BS=82), and the two unresolved samples of *I. bartlingii*. *Ixora luzoniensis* and *Ixora* sp. 5 from the province of Batanes (PP=1.00, BS=100) are sister to the rest of Philippine species in clade A1. Compared to clade A1, clades B1 to B4 are nested within the other Asian species of *Ixora* included in the study. Clade B1contains two of the widespread species of *Ixora* in the Philippines, *I. macrophylla* and *I. philippinensis. Ixora alejandroi* is sister to *I. macrophylla* and two samples of *I. philippinensis*, while *I. longistipula* is more closely related to the other three species of *I. philippinensis* (PP=1.00, BS=94). Clades B2, B3 and B4 are unresolved among several Asian samples in clade B. Clade B2 includes *I. cumingiana*, *I. myriantha* and two species, *Ixora* sp. 3 and *Ixora* sp. 4, both collected in Sorsogon province (PP=0.68, BS=62). Clade B3 is exclusively formed by species collected from the province of Palawan comprising *I. palawanensis*, *I. leucocarpa* and *Ixora* sp. 2 (PP=0.98, BS=50). *Ixora gigantifolia*, *I. longifolia*, *I. magnifica*, *I. salicifolia* and *Ixora* sp. 1 group together in clade B4 (PP=0.97) but are not supported in the parsimony analysis. Clades A1 and B1 are fully recovered in both separate and combined nuclear and chloroplast topologies (Fig. 1A and 1B; Fig 2).

Two taxa represented by three or five specimens each did not form natural lineages: *I. salicifolia* and *I. philippinensis* (Fig. 2; also observed from separate nr- and cpDNA analyses in Fig. 1A and1B).

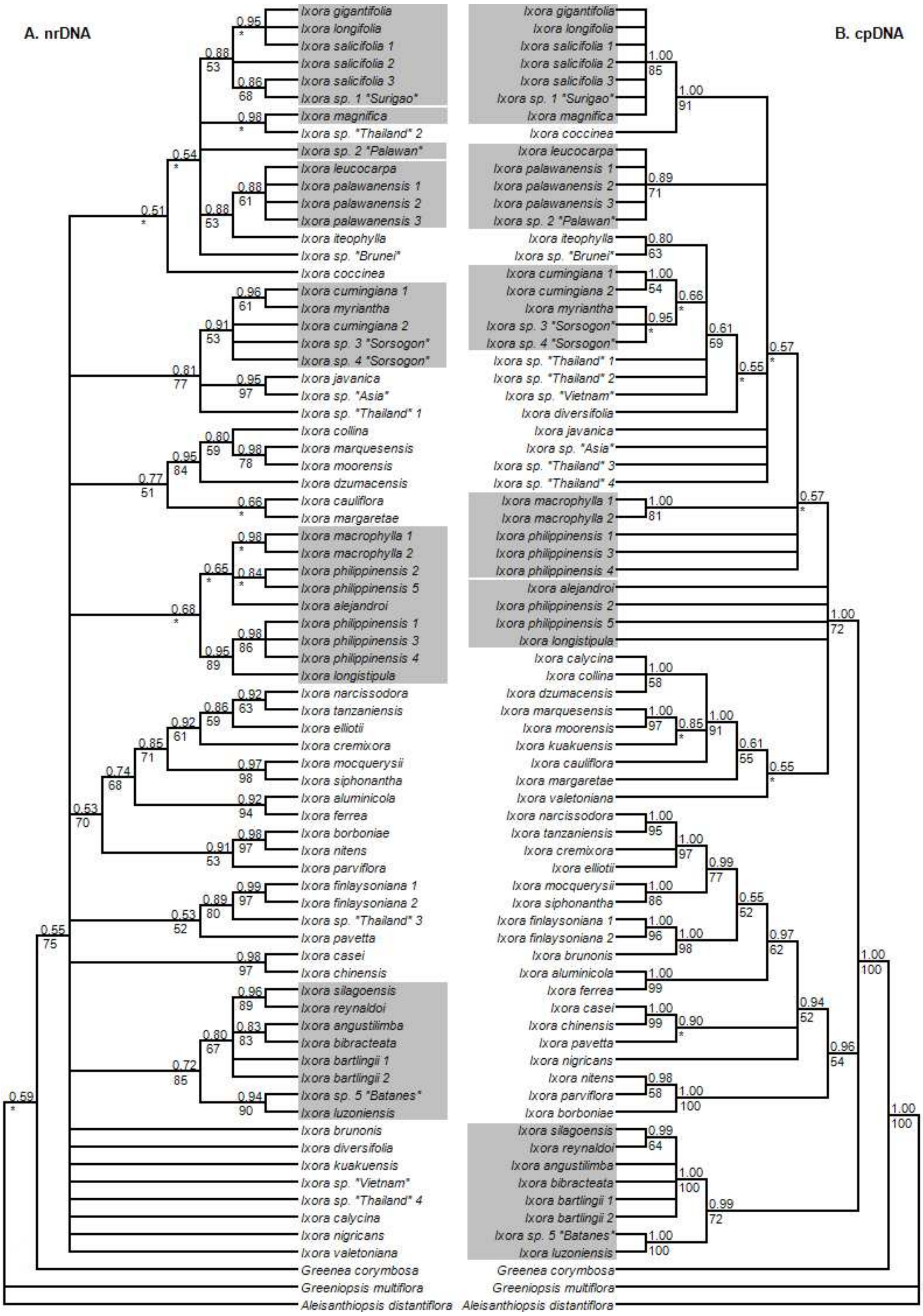

Fig. 1. Cladogram of the Bayesian analysis majority rule consensus tree for the A) nuclear and B) chloroplast data sets. Philippine species of *Ixora* indicated in grey boxes. Asterisks (*) denote nodes that have bootstrap support < 50 in the parsimony analysis.

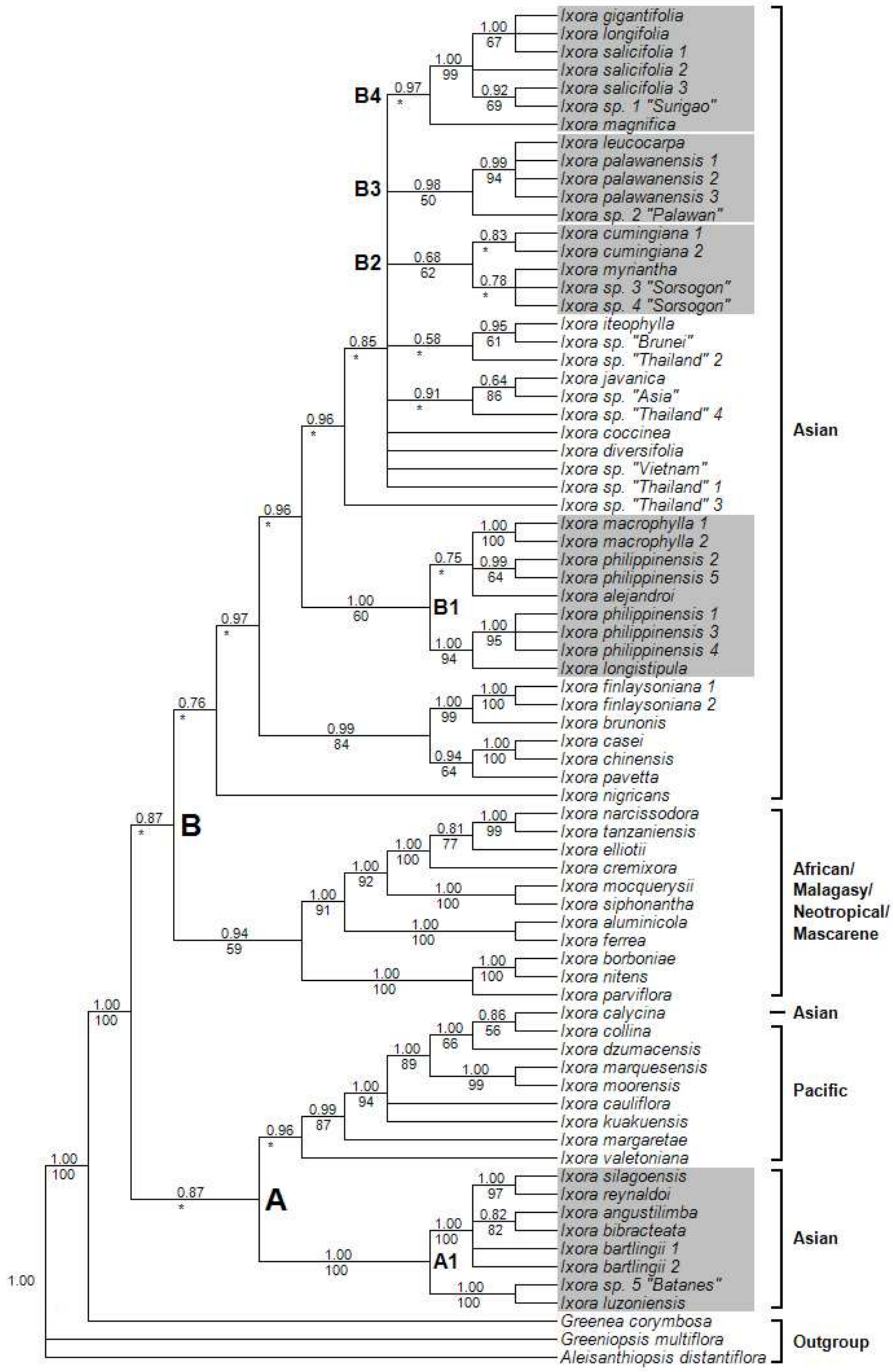

Fig. 2. Cladogram of the Bayesian analysis majority rule consensus tree for the nuclear and chloroplast combined data sets. Philippine species of *Ixora* is indicated in grey boxes. Asterisks (*) denote nodes that have bootstrap support < 50 in the parsimony analysis.

S-DIVA Analysis

The results of S-DIVA (Fig. 3) indicate a complex biogeographical history for *Ixora.* S-DIVA postulates one extinction, ten vicariance and twenty dispersal events that have led to the current distribution of *Ixora*. Asia (area B) was inferred as most probable ancestral area of *Ixora* (node 146, Fig. 3). Node 146 indicates the fundamental dispersal event in the genus, splitting it into an Eastern Asian-Pacific lineage (clade A in Fig. 2) and a Western Asian-African lineage (clade B in Fig. 2). In clade A, a vicariance event split off a Philippine radiation (clade A1 in Fig. 2) and wider Pacific radiation. *Ixora valetoniana*, sister to the remaining taxa in the Pacific radiation, occurs in New Guinea, and thus in the same floristic region (Malesian region; Takhtajan, 1986) as the Philippines, while a vicariance event brought *I. calycina* much further east, to southern India and Sri Lanka. In clade B, extinction and vicariance event (node 129) separated a large Asian radiation from an African one (including Madagascar and the Mascarenes). The New World taxa are the result of a vicariance event from inside this African lineage (node 82). In the large Asian radiation, several dispersal events to the Philippines have taken place. An early one (node 126) leading to clade B1, and possibly three later ones, leading to clades B2-B4. According to our S-DIVA reconstruction, a dispersal event from Asia (node 111) led to the Philippine radiation in clade B2, while dispersal (node 104) and vicariance (node 97) events are responsible for clades B3 and B4.

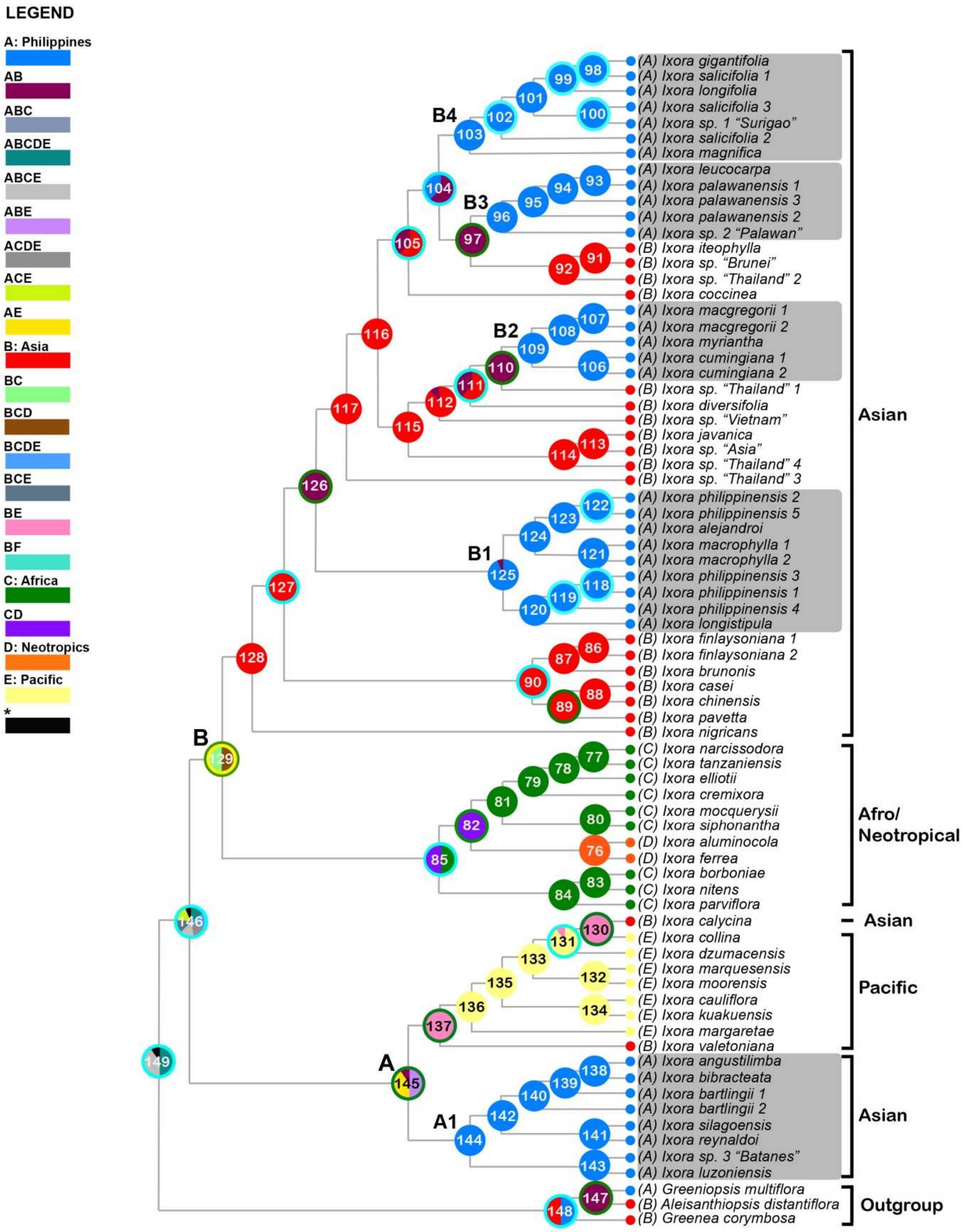

Fig. 3. Graphical output from S-DIVA implemented in RASP. Graphical results of ancestral distributions at each node of the phylogeny of the genus *Ixora* obtained by S-DIVA. Blue circles indicate dispersal, green circles indicate vicariance and yellow circle indicate extinction. Philippine species of *Ixora* is indicated in grey boxes. Color key indicates possible ancestral ranges; letter combinations indicate a combination of ranges; black with an asterisk represents other ancestral ranges.

DISCUSSION

Phylogenetic relationships of Philippine Ixora spp.

Our results suggest that combining data and thus using all available information, results in more robust and better resolved topologies (Andreasen & Bremer, 2000). This effect, that is independent of rather large amounts of missing data, in particular ITS and ETS sequences, corroborates the results of Mouly & al. (2009b) and Tosh & al. (2013), who favor the combined dataset for large genera such as *Ixora.*

A total of 35 samples of Philippine *Ixora* was included in this phylogenetic study, of these, only three species are not endemic in the Philippines, *I. salicifolia, I. philippinensis* and *I. finlaysoniana*. All samples were collected in their natural habitat except for *I. finlaysoniana* 2 which is only known to be cultivated in the Philippines. Six more *Ixora* accessions included in this study are cultivated species (*I. casei, I. chinensis, I. coccinea, I. finlaysoniana* 1*, I. pavetta* and *I. valetoniana*) (Mouly & al., 2009b). These species have conflicting position in the nr- and cpDNA trees (Fig. 2 and 3) which can be indicative of hybridization (Linder & Rieseberg, 2004; Tosh & al., 2013; Mouly & al., 2009b). However, we still included these cultivated species in our analysis since they did not affect the topologies nor decreased the branch support of clades recovered in the combined analysis after restrictive sampling (excluding putative hybrids) was done in the preliminary analyses (data not shown).

In our phylogenetic tree, the ingroup taxa are resolved in two large lineages: the Asian-Pacific clade and Asian-Afro-Malagasy-Neotropical-Mascarene clade. The main clades of Mouly & al. (2009b), namely the African-Malagasy-Neotropical and the Pacific clades are also retrieved in our study. However, in contrast to Mouly & al. (2009b), Asian species are retrieved in several parts of the tree. Most likely, this effect is due to the much reduced sampling of Asian, in particular Philippine material in Mouly & al. (2009b). The fact that Asian *Ixora* might not be monophyletic is indicated in Mouly & al. (2009b), but the level of polyphyly observed here is entirely unexpected.

The representative species from the Philippines are recovered in at least three, possibly five different clades, since clades B2, B3, and B4 are unresolved in the top clade with various tropical Asian species (Fig. 2) leaving it open whether these three clades would be retrieved as monophyletic if more Asian species and / or characters would be included or whether they are indeed derived from three independent colonization events. Thus, the biogeographical relationships of the Philippine species are entirely different. Species of clade A1 belong to an Eastern radiation, that is - with exception of *I. calycina*- restricted to Malesia and the larger Pacific region (Mouly & al., 2009b). Interestingly, clade A1 has a strong focus on the Northern Philippines, with *I. luzoniensis* and a divergent species from Batanes island (*Ixora* sp. 5) being sister to all other taxa in clade A1 (Fig. 2). Also, *I. angustilimba* and *I. bibracteata* are strongly supported sister species from northern Luzon, both characterized by solitary or, at the most three, flowers in an inflorescence supported by leaves (Elmer, 1906; Merrill, 1920). Sister to these two species in our phylogenetic analysis are two recently described species from eastern Visayas, *I. reynaldoi* and *I. silagoensis,* collected in Samar and Leyte, respectively (Banag & al., 2014; Banag & al., submitted). Both species are characterized by subsessile leaves, sessile or shortly pedunculate, erect and lax inflorescences. Nested but unresolved in clade A1 are the two samples of *I. bartlingii*, a widely distributed species found in most islands or provinces but never recorded from the island of Palawan. This species has long-pedunculate, pendulous inflorescences with numerous flowers.

In clade B, mainland Asian and Philippine taxa are sister to an African-Malagasy-Neotropical-Mascarene clade. Corresponding to Mouly & al. (2009b), the Indian *I. nigricans* is sister to the remaining clade, followed by a clade termed "Ornamental" Asian by Mouly & al. (2009b), comprising the ornamental *I. finlaysoniana.* Next, an exclusively Philippine clade is retrieved, containing the multiple accessions of the widespread species *I. philippinensis* which did not form a natural group (Fig. 2). Instead, collections from the northern part of the Philippines (Ilocos Norte and Batanes) are retrieved as sister of *I. longistipula* collected in Panay, and are separated from the collections made in southern part of the country including Palawan, Surigao and Davao. The latter are sister of the widespread *I. macrophylla* and *I. alejandroi* from Palawan. Tosh & al. (2013) observed a similar pattern for the populations of *I. mangabensis* from northern and southern Madagascar which did not form a natural group and at the same time observed morphological differences between the two populations. Indeed, in our case the material collected from Ilocos Norte and Batanes has longer peduncles and more flowers per inflorescence as compared to the sessile to shortly pedunculate inflorescence with ten or usually less flowers in each cyme from the materials collected in Palawan, Surigao and Davao. Re-evaluation of the taxonomy of *I. philippinensis* is required given the genetic differentiation and morphological variation observed between these populations that are currently united under this species.

Another widespread species, *I. macrophylla,* forms a well supported clade nested with the two *I. philippinensis* accessions from Ilocos Norte and Batanes and *I. alejandroi,* which is only found in Palawan. Surprisingly, *I alejandroi* did not group with the other endemic species of Palawan which are nested in clade B3 (Fig. 2). Neither does it share any morphological characters with *I. macrophylla* and *I. philippinensis,* except for the pubescent inflorescence. *Ixora alejandroi* is characterized by its panicled cymose inflorescence, bifid stigmatic branches which are shortly cleft in the middle and rounded at the top, characters which are not known from other Philippine species (Banag & al., submitted).

In clade B2, *I. cumingiana* is sister to *I. myriantha* and two unidentified samples from Sorsogon (Fig. 2). Both species have lax inflorescences and white flowers, but differ in their geographic distribution as *I. cumingiana* is found in most islands in the Philippines while *I. myriantha* is only known from two provinces, Samar and Davao. Detailed morphological investigation between these two species is needed to decide whether they are probably conspecific. The two *Ixora* spp. from Sorsogon are only known from their fruits while their flowers are yet to be collected to further establish their relationship with *I. cumingiana* and *I. myriantha*.

Clade B3 is restricted to the island of Palawan comprising *I. palawanensis* and *I. leucocarpa* (Fig. 2), sister to these species is *Ixora* sp. 2 which is also collected in Palawan. Though sharing similar habitat types, forested ravines or humid forest, these species differ morphologically in terms of their flower color (*I. palawanensis*, salmon-red; *I. leucocarpa*, white; *Ixora* sp. 2, orange).

Another Philippine endemic *Ixora* with showy bright red flowers, *I. magnifica*, is resolved as sister to all other accessions forming clade B4. The three accessions of *I. salicifolia* are all nested in clade B4 but are not resolved as a natural group. *Ixora salicifolia* 3 and *Ixora* sp. 1, both from Surigao del Sur, form a monophyletic subclade. Nested with *I. salicifolia* 1 collected in Leyte are *I. longifolia* from Cebu and *I. gigantifolia* from Surigao del Sur, *while I. salicifolia* 2 remains unresolved. All species in clade B4 possess pedunculate, erect and compact inflorescences and long pedicellate flowers. The present species concept in *Ixora* (Mouly & al., 2009b) understands *I. salicifolia* as a widespread species, found in Indonesia, Malaysia and Philippines. However, our present results show that many species considered widespread are in fact polyphyletic, thus necessitating a re-evaluation of the species concept of *I. salicifolia*.

Our study shows that some species thought to be closely related based on morphological characters were not retrieved in the same clade in the phylogenetic trees. This includes *I. macrophylla, I. bartlingii* and *I. longistipula.* These three species are often misidentified in herbarium collections due to their long-pedunculate, pendulous inflorescences with white corollas and overlapping shape of the leaves. However, other morphological characters support their separation in the phylogenetic tree, particularly the articulate inflorescence of *I. bartlingii* as opposed to the non-articulate inflorescences of *I. macrophylla* and *I. longistipula* as well as the sessile to capitate flowers of *I. longistipula* as opposed to the pedicellate flowers of *I. bartlingii* and *I. macrophylla.* In addition, both *I. longistipula* and *I. bartlingii* have terminal inflorescences while *I. macrophylla* has cauliflorous (sometimes ramiflorous) inflorescences.

Although our focus is on the phylogenetic diversity of Philippine *Ixora,* our results provide clear evidence that broader phylogenetic study of the genus *Ixora* is needed to accurately estimate the species-level diversity as low support was observed for several internodes among Asian species including the Philippine samples (Fig. 2).

Biogeography

Our study presents an opportunity to make several inferences on the biogeographical patterns and diversification of Philippine *Ixora* and the genus as a whole. Mouly & al. (2009a) have shown that *Ixora s.l.* is sister to the South-East Asian Greeneeae and both to the Indo-Malayan Aleisanthieae. Thus, an origin of *Ixora* in Asia is most likely and also indicated by S-DIVA (Fig. 3).

The onset of divergence between the clades A (Pacific) and clades B (Asian) *Ixora* has been estimated between 14 to 15 Mya (Mouly, 2008; Bremer & Eriksson, 2009; Tosh & al., 2013). Thus, arrival of the members of Ixoreae in the Philippines would have been possible at a date ranging from the Miocene to the Pleistocene. Our results coincide with the biogeographical history of the Philippine archipelago that during the Miocene (15 Mya) part of the country is situated east of the Sulawesi landmass, north of, but relatively close to New Guinea (Atkins & al., 2001; Hall, 2012). Thus, it is not surprising that the New Guinean *I. valetoniana* is sister to the remaining Pacific taxa, taking into account the vicariance event at node 137. This may indicate another way of historical colonization of the Philippines by *Ixora* or of the role of South-East Asia in the colonization of the Pacific Islands, through the Pacific Ocean.

In the Philippines, four major colonization routes, or biogeographic umbilici (Diamond & Gilpin, 1983) have been identified as entryways to parts of the archipelago that has never been connected to a mainland. One colonization route include the eastern island arc involving Sulu Archipelago-Mindanao-Leyte-Samar-Luzon which is most likely the route followed by the species of clade A1 as their distribution is recorded in these areas.

Clades B1 to B4 are derived from a continental Asian origin, with the Philippine species of clades B2 and B4 in direct sister group position to Continental South-East Asian species. However, the number of colonization events of Asian *Ixora* to the Philippines remains unclear. Even though four clades of Philippine native species are retrieved inside clade B, only B1 is with certainty an independent conquest of the Philippines, while the interplay between the Philippines and the South-East Asian mainland is not well resolved in the top clade comprising subclades B2 to B4 in our phylogenetic analysis (Fig. 2). Therefore, we cannot state with certainty whether the Philippines have been conquered one more time, or three more times from continental Asia. However, the species composition in the five clades comprising Philippine species according to our S-DIVA analysis is strongly different, which might be considered as indicator for the latter hypothesis.

While clades A1, B2 and B3 comprise only endemic species, clades B1 and B4 contain both species endemic to the Philippines and species also reported from some Asian mainland areas. The first branching clade B1, comprises the two taxa most widespread in the Philippines, *I. macrophylla* and *I. philippinensis*. While both are reported from all major islands including Palawan, only *I. philippinensis* occurs in other areas of Malesia, as far as southern China. However, in our analysis, not even the accessions from the northern and the southern Philippines are monophyletic, so that additional material from other islands and from the mainland needs to be studied to test whether *I. philippinensis* in its present circumscription is a monophyletic species or whether the name is used for superficially similar, but unrelated lineages. It is noteworthy that *I. alejandroi*, the aberrant Palawan endemic, is sister to two *I. philippinensis* accessions from the northern Philippines, while the *I. philippinensis* accession from Palawan is member of the "southern" group of *I. philippinensis*. This pattern, which indicates easy exchange between Palawan and the remaining islands supports the view that it constitutes a very recent radiation, because Palawan has only come close to the remainder of the archipelago in the last 5 Mya (Brown & al. 2013). Clade B4 comprises species mostly restricted to Mindanao with the exception of *I. salicifolia,* that is broadly distributed in the Philippines and also found in Borneo and Java. Again, the non-monophyly of the three *I. salicifolia* accessions studied raises the question as to the correctness of the present species concept in *Ixora*. If *I. salicifolia* turns out as an emigrant from the Philippines, it would underpin the key role of Mindanao as stepping stone for *Ixora* dispersal in the region (Jones & Kennedy, 2008).

Palawan is playing a special role for the understanding of south-east Asian biogeography. While the famous Wallace's line (Wallace, 1863) is separating Wallacea from the Sunda-Region including the Philippines, Huxley's line (Huxley, 1868), separated the Philippines (except for Palawan) from the Sunda-Region, thus linking the island of Palawan biogeographically with Borneo. Recent analyses by Van Welzen & al. (2011) revealed evidence for partitioning of Malesia into three instead of two regions: the western Sunda Shelf minus Java (Malay Peninsula, Sumatra, Borneo), central Wallacea (Philippines, Sulawesi, Lesser Sunda Islands, Moluccas, Java), and the eastern Sahul Shelf (New Guinea). In our study, we have included 5 of 11 *Ixora* species occurring in Palawan. For clade A1, our results indeed support the separation of the island from the Philippines along the traditional Huxley's line, because the only widespread species included in this clade, *I. bartlingii*, was never recorded from Palawan. In clade B, however, all four Philippine clades B1-B4 have representatives in Palawan. In clade B1, the widespread species *I. philippinensis* and *I. macrophylla* are both reported from the island, and the fact that the Palawan endemic *I. alejandroi* groups with the northern accessions of *I. philippinensis* and not with the *I. philippinensis* accession from Palawan in the southern group of accessions indicates that, at least for this group of species, regular exchange between all Philippine islands, including Palawan, is taking place. Likewise, the widespread species in clades B2 and B4, *I. cumingiana* and *I. salicifolia*, respectively, are present on Palawan as well as on the other islands. Because our study does not comprise samples of these species from Palawan, the migration routes of these species inside the Philippine archipelago remain to be studied. Clade B3 is special in uniting endemic species from Palawan and our S-DIVA reconstruction (Fig. 3) suggests affinities to species from Thailand and the island of Borneo, thus supporting Huxley's line in its traditional sense. However, our sampling of material from Indonesia, and in particular from Borneo, is not sufficient to conclusively resolve the role of Palawan for the biogeography of *Ixora*. Nevertheless, our present results support the conclusion of Atkins & al. (2001) in *Cyrtandra* (Gesneriaceae), who found that Palawan has both strong biogeographical ties with the other Philippine islands and, via Borneo, with the remainder of Sundaland.

Thus, for *Ixora*, the Philippines seem to constitute an overlay zone into which species from both major lineages in *Ixora*, the Pacific and the African-Asian one, have immigrated and subsequently radiated. Our results indicate further, that, at least in the species studied, there has been no secondary mixing between the members of the two immigrant waves, as both nrDNA and cpDNA retrieve the same species groups. A more detailed study of clade B, focusing on Asian material, is needed to understand the complex biogeographical patterns in *Ixora* inside the Malesian Region. Future studies should also include more populations especially of species with wider distributions – be it on several islands or a presumed distribution on mainland Asia - in order to more finely resolve the phylogeography of Philippine *Ixora* species.

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LITERATURE CITED

Akaike, H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716–723.

Alejandro, G.J.D. 2007. The Current Status of the Philippine Rubiaceae. *Philippine Journal of Systematic Biology* 1 (1): 47–60.

Alejandro, G.J.D. & Liede-Schumann, S. 2003. The Philippine Rubiaceae genera. Updated synopsis in INTKEY databases of the DELTA system. *Blumea* 48: 261–277.

Andreasen, K. & Bremer, B. 1996. Phylogeny of the subfamily Ixoroideae (Rubiaceae). *Opera Bot. Belg.* 7: 119–138.

Andreasen, K. & Bremer, B. 2000. Combined phylogeneteic analysis in the Rubiaceae-Ixoroideae: morphology, nuclear and chloroplast DNA data. *Amer. J. Bot.* 87: 1731–1748.

Atkins, H., Preston, J. & Cronk, Q.C.B. 2001. A molecular test of Huxley's line: *Cyrtandra* (Gesneriaceae) in Borneo and the Philippines. *Biol. J. Linn. Soc.*72: 143–159.

Baldwin, B.G. & Markos S. 1998. Phylogenetic utility of the external transcribed spacer (ETS) of 18S–26S rDNA: congruence of ETS and ITS trees of *Calycadenia* (Compositae). *Molec. Phylog. Evol.* 10: 449–463.

Banag, C.I., Manalastas, N.M.B.& Alejandro, G.J.D. 2014. Synonymy of Philippine *Ixora* (Ixoreae, Rubiaceace) and *Ixora silagoensis* sp. nov. *Nord. J. Bot.* doi: 10.1111/njb.00411.

Bremekamp, C.E.B. 1937. The Malesian species of the genus *Ixora* (Rubiaceae). *Bulletin du Jardin Botanique de Buitenzorg* , série 3, 14: 197–367.

Bremer, B. & Eriksson, T. 2009. Time tree of Rubiaceae: phylogeny and dating the family, subfamilies, and tribes. *Int. J. Plant Sci*. 170: 766–793.

Bremer, B., Bremer, K., Heidari, N., Erixon, P., Olmstead, R.G., Anderberg, A.A., Källerjö, M.K. & 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. *Molec. Phylog. Evol.*24: 274–301 .

Brown, R.M. & Diesmos, A.C. 2009. Philippines, biology. pp. 723–32 in: Gillespie RG, Clague DA, eds. 2009. *Encyclopedia of Islands.* Berkeley: Univ. Calif. Press

Brown, G.K., Craven, L.A., Udovicic, F.& Ladiges, P.Y. 2006. Phylogenetic relationships of *Rhododendron* section *Vireya* (Ericaceae) inferred from the ITS nrDNA region. *Aust. Syst. Bot.* 19: 329–342. http://dx.doi.org/10.1071/SB05019

Brown, R.M., Siler, C.D., Oliveros, C.H., Esselstyn, J.A., Diesmos, A.C., Hosner, P.A., Linkem, C.W., Barley, A.J., Oaks, J.R., Sanguila, M.B., Welton, L.J., Moyle, R.G., Peterson, A.T. & Alcala, A.C. 2013. Evolutionary processes of diversification in a model island archipelago. *Annu. Rev. Ecol. Evol. Syst*. 44:411–435. doi:10.1146/annurev-ecolsys-110411-160323

Chase, M.W. & Hills, H.H. 1991. Silica gel: an ideal material for field preservation of leaf samples for DNA studies. *Taxon* 40: 215–220.

Davis, A.P., Govaerts, R., Bridson, D.M., Ruhsam, M. & Moat, J. 2009. A global assessment of distribution, diversity, endemism, and taxonomic effort in the Rubiaceae. *Ann. Missouri Bot. Gard.* 96: 68–78.

De Block, P. 1998. The African species of *Ixora* (Rubiaceae - Pavetteae). *Opera Bot. Belg.* 9: 1–217.

De Block, P. 2013. The Malagasy species of *Ixora* (Rubiaceae–Pavetteae). *Opera Bot. Belg.* 16: in press.

Diamond, J.M. & Gilpin, M.E. 1983. Biogeographic umbilici and the origin of the Philippine avifauna. *Oikos* 41:307–21.

Elmer, A.D.E. 1906. New and noteworthy Rubiaceae. *Leafl. Philipp. Bot.* 1: 8–9.

Esselstyn, J.A., Maher, S.P. & Brown, R.M. 2011. Species interactions during diversification and community assembly in an island radiation of shrews. *PLoS One* 6:e21885.

Farris, J.S. 1989. The retention index and the rescaled consistency index. *Cladistics* 5: 417–419.

Felsenstein, J. 1985. Confidence limits on phylogenies: An approach using the bootstrap. *Evolution* 39: 783–791.

Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SWPacific: computer-based reconstructions, model and animations. *J. Asian Earth Sci.* 20:353–431.

Hall, R. 2012. Late Jurassic–Cenozoic reconstructions of the Indonesian region and the Indian Ocean. *Tectonophysics* 570–571: 1–41.

Heaney L.R. 2007. Is a new paradigm emerging for oceanic island biogeography? *J. Biogeogr.* 34: 753–57

Huelsenbeck, J.P. & Ronquist, F. 2001. MrBayes: Bayesian inference of phylogenetic trees. *Bioinformatics*17: 754–755.

Huelsenbeck, J.P., Larget, B., Miller, R.E. & Ronquist, F. 2002. Potential applications and pitfalls of Bayesian inference of phylogeny. *Syst. Biol.*51: 673–688.

Huxley, T.H. 1868. On the classification and distribution of the Alectoromorphae and Heteromorphae. *Proceedings of the Zoological Society of London.* 294–319.

Jones, A.W. & Kennedy, R.S. 2008. Evolution in a tropical archipelago: comparative phylogeography of Philippine fauna and flora reveals complex patterns of colonization and diversification. *Biol. J. Linn. Soc.* 95: 620–639.

Kluge, A.G. & Farris, J.S. 1969. Quantitative phyletics and the evolution of anurans. *Syst. Zool.* 18: 1–32.

Lantz, H. & Bremer, B. 2004. Phylogeny inferred from morphology and DNA data: characterizing well-supported groups in Vanguerieae (Rubiaceae). *Bot. J. Linn. Soc.* 146: 257–283. doi: 10.1111/j.1095-8339.2004.00338.x

Linder,C.R. & Rieseberg, L.H. 2004. Reconstructing patterns of reticulate evolution in plants. *Amer. J. Bot.* 91: 1700–1708.

Lorence, D.H., Wagner, W.L., Mouly, A. & Florence, J. 2007. Revision of *Ixora* (Rubiaceae) in the Marquesas Islands (French Polynesia). *Bot. J. Linn. Soc.* 155: 581–597.

Merrill, E.D. 1920. New or noteworthy Philippine Plants, XVI. *Philippine Journal of Science* 320–321.

Merrill, E.D. 1923. An enumeration of Philippine Flowering Plants. Manila Bureau of Printing. 2: 492–576.

Mouly, A. 2008. Systématique de la tribu des Ixoreae A. Gray (Rubiaceae): phylogénie, biogéographie et taxinomie. *Acta Botanica Gallica* 155 (3): 457–464.

Mouly, A., Razafimandimbison, S., Florence, J., Jeremie, J. & Bremer B. 2009a. Paraphyly of *Ixora* and new tribal delimitation of Ixoreae (Rubiaceae): inference from combined chloroplast (*rps16*, *rbc*l, and *trn*T-F) sequence data. *Ann. Missouri Bot. Gard.* 96: 146–160.

Mouly, A., Razafimandimbison, S., Khodabandeh, A. & Bremer, B. 2009b. Phylogeny and classification of the species-rich pantropical showy genus *Ixora* (Rubiaceae-Ixoreae) with indications of geographical monophyletic units and hybrids. *Amer. J. Bot.* 96(3): 686–706.

Nylander, J.A.A. 2004. MrModeltest 2.0. Program distributed by the author. Evolutionary Biology Centre, Uppsala University, Uppsala, Sweden.

Oxelman, B., Liden, M. & Berglund, D. 1997. Chloroplast *rps16* intron phylogeny of the tribe Sileneae (Caryophyllaceae). *Pl. Syst. Evol.* 206: 393–410.

Razafimandimbison, S.G., Lantz, H., Mouly, A. & Bremer, B. 2009. Evolutionary trends, major lineages, and new generic limits in the dioecious group of the tribe Vanguerieae (Rubiaceae): Insights into the evolution of functional dioecy. *Ann. Missouri Bot. Gard.*96(1):161–181.

Reynolds, S.T. & Forster, P.I. 2006. A taxonomic revision of *Ixora* L. (Rubiaceae: Ixoroideae) in Australia. *Austrobaileya* 7: 253–278.

Robbrecht, E. & Manen, J.F. 2006. The major evolutionary lineages of the coffee family (Rubiaceae, angiosperms). Combined analysis (nDNA and cpDNA) to infer the position of *Coptosapelta* and *Luculia*, and supertree construction based on *rbcL*, *rps16*, *trnL-trnF* and *atpB-rbcL* data. A new classification in two subfamilies, Cinchonoideae and Rubioideae. *Syst. Geogr. Plants* 76: 85–146.

Siler, C.D., Diesmos, A.C., Alcala, A.C., & Brown, R.M. 2011. Phylogeny of Philippine slender skinks (Scincidae: *Brachymeles*) reveals underestimated species diversity, complex biogeographical relationships, and cryptic patterns of lineage diversification. *Molec. Phylog. Evol.* 59:53–65

Swofford, D.L. 2002. PAUP*: Phylogenetic Analysis Using Parsimony (*and Other Methods) version 4.0 Beta. Sinauer Associates,Sunderland: Massachusetts.

Taberlet, P., Gielly, L., Patou, G. &Bouvet J. 1991. Universal primers for amplification of three noncoding regions of chloroplast DNA. *Pl. Molec. Biol.* 17: 1105–1109.

Thomas, D.C., Hughes, M., Phutthai, T. , Ardi, W.H., Rajbhandary, S., Rubite, R., Twyford, A.D. & Richardson, J.E. 2012. West to east dispersal and subsequent rapid diversification of the mega-diverse genus Begonia (Begoniaceae) in the Malesian archipelago. *J. Biogeogr.* 39: 98–113

Tosh, J., Dessein, S., Buerki, S., Groeninckx, I., Mouly, A., Bremer, B., Smets, E.F,&De Block, P. 2013. Evolutionary history of the Afro-Madagascan *Ixora* species (Rubiaceae): species diversification and distribution of key morphological traits inferred from dated molecular phylogenetic trees. *Ann. Bot.*112(9):1723–1742.

Urbatsch, L.E., Baldwin, B.G. & Donoghue, M.J. 2000. Phylogeny of the coneflowers and relatives (Heliantheae: Asteraceae) based on nuclear rDNA internal transcribed spacer (ITS) sequences and chloroplast DNA restriction site data. *Syst. Bot.* 25: 539–565.

Van Welzen, P.C., Parnell, J.A.N. & Ferry Slik, J.W. 2011. Wallace's Line and plant distributions: two or three phytogeographical areas and where to group Java? *Biol. J. Linn. Soc.* 103: 531–545.

Wallace, A.R. 1863. On the physical geography of the Malay Archipelago. *J.R. Geogr. Soc.* 32: 217–234.

White, T.J., Bruns, T., Lee, S. & Taylor, J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. Pp 315–322 in Innis, M.A., Gelfand, D.H., Sninsky, J.J., White, T.J., eds. PCR protocols: a guide to methods and applications. San Diego, CA: Academic Press.

Yang, Z. & Rannala, B. 1997. Bayesian phylogenetic inference using DNA sequences: A Markov chain Monte Carlo method. *Molec. Biol. Evol.*14 : 717–724 .

Yang, Z. 1994. Maximum likelihood phylogenetic estimation from DNA sequences with variable rates over sites: Approximate methods. *J. Molec. Evol.* 39: 306–314.

Yu, Y., Downie, S.R., He, X-J., Deng, X-L.&Yan, L. 2011. Phylogeny and biogeography of Chinese Heracleum (Apiaceae tribe Tordylieae) with comments on their fruit morphology. *Pl. Syst. Evol.* 296(3–4): 179–203

Yu, Y., Harris, A.J. &He X-J. 2010. S-DIVA (Statistical Dispersal-Vicariance Analysis): a tool for inferring biogeographic histories. *Molec. Phylog. Evol.*. 56: 848–850.

Appendix. Accessions sampled for the study.

Taxon; locality; *voucher specimen* (herbarium code); GenBank accession numbers (*rps16, trnT–F,* ITS, ETS; an n-dash denotes missing taxa).

Aleisanthiopsis distantiflora (Merr.) Tange; Indonesia; *Kessler & al. 41* (P); EU817434, EU817453, JQ398731, FJ150425. ***Greenea corymbosa*** K.Schum.; Thailand; *Beusekom & al. 752* (P); AF242961, AF152657, – , FJ150435. ***Greeniopsis multiflora*** Merr.; Philippines; *Uy & Tandang25007* (USTH); GQ981432, GQ981424, JQ398734, –. ***Ixora alejandroi*** Banag*; Philippines: Palawan; *Tandang 254886* (PNH); HG970792, HG970757, HG964391, HG970820. ***Ixora aluminicola*** Steyerm.; French Guiana; *Prévost 4160* (P); FJ150617, FJ150541, HG315441, FJ150436. ***Ixora angustilimba*** Merr.; Philippines: Aurora; *Banag 11032* (USTH); HG323826, HG970758, HG964361, HG970821. ***Ixora bartlingii*** Elmer 1; Philippines: Samar; *Pinarok 121008* (USTH); HG970793, HG970760, HG964363, –. ***Ixora bartlingii*** Elmer 2; Philippines: Laguna; *Banag IM003* (USTH); HG323827; HG970759; HG964362; HG970822. ***Ixora bibracteata*** Elmer; Philippines: Ilocos Norte; *Arriola 13016* (USTH); HG970794; HG970761, HG964364; HG970823. ***Ixora borboniae*** Mouly & B.Bremer; Mascarene Is.; *Friedmann F. 3049* (P): FJ150685, FJ150609; HG315450; FJ150530. ***Ixora brunonis***Wall. & G. Don; Thailand; *Larsen K. & al. 43463* (P); EU817446, EU817470, –, FJ150443. ***Ixora calycina*** Thwaites; Sri Lanka; *Tirvegadum & al. 18* (P); FJ150622, FJ150546, –, –. ***Ixora casei*** Hance; cultivated Taihiti, French Polynesia; *Mouly & Florence 348* (P); FJ150623, FJ150547, –, FJ150444. ***Ixora cauliflora*** Montrouz.; New Caledonia; *Mouly & Innocente 267* (P); FJ150624, FJ150548, HG315455, FJ150445. ***Ixora chinensis*** Lam.; cultivated Uppsala, Sweden; *no voucher*; FJ150625, FJ150549, –, FJ150446. ***Ixora coccinea*** L.; cultivated Uppsala, Sweden; *Bremer 2719* (UPS); EF205641, EU817464, AJ224826, FJ150448. ***Ixora collina*** Beauvis.; New Caledonia; *Mouly & Innocente 236* (P); FJ150626, FJ150550, HG315456, FJ150449. ***Ixora cremixora*** Drake; Madagascar; *Leeuwenberg 13879* (P); FJ150628, FJ150552, HG315458, FJ150451. ***Ixora cumingiana*** Vid. 1; Philippines: Rizal; *Banag AN004* (USTH); HG970797; HG970764; HG964378; –. ***Ixora cumingiana*** Vid. 2; *Banag BO001* (USTH); Philippines: Pangasinan; HG970796; HG970763; HG964366; HG970824. ***Ixora diversifolia*** R.Br.; Thailand; *Charoenphol & al. 3719* (P); FJ150629, FJ150629, –, –. ***Ixora dzumacensis*** Guillaumin; New Caledonia; *Mouly & al. 275* (P); FJ150630, FJ150554, –, FJ150453. ***Ixora ellioti*** Drake ex De Block; Madagascar; *Dumetz 1175* (P); FJ150632, FJ150556, HG315461, FJ150454. ***Ixora ferrea*** (Jacq.) Benth.; Puerto Rico; *Taylor 11693* (MO); EF205642, EU817465, HG315465, FJ150456. ***Ixora finlaysoniana***

Wall. & G.Don. 1; cultivated Tanzania; *Luke 9042* (S); EU821619, EU817466, –, FJ150458. ***Ixora finlaysoniana*** Wall. & G.Don. 2; Philippines: Laguna; *Cua 1107c* (USTH); HG970798; HG970765; HG964367; HG970825. ***Ixora gigantifolia*** Elmer; Philippines: Surigao del Norte; *Banag SU012A* (USTH); HG970800; HG970767; HG964369; HG970826. ***Ixora iteophylla*** Bremek.; Malaysia; *Schaller & al. 3932* (P); FJ150640, FJ150563, –, FJ150469. ***Ixora javanica*** DC.; Laos; *Munzinger 119* (P); –, FJ150602, –, FJ150519. ***Ixora kuakuensis*** S.Moore; New Caledonia; *Munzinger 2180* (NOU); FJ150642, FJ150565, –, FJ150471. ***Ixora leucocarpa*** Elmer; Philippines: Palawan; *Banag I010* (USTH); HG970801; HG970768; HG964370; HG970827. ***Ixora longifolia*** Sm.; Philippines: Cebu; *Paraguison L010* (USTH); HG970815; HG970785; HG964388; –. ***Ixora longistipula*** Merr.; Philippines: Panay; *Chavez, 12093* (USTH); HG970802; HG970769; HG964373, HG970828. ***Ixora luzoniensis*** Merr.; Philippines: Zambales; *Banag MA008* (USTH); HG970803, HG970770; HG964374; HG970829. ***Ixora macrophylla*** Bartl. 1; Philippines: Aurora; *Banag 11053* (USTH); HG323830, HG970771, HG964375, HG970830. ***Ixora macrophylla*** Bartl. 2; Philippines: Cebu; *Paraguison L009* (USTH); HG970804, HG970772, HG964376, –. ***Ixora magnifica*** Elmer; Philippines: Laguna; *Banag IM001* (USTH); HG970805, HG970773, HG964377, HG970831. ***Ixora margaretae*** (N. Halle) Mouly & B.Bremer; New Caledonia; *Mouly & Innocente 222* (P); EU817436, EU817456, –, FJ150426. ***Ixora marquesensis*** F.Br.; Marquesas Is.; *Mouly 504* (P); FJ150645, FJ150568, –, FJ150475. ***Ixora mocquerysii*** DC.; Madagascar; *Malcomber 2805* (MO); FJ150647, FJ150570, HG315487, FJ150477. ***Ixora moorensis*** (Nad.) Forberg; Society Is.; *Florence s.n.* (P); EU817441, EU817462, –, FJ150478. ***Ixora myriantha*** Merr.; Philippines: Davao del Sur; *Lemana BL005* (USTH); HG970806, HG970774, HG964379, HG970832. ***Ixora narcissodora*** K.Schum.; Kenya; *Luke 8324* (UPS); FJ150648, FJ150571, HG315488, FJ150479. ***Ixora nigricans*** R.Br.; Thailand; *Larsen & al. 43037* (P); FJ150650, FJ150573, –, FJ150482. ***Ixora nitens*** (Poir.) Mouly & B.Bremer; Mascarene Is.; *Friedman 2631* (P); FJ150684; FJ150608; HG315490; FJ150529. ***Ixora palawanensis*** Merr. 1; Philippines: Palawan; *Banag LM002* (USTH); HG970808, HG970776, HG964380, HG970833. ***Ixora palawanensis*** Merr. 2; Philippines: Palawan; *Medecillo MPM 471* (USTH); HG970807, HG970775, HG964381, –. ***Ixora palawanensis*** Merr. 3; Philippines: Palawan; *Banag I008* (USTH); HG970799, HG970766, HG964368, –. ***Ixora parviflora*** Lam.; Mascarene Is.; *Lorence 1526* (P); EU817449, EU817473, AJ224840, FJ150533. ***Ixora pavetta*** Andrews; cultivated Uppsala, Sweden; *FTG 1738* (UPS); FJ150653, FJ150576, –, FJ150485. ***Ixora philippinensis*** Merr. 1; Philippines: Davao del Sur; *Lemana BL006* (USTH);

HG970809, HG970777, HG964385, –. ***Ixora philippinensis*** Merr. 2; Philippines: Ilocos Norte; *Banag BU002* (USTH); HG970810, HG970778, HG964384, HG970834. ***Ixora philippinensis*** Merr. 3; Philippines: Palawan; *Alejandro 12400* (USTH); HG970811, HG970779, HG964383, HG970835. ***Ixora philippinensis*** Merr. 4; Philippines: Surigao del Norte; *Alejandro 11102* (USTH); HG970812, HG970780, HG964382, HG970836. ***Ixora philippinensis*** Merr. 5; Philippines: Batanes; *Tandang DT548* (PNH); HG970813, HG970781, HG964386, HG970837. ***Ixora reynaldoi*** Banag*; Philippines: Samar; *Banag SA004* (USTH); HG970814, HG970782, HG964390, HG970838. ***Ixora salicifolia*** (Blume) DC. 1; Philippines: Leyte; *Banag 12026* (USTH); HG323828, HG970783, HG964371, HG970839. ***Ixora salicifolia*** (Blume) DC. 2; Philippines: Leyte; *Banag SJ005* (USTH); HG323829, HG970784, HG964372, HG970840. ***Ixora salicifolia*** (Blume) DC. 3; Philippines: Surigao del Sur; *Banag SU002* (USTH); HG323831, HG970786, HG964387, HG970841. ***Ixora silagoensis*** Manalastas, Banag & Alejandro; Philippines: Leyte; *Banag 12037* (USTH); HG323832, HG970787, HG964389, HG970842. ***Ixora siphonantha*** Oliv.; Madagascar; *Rabenantoandro & al. 944* (MO); FJ150661, FJ150584, HG315499, FJ150495. ***Ixora sp.*** **"Asia"**; Asia; *Martin 1314* (P); FJ150670, FJ150593, –, FJ150507. ***Ixora sp.*** **"Brunei"**; Brunei; *Malcomber & al. 2980* (MO); FJ150676, FJ150599, HG315500, FJ150516. ***Ixora sp.*** **"Thailand" 1**; Thailand; *Geesink 7226* (P); FJ150671, FJ150594, –, FJ150510. ***Ixora sp.*** **"Thailand" 2**; Thailand; *Larsen & al. 86KL14* (UPS); FJ150677, FJ150600, –, FJ150517. ***Ixora sp.*** **"Thailand" 3**; Thailand; *Vidal 5758B* (P); FJ150673, FJ150596, –, FJ150511. ***Ixora sp.*** **"Thailand" 4**; Thailand; *Vidal 5771* (P); FJ150672, FJ150595, –, –. ***Ixora sp.*** **"Vietnam"**; Vietnam; *Poilane 103* (P); FJ150675, FJ150598, –, –. ***Ixora tanzaniensis*** Bridson; Tanzania; *Luke 9304* (UPS); EU817447, EU817471, HG315502, FJ150520. ***Ixora valetoniana*** Mouly & B.Bremer; cultivated Bogor, Indonesia; *Ridsdale s.n.* (UPS); FJ150687; FJ150611, –, FJ150536. ***Ixora sp.*** **1 "Surigao"**; Philippines: Surigao del Norte; *Alejandro 11068* (USTH); HG970816, HG970788, HG964392, HG970843. ***Ixora sp.*** **2 "Palawan"**; Philippines: Palawan; *Alejandro 12406* (USTH); HG970817, HG970789, HG964393, HG970844. ***Ixora sp.*** **3 "Sorsogon"**; Philippines: Sorsogon; *Chavez 13315* (USTH); HG970818, HG970790, HG964394, HG970845. ***Ixora sp.*** **4 "Sorsogon"**; Philippines: Sorsogon; *Chavez 13336* (USTH); HG970819, HG970791, HG964395, HG970846. ***Ixora sp.*** **5 "Batanes"**; Philippines: Batanes; *Tandang DT588* (PNH); HG970795, HG970762, HG964365, –.

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* sp. nov. ined.

PUBLICATION 2

BIOCLIMATIC NICHES OF ENDEMIC *IXORA* SPECIES ON THE PHILIPPINES: POTENTIAL THREATS BY CLIMATE CHANGE

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PLANT ECOLOGY (under Review)

Bioclimatic niches of endemic *Ixora* species on the Philippines: potential threats by climate change

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Abstract

The pantropical genus *Ixora* is highly diverse, with several species endemic to the Philippines. Owing to their endemic nature, many of these species are endangered and little is known about their basic biology. This study aimed to establish baseline information about climatic niches of *Ixora* species endemic to the Philippines, identify suitable areas and potential range shifts under future climate conditions, and identify priority areas for conservation and future research. We used a set of 19 bioclimatic variables from the

WorldClim database at 2.5′ resolution. Mean annual temperature, mean annual precipitation and measures of their seasonality were the main environmental factors for the distributions of the seven investigated endemic species of *Ixora* in the Philippines. Ecological niche modelling was carried out for the two species with most occurrence records, *I. bartlingii* and *I. auriculata*, using Maxent. Model results suggest that these two *Ixora* species will shift their geographic distributions under predicted levels of climate change. The models can also assist design of conservation strategies for the species, identifying localities and areas with the potential to withstand climate change until at least 2080.

Keywords: *climate change; ecological niche modelling; endemic; Ixora auriculata; Ixora bartlingii; Maxent; Rubiaceae*

Introduction

Climate is considered to be a primary factor that constrains distributions of plant species (Cox and Moore 1993; Woodward 1996; Vetaas 2002). Changes in climate are expected to affect distributions of plant species negatively if climatic conditions diverge from climatic optima (Miller and Urban 1999; Ferranini 2012). Indeed, future climate change is likely to intensify endangerment and extinction of species with limited ranges or narrow ecological niches, and limited dispersal capabilities.

Among species with narrow ranges, endemic species are of particular concern. An endemic species is confined to a particular geographic area and may have a small population size associated with relatively high risk of extinction (Ndayishimiye et al. 2012). They are more likely to be dispersal limited than other species, and to be less able to track a rapidly changing climate (Morueta-Holme et al. 2010). Endemic species are thus particularly sensitive to climate change, and several studies indicate that their presence coincides with areas of long-term climate stability (Svenning and Skov 2007; Ohlemüller et al. 2008; Fløjgaard et al. 2010; Morueta-Holme et al. 2010). Therefore, understanding of climatic and ecological requirements and distribution constraints of endemic species is crucial in developing effective conservation strategies that are robust to future climate changes.

The Philippines is identified as one of the world's biologically richest countries and ranks second among the biodiversity hotspots in the world, next to Madagascar (Myers et al. 2000). The country hosts about five percent of the world's species of flora; more than half of its 10,000 vascular and 14,000 non-vascular plants are endemic to the archipelago (Ong et al. 2002). For the Rubiaceae family alone, for example 83 percent of the 535 species found in the Philippines are endemics (Davis et al. 2009). The pantropical genus *Ixora* L. (Ixoreae; Andreasen and Bremer 2000), a member of the Rubiaceae, provides an exemplary case, with a particularly high number of endemic species known (30 out of 41 species) in the country (Alejandro 2007).

Yusuf and Francisco (2009), identified the Philippines, Indonesia, and Malaysia as among the most vulnerable countries in Southeast Asia climatically, based on the high exposure frequencies of droughts, cyclones, landslides, and floods, perhaps evidenced by the more frequent occurrence of destructive typhoons during the past three years adds credibility to these projections (Alcala et al. 2012). According to the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), climate change by 2020 and 2050 will likely affect Philippine flora and fauna (PAGASA 2011). The projected rise in mean annual temperature for the country lies between 0.9°C to 1.4°C for 2020 and 1.7°C to 2.4°C by 2050. Furthermore, the dry months of March to May are likely to become even drier and the wet months of June through November will likely become wetter. Reduction in rainfall is expected across Mindanao for all seasons, and stronger southwest monsoon winds are anticipated for Luzon and the Visayas. Areas with increasing elevation in slope gradients will be more vulnerable to excessive rains, landslides, and flash floods than areas that are gently sloping at lower elevations, which will emphasize central and northern Luzon, Mindanao, and parts of Mindoro, Negros and Panay Islands, all also reported as areas of high endemism (Brown and Alcala 1970; Heaney and Roberts 2009; Alcala et al. 2012). There is compelling evidence showing that species are already shifting their ranges in response to on-going changes in regional climates (Parmesan and Yohe 2003; Root et al. 2005; Walther et al. 2005; Thuiller et al. 2008; Davis et al. 2012). Whereas such shifts are well documented for species in the temperate zones, much fewer studies have been conducted in the tropics, where species are predicted to be more sensitive to altered temperatures (Freeman and Freeman 2014).

To date, only three studies dealing with potential effects of climate change have been carried out in the Philippines focusing particularly on forest ecosystems (Cruz 1997; Lasco et al. 2008) and selected threatened forest tree species (Garcia et al. 2013). No studies have investigated potential impacts of climate change on Philippine endemic and rare plant species. With this research gap in mind, and given the potentially drastic climate change in the Philippines, we posed the question how the occurrence of endemic *Ixora* species relates to bioclimatic conditions and how climate change may affect species' distributions. *Ixora* was chosen as a focus in this study for several reasons. It belongs to the family Rubiaceae, which shows great species diversity across tropical Asia (Davis et al. 2009; Mouly et al. 2009), and currently with 30 endemic species known from the Philippines (Alejandro 2007). The genus also has importance as a potential source of pharmaceuticals (Inouye et al. 1988; Wen et al. 2011; Wahab et al. 2012; Yoga Latha et al. 2012; Rajendra et al. 2013). Finally, large gaps still exist in knowledge of species' distribution for *Ixora* in the Philippines such that basic information about their ecology is limited. Preliminary studies on the distribution of Philippine endemic *Ixora* using herbarium records show that most species are single island endemics and only few species are widely distributed across the country. Ongoing climate change has been identified as most likely cause for range shifts in various species (Huntley 1991; Prentice et al. 2000; Davis and Shaw 2001; Walther et al. 2005; Parmesan 2006; Thuiller et al. 2008; Trisurat et al. 2011; Davis et al. 2012). Similarly, geographical range shifts driven by warming was recorded in 87 percent of 124 endemic plant species studied in Himalayan biodiversity epicentre (Telwala et al. 2013). Therefore, our study aims to test the hypothesis that endemic Philippine *Ixora* species will shift their geographic distributions and habitat suitability under conditions of climate change. Specifically it aims to establish baseline information about climatic niches of two *Ixora* species endemic to the Philippines, identify presently suitable areas, anticipate potential range shifts under future climate conditions, and to identify priority areas to facilitate appropriate decision-making for conservation and future research.

Materials and Methods

This present study aims to derive information on environmental requirements of *Ixora* species endemic to the Philippines with a particular focus on the two more common species *I. bartlingii* and *I. auriculata*. As a first step, environmental relationships of endemic species were analyzed to provide basic information on species' niches. As a second step, the potential distributions of the two species with sufficient presence records were modeled under present and future climatic conditions with the algorithm Maxent (Phillips et al. 2006; Phillips and Dudik 2008; Elith et al. 2011).

Study Region and Distribution Data

Locality data of the naturally occurring Philippine *Ixora* were derived from three sources. Herbarium specimens were surveyed at the following herbaria: BR, HUH, NY, PNH, and US (abbreviations after Holmgren et al. 1990). Data were also downloaded from online databases such as the Global Biodiversity Information Facility (http://www.gbif.org/)

and Co's Digital Flora of the Philippines (http://www.philippineplants.org). Finally data were from the authors' own field surveys during 2008 - 2012. Owing to the large spatial extent and topographic complexity of the study region, no systematic surveys are available, therefore records were considered as presence-only data.

In all, 492 locality records were collated. Records lacking coordinates were georeferenced using World Gazetteer (http://worldgazetteer.com) and Geonames (http://www.geonames.org/export/web-services.html). All coordinates were carefully checked for plausibility and/or error-corrected using Google Earth (version 7; Google 2013). The final data set comprised 150 unique locality records (meaning no duplication of localities for identical georeferenced points) for 18 endemic *Ixora* species (Fig. 1). However, a few common species (e.g. *I. bartlingii*, *I. auriculata*) dominated these records; most of the endemic species were represented by few (< 10) observation points.

Low numbers of records posed the main constraint for modelling potential distributions of the species. Since results would be of limited reliability and could lead to unreasonable results, we decided not to consider species with <10 known localities in the modelling exercises. Hence, species distribution modelling was conducted only for *I. auriculata* (17 records) and *I. bartlingii* (45 records).

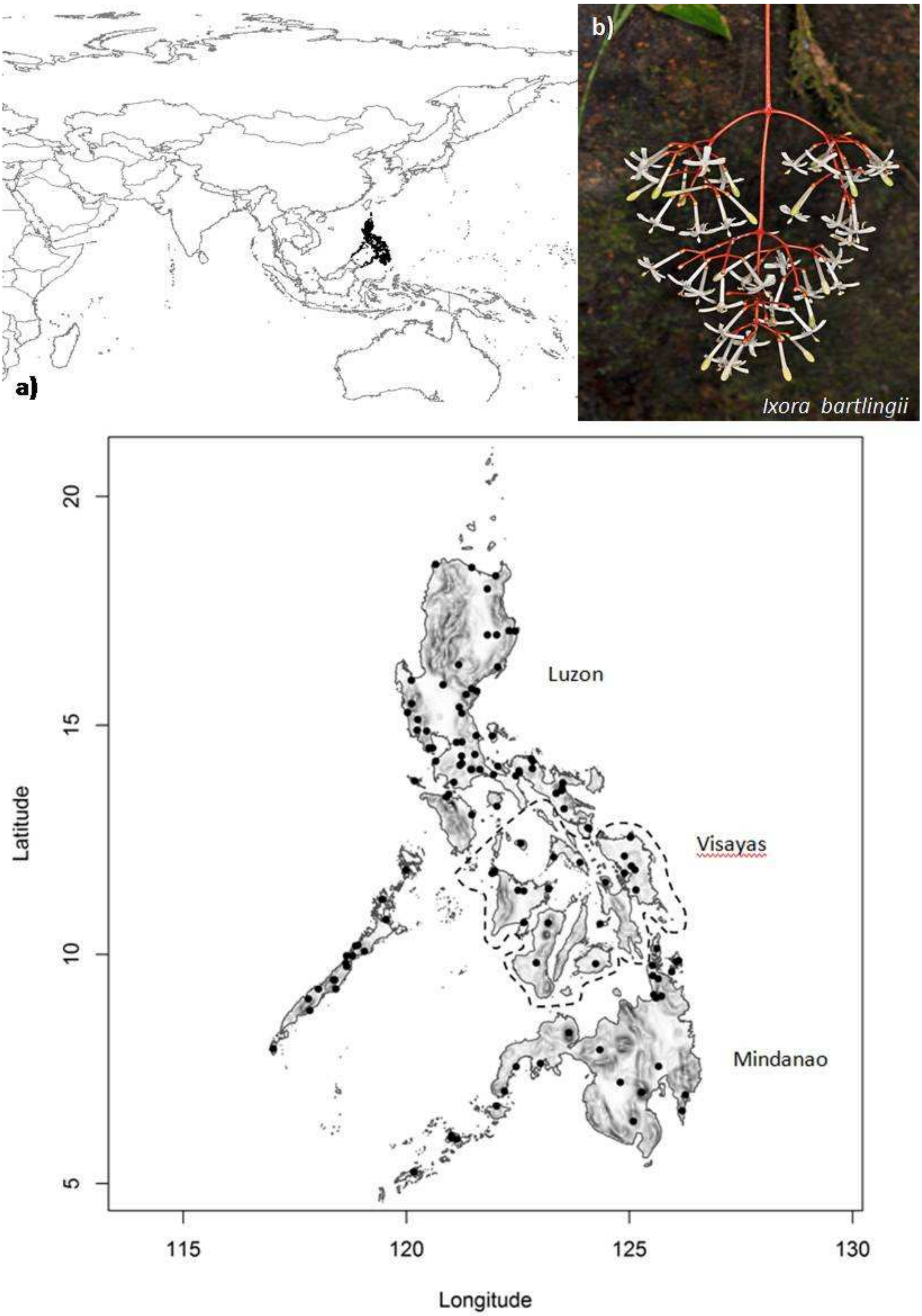

Figure 1. Distribution of *Ixora* presence locations in the Philippines. A) Map of Southeast Asia showing location of the Philippines. B) Inflorescence of *I. bartlingii* (Pelser *et al.* 2011). Dashed lines show boundaries of the three major islands Luzon, Visayas and Mindanao.

Environmental data

For analyzing species' distributions, 19 bioclimatic variables were considered. These bioclimatic variables were retrieved from the WorldClim database at 2.5′ resolution (approx. 3.5 km in the Philippine archipelago) for the period 1950-2000 (http://www.worldclim.org; see also Hijmans et al. 2005).

A preliminary analysis also explored human population density in 2000 (CIESIN 2013) as an additional predictor. Given the known association of *Ixora* with undisturbed rainforests, we assumed that human impact would affect the probability of species presence negatively. However, the low spatial resolution of the data (town level) and a possible sampling bias (sampling concentrated near settled and accessible areas) resulted in unreasonable results indicating higher probability of presence with increasing human population density. We therefore chose to exclude effects of human presence and focus instead on bioclimatic niche space only.

In order to limit the potential effect of collinearity between environmental variables which can reduce predictive power and cause difficulties in the interpretation (Dormann et al. 2013), predictor pairs with Pearson's correlation coefficient |r|>= 0.7 were identified, and only the variable with the better ecological interpretability was retained (see Table 1). We visualized relationships between species occurrence and climatic variables with best ecological interpretability (i.e. mean annual temperature and precipitation, as well as temperature and precipitation seasonality) for the seven endemic species that had > 5 locality records.

For future climate projections, two scenarios (A2 and B1) for the year 2080 from the GCM data portal (http://www.ccafs-climate.org) were chosen to represent the maximum range between lowest and highest expected climate change.

Raster data sets were processed using R (R Development Core Team 2012) with the packages *raster*, *sp* and *rgdal*.

Table 1. Pearson's correlation coefficients between the variables used in the distribution modelling for *Ixora*.

	AMT	MDR	TS	TAR	AP	PSeason	PWQ
Annual mean temperature (AMT)							
Mean diurnal range (MDR)	-0.220						
Temperature seasonality (TS)	0.095	-0.319					
Temperature annual range (TAR)	-0.152	0.479	0.629				
Annual precipitation (AP)	-0.237	-0.264	0.064	-0.213			
Precipitation seasonality (PSeason)	0.161	-0.298	0.444	0.350	0.051		
Precipitation of warmest quarter (PWQ)	-0.398	0.100	0.050	0.126	0.639	0.005	

Distribution modelling

Models were developed for *I. bartlingii* and *I. auriculata* using Maxent version 3.3.3k (http://www.cs.princeton.edu/~schapire/maxent/). Maxent (Phillips et al. 2006; Phillips and Dudik 2008; Elith et al. 2011) is an evolutionary-computing method based on the maximum entropy algorithm. It thereby provides an estimate of the species realized niche, and projects it into geographic space (Phillips et al. 2006). Maxent is among the most frequently used methods for modelling and has been shown to often perform better than many other presence-only models (Phillips et al. 2006; Fischer et al. 2011). A detailed description of Maxent is given in Phillips et al. (2006) and Phillips and Dudik (2008).

Maxent has been found to be robust to changes in sample size and can still have good predictive ability at low sample sizes making it the ideal model for the prediction of distributions for rare species (Hernandez et al. 2006; Wisz et al. 2008; Garcia et al. 2013). However, since our models only include environmental conditions, important aspects such as dispersal barriers and biotic interactions are not considered; model results therefore have to be interpreted with care, taking these restrictions into account.

Model settings were kept at default values, i.e., simulations were carried out with a convergence threshold of 10^{-5} and a maximum number of iterations of 500. Model runs were performed with cross-validation, setting the number of folds equal to the number of records (17 replicates for *I. auriculata* and 25 replicates for *I. bartlingii*), thus performing leave-one-out cross-validation. Model outputs were generated using logistic output.

Variable selection followed Morueta-Holme et al. (2010). All predictors that showed no strong collinearity (see above) were included in the model. The model was then simplified progressively by excluding the variable with the least predictive power according to variable contribution statistics (Table 1), until all variables with < 1 percent contribution were discarded (with the exception of annual precipitation, which was maintained due to its high a priori assumed ecological relevance). This procedure resulted in the selection of 4 most important variables for each species (see Table 2).

Table 2. Bioclimatic variables used in the Maxent models for the two species (shown as variable contribution and variable training gain determined by the Jackknife test of variable importance). Variables without any values (indicated by -) were removed because of low predictive power.

	I. auriculata		*I. bartlingii*	
Presence records	17		45	
AUC (Training data)	0.86		0.76	
AUC (Test data)	0.78		0.68	
Bioclimatic variable	**var. contribution (%)**	**var. gain**	**var. contribution (%)**	**var. gain**
Annual Mean Temperature (Bio 1)	1.27	0.62	-	-
		0.02		-
Mean Diurnal Range (Bio 2)	-	-	45.54	0.28
		-		0.17
Temperature Seasonality (Bio 4)	92.37	0.19	34.91	0.25
		0.58		0.24
Temperature Annual Range (Bio 7)	-	-	18.26	0.26
		-		0.06
Annual Precipitation (Bio 12)	0.95	0.62	1.29	0.30
		0.01		0.03
Precipitation Seasonality (Bio 15)	5.41	0.60	-	-
		0.17		-
Precipitation of Warmest Quarter (Bio 18)	-	-	-	-
		-		-

Performance of the Maxent model was assessed using the Area Under the receiver operating characteristics Curve (AUC, see also Hanley and McNeil 1982). The AUC provides a measure of the model's discriminatory ability between suitable and unsuitable areas for a species and is a well-established approach for model evaluation (Reineking and Schröder 2006).

RESULTS

Climatic Niche Differentiation

Analysis of the endemic species relationships with the bioclimatic variables suggest that species are differentiated in respect to mean annual temperature, mean annual precipitation and particularly seasonality variables.

Bioclimatic niches of each species (Fig. 2.) indicate that species generally have narrow temperature and wider precipitation niches. The occurrence of Philippine *Ixora* species is mainly concentrated in areas where the mean annual temperature is within 25°C to 28°C and mean annual precipitation between 1500 mm to 3500 mm. Among the seven endemic species, *I. bartlingii* and *I. auriculata* are mainly distinguished by low and high temperature seasonality, respectively, however both showed generally similar niches in respect to precipitation seasonality. *Ixora intermedia* and *I. magnifica* show similar distributions while *I. ebracteolata*, *I. tenuipedunculata* and *I. palawanensis* are mainly distinguished by seasonality of temperature and precipitation. *Ixora ebracteolata* was distributed along a rather wide range of precipitation regimes but showed a rather narrow niche in respect to temperature seasonality. The distribution of *I. tenuipedunculata* was associated with intermediate temperature and precipitation conditions. *Ixora palawanensis* was only found under very narrow conditions of temperature seasonality but under fairly wide ranges of precipitation seasonality.

Comparing the species bioclimatic preferences, species tend to separate most along the axis of precipitation seasonality (Fig. 2).

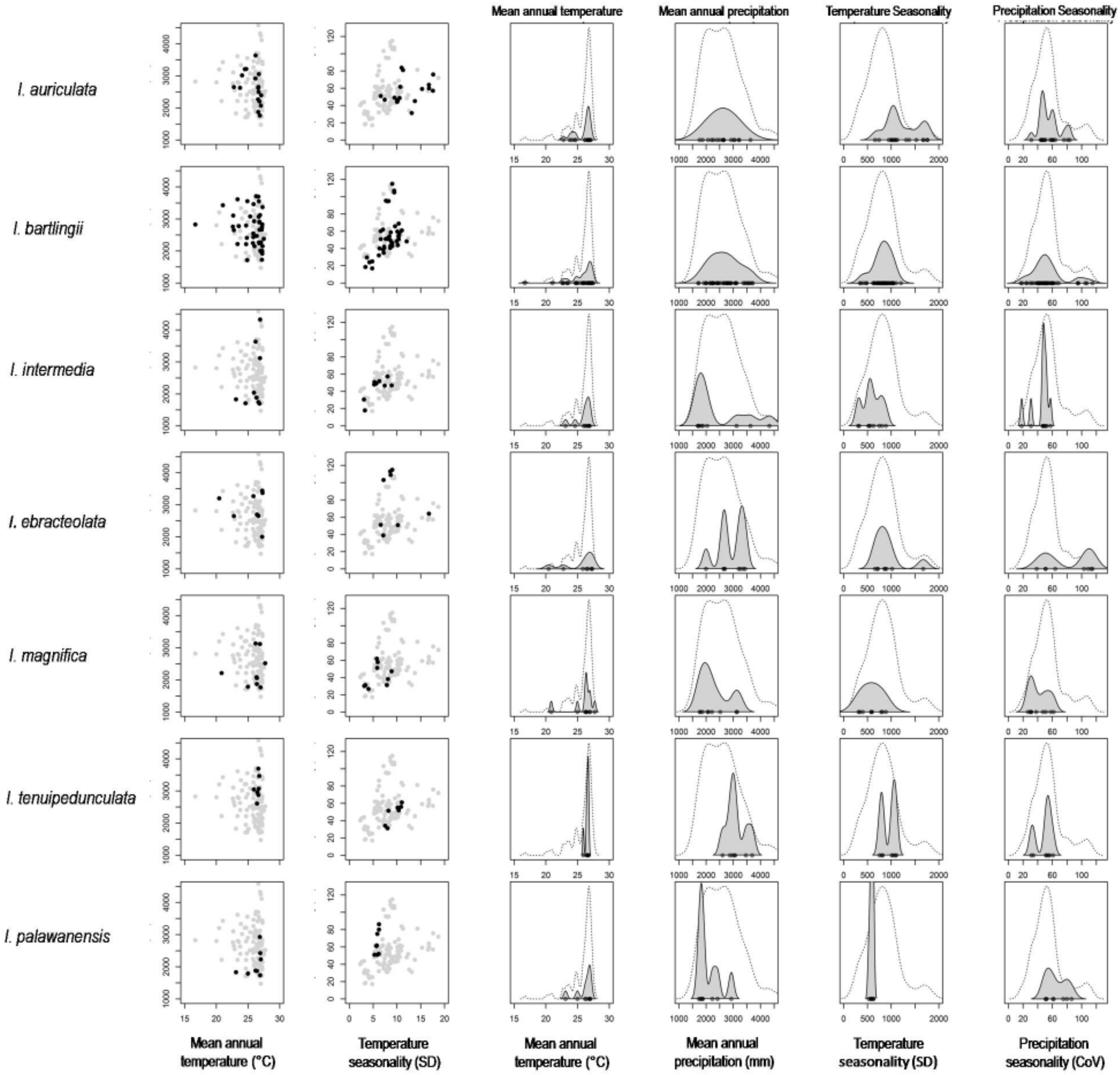

Figure 2. Scatter plots and Kernel density plots of the four climatic variables for the seven endemic Philippine species of *Ixora.* (Gray points in the scatterplots show distribution of all recorded *Ixora* species on the Philippines, both native and non-native. Dotted lines in the background of density plots indicate density of all recorded *Ixora* species. For better visual comparability, density curves of all *Ixora* species were super-elevated by a factor of 4. Temperature seasonality is shown as standard deviation (SD), precipitation seasonality as coefficient of variation (CoV) for all plots).

Niche Modelling

Niche models were developed for two endemic *Ixora* species, *I. auriculata* and *I. bartlingii,* which were documented in more than ten locations. The relative contributions and variable importance of different environmental factors as derived by Maxent are shown in Table 2. The current distribution of *I. bartlingii* was affected most by the temperature variables, whereas *I. auriculata* distribution was influenced by both temperature and precipitation variables (Table 2). Habitat suitability of *I. auriculata* increased with increased temperature seasonality, but decreased sharply with increased precipitation seasonality (Fig. 3a-b). Habitat suitability of *I. bartlingii* decreased with increased in mean diurnal range and showed intermediate optimum as regards temperature seasonality (Fig. 3c-d).

Model performance for *I. auriculata* and *I. bartlingii* were in an acceptable AUC range (values>0.7). Suitable areas were identified for *I. auriculata* in northern Luzon and eastern Visayas (Fig. 4a). However, by 2080, under both climate scenarios, some suitable areas in Luzon will be reduced in suitability for the species. The model also shows future increases of moderately suitable areas in the western and southern parts of the country (Fig. 4b-c).

Current suitable climatic areas were identified for *I. bartlingii* mostly in southern Luzon and the Visayas, with isolated patches in northern Luzon (Cordillera Administrative Region) and Mindanao (Surigao del Sur) (Fig. 4d). Suitable areas appear more likely to increase by 2080 under both climate scenarios. However, most areas in Luzon will be no longer suitable for the species in the future, and the model shows a general southward shift of suitable areas for *I. bartlingii* (Fig. 4e-f).

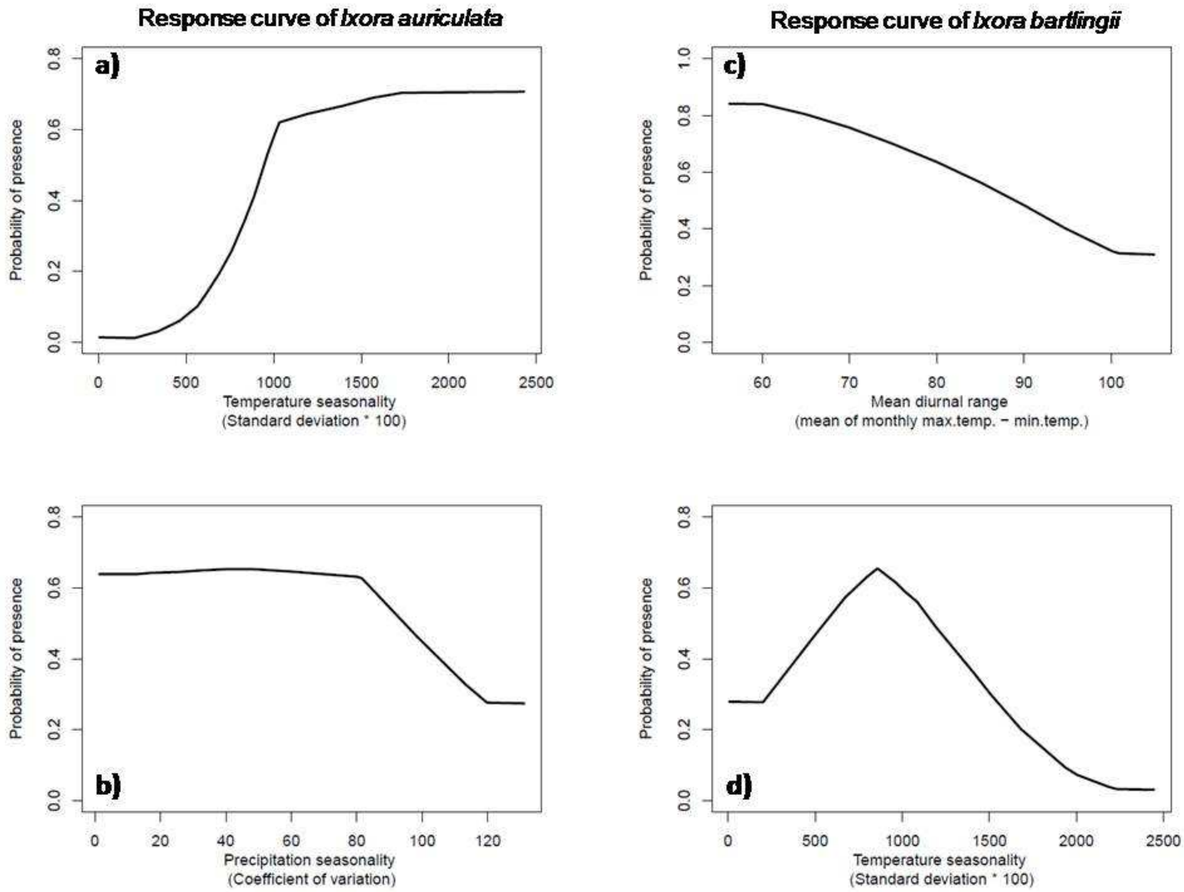

Figure 3. Response curves showing the relationships between the probability of presence of a species and two most important bioclimatic predictors of (A, B) *I. bartlingii*, and (C, D) *I. auriculata*. Values shown are average over 25 replicate runs for *I. bartlingii* and 17 replicate runs for *I. auriculata.*

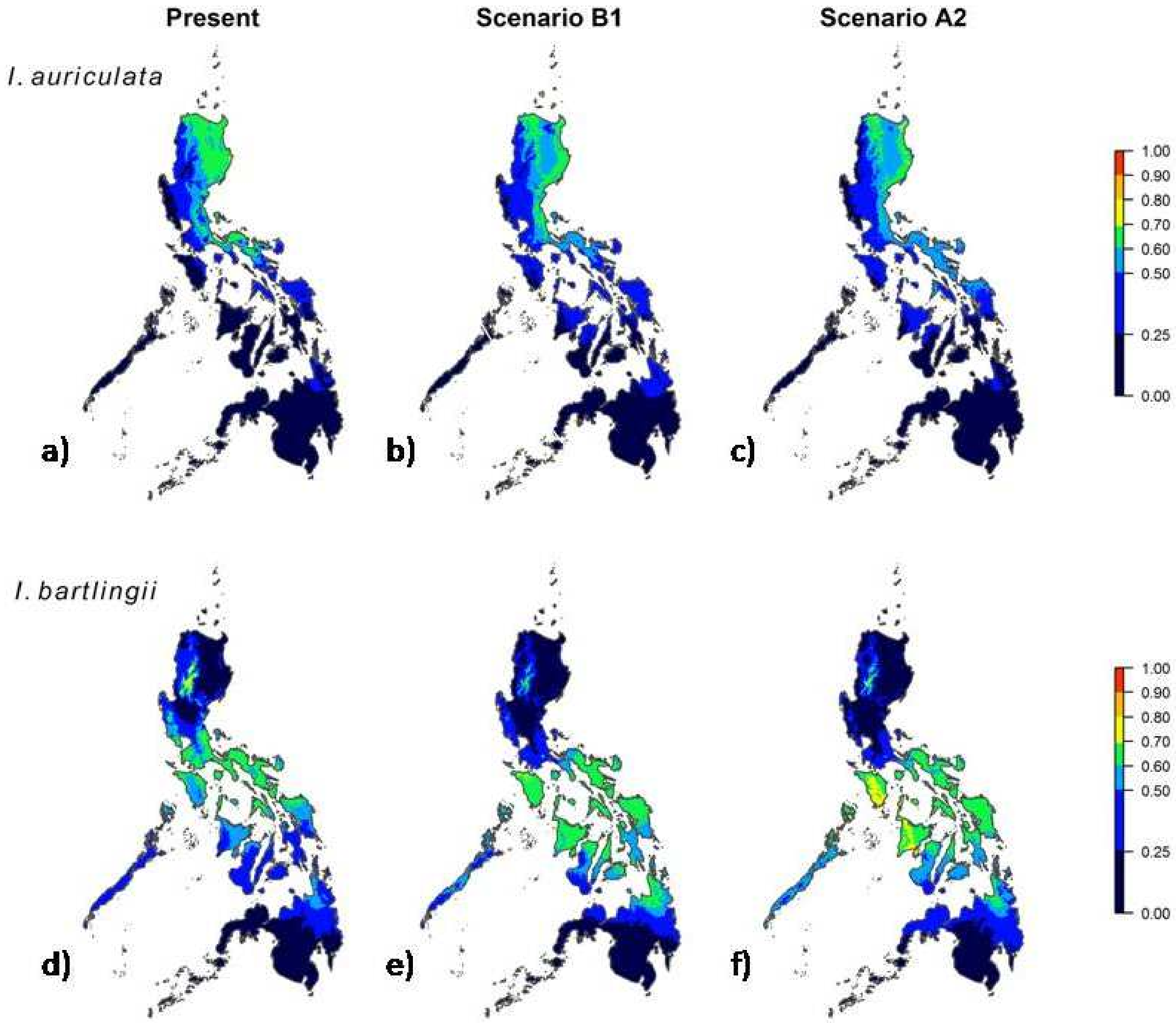

Figure 4. Maps of habitat suitability (expressed as probability of presence) of (A-C) *Ixora auriculata* and (D-F) *Ixora bartlingii* under current conditions and predicted climate change conditions for the two emission scenarios (B1 and A2 from IPCC, 2007) for 2080.

Multivariate Environmental Similarity Surfaces (MESS) within Maxent (see Elith et al. 2010) also revealed novel climates (portions of climate space that do not presently occur in the Philippines but may appear with future climate change) by the year 2080 that would affect the distribution of the two species. Climatic variables that change most in the future or are outside of the training range for *I. bartlingii* are annual mean temperature (mostly Northern Luzon particularly in Isabela) or mean diurnal range (mostly in Mindanao) while for *I. auriculata* annual mean temperature is within a novel range in the future.

DISCUSSION

Climatic niche of endemic Philippine *Ixora*

Our results reveal for the first time bioclimatic relationships of endemic Philippine *Ixora*. Temperature and precipitation seasonality were the factors that discriminated species occurrences best. Knowledge of individual species responses to present temperature and rainfall is important especially in attempts to predict plant responses to future climatic change (Austin 1992; Vetaas 2002). Our results suggest that the differentiation of the species is driven by these four bioclimatic factors. However it should be emphasized that these are not necessarily the only and actual environmental factors determining the occurrence of the species as species are furthermore affected by other environmental factors and biotic interactions (Gaston 2003). The bioclimatic preference of *Ixora* species as revealed in our study showed a constant pattern with respect to mean annual temperature and the amount of temperature variation over the year, but exhibited a stronger differentiation regarding the amount of precipitation and precipitation seasonality. The species' preference towards areas with lower amount of annual rainfall and regions with higher annual precipitation variance (standard deviation) may indicate the species' potential to adapt to the changing climate or an adaptation of the species to monsoon seasons in the Philippines. This is of particular importance as it was reported that Philippines will experience a substantial difference in terms of seasonal rainfall change in most parts of the country, and that climate change will probably lead to an active southwest monsoon in Luzon and Visayas. This will be due to future increases in rainfall which is more pronounced in the months of June to August and a reduction in rainfall in most provinces during the summer season making the usually dry season drier, implying likelihood of both droughts and floods (PAGASA 2011). However, the reported patterns in this study only give a first indication about the potential climatic niches of *Ixora* species in the Philippines. Knowledge of the baseline information about climatic variables which plants are adapted is needed to design and understand future experiments and model simulations investigating vulnerability of terrestrial plants to climate change. Furthermore, knowledge of the plants' response to specific environmental conditions such as climatic variables is needed to explain their specialized traits that allow them to occupy and survive in a particular habitat (Körner 1998, 2003). In Rubiaceae, such studies on the ecological requirements of species are scarce and mainly restricted to *Coffea* (Teketay 1999). For *Ixora*, *in-situ* experiments with the ornamental *I. coccinea* from India have revealed that floral initiation was promoted at temperatures between 10 and 20°C and inhibited at 30°C (Chen et al. 2003). Similar experimental approaches using the endemic Philippine species are needed to elucidate the specific requirements of the Philippine endemic *Ixora* species.

Looking at the individual species' response to specific bioclimatic variables, most species showed a substantial niche overlap which may allow the conclusion that at least *Ixora* species may react in a similar way to climate change. This result suggests that although some factors (e.g., range size, habitat and distribution) differ among species, closely related species tend to share similar climatic niches.

Modelling

For modelling studies, it is important to know the crucial role of the areas that have been accessible to the species via dispersal over relevant periods of time (Barve et al. 2011). However the insular nature of the Philippines and its complex geologic history have made it difficult to understand fully the distribution patterns of plants as compared to animals (Brown et al. 2013 and references therein) which have been well studied. The two species of *Ixora* used in the modelling part of this study have a wider distribution and have been recorded in several provinces across the country as compared to other endemic species of *Ixora* which are found in a single province or locality in the Philippines. *Ixora bartlingii* have been collected mainly in Luzon and Visayas and a few records in Mindanao, while *I. auriculata* is mainly distributed in provinces of Luzon and Visayas islands. There is still a need for more evidence to explain the distribution patterns of plants particularly of *Ixora* in the different islands of the Philippines but given that these two species are Philippine endemics and is not found anywhere even in neighboring countries in Southeast Asia, the explorations where made for the whole Philippine archipelago and did not focused on a single island or province. In regard to future potential distributions of the two *Ixora* species, model transfers to future conditions suggest that geographic distributions will shift substantially. The Maxent model performed better than random for the two *Ixora* species endemic in the Philippines, with reasonable

AUC values. Maxent predicted gains in suitable habitat for *I. bartlingii* in Mindanao, particularly in the provinces of Misamis Occidental, Zamboanga del Sur, and Zamboanga del Norte, but loss of habitat in northern Luzon, in the Cordillera Administrative Region (CAR), and Pampanga, Bulacan, and Bataan provinces (Fig. 3). *Ixora auriculata* also showed loss of potential area in northern parts of Luzon, in Cagayan, Isabela, and Nueva Vizcaya provinces (Fig. 3). Models anticipated greater risk of distributional loss for *I. auriculata* than for *I. bartlingii.*

Species projected to experience shrinkage or shift in geographical range under climate change are considered as the most sensitive (Midgley et al. 2003). The loss of suitable areas in Luzon and shift of potential distribution towards the western Visayas and Mindanao for *I. auriculata* and *I. bartlingii* is an indication of their sensitivity to climate change as predicted with Maxent. The loss or shift of suitable habitats for the two species is likely a result of appearance of novel climates by 2080. This finding is supported by recent analyses of climate projections in the Philippines, finding that extreme rainfall is projected to increase in Luzon and Visayas only (PAGASA 2011). The expected decline of suitable areas in Luzon also coincides with Yusuf and Francisco (2009), who reveal that the northern Philippines will show highest vulnerability to climate change owing to exposure to tropical cyclones.

Moreover, our study and that of Garcia et al. (2013) which demonstrated for 14 threatened forest tree species, that species distribution modelling with Maxent provides a strong tool to improve our understanding of climate related range shifts in areas like the Philippines.

Relevance to Conservation

In recent years, scientific knowledge of the Philippine biota has taken great steps forward, however, much remains to be learned, as basic biological information for many species remains incomplete (Posa et al. 2008). These gaps are also evident in this study, as only two of the 30 Philippine endemic *Ixora* species had sufficient known occurrences to permit species distribution modelling. More studies like the present one are required to understand the distributional potential of the species, particularly for rare endemics, to improve information for management plans and assure better outcomes.

Furthermore, conservation practitioners need to know whether and how species will shift their ranges in response to global warming (Pimm 2009). Despite the possible appearance of new suitable habitats for both *I. auriculata* and *I. bartlingii* in the western and southern parts of the Philippines, it is still necessary to establish measures to prevent the loss of the suitable habitats and to conduct future studies to ensure that these suitable habitats in the future can actually be occupied by the species. Aside from identifying these habitats, it is also important to investigate whether the species will be able to disperse to these areas and whether they will be able to successfully compete with other species and overcome other environmental barriers (Soberon 2007; Hirzel and Le Lay 2008; Olalla-Tarraga et al. 2011). The Philippine archipelago consists of several islands and the sea between them poses a potential dispersal barrier for successful population of suitable areas. In general, the dispersal potential of the genus is limited as the fruits of *Ixora* are eaten by frugivorous birds and small mammals, which can only disperse the seeds within the local habitat (De Block 1998). The actual occurrence of the species may deviate from the predicted suitable habitats since the model prediction did not account for landcover changes (e.g. deforestation, agriculture). Furthermore niche saturation could prevent the species from establishing (Davis et al. 2012). Given the limited dispersal abilities of *Ixora* species and the archipelagic nature of the Philippines, assisted migration may become a necessary future conservation strategy for Philippine endemic *Ixora.* However, field surveys and experiments should be conducted in advance to test for any adverse effects of introductions to a given area and to assess its probability of success.

The scope, sequence and effects of climate change cannot be predicted with absolute certainty. Under these conditions, detailed knowledge considering the adaptive capacity of a species such as its ability to disperse to and colonize new habitats (Davis and Shaw 2001; Carvahlo et al. 2010) becomes an essential asset for its conservation as it faces a climate-defined future.

In the same sense it is hoped that the assessments emerging from this study may be useful in future modelling studies and development of conservation strategies particularly for the endemic *Ixora* species in the Philippines. Our models can also assist the design of conservation strategies for the species, as they identify areas predicted to have potential to withstand climate change until at least 2080, representing assessment priorities for *in situ* conservation of the Philippine endemic *Ixora.*

Limitations of the Study

Criticisms of the bioclimatic approach include the fact that many other factors beyond climate play a part in structuring species' distributions, such as plant to plant interactions, pollinator availability, and dispersal ability, and that this approach does not consider plant plasticity (Pearson and Dawson 2003; Heikkinen et al. 2006; Hijmans and Graham 2006;

Oney et al. 2013). Other environmental variables that might be potentially important to *Ixora* like soil type, topography, vegetation type, and anthropogenic factors or other threats to conservation should be included in future modelling studies (Tsisurat et al. 2011; Ndayishimiye et al. 2012). Future efforts in creating these data at a sufficient spatial (and temporal) resolution are of pivotal importance to improve model quality for *Ixora* and other Philippine endemic species.

Owing to the paucity of locality records available for the Philippine endemic *Ixora*, only two species were considered in detail. Data points (especially of the rare species) most likely do not cover the entire niche of the species. This problem calls for a need of better primary documentation of plant distributions in the country. Thus, the resulting distribution maps should not be interpreted as representing the actual limits to the range of the species (Pearson et al. 2007), rather, these models tried to identify regions that have similar environmental conditions where the species could possibly maintain populations with respect to the current and future climate conditions. Despite these limitations, this research can be considered as a first step towards a better understanding of the endemic *Ixora* species in the Philippines.

Finally, the present study did not consider the impact of population density, land use and habitat fragmentation, so in face of a strongly increasing landuse and population in the future, the actual fraction of suitable areas is likely to be substantially lower. The improvement of the data situation, in particular in respect to species occurrence and human landuse changes, are recommended to test the implications from the present study and to draw more general conclusions on the ecology of endemic *Ixora* species on the Philippines.

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References:

Aktar F, Kaiser MA, Kabir ANMH, Hasan CM, Rashid MA (2009) Phytochemical and Biological Investigations of *Ixora arborea* Roxb. Dhaka University Journal of Pharmaceutical Sciences 8:161–166.

Alcala AC, Bucol AA, Diesmos AC, Brown RM (2012) Vulnerability of Philippine amphibians to climate change. Philipp J Sci 141:77–87.

Alejandro GJD (2007) The Current Status of the Philippine Rubiaceae. Philipp J Syst Biol 1:47–60.

Andreasen K, Bremer B (2000) Combined phylogeneteic analysis in the Rubiaceae-Ixoroideae: morphology, nuclear and chloroplast DNA data. Am J Bot 87:1731–1748.

Austin MP (1992) Modelling the environmental niche of plants: implications for plant community response to elevated CO2. Aust J Bot 40:615–630.

Barve N, Barve V, Jimenez-Valverde A, Lira-Noriega A, Maher SP, Peterson AT, Soberon J, Villalobos F (2011) The crucial role of the accessible area in ecological niche modeling and species distribution modeling. Ecol Mod 222:1810–1819.

Brown WC, Alcala AC (1970) The zoogeography of the herpetofauna of the Philippine Islands, a fringing archipelago. Proceedings of the California Academy of Sciences 38:105–130.

Brown RM, Siler CD, Oliveros CH, Esselstyn JA, Diesmos AC, Hosner PA, Linkem CW, Barley AJ, Oaks JR, Sanguila MB, Welton LJ, Blackburn DC, Moyle RG, Peterson AT, Alcala AC (2013) Evolutionary processes of diversification in a model island archipelago. Annu Rev Ecol Evol Syst 44:411–435.

Carvalho SB, Brito JC, Crespo EJ, Possingham HP (2010) From climate change predictions to actions – conserving vulnerable animal groups in hotspots at a regional scale. Global Change Biology 16:3257–3270.

Chen L, Chu C, Huang M (2003) Inflorescence and flower development in Chinese *Ixora*. J Am Soc Hortic Sci 128:23–28.

CIESIN (2013) Available at: http://sedac.ciesin.columbia.edu/data/collection/gpw-v3. Accessed 06 September 2012.

Cox CB, Moore PD (2000) Biogeography an ecological and evolutionary approach, 6th edn, P. 298. Blackwell Science Ltd, Oxford.

Cruz RVO (1997) Adaptation and mitigation measures for climate change: impacts on the forestry sector. In proceedings of the consultation meeting for the international conference on tropical forests and climate change. College, Laguna, Philippines: Environmental Forestry Programme, College of Forestry and Natural Resources, University of the Philippines Los Baños.

Davis AP, Gole TW, Baena S, Moat J (2012) The impact of climate change on indigenous Arabica coffee (*Coffea arabica*): predicting future trends and identifying priorities. PLoS ONE 7 (11): e47981.

Davis AP, Govaerts R, Bridson DM, Ruhsam M, Moat J (2009) A global assessment of distribution, diversity, endemism, and taxonomic effort in the Rubiaceae. Ann Mo Bot Gard 96:68–78.

Davis MB, Shaw RG (2001) Range shifts and adaptive responses to quaternary climate change. Science 292:673–679.

De Block P (1998) The African species of *Ixora* (Rubiaceae - Pavetteae). Opera Bot Belg 9:1–217.

Dormann CF, Elith J, Bacher S, Buchmann C, Carl G, Carré G, Marquéz JRG, Gruber B, Lafourcade B, Leitão PJ, Münkemüller T, McClean C, Osborne PE, Reineking B, Schröder B, Skidmore AK, Zurell D, Lautenbach S (2013) Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography 36:27–46.

Elith J, Kearney M, and Phillips, S (2010) The art of modelling range-shifting species. Methods in Ecology and Evolution 1:330–342.

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE, Yates CJ (2011) A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17:43–57.

Ferranini A (2012) I think different: models of climate warming impact on plant species are unrealistic. Environmental Skeptics and Critics 1:30–33.

Fischer D, Thomas SM, Niemitz F, Reineking B, Beierkuhnlein C (2011) Projection of climatic suitability for *Aedes albopictus* Skuse (Culicidae) in Europe under climate change conditions. Global and Planetary Change 78:54–64.

Fløjgaard C, Normand S, Skov F, Svenning JC (2010) Deconstructing the mammal species richness pattern in Europe- towards an understanding of the relative importance of climate, biogeographic history, habitat heterogeneity and humans. Global Ecol Biogeogr 20:218–230.

Freeman BG, Freeman AM (2014) Rapid upslope shifts in New Guinean birds illustrate strong distributional responses of tropical montane species to global warming. Proc Natl Acad Sci USA 111:4490–4494.

Garcia K, Lasco R, Ines A, Lyon B, Pulhin F (2013) Predicting geographic distribution and habitat suitability due to climate change of selected threatened forest tree species in the Philippines. Appl Geogr 44:12–22.

Gaston KJ (2003) The structure and dynamics of geographic ranges. Oxford University Press, Oxford.

Hanley JA, McNeil BJ (1982) The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiology 143:29–36.

Heaney L, Roberts TE (2009) New Perspectives on the Long–Term Biogeographic Dynamics and Conservation of Philippine Fruit Bats. In: Ecology, Evolution, and Conservation of Island Bats. Fleming TH, Racey P. eds. Chicago, Illinois: University of Chicago Press. p.17–58.

Heikkinen RK, Luoto M, Araujo MB, Virkkala R, Thuiller W, Sykess MT (2006) Methods and uncertainties in bioclimatic envelope modelling under climate change. Prog. Phys. Geog. 30:1–27.

Hernandez PA, Graham CH, Master LL, Albert DL (2006) The effect of sample size and species characteristics on performance of different species distribution modelling methods. Ecography 29:773–785.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. Int J Climatol 25:1965–1978.

Hijmans RJ, Graham CH (2006) The ability of climate envelope models to predict the effect of climate change on species distributions. Glob Change Biol 12:2272–2281.

Hirzel AH, Le Lay G (2008) Habitat suitability modelling and niche theory. J Appl Ecol 45:1372–1381.

Holmgren PK, Holmgren NH, Barnett LC (1990) Index herbariorum. Part 1: the herbaria of the world, 8th edn. Regnum Vegetabile. New York: New York Botanical Garden. 693 p.

Huntley, B (1991) How plants respond to climate change: migration rates, individualism and the consequences for plant communities. Ann Bot 67:15–22.

Inouye H, Takeda Y, Nishimura H, Kanomi A, Okuda T, Puff C (1988) Chemotaxonomic studies of rubiaceous plants containing iridoid glycosides. Phytochemistry 27:2591–598.

IPCC (2001) Climate Change 2001. Impacts, adaptation, and vulnerability. Summary for policymakers. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Körner C (2003) Limitation and stress - always or never? J Veg Sci 14:141–143.

Körner C, Basler D (2010) Phenology Under Global Warming. Science 327:1461–1462.

Lasco R, Pulhin F, Cruz R, Roy S, Sanchez P (2008) Forest responses to changing rainfall in the Philippines. In N. Leary, C. Conde, J. Kulkarni, A. Nyong, J, Pulhin (eds), Climate Change and vulnerability, pp. 49–66. Earthscan, UK and U.S.A.

McLachlan JS, Clark JS, Manos PS (2005) Molecular indicators of tree migration capacity under rapid climate change. Ecology 86:2088–2098.

Merrill ED (1923) An enumeration of Philippine Flowering Plants. Manila Bureau of Printing 2:492–576.

Midgley GF, Hannah L, Millar D, Thuiller W, Booth A (2003) Developing regional and species-level assessments of climate change impacts on biodiversity in the cape floristic region. Biological Conservation 112:87–97.

Miller C, Urban DL (1999) Forest pattern, fire, and climatic change in the Sierra Nevada. Ecosystems 2:76–87

Morueta-Holme N, Fløjgaard C, Svenning JC (2010) Climate Change Risks and Conservation Implications for a Threatened Small-Range Mammal Species. PLoS ONE 5(4): e10360.

Mouly A, Razafimandimbison S, Florence J, Jeremie J, Bremer B (2009a) Paraphyly of *Ixora* and new tribal delimitation of Ixoreae (Rubiaceae): inference from combined chloroplast (*rps16*, *rbc*l, and *trn*T-F) sequence data. Ann Mo Bot Gard 96:146–160.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2012) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Ndayishimiye J, Greve M, Stoffelen P, Bigendako MJ, De Canniere C, Svenning J, Bogaert J (2012) Modelling the spatial distribution of endemic Caesalpinioideae in Central Africa, a contribution to the evaluation of actual protected areas in the region. International Journal of Biodiversity and Conservation 4:118–129.

Ohlemüller R, Anderson BJ, Araújo MB, Butchart SHM, Kudrna O, Ridgely RS, Thomas CD (2008) The coincidence of climatic and species rarity: high risk to small-range species from climate change. Biology Letters 4:568–572.

Olalla-Tarraga MA, McInnes L, Bini LM, Diniz-Filho JAF, Fritz SA, Hawkins BA, Hortal J, Orme CDL, Rahbeks C, Rodriguez MA, Purvis A (2011) Climatic niche conservatisim and the evolutionary dynamics in species range boundaries: global congruence across mammals and amphibians. J Biogeogr 38:2237–2247.

Oney B., B. Reineking, G. O'Neill, and J. Kreyling. 2013. Intraspecific variation buffers projected climate change impacts on *Pinus contorta*. Ecology and Evolution 3:437–449.

Ong PS, Afuang LE, Rosell Ambal RG (eds.) (2002) Philippine Biodiversity Conservation Priorities: A Second Iteration of the National Biodiversity Strategy and Action Plan.

Department of Environment and Natural Resources-Protected Areas and Wildlife Bureau, Conservation International Philippines, Biodiversity Conservation Program-University of the Philippines Center for Integrative and Development Studies, and Foundation for the Philippine Environment, Quezon City, Philippines.

PAGASA (2011) Available at: http://kidlat.pagasa.dost.gov.ph/cab/climate_change/. Accessed 26 November 2012.

PAGASA (2012) Philippine climate information and statistics. Available at: http://kidlat.pagasa.dost.gov.ph/cab/statfram.htm. Accessed 26 November 2012.

Parmesan C, Yohe G (2003) A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37–42.

Parmesan C (2006) Ecological and evolutionary responses to recent climate change. Annu Rev Ecol Evol Syst 37:637–669.

Pearson R, Dawson T (2003) Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful?. Global Ecol Res 12:361–371.

Pearson RG, Raxworthy CJ, Nakamura M, Peterson AT (2007). Predicting species distributions from small numbers of occurence records: a test case using cryptic geckos in Madagascar. J Biogeogr 34:102–117.

Pelser PB, Barcelona JF, Nickrent DL (Ed.). (2011) onwards. Co's Digital Flora of the Philippines. Available at: www.philippineplants.org. Accessed 02 June 2013.

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161–175.

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecol Model 190:231–259.

Pimm SL (2009) Climate disruption and biodiversity. Curr Biol 19:595–601.

Posa MRC, Diesmos AC, Sodhi NS, Brooks TM (2008) Hope for threatened tropical biodiversity: lessons from the Philippines. BioScience 58:231–240.

Prentice IC, Jolly D (2000) Mid-Holocene and glacial-maximum vegetation geography of the northern continents and Africa. J Biogeogr 27:507–519.

R Development Core Team (2012) *R: A language and environment for statistical computing.* Vienna, Austria.

Rajendra K, Nitin G, Mahavir G, Sudhir V, Mangesh K (2013) Evaluation on anti-inflammatory and antioxidant potential of *Ixora coccinea,* Linn ethanolic root extract. International Journal of Drug Development and Research 5:1–10.

Reineking B, Schröder B (2006) Constrain to perform: Regularization of habitat models. Ecol Model 193:675–690.

Root TL, MacMynowski DP, Mastrandrea MD, Schneider SH (2005) Human-modified temperatures induce species changes: joint attribution. Proc Natl Acad Sci USA 102:7465–7469.

Soberón J (2007) Grinellian and Eltonian niches and geographic distributions of species. Ecol Lett 10:1115–1123.

Svenning JC, Skov F (2007). Ice age legacies in the geographical distribution of tree species richness in Europe. Global Ecol Biogeogr 16:234–245.

Teketay D (1999) History, botany and ecological requirements of Coffee. Walia J Ethiopian Wildlife Nat Hist Soc 20:28–50.

Telwala Y, Brook BW, Manish K, Pandit MK (2013) Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. PloS ONE 8: e57103. doi:10.1371/journal.pone.0057103.

Thuiller W, Albert C, Araujo MB, Berry PM, Cabeza M, Guisan A, Hickler T, Midgley GF, Paterson J, Schurr FM, Sykes MT, Zimmermann NE (2008) Predicting global change impacts on plant species distributions: future challenges. Perspect Plant Ecol Evol Syst 9:137–152.

Trisurat Y, Shrestha RP, Kjelgren R (2009) Plant species vulnerability to climate change in Peninsular Thailand. Appl Geogr 31:1106–1114.

Vallejo Jr. B (2011) The Philippines in Wallacea. Biodiversity, Biogeography and Nature Conservation in Wallacea and New Guinea 1:27–42.

van Zonneveld M, Koskela J, Vinceti B, Jarvis A (2009) Impact of climate change on the distribution of tropical pines in Southeast Asia. Unasylva 60:24–28.

Vetaas OR (2002) Realized and potential climate niches: a comparison of four *Rhododendron* tree species. J Biogeogr 29: 545–554.

Wahab F, Subramaniam K, Suriyamoorthy S, Subburaj SP (2012) Phytochemical analysis and antagonistic activity of *Ixora macrothyrsa* on multidrug resistant bacteria. Asian Pacific Journal of Tropical Biomedicine 2:1312–1216.

Walther GR, Post E, Convey P, Menzel A, Parmesan C, Beebee TJC, Fromentin J M, Hoegh-Guldberg O, Bairlein F (2002) Ecological responses to recent climate change. Nature 416:389–395.

Walther G-R, Berger S, Sykes MT (2005) An ecological ‘‘footprint’’ of climate change. Proc Roy. Soc London B 272:1427–1432.

Wen K, Chiu H, Fan P, Chen C, Wu S, Chang J, Chiang H (2011) Antioxidant activity of *Ixora parviflora* in a cell/cell-free system and in UV-exposed human fibroblasts. Molecules 16:5735–5752.

Wisz MS, Hijmans RJ, Li J, Peterson AT, Graham CH, Guisan A (2008) Predicting species distributions working group. Effects of sample size on the performance of species distribution models. Diversity and Distributions 14:763–773.

Woodward FI (1996) Climate and plant distribution. Cambridge University Press, Cambridge.

Yoga Latha L, Darah I, Jain K, Sasidharan S (2012) Pharmacological screening of methanolic extract of *Ixora* species. Asian Pacific Journal of Tropical Biomedicine 2:149–151.

Yusuf AA, Francisco HA (2009) Climate Change Vulnerability Mapping for Southeast Asia. Singapore: Economy and Environment Program for South East Asia, 32p.

PUBLICATION 3

TWO NEW SPECIES OF *IXORA* (IXOROIDEAE, RUBIACEAE) ENDEMIC TO THE PHILIPPINES

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PHYTOTAXA (under Review)

Two new species of *Ixora* (Ixoroideae, Rubiaceae) endemic to the Philippines

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Abstract

Two new species of *Ixora* are described from the provinces of Palawan and Samar, Philippines: *I. alejandroi* and *I. reynaldoi*. The two new species are compared mostly with other species of the genus from the Philippines and neighbouring Asian countries. *Ixora alejandroi* is characterized by its elongated cyme with congested secondary axes, reddish brown corolla, stigmatic lobes shortly cleft in the middle, round at tip; while *I. reynaldoi* is easily recognised by its pseudanthium type of inflorescence with 9–15 flowers, long bracteoles (3.5–8 mm long) and keeled, foliaceous calyx lobes (8–10 mm long). The conservation status of each species is proposed, using IUCN Red List Categories and Criteria.

Introduction

Ixora Linnaeus (1753: 110), is a large pantropical genus of Rubiaceae with more than 500 species worldwide (Mouly *et al.* 2009), growing mostly in humid forests. It is a genus of shrubs and small trees easily recognizable because of its articulate petioles, hermaphroditic flowers, hypocrateriform corollas, two-locular ovaries with a solitary ovule per locule, bilobed stigma, and drupaceous fruits (Mouly *et al.* 2009; De Block 1998). To date, species diversity of *Ixora* in the Philippines remains poorly known and basic information on species distribution and ecology, taxonomic keys and diagnostic illustrations are limited or non-existent. Moreover, the genus and species descriptions of Philipine *Ixora* are inadequate for both the vegetative and reproductive parts which are important in understanding the genus and its species. According to Merrill (1923), the genus is represented in the Philippines by 38 species and 2 varieties (excluding the four cultivated species, *I. coccinea* Linnaeus (1753: 110), type species of the genus, *I. chinensis* Lamarck (1789: 344), *I. finlaysoniana* Wallich &

Don (1834: 572), *Ixora rosea* Wallich in Roxburgh & Carey (1820: 398)). Three species that were described after 1923 were not included in Merrill's list, *I. tenelliflora* Merrill (1926: 423), *I. brachyantha* Merrill (1929: 287) and *I. irosinensis* Elmer (1934: 3251), raising the total number of species to 41. Alejandro (2007) provided an updated list where he recognized 38 species (again excluding *I. coccinea, I. chinensis, I. finlaysoniana* and *I. rosea*), of which 30 were identified as endemic. During the preparation of a taxonomic revision of Philippine *Ixora,* two new species were collected during fieldworks in Palawan and Samar and are here described, illustrated and compared with other species of the genus.

Materials and Methods

Herbarium materials from the following institutions were studied: A, BK, BR, C, CAHUP, K, L, NY, P, PNH, PPC, SAN and US (Thiers 2013). All measurements given herein are taken from dried herbarium specimens. Some features such as shapes were recorded based on alcohol–preserved flowers and fruits, all colours are those reported by collectors for living material or digital photos when possible unless explicitly stated otherwise. Measurements are presented as: length × width, followed by the units of measurement (mm or cm). Conservation status was assessed applying the 2014 IUCN Red List Categories and Criteria version 11.

Taxonomy

Ixora alejandroi Banag & Tandang *sp. nov.* (Fig.1)

Ixora alejandroi differs from other species of the genus by its elongated cyme with congested secondary axes, reddish brown corolla and stigmatic lobes shortly cleft in the middle, round at tip.

Type:—PHILIPPINES. Luzon: Palawan: Mt. St. Paul, Sabang, 10°9'43.9914"N, 118°54'30.9954"E, 400 m, 31 May 2012, *G.J.D. Alejandro, A. Arriola & A. Wong 12439* (Holotype PNH 254886, isotypes USTH, K, US).

Shrub, 0.5–3 m tall; young internodes brown, older internodes grayish brown; all external parts glabrous except the inflorescence axes, pedicels, bracts and bracteoles, hypanthium, calyces and corollas moderately to densely covered with short erect trichomes. Stipules narrowly triangular, 2–3 mm long, awn 6–7 mm long. Leaves with petioles 1.5–2 cm long; blades elliptic to lanceolate, 18.2–27.5 × 4–9.8 cm, coriaceous, drying brown or dark brown above, paler brown below; apex acuminate; base cuneate to round; secondary veins 9–19 on each side. Inflorescences terminal, elongated cyme with congested secondary axes, 3.5–6 × 0.5–1 cm, pendulous, non-articulate throughout, puberulous throughout; leaf-like bracts subtending the inflorescence1(–2) pairs, subsessile, blades narrowly elliptic to lanceolate, 1.5–2 × 0.6–1 cm, base cuneate to round; peduncles 10–18 cm long, reddish brown; central first order axis 1–2 cm long, lateral first order axes ≤ 0.5 cm long; first order bracts with stipular parts absent and the foliar parts narrowly triangular, up to 3 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular to filiform, 1–2 mm long. Ultimate flower triad with pedicellate flowers; pedicels 1.9–2.1 mm long (3.6–5 mm long in fruiting stage), pedicel of the central flower as long as or usually somewhat shorter than the pedicels of the lateral ones, bracteoles present on most pedicels, sub-opposite at the base of the ovary or more often just underneath it on the pedicels, triangular, apices acute, 0.5–1 mm long, reaching the base of the ovary. Hypanthium, calyx and corolla reddish brown, filaments, anthers, style and stigma yellow; flower bud obtuse or round at apex. Calyx tube ca. 0.5 mm long; lobes widely triangular, 1.4–1.8 mm long, their bases not overlapping Corolla tube 10–20 mm long; lobes 4, 4–4.4 × 3–3.5 mm, elliptic, obtuse at apex. Stamens inserted at corolla mouth, filaments 0.5–0.8 mm long; anthers 3–4 mm long. Hypanthium 1.2–2.3 mm long; style exserted 1–2 mm beyond the corolla mouth; stigmatic lobes 1.2–2 mm long, shortly cleft in the middle, round at tip. Fruits subglobose, 4.4–5.9 × 4.6–6.4 mm, green when young, pinkish when ripe, with persistent calyx; fruit wall ca. ≤ 1 mm thick; seeds 2.4–3.5 × 1.5–2.5 mm.

Distribution and Habitat:—*Ixora alejandroi* is endemic in Palawan and thrives in limestone forest, at 400–600 m elevation.

Etymology:—The specific epithet is dedicated to Dr. Grecebio Jonathan D. Alejandro, University of Santo Tomas, Manila, who has made significant contributions to the knowledge of Philippine Rubiaceae.

Phenology:—Flowering specimens were collected in April–May, and September; fruiting specimens were collected in January and May.

Conservation Status:—IUCN Red List Category (2014): Endangered (EN; B2a; B2b (i–v); D). B2: total area of occupancy less than 500 km^2; B2a: less than five locations known; b (i–v): continuing habitat decline inferred; D: less than 250 mature individuals. Tourism is identified as a major threat for the suitable habitat of *I. alejandroi* due to the increasing environmental effects of uncontrolled access of visitors in the mountain and number of tourist activities at the Puerto Princesa Subterranean River National Park, a well-known tourist attraction in Palawan also located in the St. Paul Mountain Range. Other threats to the habitat of *I. alejandroi* include activities such as forest clearing and agriculture of the local inhabitants. The rarity of the species is suspected by the authors based on the number of mature individuals after careful exploration of the area and several field surveys conducted in Palawan.

Discussion:—*Ixora alejandroi* has short, round stigmatic lobes, a rare feature for *Ixora* as most species of the genus has elongate branches recurved at maturity. Short, round stigmatic lobes have been recorded only for two species from India, *I. katchalensis* Husain & Paul (1984: 153) with lobes 2–3 mm long, and *I. brachiata* Roxburgh (1820: 381) with lobes 4–8 mm long (Mouly 2008). *Ixora alejandroi* is most similar to *I. tenelliflora*, a non–endemic species also found in Palawan, because of the pendulous inflorescences with clusters of flowers along the central axis but differing from it by the stigmatic lobes, shortly cleft in the middle and round at tip (vs. stigmatic lobes elongate), the length of the central first order axis 1–2 cm long (vs. 9–12 cm long), lateral order axes ≤ 0.5 cm long (vs. 3–5 cm long) and first order bracts with stipular parts absent (vs. stipular parts fused to an ovate blade with central awn). Florally, *I. tenelliflora* is easily distinguishable from *I. alejandroi* by its white corolla, much longer corolla tube and long, narrowly elliptic corolla lobes.

Additional specimens examined (paratypes):—PHILIPPINES. Luzon: Palawan: Mt. Cleopatra's Needle, Puerto Princesa, 20 January 1998, *G.C.G Argent, Q. Cronk, M. Mendum, D.J. Middleton, P. Wilkie, R. Fuentes & R.V. Chavez 5387* (K, L, SAN) & *25396* (L); Mt. St. Paul, Sabang, May 2012, *D. Tandang MH1707* (PNH).

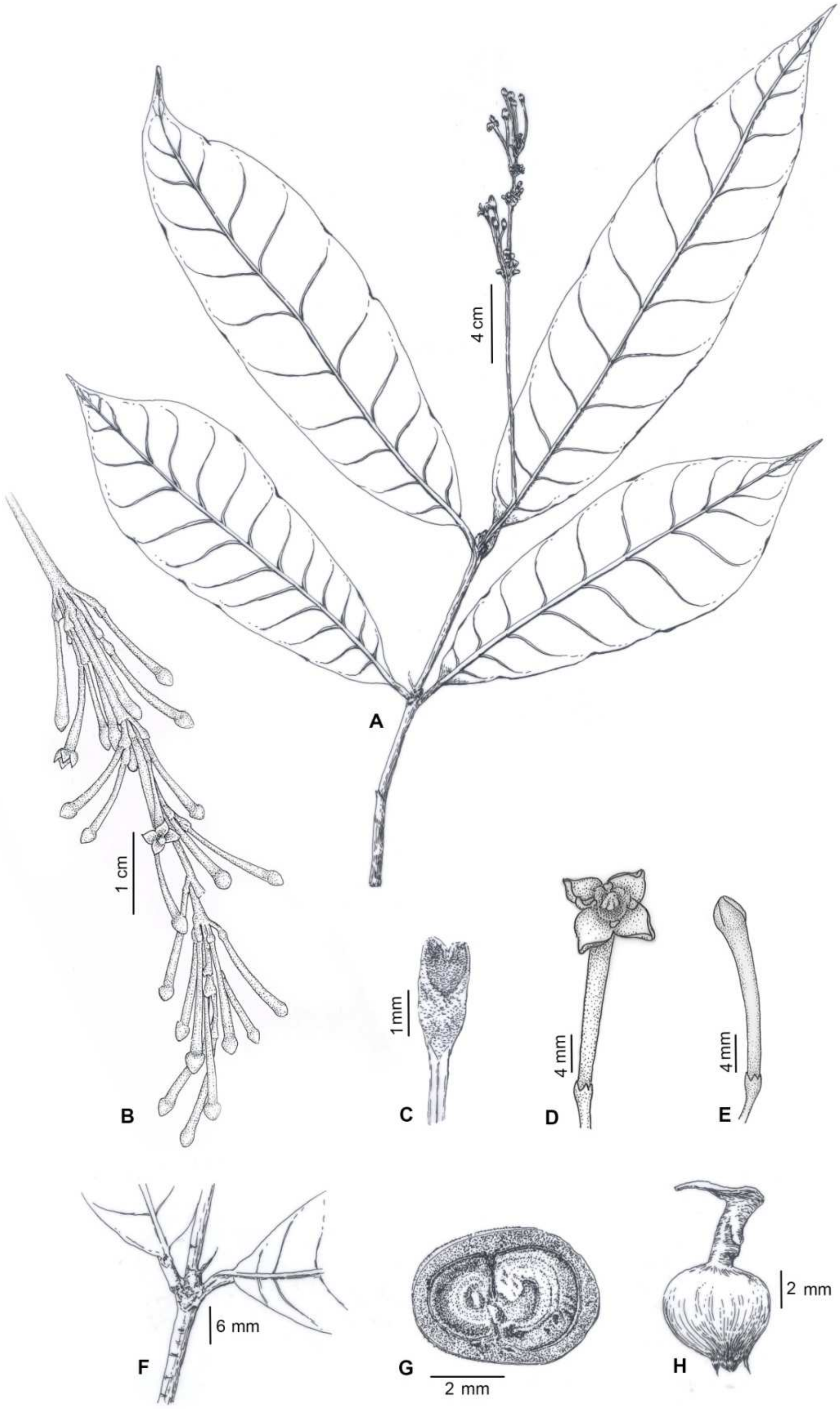

FIGURE 1. *Ixora alejandroi*. **A.** Flowering branch. **B.** Inflorescence. **C.** Stigma. **D.** Open flower. **E.** Flower bud. **F.** Stipules. **G.** Cross section of fruit. **H.** Dried fruit. Drawn from *G.J.D. Alejandro, A. Arriola & A. Wong 12439* (A, F–H) and *D. Tandang MH1707* (B–E) by Arianne Zacarias (A, C, F–H) and Nemesio B. Diego, Jr. (B, D–E).

Ixora reynaldoi Banag *sp. nov.* (Fig. 2)

Ixora reynaldoi differs from the other species of the genus by its pseudanthium type of inflorescence, with 9–15 flowers, long bracteoles (3.5–8 mm long) and keeled, foliaceous calyx lobes (8–10 mm long).

Type:—PHILIPPINES. Visayas: Eastern Samar: Maydolong, Borongan, 11°26'0.0888"N, 125°23'0.3336"E, 200 m, 28 August 2011, *C. Banag, C. Cremen & N. Pinarok SA004* (Holotype PNH 254887, isotypes USTH, K, US).

Shrub, 1–2 m tall; young internodes brown, older internodes grayish to brown; all external parts glabrous. Stipule sheath subtruncate, 1–2 mm long, awn 4–6 mm long. Leaves with petioles 0.5–1 mm long, canaliculate; blades elliptic to obovate, 8–15 × 1–3 cm, coriaceous, drying olivaceous above, paler below; apex narrowly acute to acuminate; base acute to round; secondary veins 10–15 pairs on each side. Inflorescences terminal, sessile, pseudanthium type, consisting of 9–15 flowers; glabrous throughout; leaf-like bracts subtending the inflorescence absent; bracts triangular, 5–6 mm long, apices narrowly acute. Hypanthium and calyx red, corolla white, filaments, anthers, style and stigma cream-colored; flower buds acute at apex; bracteoles linear or narrowly triangular, keeled, 3.5–8 mm long, reaching half of the calyx lobes. Calyx tube 2–5 mm long; lobes foliaceous, triangular to narrowly triangular, keeled, 8–10 mm long, their bases overlapping. Corolla tube 20–22.5 mm long; lobes 4, 5.5–6.5 × 2–3.5 mm, elliptic to ovate, acuminate at apex. Stamens inserted at corolla mouth, filaments 0.5–1 mm long; anthers 5–7 mm long. Hypanthium 1.2–2.3 mm long; style exserted 2–2.4 mm beyond the corolla mouth, stigmatic lobes 1.5–2.5 mm long. Fruits unknown.

Distribution and Habitat:—*Ixora reynaldoi* is endemic in Eastern Samar and thrives in secondary forests, at 200–400 m elevation.

Etymology:—The specific epithet is dedicated to Reynaldo J. Banag, the late father of the first author of this paper.

Phenology:—Flowering specimens were collected in May.

Conservation Status:—IUCN Red List Category (2014): Critically Endangered (CR; B2a; B2b (i–v); D). B2: total area of occupancy less than 10 km^2; B2a: a single location known; b (i–v): continuing habitat decline inferred; D: less than 50 mature individuals. The suitable habitat for *I. reynaldoi* on Maydolong, Eastern Samar is indicated as an endangered environment, threatened by human activity (deforestation, agricultural expansion), reducing the extent of the forest, and the geographic location of Eastern Samar being one of the provinces in the Philippines frequently hit by typhoons. The rarity of the species is suspected by the authors based on the low number of mature individuals found after careful exploration of the area and several field surveys conducted in Samar.

Discussion:—The Philippine species of *Ixora* have small calyces. Only *I. reynaldoi* has calyx lobes 8–10 mm long, whereas the other species have calyx lobes 2–3.5 mm long. Calyces less than 2 mm long are also rare and occur in e.g. *I. philippinensis* Merrill (1910: 238) (0.8–1.5 mm long). Although the long bracteoles and calyx lobes observed in *I. reynaldoi* are rare features in Philippine *Ixora*; however, they are known to occur in some non-Philippine representatives, e.g. *I. amplexicaulis* Gillespie (1930: 30) from Fiji (bracteoles ca. 9 mm long, calyx lobes narrowly triangular, 7–8 mm long) and *I. homolleae* De Block (2014: 122) from Madagascar (bracteoles 8–10 mm long, calyx lobes 5–12 mm long). *Ixora reynaldoi* differs from *I. amplexicaulis* by having 9–15 flowers per inflorescence (vs. more than 30 flowers per inflorescence) and bracteoles reaching half of the calyx lobes (vs. bracteoles exceeding the calyx lobes). Furthermore, *I. reynaldoi* differs from *I. homolleae* by its 2-locular ovaries (vs. 4-locular ovaries).

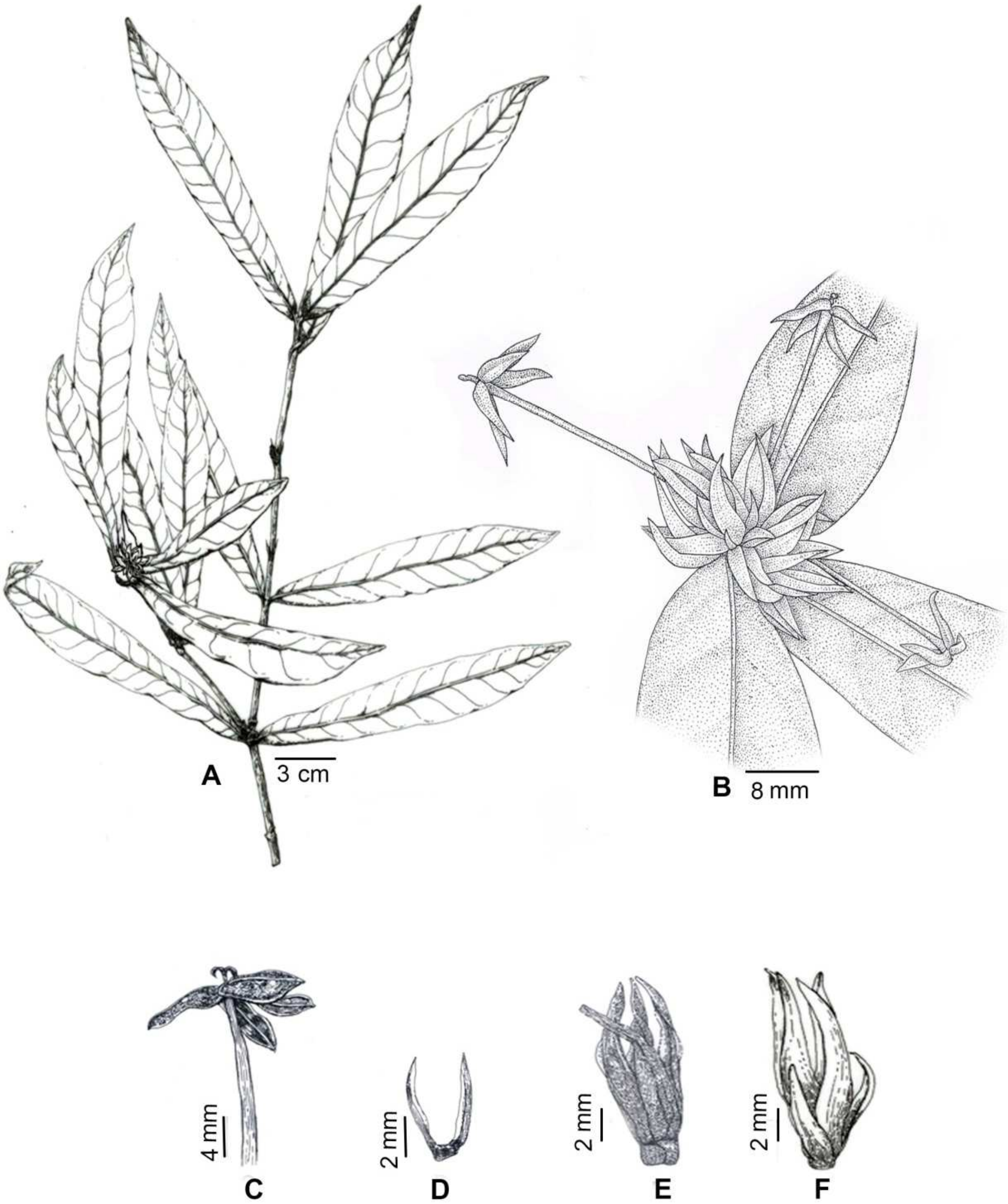

FIGURE 2. *Ixora reynaldoi*. **A.** Flowering branch. **B.** Inflorescence. **C.** Open flower. **D.** Bracteoles. **E.** Calyx. **F.** Calyx with bracteoles attached. Drawn from *C. Banag, C. Cremen & N. Pinarok SA004* by Arianne Zacarias (A, C–F) and Nemesio B. Diego, Jr. (B).

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References

Alejandro, G.J.D. (2007) The current status of the Philippine Rubiaceae. *Philippine Journal of Systematic Biology* 1: 47–60.

De Block, P. (1998) The African species of *Ixora* (Rubiaceae–Pavetteae). *Opera Botanica Belgica* 9: 1–217.

De Block, P. (2014) A synopsis of the multilocular species of *Ixora* (Rubiaceae) from Madagascar. *Phytotaxa* 162: 121–133.

Elmer, A.D. (1934) New Urticaceae and Rubiaceae. *Leaflets of Philippine Botany* 9: 3251–3252.

Gillespie, J.W. (1930). *Ixora. New plants from Fiji.* Bernice Pauahi Bishop Museum, Honolulu, p. 30.

Husain, T. & Paul, S.R. (1984) A new species of *Ixora* (Rubiaceae) from the Andaman & Nicobar Islands. *Blumea* 30: 153–156.

IUCN (2014) *Guidelines for using the IUCN Red List Categories and Criteria*, Version 11. IUCN Red List Unit, Cambridge, U.K. Available from: http://www.iucnredlist.org/documents/RedListGuidelines.pdf (accessed: 05 September 2014).

Lamarck J.-B. de (1792) *Tableau encyclopédique et méthodique des trois règnes de la nature. Botanique,* tome 1. Panckoucke, Paris, iii–xvi, p. 496.

Linnaeus, C. (1753) *Ixora*. *Species Plantarum*. Impensis Laurentii Salvii, Stockholm, p. 560.

Merrill, E.D. (1910) *Ixora.* New and noteworthy Philippine plants. *Philippine Journal of Science* 5: 233–240.

Merrill, E.D. (1923) *Ixora*. *An enumeration of Philippine flowering plants*, vol. 2. Manila Bureau of Printing, Manila, p. 492.

Merrill, E.D. (1926) *Ixora.* The Flora of Banguey Island. *Philippine Journal of Science* 29: 423.

Merrill, E.D. (1929) *Ixora. Plantae Elmerianae Borneenses*. University of California Press, Berkeley, p. 287.

Mouly, A. (2008) Systématique de la tribu des Ixoreae A. Gray (Rubiaceae): phylogénie, biogéographie et taxinomie. *Acta Botanica Gallica* 155: 457–464.

Mouly, A, Razafimandimbison, S., Florence, J., Jérémie, J. & Bremer, B. (2009) Paraphyly of *Ixora* and new tribal delimitation of Ixoreae (Rubiaceae): inference from combined chloroplast (*rps16*, *rbcL*, and *trnT-F*) sequence data. *Annals of Missouri Botanical Garden* 96: 146–160.

Roxburgh, W. (1820) *Ixora brachiata.* In Roxburgh, W. & Carey, W. (eds.), *Flora Indica or Descriptions of Indian Plants,* vol. 1. Mission Press, Serampore, p. 381.

Thiers, B. (2013) *Index Herbariorum: A global directory of public herbaria and associated staff.* New York Botanical Garden Virtual Herbarium. Available from http://sweetgum.nybg.org/ih/ (Accessed 8 September 2014).

Wallich, N. (1820) *Ixora rosea.* In: Roxburgh, W. & Carey, W. (eds.), *Flora Indica or Descriptions of Indian Plants,* vol. 1. Mission Press, Serampore, p. 398.

Wallich, N. & Don, G. (1834) *A General History of the Dichlamydeous Plants*, vol. 3. J.G. and F. Rivington, London, p. 572.

PUBLICATION 4

THE PHILIPPINE SPECIES OF *IXORA* (RUBIACEAE)

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PHYTOTAXA (in preparation)

THE PHILIPPINE SPECIES OF *IXORA* (RUBIACEAE)

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Abstract

The genus *Ixora,* is a pantropical genus of shrubs and small trees with approximately 530 species. A revision of the Philippine species of *Ixora* was done following the methods of classical herbarium taxonomy. A total of 31 species are recognized. A detailed morphological, anatomical and biological documentation of Philippine species of *Ixora* is given. All species are extensively described, native species illustrated and a taxonomic key to native and cultivated species are provided, 27 taxa are lectotypified and three species are neotypified. Distribution maps with full citations of all specimens seen are supplied for each taxon.

Keywords: Ixoreae, lectotypification, nomenclature, Philippines, taxonomy

Introduction

Ixora Linneaus (1753: 110) is one of the largest genera of the Rubiaceae with approximately 530 species (Davis *et al.* 2009). This pantropical genus of shrubs and small trees is poorly known taxonomically as no worldwide monograph exists (De Block 2014b). However there have been a number of flora treatments and revisions focusing on specific geographical regions, e.g. in Africa (De Block 1998), Madagascar (De Block 2014a,b), Marquesas Islands (Lorence *et al.* 2007) and Australia (Reynolds & Forster 2006). Recently, a detailed molecular study on *Ixora* by Mouly *et al.* (2009), placed *Captaincookia* Hallé (1973: 197), *Doricera* Verdcourt (1983: 37), *Hitoa* Nadeaud (1899: 2), *Myonima* Commerson ex Jussieu (1789: 206), *Thouarsiora* Homolle ex Arènes (1960: 19) and *Versteegia* Valeton (1911: 483) into synonymy of *Ixora,* resulting in a boader circumscription of the genus.

Ixora is one of the most easily recognizable genera in Rubiaceae, diagnostic features for the genus (adapted from De Block 2014b) include: petioles articulate, inflorescences terminal;

inflorescence branching trichotomous; flowers narrowly tubular, 4-merous; aestivation contorted; stigma with 2, 3, or 4 lobes; ovary bi-, tri- or tetralocular with a single ovule per locule; fruits drupaceous; seeds with a large adaxial excavation. However identification is much more difficult at the species level, with the species distinguished on the basis of minor and often continuous characters, usually involving features of the inflorescences and flowers, e.g. corolla tube/lobe ratio and pubescence of the inflorescence (Tosh *et al.* 2013, De Block 1998).

Although pantropical, the distribution of *Ixora* is centered in Asia with the highest species numbers recorded in Southeast Asia (De Block 1998) with approximately 280 or up to 300 species (Mouly 2008). According to Merrill (1923), the genus is represented in the Philippines by 38 species and 2 varieties (excluding the four cultivated species, *I. coccinea* Linnaeus (1753: 110), type species of the genus, *I. chinensis* Lamarck (1789: 344), *I. finlaysoniana* Wallich & Don (1834: 572), *Ixora rosea* Wallich (1820: 398)). Three species which were described after 1923, were not included in Merrill's list, *I. tenelliflora* Merrill (1926: 423), *I. brachyantha* Merrill (1929: 287) and *I. irosinensis* Elmer (1934: 3251) raising the total number of species to 41. Alejandro (2007) provided an update listing 38 species (again excluding *I. coccinea, I. chinensis, I. finlaysoniana, I. rosea*), of which 30 were identified as endemic. However, Alejandro (2007) failed to include *I. brachyantha*, *I. irosinensis* and *I. tenelliflora* in his updated list of Philippine *Ixora*.

The taxonomic history of Philippine *Ixora* began in 1830 when De Candolle described *I. macrophylla* De Candolle (1830: 487) based on collections made by Haenke in Manila. In 1837 Blanco described a species he called *I. arborea* Blanco (1837: 61), which was later transferred by Fernandez-Villar (Naves & Fernandez-Villar, 1883) to *I. stricta* Roxburgh (1814: 10). But Merrill (1918) later regarded *I. arborea* as a synonym of *I. macrophylla*, stating that Blanco's description is in entire agreement with *I. macrophylla* and does not agree with Roxburgh's species. Another taxon named by Blanco in 1845, *Taligalea umbellata* Blanco (1845: 337) was later identified by Fernandez-Villar (Naves & Fernandez-Villar,1883) as a species of *Ixora*, and treated *T. umbellata* as a synonym of *I. macrophylla.* Later, Merrill (1918) transferred *T. umbellata* as a synonym to *I. cumingiana* Vidal (1885: 183), arguing that Blanco described *I. macrophylla* under the name of *I. arborea.* It was only during the arrival of A.D.E. Elmer in the Philippines in 1904 when intensive work on Philippine *Ixora* begun. From 1906 to 1934, Elmer published a total of 13 species of Philippine *Ixora* in the Leaflets of Philippine Botany, a publication which Elmer published serially for many years and whose purpose was to serve as a vehicle to describe new species based almost entirely upon his collections.

Another American botanist, E.D. Merrill, along with Elmer, stands apart from other botanists in his contributions to Philippine botany (Sohmer & Davis 2007). Merrill published nine articles in the Philippine Journal of Science (Merrill 1910, 1913, 1915, 1917a,b, 1921a,b 1922, 1926) in which 22 new species of Philippine *Ixora* were described. Towards the end of Merrill's tenure in the Philippines, he published three volumes of his work entitled "An Enumeration of Philippine Flowering Plants". In this publication, he listed the then known species of *Ixora* (Merrill 1923), including synonyms. Robinson, a Canadian botanist, added two new species of *Ixora* in 1911 which was published in the Philippine Journal of Science.

To date, species diversity of *Ixora* in the Philippines remains poorly known and basic information on species distribution and ecology, taxonomic keys and diagnostic illustrations are limited. In this work, we fill in a gap in our knowledge of the genus by presenting a taxonomic revision of Philippine *Ixora* in which a total of 31 species are recognized. All species are extensively described, native species illustrated and taxonomic key to native and cultivated species are provided, 27 taxa are lectotypified and three species are neotypified. Distribution maps with full citations of all specimens seen are supplied for each taxon.

Materials and Methods:

The revision was based mainly on the analysis of herbarium specimens deposited in the following herbaria: A, BK, BR, C, CAHUP, K, L, NY, P, PNH, PPC, SAN and US (Thiers 2013). This information was supplemented by fieldwork (C.I. Banag) and by literature review. All herbarium label data were stored in an electronic database using Microsoft Office Access 2007. For species descriptions and keys, all measurements were taken from dried herbarium specimens. Some features such as shapes were documented based on alcohol-preserved flowers and fruits, all colours are those reported by collectors for living material or digital photos when possible unless explicitly stated otherwise. In the description, inflorescence size does not include the corollas, fruit shape and size does not include the persistent calyx and the peduncle was measured from the lowermost pair of the inflorescence-supporting leaves to the inflorescence base. Measurements were presented in the following descriptions: length x width, followed by the units of measurement (mm or cm). Specimens are cited per province, alphabetically by collector. All species cited in this paper were seen from herbarium specimens or in their natural habitat by the authors. Comparisons with other representatives of the genus were made whenever appropriate. Coordinates were georeferenced using World Gazetteer (http://worldgazetteer.com) and Geonames (http://www.geonames.org/export/web-services.html). All coordinates were carefully checked for plausibility and/or error-corrected using Google Earth (version 7; Google 2013). Distribution maps were drawn using DIVA-GIS 7.5. Photos were taken by the authors during fieldworks in the Philippines or downloaded from the www.philippineplants.org website (Pelser *et al.* 2011) with written permission from the administrators of the website and or owner of the photos.

MORPHOLOGY AND TAXONOMIC CHARACTERISTICS OF PHILIPPINE *IXORA*

A detailed overview of the morphological characters of Philippine *Ixora* species is presented and their taxonomic significance is discussed. Representatives of other non-Philippine *Ixora* species are also discussed for comparison whenever appropriate.

1. Vegetative Structures

1.1. Habit

A shrubby habit is most common in the Philippine *Ixora*. Most species are described as small to medium-sized or even large shrubs, with height varying from 1m to 5m (*e.g. I. angustilimba* Merrill (1921a:320) 1–5 m; *I. leucocarpa* Elmer (1912: 1337) 1–3 m; *I. magnifica* Elmer (1913: 1865) 1–4 m). In eleven species, however, arborescent habit also occurs next to the often more common shrubby habit. These eleven species include the two non-endemic species (*I. intermedia* Elmer (1912: 1336) 2.5–15 m; *I. tenelliflora* 2–8 m) in which the tree habit is predominant. *Ixora macrophylla* and *I. mindanaensis* Merrill (1910: 237) represent the largest among the endemic Philippine species of *Ixora* reaching up to 15 m in height.

1.2. Stems

The stems are cylindrical and at least somewhat corky (De Block 1998). They are often very lignified, sometimes sarmentose. Young stems usually have rectangular stem sections and ortogonous decussate terminal branchlets, as usually observed in members of the family Rubiaceae (Mouly 2008). Young shoots are often glabrous, but pubescent shoots occur in a few species (*e.g. I. narcissodora* Schumann (1903: 356) in Africa and *I. jourdanii* Mouly &

Florence (2007: 583) in Marquesas Islands). Among the Philippine representatives puberulent young twigs are observed only in *I. leytensis* Elmer (1906: 69).

1.3. Leaves

The leaf arrangement is usually opposite and decussate. Some rare species have been reported possessing ternate or verticillate per four leaves (e.g. *I. sivarajiana* Pradeep (1997: 315) in India; *I. peculiaris* De Block (2007: 81) in Africa; *I peruviana* Standley (1931: 296) in South America). Throughout *Ixora,* the petioles are distinctly articulate in contrast to the members of its sister-clade Aleisanthieae, where the transition between the stem and the petiole is continuous. Consequently, this is a very important distinguishing character for the genus. Articulate petioles are also reported in other Ixoroideae genera, e.g. *Octotropis* Beddome (1873: 327), *Hypobathrum* Blume (1827: 1007), *Scyphiphora* Gaertner (1806: 91) and *Pouchetia* A. Rich. in de Candolle (1830: 251) (Mouly 2008). All Philippine species are petiolate except for *I. auriculata* Elmer (1911: 1018), *I. inaequifolia* Robinson (1911: 222) and *I. philippinensis* Merrill (1910: 238), which possess sessile, cordate, stem-clasping leaves. The petioles vary in length between 0.2 to 2 cm. When the base is rounded or cordate generally the leaf is sessile or subsessile.

Among the Philippine *Ixora* the leaf blades vary from 4 to 40 cm in length and 0.5 to 18 cm in width. The shape of the blades varies greatly across the genus. Blades are usually elliptic to obovate, or more rarely ovate. Elliptic to oblong-lanceolate blades are by far the most common in Philippine *Ixora.* The divergent *I. salicifolia* De Candolle (1830: 487) has linear leaves, up to 40 cm long and 3.5–5.5 cm wide. The apex is usually acuminate, although acute (*I. bartlingii* Elmer (1911: 1020)), rounded or obtuse (*I. gigantifolia* Elmer (1913: 1864), *I. magnifica*) and retuse (*I. crassifolia* Merrill (1910: 233)) apices are found in some species. The shapes of the leaf-blade bases vary from acute (e.g. *I. angustilimba*), rounded (e.g. *I. macgregorii* Robinson (1911: 223)), cordate (e.g. *I. auriculata, I. philippinensis*) and cuneate (e.g. *I. bibracteata* Elmer (1906: 8), *I. leucocarpa*). The leaf margin is slightly thickened, somewhat revolute and entire. The midrib is very prominent underneath, while hardly protruding and often impressed or canaliculate at its base above. The secondary nerves usually consist of 8 to 20 pairs and are easily distinguishable underneath. Intersecondaries are reticulate but often (in coriaceous leaves) visible with difficulty.

The blade is membranaceous, chartaceous or coriaceous in texture. Only *I. crassifolia* possesses very thickly coriaceous leaves. In *I. auriculata,* leaf texture varies from chartaceous to rigidly coriaceous while leaf texture of *I. macgregorii* varies from membranaceous to chartaceous.

The leaves are always glabrous on both sides except for the leaves of *I. leytensis* Elmer (1906: 69) which may be pubescent underneath along the midnerve and the secondary veins. Non-Philippine representatives may possess pubescent leaf blades underneath in the midnerve and secondary veins (e.g. African *I. longipedunculata* De Wildeman (1907: 177), Indian *I. brunnescens* Kurz (1872: 317)) or over the whole surface (e.g. African *I. narcissodora*).

1.4. Stipules

The stipules (Fig. 1) are interpetiolar and consist of truncate (*I. angustilimba*; Fig. 1A), triangular (*I. capitulifera* Merrill (1910: 233); Fig. 1B) or broadly ovate (*I. crassifolia*; Fig. 1C) sheath, topped by a narrow, rarely bifid awn. The limbs are joined at the base and form an amplexicaul cone and are usually free on the upper parts. The size of the stipules is very variable and depends according to their position and varies strongly according to the thickness of the nodes which they envelope (Husain & Paul 1989; De Block 1998; Mouly 2008). The sheaths vary between 0.5 to 2 or rarely up to 7 mm (*I. crassifolia*) in height, the awns between 0.5 to 5 or rarely up to 9 mm (*I. auriculata*) in length. The stipules are usually persistent although in some species, e.g. *I. bibracteata, I. capitulifera, I. gigantifolia,* they are shed very early.

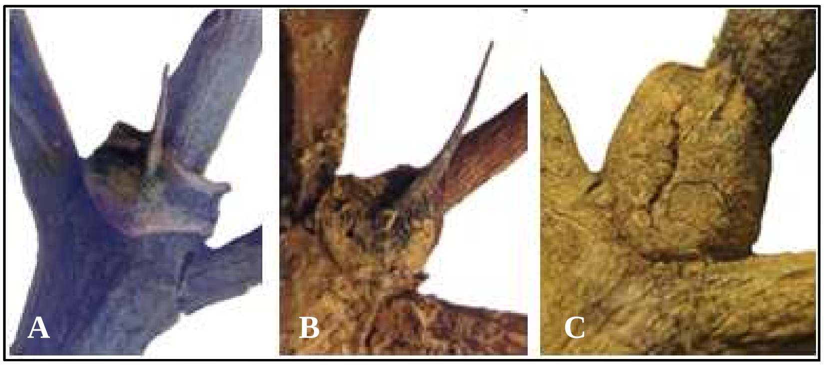

FIGURE 1. Stipule sheath. A–truncate; B–triangular; C–ovate. A–***I. angustilimba;*** B–***I. capitulifera***; C–***I. crassifolia***.

1.5. Colleters

Colleters (Fig. 2A–C) are an epidermal secretory structure that can be found mainly on the adaxial side of the stipules and or calyces (Thomas 1991), either covering only the base (forming a ring) or the entire side (De Block 1998). Most of the functional aspects of these secretory structures are unknown (Klein *et al.* 2004). However, several authors have reported that most species exsudate wax from colleters as a protection of young branches, leaves and inflorescences (Williams *et al.* 1982; Thomas & Dave 1990). According to Dave & Thomas (1991), colleters develop from a group of epidermal and hypodermal initials. They usually possess a central core of parenchymatic cells several cell-layers thick, ensheathed by a layer of epithelial cells covered by a cuticle. Colleters are present in *Ixora* as nearly generally in Rubiaceae (Robbrecht 1988) their absence is restricted to just a few species that are spread over the tribes (Lersten 1975). Four types of colleters in the Rubiaceae were described by Horner & Lersten (1968) and Lersten (1947a,b) based on the appearance of their epidermis: "standard", "reduced", "brush-like" and "dendroid". The most common type observed in Rubiaceae including *Ixora* is the "standard type" (Robbrecht 1988). Standard type colleters (Fig. 2B) consist of a central core of thin-walled, longitudinally elongated parenchymatic cells, ensheathed by radially elongated epithelial cells, covered with a thin cuticle. Dave & Thomas (1991) reported a length of 320 µm for the standard colleters of *I. coccinea.* In Philippine *Ixora,* colleters are often observed on the adaxial side of the stipules and calyx tube forming basal rings (Fig. 2A) or sparsely or densely covering the inner side.

FIGURE 2. Colleters. A–forming basal rings at the adaxial side of the calyx tubes, (10x); B–occuring at the adaxial side of the stipules (25x) C–standard type colleters (40x). A & C–***I. salicifolia***, B–***I. cumingiana***.

2. Reproductive Structures

2.1. Inflorescences

The inflorescences in *Ixora* are always terminal (De Block 1998) carried by main or secondary branches, sometimes made of successive short internodes (e.g. *I. macilenta* De Block (1998: 126) in Africa). In some South American, Indonesian, New Guinean and several Fijian species, the inflorescences may be borne on short, defoliate lateral branchlets arising from the trunk or from branches situated well below the foliage, e,g. *I. asme* Guillamin (1937: 290) in Vanuatu (Smith & Darwin 1988). Cauliflory is known from New Caledonian *I. cauliflora* Montrouzier & Baker (1921: 333) and *I. margaretae* Hallé in Mouly & Bremer (2009: 702), New Guinean *I. valetoniana* Mouly & Bremer (2009: 702) but is exhibited in the Philippines only by *I. macrophylla*.

The inflorescences may vary greatly in size. In the Philippines, the largest ones are found in *I. salicifolia* up to 15 cm high and 20 cm wide. The inflorescences can be uniflorous (*I. angustilimba*), pauciflorous (*I. philippinensis*) or multiflorous (*I. chartacea* Elmer (1913: 1861) and *I. alejandroi* Banag & Tandang (submitted)). In *I. filipes* Valeton (1913: 359), the inflorescence is reduced to a single pendulous flower (but sometimes 3–flowered), the inflorescence consisting of a ca. 10 cm long axis including the 3 cm long corolla. For non-Philippine *Ixora* usually the inflorescences consist of many (more than 100) flowers (e.g. Asian *I. macrothyrsa* (Teijsm. & Binn.) Brown (1883: 472)) or sometimes up to 300 to 350 flowers (e.g. African *I. platythyrsa* Baker (1890: 320)).

The axes of the inflorescence are usually reddish (e.g. *I. bartlingii*) or green (e.g. *I. cumingiana*). The inflorescences may be sessile or pedunculate. The length of the peduncle is very variable and may reach 15 to 19 cm (*I. auriculata*). Sessile and pedunculate inflorescences with relatively short peduncles up to ± 10 cm are erect (e.g. *I. ebracteolata* Merrill (1910: 234) and *I. macgregorii*). Long pedunculate inflorescences are drooping (e.g. *I. alejandroi* and *I. cumingiana*) or pendulous (e.g. *I. auriculata* and *I. longistipula* Merrill (1910: 236)). A very unusual multi-branched inflorescence is known from some Philippine representatives like *I. crassifolia*, *I. gigantifolia* and *I. intermedia* wherein the first order axis is tri-dimensional. Another strange and rare pattern of distribution of flowers with congested secondary axes along the primary axis is observed in *I. alejandroi*.

Fundamental differences that exist between pedunculate and sessile inflorescences is the absence and presence, shape and size of the inflorescence-supporting leaves and the structure of the first order bracts. The inflorescence-supporting leaves are much smaller than the vegetative ones and also differ in shape (*e.g. I. chartacea* and *I. bartlingii*). They can be either (sub)sessile, or elliptic to ovate with rounded to cordate bases. Also there are instances that the inflorescence-supporting leaves are similar to and as large as the vegetative ones (De Block 1998).

The organisation of branchlets within the inflorescences, which was mainly used by Bremekamp (1937) in subgeneric recognition, is more variable than usually considered. The peduncles may be articulate or non-articulate, opposite or sub-opposite and bracteolate or ebracteolate. The distribution of these characters is very variable between axis orders within an inflorescence. Many species of *Ixora* have fully opposite and articulate peduncles e.g. *I. coccinea*, all African (De Block 1998), Mascarene and most of the Malagasy species (Mouly 2008).

According to Bremekamp (1937), there are three inflorescence types that occur in the genus as a whole: type 1) articulate and opposite branching throughout the inflorescence, with bracts usually present and situated at the base of the branches, bracts and bracteoles subtending the flowers only rarely reduced or absent; type 2) articulate and opposite branching restricted to the lower part of the inflorescence (first and second order axes); higher order bracts shifting position and occuring anywhere in the axis and type 3) articulate and opposite branching absent altogether, with bracts and bracteoles shifting position and occuring anywhere along the axes and often reduced or absent. As compared with the African *Ixora* species that only have inflorescences of the first type (De Block 1998), Philippine *Ixora* species exhibit all three types which can be regarded as an important character for distinction at the species level.

For Philippine representatives, the inflorescence axes are either opposite and articulate throughout (e.g. *I. auriculata, I. bartlingii, I. magnifica*) or non-articulate throughout (e.g. *I. capitulifera, I. ebractelota, I. leucocarpa*). Among the Philippine species, only *I. crassifolia* and *I. mindanaensis* have inflorescences of type 2 with articulate and opposite branching restricted to the lower part of the inflorescence. According to Mouly (2008) some Asian and Malesian species was observed to have basal inflorescence branches consisting of opposite and articulate peduncles, but non-articulate and subopposite in higher orders or sometimes the last orders, e.g. *I. cordata* Merrill & Perry (1945: 257) and *I. pavetta* Andrews (1799: 78). In pedunculate species, the first order bracts are anvil-like consisting mainly of triangular and vaulted foliar parts and sometimes of short triangular, ovate or rounded stipular parts. In most *Ixora* species, as also the case with Philippine species, higher order bracts are present (but often absent in inflorescences of type 3). They consist of (narrowly) triangular, sometimes vaulted foliar parts with the sipular parts usually absent. In the most distal part of the inflorescence, bracts are sometimes fimbriate or filiform. The higher order bracts are always opposite for species having the type 1 inflorescences.

Another character of major importance for recognition at the specific level for the Philippine *Ixora* is the structure of the terminal or ultimate flower triad (Fig. 3). Flowers in a triad maybe (sub)sessile (e.g. *I. intermedia*; Fig. 3A), shortly (e.g. *I. macrophylla*; Fig. 3B) or longly pedicellate (e.g. *I. bartlingii*; Fig. 3C). The pedicels of the central flower in a triad can be as long as the pedicels of the lateral ones (e.g. *I. bartlingii*; Fig. 3C), (sub)sessile (e.g. *I. cumingiana*; Fig. 3D) or shorter than the pedicels of the lateral ones (e.g. *I. auriculata*; Fig. 3E).

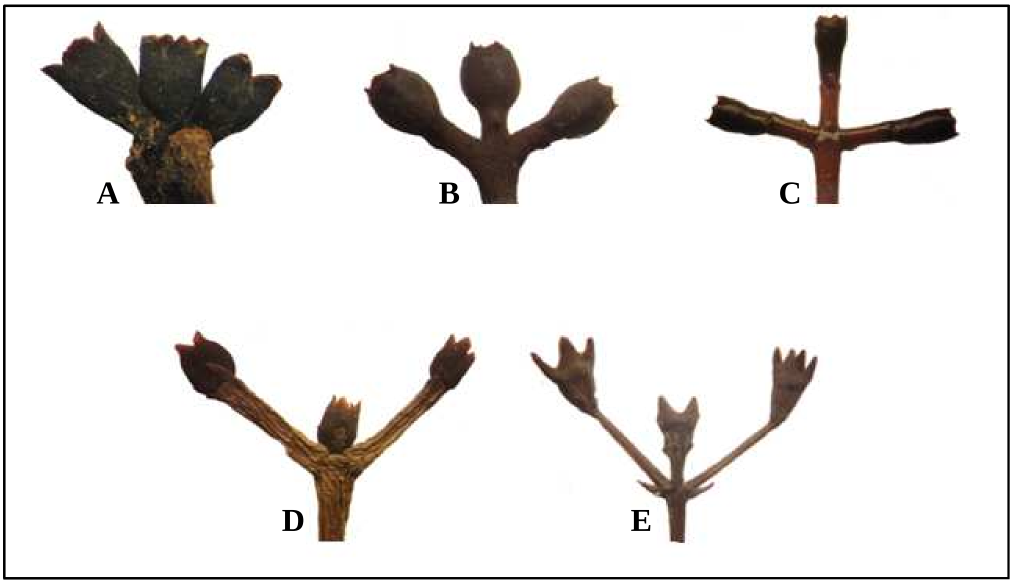

FIGURE 3. Ultimate flower triad (corollas removed). A–with (sub)sessile) flowers; B–with shortly pedicellate flowers; C–pedicels of the central flower as long as the pedicels of the lateral ones; D–pedicels of the central flower (sub)sessile; E– pedicels of the central flower shorter than the pedicels of the lateral ones. A–***I. intermedia***; B–***I. macrophylla***; C–***I. bartlingii***; D–***I. cumingiana***; E–***I. auriculata***.

In Philippine *Ixora* species, bracteoles are usually present on most pedicels. They are opposite and situated at the base of the ovary (Fig. 4B–4E) or rarely lower on the pedicel (e.g. *I. macrophylla*, Fig. 4A). The bracteoles are usually narrowly triangular (e.g. *I. filipes;* Fig. 4B) to filiform (e.g. *I. crassifolia*, *I. leucocarpa* and *I. mindanaensis*) or rarely broadly triangular or ovate (e.g. *I. auriculata*; Fig. 4E). The bracteoles rarely reach the calyx but can be unusually long as in *I. reynaldoi* Banag (submitted) with up to 8 mm in length (Fig. 4D). The Fijian *I. amplexicaulis* Gillespie (1930: 30) has a bracteole reaching up to 12 mm in length. Bracteoles are sometimes absent or reduced in *I. ebracteolata* with inflorescences of type 3.

2.2. Flowers

In *Ixora*, flowers are always actinomorphic and tetramerous (De Block 1998; Mouly 2008). The flowers have a small calyx and a long cylindrical corolla tube with relatively short corolla lobes. Flowers are often slightly to strongly fragrant (Mouly 2008). In the Philippines, aside from the cultivated *I. finlaysoniana*, only *I. cumingiana* was recorded by the collectors as sweetly fragrant.

2.3. Calyx

Calyces are basically 4–merous; though 3– to 5–merous calyces were observed in 3– to 5–merous flowers (Mouly 2008). African *I. nana* Robbrecht & Lejoly (1982: 487) is an exception to this as it possesses 6–9 calyx lobes with unequal sizes (De Block 1998). In Philippine *Ixora* species, calyces are small (Fig. 4) rarely exceeding 2 mm in height. The calyx tube is usually very reduced as in *I. macrophylla* (Fig. 4A) and *I. filipes* (Fig. 4B). Calyx tubes exceeding 2 mm in length are very rare and occur in *I. confertiflora* Merrill (1921a: 321) (Fig. 4C) and *I. reynaldoi* (Fig. 4D).

Calyx lobes differ considerably in shape, size, degree of basal overlap, and in the type of pubescence, thus yielding important characters for distinguishing the species. The lobes may be shortly apiculate (Fig. 4A–4B), narrowly to broadly triangular (Fig. 4E–4F) with acute to rounded tips, or truncate. Spectacular calyces occur in Philippine *I. reynaldoi* in which the triangular and foliaceous lobes reach 8–10 mm in length (Fig. 4D).

Calyces may be glabrous or pubescent. Often, however, when the inflorescence peduncles are pubescent, the indumentum continues on the ovary but leaves the calyx glabrous. However, the presence or absence and the density of trichomes can be highly variable within and between species (e.g. *I. philippinensis*). Colleters are often observed on the adaxial side of the calyx tube forming basal rings or sparsely or densely covering the inner side.

FIGURE 4. Variation in calyces and bracteoles in some Philippine Ixoras. A & B–calyx lobes shortly apiculate; B & D– calyx lobes narrowly triangular; E & F– calyx lobes widely triangular. A–bracteoles on the pedicels; B to F–bracteoles opposite at the base of the ovary A–***I. macrophylla***; B–***I. filipes***; C–***I. confertiflora;*** D–***I. reynaldoi***; E–***I. auriculata***; F–***I. crassifolia***.

2.4. Corolla

The merosity of the corolla usually follows the one of the flower. Corolla tubes in *Ixora* are slender, straight, rather narrow and usually much longer than the corolla lobes. In the Philippine representatives, they vary in length between 1 and 60 mm. Most species possess tubes of 5–20 mm long, shorter ones are relatively rare and occur sporadically e.g. *I. intermedia* (up to 7 mm long) and *I. mindanaensis* (1–10 mm long). Long corolla tubes are equally rare and constitute an important distinguishing character for *e.g.* *I. magnifica* (40–50 mm) and *I. salicifolia* (40–60 mm). In other Asian species, the corolla tubes are usually similar in length, usually varying between 15 and 90 mm. In Madagscar, four species (*I. crassipes* Boivin in De Block (2007: 76), *I. densithyrsa* De Block (2007: 78), *I. siphonantha* Oliver (1892: 2236) and *I. peculiaris*) possess extremely long corolla tubes, up to 230 mm long (De Block 2007).

In the Philippine species, the size of the corolla lobes range between 2 and 8 mm in length and between 1 and 5 mm in width. The lobes are usually elliptic with rounded and more commonly acute tips. In bud stage, the corolla lobes are contorted to the left, spreading or reflexed in mature flowers.

In *Ixora,* the corollas are usually glabrous outside, although the pubescence of the inflorescence and/or ovaries might rarely continue on to the base of the corolla tubes. Corollas are also rarely pubescent outside, as it is observed in some Philippines species, e.g. *I. alejandroi, I. macrophylla* and *I. philippinensis.* But *I. philippinensis* shows a considerable variation with regard to this character, as corollas may be entirely glabrous (Chinese representatives; Tao & Taylor 2011) to densely covered with short erect trichomes (Philippine representatives).

Bremekamp (1937) described some Malaysian species e.g. *I. timorensis* Decaisne (1834: 418), possessing bearded throats, but this is very rare for Philippine endemic species and is only observed in *I. salicifolia,* a species which is also growing in Malaysia.

In Philippine *Ixora* species, the corollas are usually white, white tinged with pink, red, and more rarely orange or pink. Several species, notably the ornamental ones are brightly colored in red or orange, yellow and pink, e.g. *I. coccinea* and *I. chinensis*.

2.5. Androecium

In *Ixora*, as in the vast majority of Rubiaceae, the number of stamens equals the number of corolla lobes. The stamens are always alternipetalous (alternate with the corolla lobes). At anthesis they are exserted, according to the secondary pollen presentation mechanism. Usually they are reflexed and situated among the also reflexed corolla lobes (De Block 1998). In some species, even after the anthesis, the four anthers still contain pollen grains, eitheir placed slightly upon the corolla lobes as in *I. kuakuensis* in New Caledonia, or erect as in *I. francii* Schlechter & Krause (1908: 39) and *I. jourdanii* in Pacific Islands (Mouly 2008). However, for some species like the Madagscan *I. platythyrsa*, the anthers abscise during flower opening and are absent in the fully open flower (De Block 1998). Anthers are mostly basi-medifixed, introrse, always sagittate with rounded basal sterile appendages and the connective continuing into an often conspicuous apical sterile acumen (Mouly 2008).

For Philippine species, the anthers are linear and either equalling the corolla lobes in length or somewhat shorter (2–7 mm long). The longest anthers are found in *I. macgregorii* (up to 10 mm long) and are sometimes twisted, a situation which does not occur in species with shorter anthers (De Block 1998). The anthers are yellowish or whitish with creamy to brownish connectives.

The filaments are glabrous, filiform and inserted at the throat of the corolla tube (De Block 1998). In Philippine species the length of the filaments varies between 0.5 and 3.5 mm long, never exceeding 4 mm.

2.5.1. Pollen

The monadic pollen grains of *Ixora* are isopolar, 3-zonocolporate and relatively small (polar axes 15.7–41.6 µm; equatorial axes 16.9–41.6 µm) (De Block 1998). Pollen morphological obervations of the genus *Ixora* are available for a number of Asian and some African representatives (Husain & Paul 1989; De Block 1998). *Ixora* is a stenopalynous genus having only slight pollen morphological variation in some characters, e.g. size of the grain or exine patterns. Thus, pollen morphological data can not generally be used to identify species or species groups. The pollen type found in *Ixora* predominates in the whole of Rubiaceae (Robbrecht 1988) and can be considered primitive.

2.6. Gynoecium

The ovary in *Ixora* is mostly bicarpellate. The locules are uniovulate and separated by a well-developed septum (De Bock 1998; Mouly 2008). The style is slender and cylindrical. It is glabrous, except in *I. gigantifolia* and *I. salicifolia* where at least the basal half of the style carries long spreading trichomes. The style is exserted at anthesis and the exserted part which includes the stigmatic lobes varies in length between 1 and 4 mm. The basal attachment of the style is often slightly globose. The stigma (Fig. 4) is bilobed, and the length of the lobes varies between 1 and 4 mm. Long stigmatic lobes are recurving (e.g. *I. macgregorii;* Fg. 4A; *I. macrophylla;* Fig. 4B) while the shorter ones are spreading (e.g. *I. chartacea*; Fig. 4C). Rarely in *Ixora* are the stigmatic arms shortened and rounded as the case of Philippine *I. alejandroi* (Fig. 4D), *I. katchalensis* Husain & Paul (1984: 153) and *I. brachiata* Roxburgh (1814: 10) which are both found in India (Husain & Paul 1989).

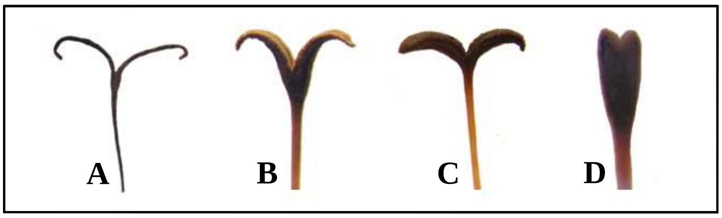

FIGURE 5. Stigmatic lobes. A–filiform and recurving; B & C–thickened and spreading; D–shortly cleft and erect. A–***I. macgregorii***; B–***I. macrophylla***; C–***I. chartacea***; D–***I. alejandroi***.

2.7. Fruits

Ixora fruits are small, subglobose, somewhat transversally flattened, bilobed drupes. The fruits are slightly wider than long and sizes range from 0.5 and 1.1 cm in length and 0.6 to 1.5 cm in width. Large ovoid fruits are never recorded for Philippine species.

The color of the fruits is usually turning from green to red (*e.g. I. angustilimba, I. bibracteata, I. confertiflora, I. luzoniensis, I. macgregorii*), purple or pink (e.g. *I. macrophylla*, *I. philippinensis*) and eventually turning black during maturation. The fruits are crowned by the persistent calyces and are inconspicuous for most of the Philippine species, except for *I. inaequifolia.* The fruits are usually smooth, the exocarp rarely pubescent for all Philippine species with pubescent ovaries (e.g. *I. philippinensis*) but the trichomes are shed when the fruits develop. Philippine *Ixora* fruits are bilocular. None of the Philippine species possess 3–4 locular fruits as in the case of Madagscan *I. homolleae* and the Australian *I. baileyana. Ixora* species have a tendency to produce more flowers than fruits, abortion levels are high and only a small number of fruits reaches maturity (De Block 1998).

2.8. Seeds

One seed is present per locule and its attachment to the septum is situated in the upper half of the locule. The seeds are characterized by a convex abaxial and a flat adaxial side. In Philippines *Ixora* species, the seeds are hemispherical in shape and an excavation is present at the adaxial side which is situated more or less centrally. The seeds are enclosed in the pyrene wall and are roughly the same shape as the pyrenes but are obviously smaller. The seeds are albuminous, as is typical for members of Rubiaceae, with the endosperm occupying most of the seeds except for a relatively large embryonical cavity at the abaxial side which contains the embryo.

2.9 Chromosomes

The first report of a chromosome number for the genus *Ixora* was by Fagerlind (1937). The chromosomes of atleast 30 *Ixora* species of Asiatic and Oceanic origin have been previously counted and yielded a basic chromosome number of n = 11, with only one species *I. duffii* Moore (1878: 76), being reported to possess a different chromosome number, n = 10 (De Block 1998). The basic chromosome number of n = 11, the most widespread in flowering plants, is also consistent in Ixoroideae and several woody tribes in Rubiaceae including Gardenieae, Psychotrieae and Pavetteae (Robbrecht 1988). Polyploidy seems to be relatively unimportant for *Ixora* as almost all species are diploid (De Block 1998) with the exception of

I. rosea (triploid; Sharma & Chatterjee 1960) and *I. notoniana* Wallich & Don (1834: 571) (tetraploid; Bir *et al.* 1984).

3. Ecology and Reproductive Biology

3.1. Flower Biology

Data regarding the flowering patterns of Philippine *Ixora* are not available and are rare for the whole genus. The Malagasy *I. platythyrsa*, was reported to have a flowering period of several months (Nilsson *et al.* 1990). Never in one day did the flowers at anthesis exceeded 4% of the total number in an inflorescence. At a rate of more than 200 flowers, this results in long-lived (up to 1 month) inflorescence. Additionally, inflorescences on an individual plant were observed to be in various stages of development.

Flowers of *Ixora* are hermaphroditic, as typical for Rubicaeae. However, the Australian *I. baileyana* Bridson & Adams (1987: 42) was reported to be androdioecious with all flowers in one (out of six) herbarium specimen were male, and from a very rudimentary undifferentiated ovary, all the gynoecial structures were completely lacking (Adams *et al*. 1987).

Ixora exhibits secondary pollen presentation, or which in the Rubiaceae family termed as "ixoroid pollen mechanism". This involves proterandry and relocation of pollen from the anthers on the "receptaculum pollinis" (De Block 1998). In bud stage, the anthers and stigmatic lobes of *Ixora* are situated inside the corolla lobes with the adaxial side of the stigmatic lobes closely surrounded by the anthers. The flowers exhibit proterandry resulting in early opening of the anthers while still in bud stage. The pollen is then shed on to the adaxial side of the closed stigmatic lobes and the upper part of the style functioning as the pollen presenting organ for pollination. At anthesis, the corolla lobes open or spread out and the pollen presenter becomes exposed. Even after anthesis, additional lengthening of the style occurs so that the pollen presenter is even further exserted or exposed. During which the pollen is readily available for pollinators, the flower is then in a functionally male stage. In functionally female stage, the previously closed stigmatic lobes separate and spread out, exposing the papillate adaxial surfaces (Puff *et al.* 1996; De Block 1998).

3.2. Pollinators

Detailed information on pollinators is relatively rare for *Ixora* and no data are available for Philippine species. Although only the Malagasy, *I. platythyrsa* was documented to be pollinated by moths during the night, according to De Block (1998), it is also most probable that *Ixora* species with long-tubed and fragrant flowers with revolute corolla lobes are also moth-pollinated. *Ixora* species with bright red and orange flowers such as *I. coccinea*, have odourless nectar-rich flowers and are visited by butterflies (Vogel, 1954).

3.2. Dispersal

Endozoochory is the dispersal mechanism exhibited by *Ixora*. Initially, the dispersal unit is the entire fruit but after passing the digestive system of the animal, the pyrene becomes the diaspore. Using species numbers per genus as a measure of success for dispersal, the possession of drupes, which invariably means dispersal by animals, combined with the possession of shrubby habit was showed to be an extremely successful strategy in Rubiaceae (Eriksson & Bremer 1991). The genus *Ixora* which consists mostly of shrubs or small trees, clearly has adopted this strategy (De Block 1998). Distribution by sea-currents was suggested by Bremekamp (1937) for some species that grows on the sea-shore (e.g. *I. timorensis*).

4. Habitat

The genus *Ixora* is essentially a rainforest genus (De Block 1998). In the Philippines, 23 out of 31 species occurs in lowland forests, four species growing in mossy forests with more than 1000m up to an altitude of 2300 m (e.g. *I. inaequifolia*). Some species prefer wet habitats and are found near rivers and streams (e.g. *I. leucocarpa*, *I. philippinensis*, *I. salicifolia*) or near the shore (e.g. *I. cumingiana*). Some species occurs on dry ground (e.g. *I. gigantifolia*) and rarely occurs on wet habitats.

5. Distribution

Ixora is pantropical but the center of its diversity is in Asia with approximately 280 or up to 300 species in continental Asia-Malesia (Mouly 2008), with 66 species in Borneo alone as recognized by Bremekamp (1937), in contrast to only 37 species in continental Africa (De Block, 1998), but ca. 40 species in Madagascar (De Block 2014b); and ± 35 species in tropical America (De Block 1998). The genus is exclusively tropical and penetrates only slightly if at all into subtropical regions (De Block 1998).

In the Philippines, most *Ixora* species are concentrated in Luzon (including Palawan and extending to Batanes islands) with the highest species diversity occuring in Palawan (11 species) followed by Quezon province (9 species), Bataan (5 species) and Cagayan (5 species). In Mindanao most number of species are recorded in Surigao del Sur (7 species) and Agusan del Norte (5 species). In the Visayas, Antique has the most number of *Ixora* (5 species) recorded. Four species (*I. bartlingii*, *I. cumingiana*, *I. macrophylla* and *I.*

philippinensis) are widely distributed throughout the Philippines, with only *I. philippinensis* extending northward into Taiwan and China.

Nearly all of the taxa treated in this revision are endemic to the Philippines. The exceptions are *I. brachyantha, I. fulgens, I. salicifolia* which are also found in Borneo and *I. filipes* which originated from Sulawesi.

6. Uses

The first record of usefulness of *Ixora* species was reported by Backer (1936) stating that in Sri Lanka, flowers of *Ixora* were used as offerings for the Hindu god Çiwa (De Block 1998). Aside from its ornamental purposes, several *Ixora* species were also reported having medicinal value (Mouly 2008). Based on personal interview, literature and information on the labels of the herbarium specimens seen for this study, indigenous use of *Ixora* is not common in the Philippines. The cultivated *I. coccinea* was more commonly encountered having medicinal importance using the flowers as decoction—as cure for bronchitis, dysentery hypertension and dysmenorrhea. The diluted tincture of roots is used as gargles for sore throat and root decoction used as sedative in treating nausea, hiccups and lost of appetite (Batugal *et al.* 2004). The macerated fresh leaves and stems are used to heal sprains, eczema and boils and decoction of leaves used for wound healing and treating skin ulcers.

For *I. macrophylla*, the fruits are rubbed on the body when a person is sick and roots mixed with betel are chewed as remedy for headache. The wood of *I. macrophylla* is used as firewood and constructing materials. *Ixora longifolia* and *I. macrophylla* are noted by collecters being used in agricultural rituals in Zamboanga del Norte.

TAXONOMY OF *IXORA* IN THE PHILIPPINES

The given characters on the genus *Ixora* are based exclusively on Philippine species. The characters in **bold** are considered implicit attributes and therefore not repeated in the individual description of the species. A practical key that puts emphasis on the most obvious unique character states of the species is presented. The species are treated in alphabetical order. Finally, vernacular names are listed in Appendix I.

Description of the Philippine *Ixora* species

Shrubs, small or medium-sized trees, 0.2–10(–26) m tall; young twigs glabrous or more rarely pubescent, usually flattened, more rarely bisulcate; older branches smooth to corky, grayish to greenish or brown. <u>Leaves</u> **opposite**, petiolate or more rarely sessile; petioles up to 2.5 cm long, glabrous or more rarely pubescent, often with cork rings, **their bases distinctly articulate**; <u>blades</u> elliptic to obovate, more rarely ovate, usually acuminate at apex, but sometimes acute or obtuse, attenuate to cordate at base, 0.7-105 x 0.5-30 cm, membranaceous to rigidly coriaceous, drying greenish to grayish to blackish brown, generally glabrous above, glabrous or more rarely pubescent underneath, the pubescence then restricted to the nerves; 6-14(-18) pairs of lateral nerves; intersecondaries reticulate; margin entire and (somewhat) revolute; **domatia and bacterial leaf nodules absent**. <u>Stipules</u> **interpetiolar**, with the truncate to triangular or more rarely ovate amplexicaul sheets basally fused forming a cone but free in their upper part, bearing a short to long awn, rarely bifid. <u>Inflorescences</u> corymbose to paniculate, terminal on main or lateral branches or more rarely terminal on short-shoots or cauliflorous, congested to extremely lax, sessile or short to long-pedunculate, in the latter case erect or drooping to pendulous, multiflorous or more rarely pauci- to uniflorous, **hermaphrodite**; branching trichotomous, articulate and opposite or non-articulate and non-opposite, bracts well developed to reduced or absent; provided with 1(–2) pair(s) of subsessile to petiolate inflorescence-supporting leaves with rounded to cordate bases and usually much smaller than the vegetative leaves, but with fully developed stipules; peduncles and inflorescence axes usually red, purplish to pink, glabrous or puberulent; first order bracts with the stipular parts fused to an ovate blade with a central awn, the foliar parts either absent or forming small leaves (in sessile inflorescences) or with or without stipular parts, the foliar ones triangular and vaulted (in pedunculate inflorescences); higher order bracts with stipular parts absent, the foliar parts narrowly triangular and vaulted, fimbriate or filiform. <u>Ultimate flower</u> triads with flowers sessile to long-pedicellate (up to 2.5 cm), the pedicel of the central flower usually as long as or shorter than the pedicels of the lateral ones sometimes (sub)sessile; bracteoles usually present on most pedicels, opposite at the base of the ovary or on the pedicel or non-opposite along the pedicels, widely triangular to filiform or ovate, with obtuse to acuminate tips. Flowers **4–merous**, hermaphrodite, fragrant; sometimes enclosed in a calicule; calyx together with ovary often red, glabrous to pubescent outside, often pubescent and provided with colleters at the base of the lobes inside; tube short, sometimes long, cylindrical to campanulate, truncate or dentate; lobes triangular to linear or ovate with rounded to acuminate or fimbriate tips, their base sometimes overlapping; corolla white, pink, yellow, orange or red, the color usually darker in bud and corolla lobes paler than tube, glabrous or more rarely pubescent outside; tube **cylindrical**, **slender, slightly widening at the throat,** 0.5-20 cm long, usually beset with spreading trichomes in the basal half inside; **lobes contorted to the left in bud**, erect, spreading or reflexed at anthesis, with obtuse to acuminate apices, mostly glabrous at the adaxial side but sometimes with long spreading trichomes near the throat; stamens **exserted at anthesis**; filaments 0.5–10 mm long, **inserted at the throat of the corolla tube**; anthers **linear, basifixed**, **sagittate**, **with sterile appendage at the apex**; ovary small to sometimes large, usually cup-shaped, glabrous to pubescent outside, its wall containing copious tannins, **two-locular** or rarely 3–7–locular, with a **solitary ovule per locule**; ovule anatropous to hemi-anatropous, pendulous, **attached to the upper half of the massive septum, with adaxial obturator**; style **slender, exserted**, glabrous or pilose at base; stigma **bilobed**, lobes often recurving or spreading rarely erect and shortly cleft at the middle. Fruit **drupaceous, more or less bilobed**, with persistent calyx, red to blackish when ripe containing (1–)2–(7) **one-seeded pyrenes**; pyrenes leathery to stony, hemispherical to hemiovate or rarely flattened longitudinally or laterally, sometimes apically and basally acute, with convex abaxial side and flat subapically perforated adaxial side, often with preformed germination slit(s); seeds the **same shape as the pyrenes**, reddish brown, **with large adaxial excavation continuing into a basal vertical groove**; extreme thickening of the seed-coat around the adaxial excavation absent; endosperm horny, in some species showing traces of rumination around the adaxial excavation; embryo dorsal, somewhat curved, with foliaceous cotyledons; radicle inferior.

KEY TO THE PHILIPPINE SPECIES OF *IXORA*

1a. Inflorescences cauliflorous or ramiflorous...**23. *I. macrophylla***

1b. Inflorescences terminal or axillary

2a. Calyx lobes 8–10 mm long; bracteoles more than 4 mm long............**27. *I. reynaldoi***

2b. Calyx lobes less than 8 mm long; bracteoles less than 4 mm long

3a. Petioles, young internodes and abaxial side of the leaves pilose....**18. *I. leytensis***

3b. Petioles, young internodes and abaxial side of the leaves glabrous

4a. Bracts of the first (sometimes second) order axis with stipular parts present

5a. Inflorescences pendulous or drooping

6a. Leaves (sub)sessile with cordate or auriculate bases

7a. Leaf blades linear oblong; corolla tube more than 10 mm long; corolla lobes elliptic...............................**6. *I. auriculata***

7b. Leaf blades oblanceolate; corolla tube less than 10 mm long; corolla lobes lanceolate...............................**16. *I. inaequifolia***

6b. Leaves distinctly petiolate

8a. Inflorescence branching non-articulate throughout...**30. *I. tenelliflora***

8b. Inflorescence branching articulate throughout

9a. Calyx lobes shortly apiculate, less than 1 mm long...**7. *I. bartlingii***

9b. Calyx lobes triangular, more than 1 mm long..**10. *I. chartacea***

5b. Inflorescences erect

10a. Bracteoles reduced or absent

11a. Leaves thickly coriaceous; inflorescences with articulate and opposite branching restricted to the first and second axes..**12. *I. crassifolia***

11b. Leaves chartaceous; inflorescences without articulate branching throughout................................**15. *I. gigantifolia***

10b. Bracteoles fully developed and present on most pedicels

12a. Flowers white or pinkish; corolla tube 1–10 mm ....**25. *I. mindanaensis***

12b. Flowers red, orange or yellow; corolla tube 25–50 mm

13a. Corolla lobes broadly ovate; calyces with bases not overlapping...**9. *I. longifolia***

13b. Corolla lobes elliptic; calyces with bases overlapping

14a. Inflorescences pubescent; leaves linear, more than 25 cm long.........................**28. *I. salicifolia***

14b. Inflorescences glabrous; leaves broadly oblong, lanceolate, or elliptic, less than 25 cm long

15a. Leaf blades broadly oblong with obtusely rounded or occasionally shortly acute apices, 20–25.5 × 4.5–7 cm ....**24. *I. magnifica***

15b. Leaf blades lanceolate to oblong-lanceolate, rarely oblanceolate with sharply acuminate apices, 7–13(–17) × 1.5–4.5(–6) cm...........**26. *I. palawanensis***

4b. Bracts of the first order axis with stipular parts absent

16a. Inflorescences glabrous

17a. Leaves sessile with cordate or subemarginate base

18a. Leaf blades linear, 6–19 × 1–1.5 cm, rigidly coriaceous ....**29. *I. silagoensis***

18b. Leaf blades triangularly acuminate, 5–8 × 2–3 cm, submembranous.......................................**30. *I. sparsiflora***

17b. Leaves petiolate with acute, cuneate or rounded base

19a. Bracteoles reduced or absent on most pedicels; calyx lobes widely triangular to ovate.............**17. *I. leucocarpa***

19b. Bracteoles fully developed and present on most pedicels; calyx lobes triangular to narrowly triangular

20a. Stipule sheath truncate; stipular awn < 2 mm long

21a. Leaves subcoriaceous; secondary veins 20–25 pairs; corolla lobes narrowly oblong, 5–6 × 2.5–3 mm.........................**2. *I. angustilimba***

21b. Leaves membranceous; secondary veins 9–12 pairs; corolla lobes elliptic to oblong, 7–9 × 1–2 mm.................................**5. *I. bibracteata***

20b. Stipule sheath subtruncate, triangular or broadly ovate; stipular awn at least 3 mm long

22a. Flowers (sub)sessile; pedicels < 1 mm

23a. Inflorescences erect or sometimes drooping; peduncle 1–4 cm long ....**6. *I. capitulifera***

23b. Inflorescences pendulous; peduncle 9–15 cm long.................**19. *I. longistipula***

22b. Flowers pedicellate; pedicels at least 2 mm

24a. Bracteoles 2–3 mm long, reaching the middle of the calyx lobes ....**8. *I. confertiflora***

24b. Bracteoles 0.5–1.5 mm long, reaching the base or middle of the ovary

25a. Inflorescence terminal or axillary, uniflorous or with 3(–9) flowers; corolla white; stipule sheath subtruncate.................**12. *I. filipes***

25b. Inflorescence terminal, with more than 9 flowers; corolla pink; stipule sheath triangular ....**20. *I. luzoniensis***

16b. Inflorescences at least in the upper parts sparsely to densely pubescent

26a. Flowers reddish brown; stigmatic lobes shortly cleft, rounded at the top, erect...**1. *I. alejandroi***

26b. Flowers white; stigmatic lobes elongate, spreading or recurving

27a. Inflorescence branching non-articulate throughout

28a. Calyx lobes with bases not overlapping; corolla tube 3–10 mm long; corolla lobes elliptic, 4.5–5 × 1–1.2 mm...**10. *I. cumingiana***

28b. Calyx lobes with bases overlapping; corolla tube 5–20 mm long; corolla lobes lanceolate, 6–10 × 2–4 mm...**21. *I. macgregorii***

27b. Inflorescence branching articulate throughout

29a. Leaves (sub)sessile; leaf base cordate or rarely rounded; calyx lobes shortly apiculate to truncate ....**26. *I. philippinensis***

29b. Leaves petiolate; leaf base acute or cuneate; calyx lobes triangular to ovate

30a. Bracts and bracteoles reduced or absent ....**11. *I. ebracteolata***

30b. Bracts and bracteoles fully developed ....**15. *I. intermedia***

SPECIES DESCRIPTIONS

1. *Ixora alejandroi* Banag & Tandang (2014: submitted) (Fig. 6).

Type:—PHILIPPINES. Luzon: Palawan: Mt. St. Paul, Sabang, 31 May 2012, *Tandang PNH254886* (holotype PNH!; isotypes USTH!, K!, US!).

Shrub 0.5–3 m tall; young internodes, brown, terete, older internodes grayish-brown, terete or corky; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas moderately to densely covered with very short erect trichomes. Stipules persistent, sheath narrowly triangular, 2–3 mm long, awn 5–7 mm long. Leaves with petioles 1.5–2 cm long, canaliculate; blades elliptic to lanceolate, 18.2–27.5 × 4–9.8 cm, coriaceous, drying brown or dark brown above, paler brown below; apex acuminate; base cuneate to rounded; secondary veins 15–19 each side. Inflorescences terminal, multiflorous, pendulous or drooping, non-articulate throughout, lax, 3.5–6 × 0.5–1 cm; one or two pairs of inflorescence–supporting leaves present, subsessile, blades narrowly elliptic to lanceolate, 1.5–2.0 × 0.6–1.0 cm, base cuneate to rounded; peduncles 10–18 cm long, reddish brown; central first order axis 1–2 cm long, lateral first order axes ≤ 0.5 cm long; first order bracts with stipular parts absent and the foliar parts narrowly triangular, up to 3 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular to filiform, 1–2 mm long. Ultimate flower triad with flowers pedicellate; pedicels 1.9–2.1 mm long (3.6–5.0 mm long in fruiting stage), pedicel of central flowers as long as or usually somewhat shorter than the pedicels of the lateral ones. Flowers with ovary and calyx reddish brown, corolla red, filaments, anthers, style and stigma yellow; flower bud with obtuse or rounded apex; bracteoles present on most pedicles, sub-opposite at the base of the ovary or more often just underneath it on the the pedicels, triangular, apices acute, 0.5–1 mm long, reaching the base of the ovary; calyx with colleters inside; calyx tube up to 0.5 mm long; calyx lobes widely triangular or narrowly triangular, 1.4–1.8 mm long, bases not overlapping; corolla tube 10–20 mm long; corolla lobes broadly ovate, 4–6 × 3–5 cm, apices obtuse; stamens alternating with corolla lobes, inserted in corolla throat, with filaments 0.5–0.8 mm long; anthers yellow, 3–4 mm long; ovary 1.2–2.3 mm long; style exserted, 18.0–20.8 mm, including $\pm$ 1.2–2.0 mm long, bifid stigmatic branches, shortly cleft in the middle, rounded at the top. Fruits subglobose, 4–7 × 4.5–9.5 mm, with persistent calyx, pinkish when ripe, green when young; fruit wall $\leq$ 1 mm thick; pyrenes 4–7 × 3.5–5 mm; seeds 3.5–6.5 × 2–4.5 mm.

Habitat:—Thrives in limestone forests; elevation 400–600 m.

Distribution:—Known only in the island of Palawan (Fig. 7).

Phenology:—Flowers: April–September; fruits: October–March.

Notes:—*Ixora alejandroi* is most closely related to *I. tenelliflora*, a non–endemic species also found in Palawan, but differs from it in having bifid stigmatic branches and panicled cymose inflorescences.

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Mt. St. Paul, Sabang, May 2012 *Alejandro et al.12404* (USTH) *& 12439* (USTH); Mt. Cleopatra's Needle, Puerto Princesa, 20 January 1998, *Argent et al. 25387* (K, L, SAN) & *25396* (L).

FIGURE 6. *Ixora alejandroi*. A—inflorescence, B—open flower, C—infructescence. Locality of A–C: Mt. St. Paul, Sabang, Palawan (*Tandang PNH254886*). Credit: D. Tandang.

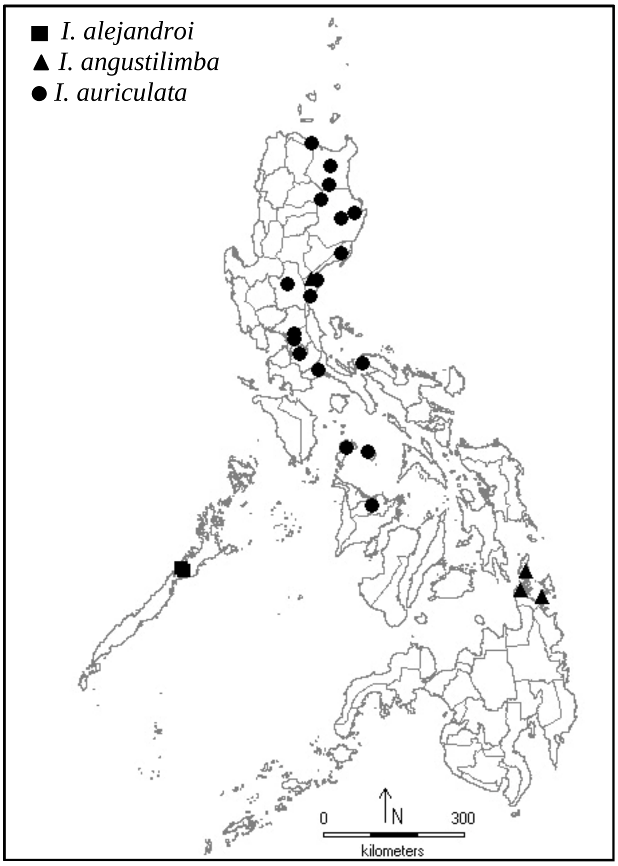

FIGURE 7. Distribution of *I. alejandroi, I. angustilimba* and *I. auriculata*.

2. *Ixora angustilimba* Merrill (1921:320) (Fig. 8).

Type:—PHILIPPINES. Mindanao: Surigao Province: *s. loc.*, 24 April 1919, *Ramos & Pascasio 34588* (holotype PNH, destroyed; lectotype US! **here designated**; isolectotype K!).

Shrub or small tree 1–5 m tall; young internodes brown, smooth, older internodes brown, corky; all external parts glabrous. Stipules persistent, sheath truncate, 1–1.5 mm long, awn 0.5–1.5 mm long. Leaves with petioles 2–4 mm long; blades linear to narrowly lanceolate or sometimes oblanceolate, 7–23 × 0.5–3 cm, subcoriaceous, drying brown or green above, somewhat paler below; apex acute or acuminate (acumen 1–2 mm long); base usually acute; 20–25 pairs of lateral nerves, not discoloured when dry. Inflorescences terminal on short axillary shoots, subsessile, uniflorous (or up to three flowers); one pair of modified inflorescence supporting leaves present, subsessile, blades ovate, 0.5–2 × 0.3–1 cm, apex acute, base rounded. Flowers sessile to shortly pedicellate; pedicels $\leq$ 2 mm long; ovary and calyx green, reddish when mature, corolla white tinged with pink, filaments and anthers white or yellow; flower bud with acute apex; bracteoles lanceolate or acuminate, up to 1.5 mm long; calyx tube 1–2 mm long; calyx lobes triangular, up to 2 mm long, base not overlapping; corolla tube 10–18 mm long, base enclosed within the inflorescence-supporting leaves; corolla lobes narrowly oblong, 5–6 × 2.5–3 mm, apices acuminate; filaments ca. 1 mm long, anthers 2–4 mm long; ovary 2-locular; style slightly exserted from corolla tube for 1–2 mm, stigmatic lobes 1.5–2 mm long. Fruits ovoid or globose, 6–11 × 6–8(–12) mm, with persistent calyx, red when ripe; fruit wall 1–2 mm thick; pyrenes ca. 2 mm thick; seeds 3–8 × 4–7 mm.

Habitat:—On dry forested slopes and ridges at low altitudes; elevation 300–700 m.

Distribution:— Endemic to Luzon: Aurora; Mindanao: Dinagat Island, Surigao del Norte (Fig. 7).

Phenology:—Flowers and fruits: April.

Notes:—*I. angustilimba* was described by Merrill (1921) based from a collection from Surigao province in Mindanao without citing the locality. He also mentioned in the protologue that this species is strongly characterized by its narrow leaves. However, the two specimens collected from Bucas Grande Island (*Ramos & Pascasio 35087*) and Dinagat Island (*Ramos & Pascasio 35222*) also cited by Merrill in the protologue have oblanceolate leaves. Since both specimens are sterile, it is difficult to tell whether they are another species or a subspecies. The holotype of *I. angustilimba* was destroyed in PNH, thus the remaining isotype, *Ramos & Pascasio 34588* deposited in the US herbarium is designated as the lectotype. *Ixora angustilimba* is most closely allied to *I. bibracteata* in having uniflorous inflorescence. But differs from the latter in terms of the sheath of the stipules that are truncate. This species is recorded for the first time in Luzon particularly in the province of Aurora during a botanical exploration in Maria Aurora in 2010.

Additional specimens examined:—PHILIPPINES. Luzon: **Aurora:** Mt Udok, Brgy Bazal, Maria Aurora, 2010, *Banag et al. 11032* (USTH), *11033* (USTH). Mindanao: **Dinagat Island**: *s. loc.*, June 1919, *Ramos & Pascasio 35087* (US!); **Surigao del Norte**: Bucas Grande Island, Socorro, 1919, *Ramos & Pascasio 35222* (K!, P!, US!).

FIGURE 8. *Ixora angustilimba* (*Ramos & Pascasio 34588*) (US, lectotype).

3. *Ixora auriculata* Elmer (1911: 1018) (Fig. 9).

Type:—PHILIPPINES. Luzon: Romblon: Mt. Giting-giting, Magallanes, Sibuyan Island, May 1910, *Elmer 12483* (holotype PNH, destroyed; lectotype US! **here designated**; isolectotypes A!, K!, L!, MO, NY!).

Shrub up to 3 m tall; young internodes terete, 3.5 cm thick; all external parts glabrous. Stipules persistent, sheath triangular or ovate, 1–2 mm long, awn 6–9 mm long. Leaves sessile, mostly descending; blades linear oblong, 20–30 × 5–9 cm, chartaceous to rigidly coriaceous, dull green above, much paler beneath, drying brown; apex acute or shortly acuminate; base rounded with shallow auriculate lobes; midvein very prominent beneath, the lateral ones irregularly scattered, 13–16 on each side, nearly at right angles to the midvein, faint and obscure. Inflorescences terminal, multiflorous, pendulous, trichotomously branched, articulate throughout, lax, 2–4 × 4–5.5 cm; one pair of modified inflorescence supporting leaves absent or present, if present, subsessile, blades linear or similar in shape with the vegetative leaves, 0.8–2 × 0.2–1 cm, apices acute, base cordate; peduncle 7–19 cm long, deep red; central first order axis 0.5–2 cm long, lateral first order axes 0.5–3 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular and vaulted, up to 3 mm long; higher order bracts with stipular parts absent and foliar parts triangular and vaulted, up to 2 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 6–9 mm long, central flower sessile or with pedicels 1–1.5 mm long. Flowers with ovary and calyx greenish or red, corolla, style, stigma, filaments and anthers white; flower bud with rounded apex; bracteoles present on most pedicles, opposite at the base of the ovary, broadly triangular or ovate, apices acuminate, 1–1.5 mm long, reaching the base of the calyx tube but often the middle of the ovary; calyx tube 1–1.5 mm long; calyx lobes broadly triangular or ovate, 0.5–1.3 mm long, apices rounded or acute, bases not overlapping; corolla tube 10–12.5 cm long; corolla lobes elliptic, 5–8 × 2–4 mm, apices obtuse or acute; filaments ca. 1 mm long, anthers 3–4.5 mm long; ovary 1–1.5 mm long; style exserted from corolla tube for 2–3 mm, stigmatic lobes 2–3 mm long, spreading. Fruits subglobose, 5–7.5 × 7–9.5 mm, with persistent calyx, pinkish when ripe; mature seeds unknown.

Habitat:—In primary forests at low and medium altitudes; elevation 200–600 m.

Distribution:—Endemic to Luzon in the provinces of Aurora, Cagayan, Isabela, Nueva Ecija, Quezon, Rizal, Romblon (Fig. 7).

Phenology:—Flowers: February–March, May–June, August–September; fruits: March, May–June, August, October.

Notes:—This species is very close to *I. inaequifolia* and the New Guinean *I. amplexifolia* Schumann & Lauterbach (1900: 572), in having similar habit, pendulous inflorescences, sessile leaves with cordate bases and white flowers. However *I. auriculata* differs from *I. inaequifolia* in having linear oblong leaves with faint and obscure secondary veins and is usually rigidly coriaceous and differs markedly from *I. amplexifolia* in having articulate branching in the inflorescences. A number of specimens (*Adduru 253, Co 3594*, *Curran 19557, Weber 1541*) deviate in that their leaves are chartaceous and not rigidly coriaceous. These atypical specimens are located in the northern part of the distribution of *I. auriculata* and might represent an infraspecific taxon. More collections with mature flowers are needed for these specimens to establish their morphological variations .

Additional specimens examined:— PHILIPPINES. Luzon: **Aurora:** Sierra Madre Mountains NNE of Dingalan, 1968, *Jacobs 7668 & s.n.* (L); Baler, *s.d., Tandang DNT-BA040* (PNH); **Cagayan:** Lagum vicinity of Peñablanca, May–June 1917, *Adduru 153* (P); s.*loc.*, January 1912, *Curran 19557* (P, US); Abulug River, January 1912, *Weber 1541* (A, P, PNH, US); **Isabela:** Sitio Minorma, Bintacan, 20 March 1992, *Balete 55755* (CAHUP); Sierra Madre Mountain Range (E foothills), Sitio Diago, Brgy. San Isidro, Palanan, 27 May 1991, *Co 3594* (A, US); San Mariano, February–March 1926, *Ramos & Edaño 46772* (NY); **Nueva Ecija:** Mt. Umingan, August–September 1916, *Ramos & Edaño 26374* (A, US); **Quezon:** Casiguran Tayabas, May–June 1925, *Ramos & Edaño 45364 & 45482* (NY); Mt. Cadig Tayabas, December 1916, *Yates 25419* (NY); Tayabas, May–June 1925, *Ramos & Edaño 45539* (P); **Rizal:** Montalban, 1906, *Loher 6391* (K); Mt. Angilog, February 1923, *Lopez 42036* (K, US); Mt. Irig, February 1923, *Ramos 41875* (A, K, P, PNH, US); Mt. Susong Dalaga, August 1917, *Ramos & Edaño 29285* (US) *& 29409* (A, P, US); *s.loc.*, August 1911, *Ramos 13585* (K, P, US); **Romblon:** Camp 1 above Magdiwang on ridge leading to Mayos Peak, Sibuyan Island, 1989, *Argent & Reynoso 893* (L); Mt. Udok, Marigondon Sur, San Andres. Tablas Island, 2 October 1996, *Reynoso et al. 24792* (L); *s.loc.*, 1906, *Loher 6414 & 6416* (K).

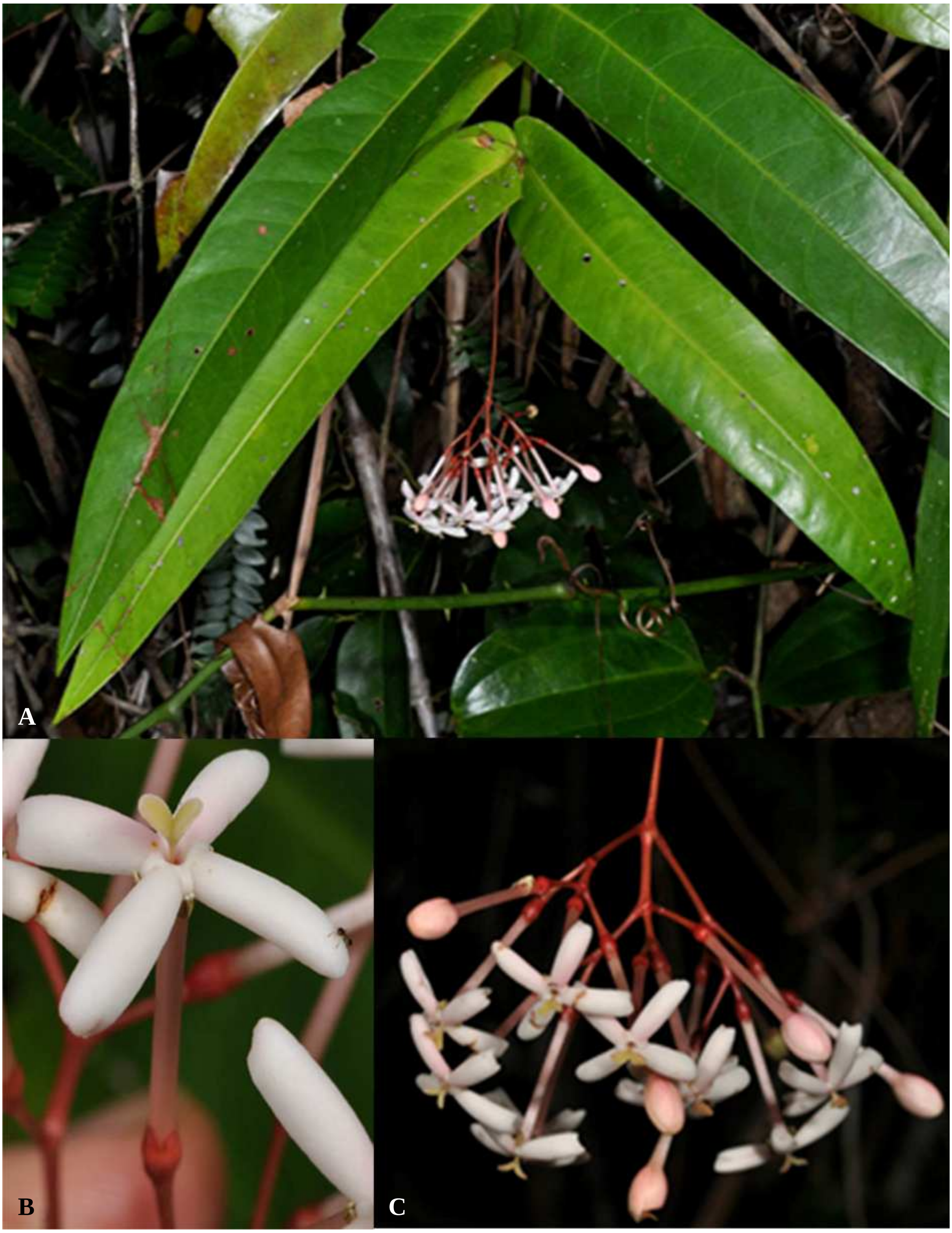

FIGURE 9. *Ixora auriculata*. A—flowering branch, B—close-up of flower, C—inflorescence. Locality of A–C: Baler, Aurora, forest east of ASCOT campus. Credit: P.B. Pelser & J.F. Barcelona.

4. *Ixora bartlingii* Elmer (1911: 1020) (Fig. 10).

Type:—PHILIPPINES. Luzon: Romblon: Mt. Giting-giting, Magallanes, Sibuyan Island, April 1910, *Elmer 12223* (holotype PNH, destroyed; lectotype A!, designated by Banag & Tandang (2014: submitted), isolectotypes BISH, K!, L!, MO, NY!).

= *Ixora samarensis* Merr. **Type:—**PHILIPPINES. Visayas: Samar: Catbalogan, July 1912, *Ramos 15399* (not traced) *syn. nov.*

= *Ixora arborea* Blanco non Roxb. **Type:** —PHILIPPINES. Luzon: Batangas: Mt. Batulao, 25 July 1914, *Ramos 734* (holotype unknown; lectotype US!, designated by Banag & Tandang (2014: submitted), isolectotypes A!, K!, L!, NY!, P!).

= *Ixora kingstoniana* Elmer non Hook. **Type:** —PHILIPPINES. *s.loc.*, *s.d.*, *s.coll.*, *s.n.* (unknown).

Shrub or small tree 1.5–7 m tall; young internodes subterete, pale brown; all external parts glabrous except the peduce, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and sometimes corollas moderately to densely covered with very short erect trichomes. Stipules persistent, sheath truncate, ca. 3 mm long; awn 5–7 mm long. Leaves with petioles 1.5–2 cm long; blades oblong, 20–25 × 7–10 cm, membranaceous or chartaceous, shining green on the upper side, much paler beneath, drying dark brown above, pale brown below; apex abruptly acute or shortly acuminate (acumen 1–3 mm long); base in the smaller blades obtuse the larger ones rounded; secondary veins brown, conspicous especially beneath, 11–17 each side of the very prominent midvein. Inflorescence terminal, multiflorous, pendulous, trichotomously branched, the branches spreading at right angles, articulate throughout, lax, 1.5–6(–15) × 2–5(–10) cm; one pair of modified inflorescence-supporting leaves present, subsessile or shortly petiolate (petioles $\leq$ 2 mm long), blades elliptic to ovate, 1–5 × 2–3 cm, apices acute or shortly acuminate; base cuneate or rounded; peduncle 8–23 cm long, slender, deep red; central first order axis 0.2–6 cm long, lateral first order axes 1–7.5 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular and vaulted; higher order bracts with stipular parts absent and foliar parts triangular and vaulted. Ultimate flower triads with flowers pedicellate, pedicels spreading at about right angles; pedicels of lateral flowers 1–5 mm long, central flower sessile or with pedicels as long or as shorter than the pedicels of the lateral ones. Flowers with ovary and calyx red, corolla white, style, stigma, filaments and anthers cream or white; flower bud with rounded or acute apex; bracteoles present on most pedicles, opposite at the base of the ovary, triangular, apices acute, 1–2 mm long, reaching the base of the ovary; calyx tube ca. 1 mm long; calyx lobes shortly triangular with acute tips or more rarely broadly triangular with rounded tips, 0.2–0.6 mm long, their base not overlapping; corolla tube 9–15 mm long; corolla lobes elliptic to oblong, 4–8 × 2–4 mm, apices rounded; filaments ca. 3 mm long, anthers 4–5 mm long; ovary 1–1.5 mm long; style exserted from corolla tube for 4–5 mm, stigmatic lobes 3–4 mm long, spreading. Fruits globose, 3–6 × 5–7.5 mm, with persistent calyx, red or pink when ripe; fruit wall ca. 2 mm thick; pyrenes 2–4 × 4–6 mm, seeds 1–3 × 3–4 mm.

Habitat:—In forests at low and medium altitudes; elevation 300–1000 m.

Distribution:—Widely distributed from Luzon to Mindanao, but never recorded in the island of Palawan (Fig. 11).

Phenology:—Flowers: February–October; fruits: February–June, September–October, December.

Notes:—As already pointed out by Banag & Tandang (2014, submitted) the name *I. macrophylla* has frequently been misapplied to specimens of *I. bartlingii*. Furthermore, earlier collections were confused with *I. cumingiana* and *I. longistipula. Ixora bartlingii* can be distinguished easily from these three *Ixora* species based on the following morphological characters. Articulate inflorescence of *I. bartlingii* as opposed to non-articulate inflorescence of *I. macrophylla* and capitate inflorescence of *I. longistipula* and the terminal inflorescence of *I. bartlingii* as opposed to cauliflorous (sometimes ramiflorous) inflorescence of *I. macrophylla. Ixora bartlingii* is also distinguished by its bluntly toothed, turbinate calyx, as compared to the triangular calyx lobes with acute tips of *I. cumingiana*. The inflorescences of *I. bartlingii* are puberulent, and not glabrous as described. The type specimen of *I. samarensis* were not traced, however, the description in the protologue leaves no doubt that this is *Ixora bartlingii.*

Additional specimens examined:—PHILIPPINES. *s.loc.*, 1906, *Loher 6438 & 6395* (K); *s.loc.*, 10 July 1907, *Usteri 111* (K); Luzon: **Albay:** *s.loc.*, September–October 1958, *Vidal 812c* (A); **Bataan:** Lamao River, Mt. Mariveles, July–August 1904, *Ahern 1437* (NY); Lamao River, Mt. Mariveles, August 1904, *Borden 1759* (K, NY); Mt. Mariveles, November 1904, *Elmer 6728* (NY); Lamao Forest Reserve, December 1906, *Foxworthy 1883* (NY, P); Dinalupihan, January–February 1903, *Merrill 1511* (K, NY, P); Lamao River, Mt. Mariveles,

FIGURE 10. *Ixora bartlingii*. A—flowering branch, B—calyces and corollas, C—infructescence, D—adaxial side of the leaf, E—young stipule pair and modified inflorescence-supporting leaf. Locality of A & B: Bulanao river, Libertad, Panay Antique; C: Mt Banahaw, Brgy. Kinabuhayan, Dolores, Quezon; D & E: vicinity of Sibaliw field station, Brgy. Tagusip, Buruanga, Aklan. Credit: P.B. Pelser & J.F. Barcelona.

October 1903, *Merrill 3145* (K, NY); **Batangas:** *s.loc.*, April–May 1915, *Ramos & Deroy 22657* (A); **Camarines Norte:** Mt Bagacay, November–December 1918, *Ramos & Edaño 33884* (US); **Camarines Sur:** Sagnay, December 1913, *Ramos 22141* (K, L, P); Brgy. Guijalo, 1995, *Reynoso et al. 14673* (L); Tigaon, September–October 1958, *Vidal 385bis* (A); **Cavite:** Mt. Palay-palay, Mataas na Gulod National Park, So. Malauyas, Brgy. Sapang, Ternate, 1996, *Gaerlan et al. 26272* (L); Mt. Palay-palay National Park, Ternate, 2010, *Lemana et al.* GC004 (USTH); Cavite-Batangas Road, Km. 74, 13 December 1959, *Mendoza & Steiner 41369* (L, PNH); *s.loc.*, 1915, *Ramos & Deroy 22484* (L); Mt. Palay-palay National Park, Ternate, 1995, *Reynoso et al. 17023* (L); **Laguna:** Mt. Makiling, 5 September 2011, *Banag et al. IM003* (USTH); Mt. Makiling, 21 February 1954, *Delfinado 3397* (CAHUP); College of Forestry Campus University of the Philippines Los Baños, 9 March 1997, *Dorji 62715* (CAHUP); Los Baños, April 1906, *Elmer 8199* (K, NY); Mt. Makiling, June–July 1917, *Elmer 17864* (K, NY); Mt. Makiling, 29 October 1913, *Gates 2564* (CAHUP); Mt. Makiling, 3 March 1913, *Guerrero 2563* (CAHUP); College of Forestry Campus University of the Philippines Los Baños, 19 November 1963, *Hernaez 19069* (CAHUP); Mt. Makiling, 2 February 1954, *Pancho 3212* (CAHUP); Bo. Puting Lupa, Calamba, 25 May 1977, *Payawal et al. 26169* (CAHUP); back of Paete, 28 September 1913, *Reyes 6974* (NY); Makiling National Park, 25 September 1945, *Sulit 7088* (A, PNH); Makiling National Park, 18 August 1946, *Sulit 3417* (PNH); Mt. Makiling, 19 March 1949, *Valderama 9548 & 9648* (PNH); Calauan, September–October 1958, *Vidal 385* (A, L); **Marinduque:** Hawillian, So. Maulawin, Brgy. Dampulan, Torrijos, 26 October 1996, *Romero & Chavez 29017* (A, L); **Masbate:** 7-R Ranch, Sitio Kalunukan, Brgy. Matipuron, Milagros, 12 February 1994, *Barbon et al. 12655* (A, K, L); *s.loc.*, August 1903, *Merrill 3025* (K, NY, P); **Nueva Vizcaya:** Mt. Alzapan, May–June 1925, *Ramos & Edaño 45584* (A, K, NY) *& 45705* (A, NY, P); **Occidental Mindoro:** Lubang Island, 1 June 2012, *Balete DSB9266* (USTH); **Oriental Mindoro:** Dimayuga Trail, Mount Malasimbo, 18 July 1978, *Griffith 160837* (PNH); Pinamalayan, June 1922, *Ramos 40947* (A) *& 41035* (A, L, P); **Quezon:** Mt. Pinagbanderahan, Atimonan, September 2012, *Chavez Q013* (USTH); Tayabas, March 1917, *Edaño 26917* (A); Talisay, Real, 20 July 1956, *Lagrimas 37054* (L, PNH); Atimonan, 26 August 1984, *Medina 40289* (CAHUP); Salakan, Guinayangan, 23 June 1965, *Mendoza 97760* (PNH); Salakan, Guinayangan, 9 January 1967, *Mendoza 97777* (PNH); Kinatakutan, Tayabas, January 1929, *Oro 30680* (NY); Mt. Dingalan, August–September 1916, *Ramos & Edaño 26607* (K, NY, P); Mt. Alabat Island, September–October 1926, *Ramos & Edaño 48108*, *48344* (C, NY) *& 48209*, *48250* (NY, P); Tayabas, January 1884, *Vidal 811* (K); **Rizal:** Montalban, 26 October 1890, *Loher 1463* (K); Bosoboso, June 1906, *Ramos 1011* (A, K, NY, P); **Romblon:** Ambunan Watershed, 1994, *Reynoso et al. 14188* (L); **Sorsogon:** Mt. Bulusan, Irosin, September 1916, *Elmer 17364* (C, K, L, NY, PNH); **Zambales:** Subic, April 1920, *Edaño 38337* (NY). Visayas: **Biliran:** *s.loc.*, June 1914, *McGregor 18554* (A) *& 18803* (A, K); **Capiz:** Janiuay, Panay, 1954, *Taleon 33800* (L); **Eastern Samar**: East of station, Sitio Catinoc, Brgy. 1 Balangiga, 1996, *Gaerlan & Chavez 26388* (L); Mt. Concord, 1969, *Gutierrez et al. 117033* (L); Bo. Guinmaayahan, Balangiga, 1971, *Madulid et al. 118331* (L); Borongan, October 2012, *Pinarok et al. 121008* (USTH); **Guimaras:** Buenavista, 25 February 1950, *Sulit 11698* (A, L, PNH, SAN); Buenavista, Bo. Salvacion, 27 February 1950, *Sulit 11734* (A, L, PNH, SAN); Buenavista vicinity of Bo. Salvacion, 1 March 1950, *Sulit 11760* (A, L, PNH, SAN); **Leyte:** Hubasan, VISCA, Baybay, 23 March 1993, *Gaerlan et al. 10506* (K, L); **Northern Samar:** Mount. Purog, 24 December 1951, *Edaño 15418 & 15432* (PNH); Catubig River, February–March 1916, *Ramos 24251, 24257* (US) (US) *& 24255* (P); Catubig River, March 1916, *Ramos s.n.* (US); **Western Samar:** Brgy. Buray, Paranas, 26 October 1992, *Reynoso et al. 7608* (A). Mindanao: *s.loc.*, March 1907, *Hutchinson 6571* (NY, P); **Agusan del Norte:** Mt. Urdaneta, Cabadbaran, October 1912, *Elmer 13982* (A, L, NY, P, PNH); **Basilan:** *s.loc.*, 1912, *Miranda 18978* (L); **Davao del Sur:** Mt. Apo, Todaya, June 1909, *Elmer 10873* (K, L, NY, PNH); Sitio Budbud, Bo. Banaoan, 19 July 1929, *Estabillo 31214* (NY); **Davao Oriental:** Magdug River, 18 August 1949, *Edaño 11076* (A, PNH); Mt. Kapok, 26 August 1949, *Edaño 11293* (A, L, SAN); Mt. Mansamuga, August–September 1949, *Edaño 11100* (PNH); Mati, March–April 1927, *Ramos & Edaño 49008* (A, L, NY, P); Mati, March–April 1927, *Ramos & Edaño 49234* (BR, NY, P); **North Cotabato:** Aroman, Carmen, 4 July 1950, *Anonuevo 13569* (A, L, PNH); **South Cotabato:** Tasaday, July–August 1972, *Gutierrez et al. 108945* & *Yen 108996, 109014* (PNH); **Surigao:** *s.loc.*, 10 August 1927, *Wenzel 3100* (A, BR, NY).

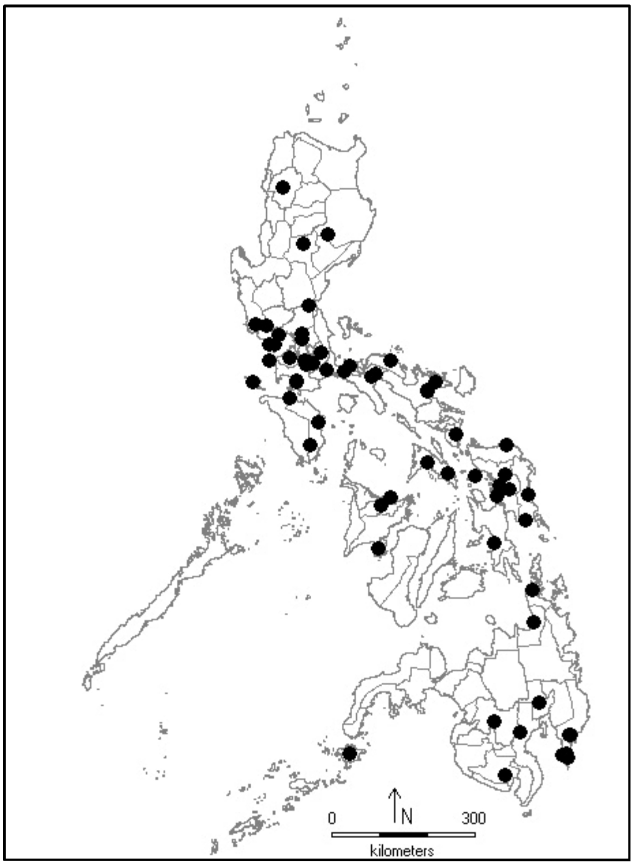

FIGURE 11. Distribution of *I. bartlingii*.

5. ***Ixora bibracteata*** Elmer (1906: 8) (Fig. 12).

Type:—PHILIPPINES. Luzon: Quezon: Tinnan River, Tayabas, September 1904, *Whitford 789* (holotype PNH, destroyed). —PHILIPPINES. Luzon: Quezon: Mt. Binuang, Tayabas, May 1917, *Ramos & Edaño 28678* (neotype A!, **here designated**; isoneotypes K!, P!).
= *Ixora ilocana* Merr. **Type:—**PHILIPPINES. Luzon: Ilocos Norte: Burgos, 11 March 1917, *Ramos 27325* (holotype PNH, destroyed; lectotype US, **here designated**), *syn. nov*.

Shrub 1–4 m tall or small tree 5–8 m tall; young internodes terete, grayish to brown, older internodes rigid and gnarly, grayish; all external parts glabrous. Stipules caducous, sheath truncate, up to 1 mm long, awn 1–1.5 mm (only visible in youngest stipule pair). Leaves subsessile or shortly petiolate; petioles 0.2–0.5 mm; blades lanceolate or oblanceolate, 9–12 × 2.5–4 cm, membranaceous, drying reddish brown beneath, darker brown above; apex abruptly or shortly acuminate (acumen 0.5–1 cm long), rarely rounded; base cuneate or attenuate; midvein prominent, 9–12 pairs of lateral nerves, obscure. Inflorescence terminal, uniflorous, sessile or subsessile (peduncle $\leq$ 0.5 cm); one pair of modified inflorescence-supporting leaves present, subsessile, blades lanceolate, 1.5–2 × 0.5–0.8 cm, apex acuminate, base cuneate. Flowers solitary, sessile to shortly pedicellate; pedicels ≤ 2(–7) mm long; ovary and calyx green, corolla, style, stigma, filaments and anthers white; flower bud with acute apex; bracteoles triangular to linear lanceolate, 1–1.5 mm long, apices acuminate; hypanthium 2–3 mm long; calyx tube 0.5–1 mm long; calyx lobes triangular, adaxial side glabrous and without colleters, apices acute. Corolla tube 20–30 mm long; corolla lobes elliptic to oblong, 7–9 × 1–2 mm, apices acuminate; filaments ca. 1 mm long; anthers 1–2 mm long; ovary 1.5–2 mm long; style exserted from the corolla tube for ca. 1.5 mm, stigmatic lobes 1–1.5 mm long, spreading. Fruits globose, 6–7 × 7–9 mm, with persistent calyx, red when ripe; fruit wall ca. 1 mm thick; mature seeds unknown.

Habitat:—Found along forested ridges or in forests along streams at low and medium altitudes; elevation 50–850 m.

Distribution:—Endemic to northern Luzon in the provinces of Cagayan, Quezon, Ilocos Norte, Isabela, Quezon (Fig. 13).

Phenology:—Flowers: May; fruits: February–April (–December).

FIGURE 12. Fruiting branch of *Ixora bibracteata*. Locality: Brgy. Villa Aurora, Maria Aurora, Aurora. Credit: P.B. Pelser & J.F. Barcelona

Notes:—The holotype of *I. bibracteata* (Tinnan River, Tayabas, Quezon, *Whitford 789*) has been destroyed in PNH and no isotypes can be traced during the revision. Several specimens collected from Quezon province (*Castro 6512, 6508*; *Lagrimas 535*; *Ramos & Edaño 28678, 48044*; *Yates 25487, 25493*), confirms well with the original description of the species, *Ramos & Edaño 28678* deposited in A was chosen as a neotype since it has mature flowers and collected from Tayabas, the same locality of the holotype. The holotype *Whitford 789* was wrongly cited in the protologue as *Whitford 779* (Elmer 1906).

Additional specimens examined:—PHILIPPINES. Luzon: **Cagayan:** Mt. Cagua, November 1929, *Edaño 78433* (A); Mt. Taggat, Kilkiling, Claveria, 1994, *Reynoso et al. 11957* (L); **Ilocos Norte:** Mt. Palemlem, April 2013, *Alejandro et al. 13016* (USTH); Mt. Quebrada, 1953, *Edaño 17881* (PNH), 27 February 1953, *Edaño 17875* (L, PNH); Mt. Darna, 1953, *Edaño 18073* (PNH), 22 March 1953, *Edaño 18143* (PNH); Bangui to Claveria, August 1918, *Ramos 33087* (P); **Isabela:** Palanan, Dipudgen, 1991, *Gaerlan et al. 3051* (L); Sierra Madre Mountains WSW of Baler, 24 March 1968, *Jacobs 7978* (A, L); Diguyo, 25 April 1991, *Ridsdale et al. 263* (A, L); **Quezon:** Polillo Island, Anibawan, 4 December 1948, *Castro 6512* (A, BR, PNH) *& 6508* (A), Pagbilao, 1964, *Lagrimas 535* (L), Alabat Island, 1926, *Ramos & Edaño 48044* (NY), Mt. Cadig, December 1916, *Yates 25487* (A) *& 25493* (P).

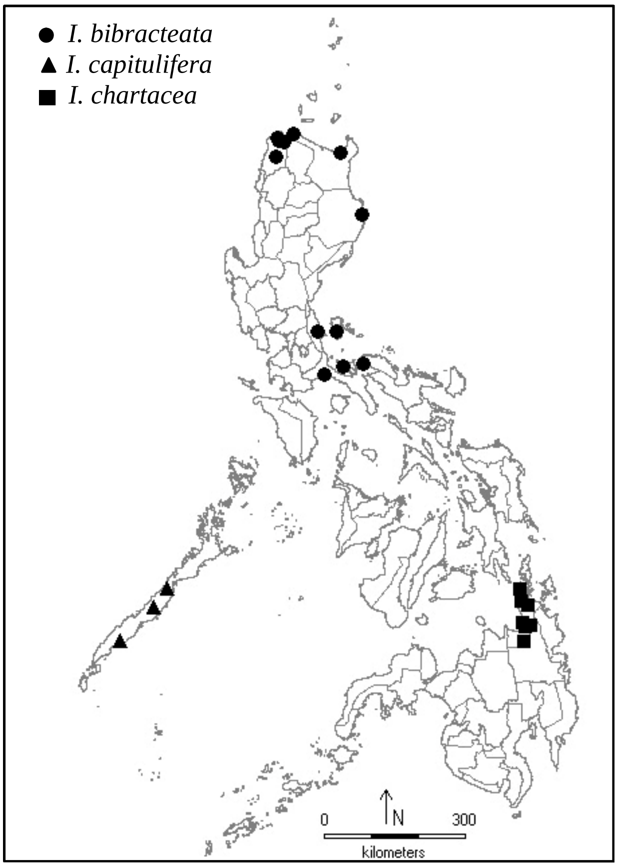

FIGURE 13. Distribution of *I. bibracteata*, *I. capitulifera* and *I. chartacea*.

6. *Ixora capitulifera* Merrill (1910: 233) (Fig. 14).

Type:—PHILIPPINES. Luzon: Palawan: Mt. Victoria, 23 March 1906, *Foxworthy 686* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotype US!).

Shrub 1–4 m tall or tree 5–10 m tall; young internodes grayish, terete, stout; all external parts glabrous. Stipules caducous; sheath triangular, 0.5–1 mm long, awn ca. 3 mm long (only visible in younges stipule pair). Leaves with petioles less than 2 mm long; blades oblong or obovate, 4–13 × 1.5–6 cm, subcoriaceous, drying brown or dark brown above, paler brown below; apex shortly and usually bluntly acuminate (acumen less than 0.5 cm long); base narrowed, somewhat rounded, rarely cuneate; secondary veins 12 each side, not discolored when dry, distinct and anastomosing. Inflorescences terminal, pauciflorous (5 to 9 flowers), shortly pedunculate, non-articulate throughout, compact, giving the impression of a capitate inflorescence, 0.2–0.5 × 0.3–0.7 cm; one pair of modified inflorescence-supporting leaves present, subsessile, blades similar in shape to vegetative leaves but smaller, 1–5 × 0.5–3 cm; peduncle 1–4 cm long; central and lateral first order axes 0.5–1 cm long; first and higher order bracts with stipular parts absent and the foliar parts absent or filiform, 2–3 mm long. Ultimate flower triads with flowers sessile or subsessile; pedicels very reduced $\leq$ 0.5 mm long. Flowers with ovary and calyx red, corolla, style, stigma, filaments and anthers white; flower bud with rounded apex; bracteoles present on most pedicels, sub-opposite at the base of the ovary, narrowly triangular to filiform, apices acute, 1–2 mm long, reaching atleast the calyx tube but often the base of the calyx lobes; calyx tube 0.2–0.5 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube up to 13 mm long; corolla lobes elliptic to oblong, 2–4 × 1–2.5 mm, apices acute, rounded or obtuse; filaments ca. 1 mm long, anthers 1–2 mm long. Fruits subglobose, 0.5–0.9 × 0.4–0.8 mm, with persistent calyx; mature seeds unknown.

Habitat:—in forests along streams; elevation up to 1100 m.

Distribution:—Endemic in the island of Palawan (Fig. 13).

Phenology:—Flowers and fruits: March to April.

FIGURE 14. *Ixora capitulifera (Foxworthy 686)* (NY, isolectotype).

Notes:—According to Merrill (1910), *I. capitulifera* is readily recognizable by its erect, few-flowered capitate inflorescences with slender peduncles. However, closer observations with the inflorescences prove that it is not capitate as described, rather the flowers are shortly pedicellate and the relatively short central and lateral first order axes gives the impression that it is capitate. This species is only known from three specimens. The most recent one was collected in 1995. Collecting efforts in the distribution area of this species should be done in order to ascertain its conservation status. *Ixora capitulifera* is similar to *I. intermedia* in having flowers with very short corolla tubes, but differs in having only up to nine flowers per inflorescence and slender and much shorter peduncles.

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Mt. Beaufort, Puerto Princesa, 29 March 1984, *Ridsdale 276* (A, L, PNH); Sandurapi Peak, Brgy. Macagua, Brooke's Point, 5 March 1995, *Soejarto et al. 8824* (A, L).

7. *Ixora chartacea* Elmer (1913: 1861) (Fig. 15).

Type:—PHILIPPINES. Mindanao: Agusan del Norte: Mt. Urdaneta, Cabadbaran, September 1912, *Elmer 13806* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotypes L!, MO).

= *Ixora oblongifolia* Elmer (1913: 1867). **Type:—**PHILIPPINES. Mindanao: Agusan del Norte: Mt. Urdaneta, Cabadbaran, September 1912, *Elmer 13775* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotypes BISH, L!, MO) *syn. nov*.

Shrub or small tree 1.5–7 m tall; young internodes brown, terete, older internodes brown, smooth; all external parts glabrous except the inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyx and corolla moderately to densely covered with very short erect trichomes. Stipules persistent, sheath truncate, 1–2 mm long, awn 4–5 mm long. Leaves with petioles 1.5–3 cm long; blades narrowly oblong or the smallest ones linearly lanceolate, 15–20 × 4–6 cm, rigidly chartaceous, dull gray or grayish brown above, lighter or yellowish green below; apex sharply acute to acuminate (acumen less than 0.5 cm long); base obtuse, cuneate or rounded; secondary veins 8–11 each side, less conspicuous, reticulations coarsely anastomosing equally plain on both sides. Inflorescences terminal, mutltiflorous, erect, trichotomously branched, articulate throughout, moderately compact, 2–4 × 3.5–5 cm; one pair of modified inflorescence-supporting leaves present, subsessile, blades ovate to oblong, 3–6 × 2–4 cm; peduncle 10–20(–30) cm long, red; central and lateral first order axes 0.5–1 cm; first order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular and vaulted, 1.5–2 mm long; higher order bracts with stipular parts absent and foliar parts triangular and vaulted, 1–1.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers at least 3 mm long, central flower sessile or with pedicels shorter than the pedicels of the lateral ones. Flowers with ovary and calyx red, corolla white occasionally tinged with red, style, stigma, filaments and anthers white; flower bud with rounded apex; bracteoles present on most pedicels but often absent from the central flower, opposite at the base of the ovary, triangular, apices acute, 1–2 mm long, reaching the middle of the ovary; calyx tube 0.5–1 mm long; calyx lobes triangular, 1–2 mm long, apices acute, their bases not overlapping; corolla tube 15–20 mm long; corolla lobes elliptic or oblong, 5–6 × 3–4 mm, apices acute or rounded; filaments ca. 2 mm long, anthers 4–5 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 2–2.5 mm long, spreading. Fruits subglobose, 5–7 × 6–10 mm, with persistent calyx, light purple to red when ripe; fruit wall 1–2 mm thick; pyrenes 3–5 × 4–8 mm; seeds 2–4 × 3–7 mm.

Habitat:—In dry humus covered soil of forested ridges; elevation 50–1000 m.

Distribution:—Endemic in Mindanao in the provinces of Agusan del Norte and Surigao del Norte (Fig. 13).

Phenology:—Flowers: March, May; fruits: March

Notes:— *Ixora chartacea* is very close to *I. bartlingii*. These two species are similar in having pedunculate inflorescences that are pendulous and flowers with white corolla that are sparsely to densely covered with short erect trichomes. Leaves are comparable in size and sometimes in shape. However, striking differences are present, e.g. in *I. chartacea* the inflorescences are moderately compact, pedicels of the central flowers usually subsessille to shortly pedicellate, and calyx triangular in shape. In *I. bartlingii* on the other hand, the inflorescences are lax, central flowers more commonly pedicellate and pedicels spreading at about right angles, calyx are shortly toothed. *Ixora oblongifolia*, here transferred as synonym of *I. chartacea*, only differs in quantitative measurements e.g. leaf size, petiole and peduncle length, and diameter of the fruits. This differences cannot be maintained as convincing characters for distuinguishing the two species. Both species were published by Elmer in the same issue of Leaflets of Philippine Botany in 1913, *I. chartacea* is chosen here to serve as accepted name.

FIGURE 15. *Ixora chartacea.* A—flowering branch, B—close-up of flowers, C—young stipule pair and modified inflorescence-supporting leaves, D–adaxial side of the leaf. Locality of A & B: Mt. Ampay, San Antonio, Remedios T. Romualdez, Agusan del Norte (*Banag & Tandang HI007*). Credit: D. Tandang. Locality of C & D: NPC, Maria Cristina Falls, Iligan City, Lanao del Norte. Credit: P.B. Pelser & J.F. Barcelona.

Additional specimens examined:—PHILIPPINES. Mindanao: **Agusan del Norte:** Mt. Ampay, San Antonio, Remedios T. Romualdez, 19 May 2012, *Banag & Tandang HI007* (USTH); Tungao II, Logging Camp, *Mabesa & Escasinas 98434* (PNH); Mt. Hilong-hilong, Cabadbaran, 19 April 1949, *Mendoza & Convocar 10758* (A, PNH); **Surigao del Norte:** Tapian, Mainit, 12 March 1949, *Mendoza & Convocar 10336* (A, L, PNH); Mt. Kabatuan, 24 March 1949, 22–24 March 1949, *Mendoza & Conovocar 10555* (A, L, PNH) *& 10498* (A, PNH); *s.loc.*, April 1919, *Ramos & Pascasio 34446 & 34534* (P).

8. *Ixora confertiflora* Merrill (1921: 321) (Fig. 16).

Type: —PHILIPPINES. Mindanao: Dinagat Island: *s.loc.*, 12 May 1919, *Ramos & Pascasio 35206* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotypes A!, L!, P!).

Shrub or small tree 3–5 m tall; young internodes brown, terete, older internodes corky, gray; all external parts glabrous. Stipules persistent, sheath triangular to broadly ovate, 1–1.5 mm long, awn 3–5 mm long. Leaves with petioles 3–10 mm long; blades oblong elliptic to somewhat oblong-obovate, 9–15 × 2–5.5 cm, coriaceous, drying dark brown above, paler brown below; apex sharply acuminate (acumen 0.5–1 cm long); base cuneate or obtuse; secondary veins 12–14 each side, spreading at nearly right angles. Inflorescences terminal, multiflorous, erect or drooping, trichotomously branched, articulate throughout; one pair of modified inflorscence-supporting leaves present, subsessile, blades similar in shape with the vegetative leaves but much smaller, 1.5–4.5 × 1–1.5 cm; peduncle 2–6 cm long; central first order axis 1–1.5 cm long, lateral first order axes 1–2 cm long; first order bracts with stipular parts absent and the foliar parts narrowly triangular to filiform and vaulted, 2–4 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular to filiform, 2–2.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels of the central and lateral flowers up to 3 mm long. Flowers with corolla white; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular, apices acute, 2–3 mm long, reaching the middle of the calyx lobes; calyx tube 0.5–1 mm long; calyx lobes narrowly triangular, apices acute, their bases not overlapping, 2.5–4 mm long; corolla tube ca. 10–12 mm long; corolla lobes elliptic, ca. 2.5 mm long. Fruits subglobose, 5.5–7 × 7–8.5 mm.

Habitat:—In damp forests at low altitudes; elevation ca. 300 m.

FIGURE 16. *Ixora confertiflora (Ramos & Pascasio 35206)* (NY, lectotype).

Distribution:—Known only in Mindanao from the type collected on Dinagat Island and one specimen collected on Surigao del Norte (Fig. 17).

Phenology:—Flowers: March; fruits: May

Notes:—This species is only known from two historical specimens. The most recent one collected in 1949. As a result, the description needs to be updated when more materials become available. In the protologue, Merrill described the inflorescence as both terminal and axillary, however, this can not be confimed as the specimen available has only terminal inflorescences. *Ixora confertiflora* is well characterized by its long calyx lobes reaching up to 4 mm. The only other Philippine species with long calyx lobes is *I. reynaldoi,* but it has sessile inflorescences and foliaceous calyx lobes and bracteoles.

Additional specimens examined:—PHILIPPINES. Mindanao: **Surigao del Norte:** Mt. Kabatuan, Alegria, 24 March 1949, *Mendoza & Convocar 10566* (A, L, PNH).

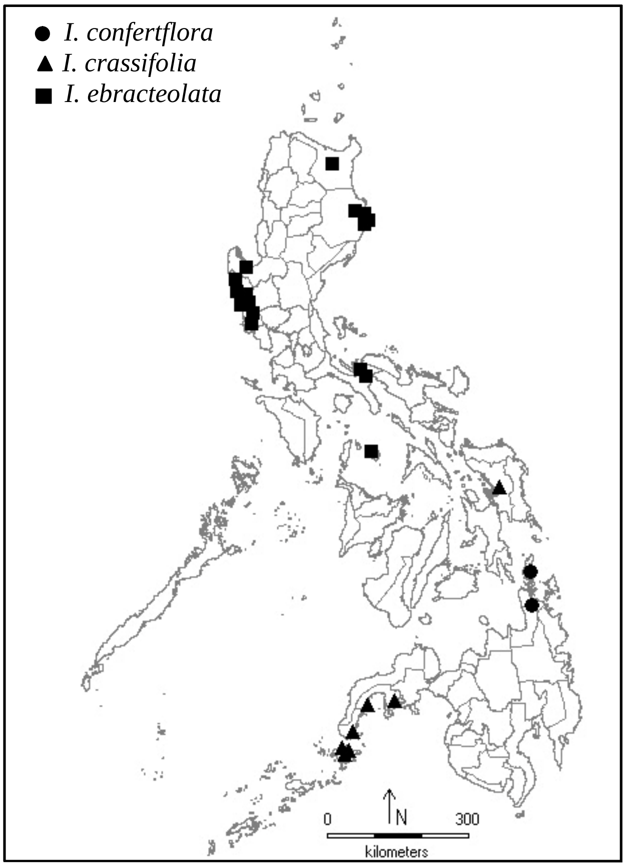

FIGURE 17. Distribution of *I. confertiflora*, *I. crassifolia* and *I. ebracteolata*.

9. *Ixora crassifolia* Merrill (1910: 233) (Fig. 18).

Type:—PHILIPPINES. Mindanao: Zamboanga del Sur: Port Banga, February 1908, *Whitford & Hutchinson 9439* (holotype PNH, destroyed; lectotype US!, **here designated**).
=*Ixora speciosa* Merrill & Quisumbing *nom. inval.* (ICN Art. 29). **Type:—**PHILIPPINES. Visayas: Western Samar: Loquilocon, Wright, 16 April 1948, *Sulit 6121* (PNH!) *syn. nov.*

Shrub or tree 1.5–9 m tall; young internodes brown or grayish, smooth, older internodes grayish, somewhat corky; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries and calyces moderately to densely covered with very short erect trichomes. Stipules persistent, sheath broady ovate, 5–7 mm long, awn 1–2 mm long. Leaves with petioles 1–2 cm long; blades elliptic, broadly elliptic or oblong elliptic, 14–25 × 7–18 cm, very thickly coriaceous, somewhat shining, when dry minutely and densely rugose on both surfaces; apex broadly rounded, sometimes slightly retuse; base acute or somewhat acuminate, rarely broadly rounded; secondary veins ca. 10 each side, midrib prominent underneath, reticulations lax. Inflorescences terminal, erect, trichotomously branched, articulate and opposite branching restricted to the lower part of the inflorescence (first and second order axes), shortly pedunculate, moderately compact to very compact, 1–2 × 1–4 cm; modified inflorescence-supporting leaves absent; peduncles 1–5 cm long; central first order axes 1–2 cm long, lateral first order axes 2–4 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts forming small leaves; higher order bracts with stipular parts absent and the foliar parts reduced or absent. Ultimate flower triads with flowers pedicellate; pedicels 1–2 mm long, the pedicel of the central flower usually somewhat shorter than the pedicels of the lateral ones. Flowers with corolla white or greenish-white; flower bud with acute or rounded apex; bracteoles often absent, if present then opposite at the base of the ovary, filiform or narrowly triangular, apices acute, ≤ 0.5 mm long, reaching at most the base of the ovary; calyx tube 0.5–1 mm long; calyx lobes broadly ovate, apices acute, their bases not overlapping; corolla tube 15–26 mm long; corolla lobes oblong or rounded, 5–7 × 2–4 mm, apices acute or rounded; filaments 1–2 mm long, anthers linear, 3–4 mm long; style exserted from corolla tube for 3–4 mm, stigmatic lobes 2–3 mm long, spreading. Fruits subglobose, 6–7 × 8–9 mm, with persistent calyx; fruit wall 0.5–1 mm thick; pyrenes 3.5–4.5 × 2–3 mm, seeds 3–4 × 1.5–2.5 mm.

Habitat:—In primary dipterocarp forests; elevation 50–600 m.

FIGURE 18. *Ixora crassifolia (Whitford & Hutchinson 9439)* (US, lectotype).

Distribution:— Endemic in Mindanao in the provinces of Basilan, Zamboanga del Norte and Zamboanga Sibugay (Fig. 17).

Phenology:—Flowers: February, April–May, September–December; fruits: January.

Notes:—*Ixora crassifolia* is well characterized by its unusually large, very coriaceous leaves, which, when dry, are rather pale and densely rugose on both surfaces. This species is closely allied to *I. grandifolia* Zollinger & Moritzi (1846: 65) in terms of vegetative structures however, only few *I. grandifolia* specimens were seen during this revision, more collections should be studied to resolve the relationships between *I. crassifolia* and *I. grandifolia*. *Ixora crassifolia* is only known from nine historical specimens and the most recent one was collected in 1953. Collecting efforts in the area of distribution of *I. crassifolia* should be undertaken in order to ascertain its conservation status.

Additional specimens examined:—PHILIPPINES. Mindanao: **Basilan:** *s.loc.*, September 1910, *Almagro 15234* (P); VP Grant Isabela, 1953, *Britton 488* (L); *s. loc.*, September 1912, *Reillo 16361* (K, P, US); Barrio Malaong, Lamitan, 1948, *Santos 4268* (L); **Zamboanga del Norte:** Siuya, 2 January 1958, *Frake 38031* (A, L, PNH); **Zamboanga del Sur:** Port Banga, December 1907, *Whitford & Hutchinson 9039* (NY!); February 1908, *Whitford & Hutchinson 9479* (P!); **Zamboanga Sibugay:** Malangas, October–November 1919, *Ramos & Edaño 37052* (K, P, US).

10. ***Ixora cumingiana*** Vidal (1885: 183) (Fig. 19).

Type: —PHILIPPINES. Luzon: Bicol: Albay, 1885, *Cuming 895* (holotype PNH, destroyed; lectotype L!, designated by Banag & Tandang (2014: submitted); isolectotype K!, MO).

= *Ixora myriantha* Merr. **Type:—**PHILIPPINES. Visayas: Samar, April 1914, *Ramos 1700* (holotype PNH, destroyed; lectotype US!, **here designated**; isolectotypes L!, MO, NY!, P!) *syn. nov.*

= Taligalea umbellata Blanco non *Ixora umbellata* Valeton. **Type: —**PHILIPPINES. Luzon: Rizal: *s.loc.*, November 1915, *Blanco 954* (holotype unknown; lectotype NY!, designated by Banag & Tandang (2014: submitted); isolectotypes K!, P!).

= *Ixora paludosa* Elmer (1906: 9), non Roxburgh. *nom. nud.* (ICN Art. 38).

= *Ixora timorensis* Merrill (1903: 55), non Decne. *nom. nud.* (ICN Art. 38).

Shrub to small tree 3–5(–8) m tall; young internodes, brown or grayish, terete, older internodes grayish or fawn; all external parts glabrous except the peduncle, inflorescence axes, pedicels sparsely covered with short erect trichomes. Stipules persistent, sheath triangular or ovate, 1–2.5 mm long, awn 1–4.5 mm long. Leaves with petiole 0.2–2 cm long; blades subelliptic, oblong or elliptic-oblong to ovate, 6–20 × 3–10 cm, membranaceous but more often chartaceous to coriaceous, drying dark brown or black above, paler brown below; apex acute or obtuse rarely acuminate (acumen less than 0.5 cm long); base acute to cuneate or obtuse to rounded; secondary veins ca. 10 each side. Inflorescence terminal, multiflorous, drooping, trichotomously branched, articulate throughout, lax to moderately compact, 3–7 × 5–11 cm; one pair of modified inflorescence-supporting leaves present, blades similar in shape to vegetative leaves but are subsessile or shortly petiolate (petioles 0.1–0.5 cm long), base broadly acute to rounded or rarely cordate; peduncle 2–6 cm long, green or sometimes reddish; central first order axis 1–3.5 cm long, lateral first order axes 1–3 cm long; first order bracts with stipular parts absent and the foliar parts narrowly triangular and vaulted or more rarely forming small leaves, 1.5–6 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular, 1–4 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 1–4(–6.5) mm long, central flower (sub)sessile or with pedicels as long or shorter than the pedicels of the lateral ones. Flowers sweetly fragrant, with ovary and calyx green to red, corolla, style, stigma white, filaments and anthers yellow; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular, 1–1.5 mm long, reaching the base of the calyx lobes; calyx tube ca. 0.5 mm long; calyx lobes triangular, apices acute, their bases overlapping; corolla tube 3–10 mm long; corolla lobes elliptic, 4.5–5 × 1–1.2 mm, apices acute; filaments 2–3 mm long, anthers 3–6 mm long; style exserted from corolla tube for 2–3 mm, stigmatic lobes 3–3.5 mm long, recurving. Fruits globose, 8–9 × 8–9.5 mm, with persistent calyx and sometimes with remnants of dried flowers, green turning purple when ripe; fruit wall ca. 1 mm thick; pyrenes 7–8 × 4–5 mm, seeds 5–5.5 × 4–4.3 mm.

Habitat:—In thickets at low and medium altitude, commonly seen growing in coastal areas; elevation 0–500 m.

Distribution:—Widely distributed in most islands or provinces of Luzon, Visayas and Mindanao (Fig. 20).

Phenology:—flowers: January–December; fruits: January–December.

FIGURE 19. *Ixora cumingiana.* A—budding branch; B—;inflorescence; C—infructescence. Locality of A & C: Initao-Libertad Protected Landscape and Seascape; Initao, Misamis Oriental; B: Mountain ridge behind Puerto Galera, Oriental Mindoro. Credit: Ravan Schneider (B), P.B. Pelser & J.F. Barcelona (A, C).

Notes:—*Ixora myriantha*, here treated as synonym of *I. cuminigiana*, only differs from the latter in having shorter corolla tubes. This difference however, is not convincing to separate the two species. All characters of the vegetative and reproductive parts are similar for the two species. In the protologue, Merrill was wrongly cited as the collector of the type specimen of *I. myriantha*, it should be Ramos as written in the herbarium sheets. *Ixora cumingiana* is similar with *I. barbata*, but differs by its glabrous, not barbate corolla throats.

Additional specimens examined:—PHILIPPINES. *s.loc.,* 1906, *Loher 6444* (K); *s.loc.* 9 December 1963, *Reynoso 87839* (PNH, SAN); Luzon: *s.loc.,* April 1903, *Merrill 955* (K); *s.loc.,* October 1883, *Vidal 3014* (K); **Abra:** Massisiat, 12 May 1946, *Alcasid et al. 1646* (PNH); Brgy. Maguyepyep, Sallapadan, 1996, *Fuentes & dela Rosa* 38573 (L); Banglas River, Gangal, Sallapadan, 1996, *Fuentes & dela Rosa 38678* (L); **Bataan:** Lamao River, Mt. Mariveles, July–August 1904, *Ahern 1490, 1473* (K, NY) *& 1487* (NY); So. Ulingan, Brgy. Banawang, Bagac, 17 November 1999, *Argent et al. 99305* (A, L); Lamao River, Mt. Mariveles, August 1904, *Borden 1772* (NY); Lamao River, Mt. Mariveles, September–December 1904, *Borden 1938* (K, NY); Lamao, Limay, June 2012, *Chavez & Cremen JC009* (USTH); *s.loc.,* December 1909, *Curran 19141* (P); Mt. Mariveles, November 1904, *Elmer 6658 & 6868* (K, NY); Mt. Mariveles, July 1904, *Leiberg 6104* (K); Mariveles, 5 November 1993, *5 Loher 1467* (K); Lamao River, Mt. Mariveles, October 1903, *Merrill 3174 & 3262* (K, NY, P); Lamao River, Mt. Mariveles, May 1905, *Meyer 3015* (K, NY); Lamao River, Mt. Mariveles, December 1904, *Meyer 2242* (NY, K); *s.loc.,* September 1918, *Miranda 27367* (K, P); *s.loc.,* October 1921, *Pascual 28680* (P); Lamao River, Mt. Mariveles, April 1904, *Whitford 31* (K, NY, P); *s.loc.,* 1906, *Whitford s.n.* (K); Lamao River, Mt. Mariveles, 29 October 1903, *Williams 14* (K, NY); Lamao River, Mt. Mariveles, 18 January 1904, *Williams 499* (NY); **Benguet:** Twin Peaks, May 1904, *Elmer 6329* (K, NY, P, PNH); Baguio, March 1907, *Elmer 8481* (A, K, NY); **Bicol:** Albay, 1885, *Cuming 1233* (K!, L!, MO); **Bulacan:** Mt. Biak na Bato, San Miguel, 1994, *Garcia et al. 15040* (L); Angat, February 1919, *Ramos & Edaño 34057 & 34173* (K) *& 34176* (NY); Environs Sibul Spring, 18 April 1986, *Ridsdale 1904* (L); Angat, March 1886, *Vidal 3036* (K); **Cagayan:** Lagum, vicinity of Peñablanca, 1 May–18 June 1917, *Adduru 249* (K, P); Calayan Island, Brgy. Cabudadan, Centro 2, *Fuentes & dela Rosa 38858* (L); **Catanduanes:** So. Boradan, Brgy. Summit, 8 November 1996, *Reynoso & Majaducon 24897* (K); **Cavite:** Mt. Palay-palay National Park, Ternate, 1995, *Reynoso et al. 17021* (L); **Ilocos Norte:** Mt. Palemlem, April 2013, *Alejandro et al. 13101* (USTH); Bacarra, 11 January 1955, *Castillo 35496* (K, L, PNH); Burgos, July 1918, *Ramos 32864* (P); *s.loc.,* November 1884, *Vidal 1482* (K); **Isabela:** Bo. Disulap, Sierra Madre Mountains, San Mariano, 26 April 1961, *Gutierrez 78084* (A, K, PNH); **La Union:** Sta. Rita, 14 October 1992, *Barbon et al. 8909* (A, K, L); **Laguna:** San Antonio, September–October 1912, *Ramos 16595* (K); **Manila:** *s.loc.,* 30 November 1890, *Loher 1468* (K); **Marinduque:** Hawillian, So. Maulawin, Brgy. Dampulan, Torrijos, 26 October 1996, *Romero & Chavez 29074* (K, L); **Masbate:** 7-R Ranch, Sitio Kalunukan, Brgy. Matipuron, Milagros, 12 February 1994, *Barbon et al. 12663* (A, L); Ticao Island, Mau–June 1904, *Clark 1037* (NY);

s.loc., August 1903, *Merrill 3066* (K, NY); **Nueva Ecija:** *s.loc.*, November 1908, *Laroca 14309* (P); *s.loc.*, October 1883, *Vidal 382* (K); **Occidental Mindoro:** Mt. Talim, Looc, Lubang Island, March 1979, *Reynoso & Fernando 126625* (PNH); Malingat, Brgy. Tilik, Lubang Island, 1996, *Romero & Fuentes 37492* (L); Mt. Gonting, Lubang Island, 1996, *Romero & Fuentes 37567* (L); Abra de Ilog, January 1951, *Sulit 13810* (K, L, PNH); **Oriental Mindoro:** Boliran, Naujan, 16–23 September 1947, *Celestino & Castro 1956 & 1968* (PNH); Badok, Naujan, 4 October 1947, *Celestino & Castro 1989* (K); Mt. Yagaw (Eastern Slope) Mansalay, 16 February 1953, *Conklin 17395* (PNH); Mt. Umlut (Eastern Slope) Mansalay, 5 May 1953, *Conklin 17514* (A, L, PNH); Mt. Yagaw (Eastern Slope), Mansalay, 15 September 1953, *Conklin 18747* (PNH); Budburan & Namalayan Mountains, 1–5 November 1939, *Ebalo 189* (PNH); Mt. Halcon, 29 January 1948, *Edaño 3385* (BR, PNH); Purto Galera, November–December 1925, *Ramos 46360* (NY); Sibuang R camp, San Teodoro, 12 February 1985, *Ridsdale 867* (A, K, L); **Palawan:** Sition Malbato, Kingfisher Park, Coron, 11 April 2013, *Alejandro et al. 13325* (USTH); s.*loc.*, January 1906, *Bermejos 301* (NY); Bo. Tamlang, Brooke's Point, 16 October 1990, *Cajano 53818* (CAHUP); Tawa-tawa, Quezon, 30 January 1994, *Gaerlan et al. 13392* (K); Ursula Island, 6 March 1957, *Kondo & Edaño 36554* (PNH); NW Coast between Smith and Lima points, Coron Island, 21 April 1992, *Madulid et al. 6632* (K, L); Pali, Busuanga Island, 22 April 1992, *Madulid et al. 6657* (K, L); Apulit Island, Taytay, 1995, *Madulid et al. 18519* (L); *s.loc.*, September 1925, *McGregor 45907* (NY); Mangangas, 25 April 1964, *Mendoza & Espiritu 91283* (PNH); Tamlangon Island, 30 April 1964, *Mendoza et al. 91430* (PNH, SAN); Taytay, May 1913, *Merrill 9293* (K, P); Bicawayan Island, Calamian Group, September 1922, *Ramos 41296* (PNH); Balabac Island, November 1927, *Ramos & Edaño 49892* (NY); Lipuun Limestone Hill, 11 December 1963, *Reynoso 87855* (PNH, SAN); island on Lake Manguao, c. 10 km SE of Taytay town, Taytay, 30 January 1991, *Soejarto & Fernando 7421* (A, L); Tagduan, South of Puerto Princesa on east coast, 26 January 1991, *Stone et al. 245* (K, L); Olympic Mines, north of Bivouac Point, 26 January 1991, *Stone et al. 225* (K, L); Lake Manguao, Taytay, 29 January 1991, *Stone et al. 306* (K, L); **Pangasinan:** Santiago Island, Bolinao, January 2010, *Banag BO001* (USTH); **Quezon:** Tayabas, January 1884, *Vidal 54* (L); **Rizal:** Antipolo, April 1904, *Ahern 474* (K, NY); *s.loc.*, January–March 1905, *Ahern 2432* (NY) *& 2886* (K, NY); Tayabas, Brgy. San Jose Antipolo, May 2011, *Banag AN004* (USTH); Antipolo, 12 April 1891, *Cuming 3018* (P); Rio Puray, Montalban, 15 November 1892, *Loher 1469* (K); Montalban, 15 April 1906, *Loher 6314* (K); Antipolo, June 1906, *Merrill 1311* (K, NY); Bosoboso, June 1906, *Ramos 1012* (K, NY); Mt. Santander, May–June 1907, *Ramos 3266*

(NY); *s.loc.*, October 1909, *Ramos 10886* (P); Mt. Lumutan, July 1917, *Ramos & Edaño 29710* (NY); **Zambales:** Mt. Cabangan, Butulan, December 1916, *Edaño 26846* (P); Subic, May 1903, *Merrill 2192* (K); Visayas: **Antique:** Balawarte, Brgy. Semirara Island, Caluya, 30 January 1997, *Romero & Majaducon 29455* (K, L) *& 29464* (L); Libo/Sigayan/Balibago, Brgy. Semirara Island, Caluya, 4–6 February 1997, *Romero & Majaducon 29581*, *29596*, *29611* (K, L); Palawan, Brgy. Semirara, Caluya, 1997, *Romero & Majaducon 29522* (L); **Bohol:** *s.loc.*, June 1906, *McGregor 1262* (NY); **Capiz:** Panay, October–November 1925, *Edaño 46101* (K, NY); **Cebu:** Lilo-an, 1997, *Bicknell 1207* (L); *s.loc.*, March 1912, *Ramos 11082* (K); Talamban, *s.d., s.coll. 92113* (PNH); **Davao del Sur:** Quinonoan River, March–April 1949, *Edaño 11447* (A, K, PNH, SAN) *& 11469* (L, PNH, SAN); Pujada Island, 29 April 1949, *Edaño 11660* (A, L, PNH); Mt. Apo**,** Todaya, July 1909, *Elmer 11097* (K, NY); Sta. Maria, *s.d.*, *Lemana BL005* (USTH); Coronan valley near Santa Cruz, April 1964, *s. coll. 1612* (A, K, L); **Guimaras:** Buenavista-vicinity of Bo. Salvacion, 25 February 1950, *Sulit 11709* (A, L, PNH, SAN); Between Negros and Panay, March 1886, *Vidal 3031* (K); **Iloilo:** *s.loc.*, March 1886, *Vidal 3012* (K); **Northern Samar:** Capul, 27 March 1957, *Kondo & Edaño 36823* (PNH); Catubig River, February–March 1916, *Ramos 24539* (K, L, NY, P); Mindanao: **Sulu:** Mt. Cabucan, January–February 1957, *Kondo & Edaño 38875* (K, PNH) *& 38878* (PNH); Mambahenauhan Islet 35 miles south of Cagayan de Sulu, 1950, *Santos 4712a* (L); Tarawan Beach, Jolo, 18 February 1957, *Kondo & Edaño 39041* (PNH); **Surigao del Norte:** Poneas Island, Sitio Dabo, Sunkoi Hill, 1993, *Stone et al. 9432* (L); **Tawi-tawi:** Sitankai, Tumindao Sibutu Island, 6–16 August 1931, *Herre 1208* (NY); *s.loc.*, July–August 1924, *Ramos & Edaño 44088*, *44103 & 44214* (NY).

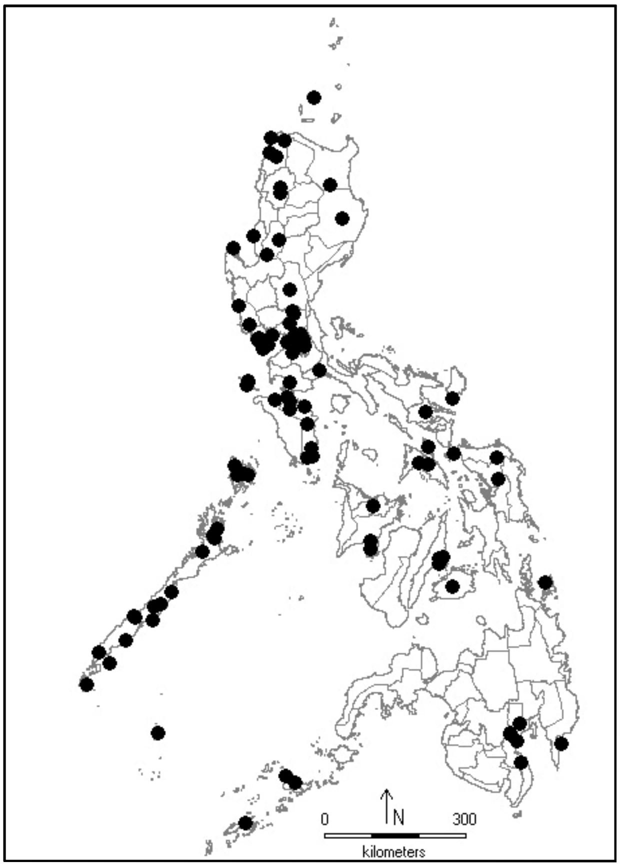

FIGURE 20. Distribution of *I. cumingiana*.

11. *Ixora ebracteolata* Merrill (1910: 234) (Fig. 21).

Type:—PHILIPPINES. Luzon: Zambales: Mahumaling, January 1907, *Curran 5845* (holotype PNH, destroyed; lectotype US! 706026, **here designated**, isolectotype NY!).

Shrub 2–4 m tall or tree 5–8 m tall; young internodes reddish-brown, older internodes brown to gray; all external parts glabrous except the peduncle, inflorescence axes, pedicels, ovaries and calyces sparsely to moderately covered with very short erect trichomes. Stipules persistent, sheath triangular, 1.5–3 mm long, awn 2–4 mm long. Leaves with petioles 0.5–1 cm long; blades oblong to oblong elliptic, 6–12 × 2.5–5 cm, subcoriaceous to thickly coriaceous, drying brown above, paler brown below; apex obtuse, rounded, or broadly and obtusely short acuminate; base acute or cuneate; secondary veins ca. 10 each side. Inflorescence terminal, multiflorous, erect, trichotomously branched, non-articulate throughout, moderately compact, 2–3.5 × 4–5.5 cm; one pair of modified inflorescence-supporting leaves present, subsessile, blades similar in shape to vegetative leaves but smaller, 1–3 × 0.5–3 cm; peduncle 2–7 cm long; central first order axis 0.5–5.5 cm long, lateral first order axes 1–4.5 cm long; first and higher order with stipular parts absent and foliar parts reduced or absent. Ultimate flower triads with flowers subsessile or pedicellate; pedicels of lateral flowers 0.5–3(–8) mm long, central flower sessile or with pedicels 0.5–3(–6) mm long. Flowers with ovary and calyx reddish, corolla filaments and style white, stigma and anthers yellowish; flower bud with acute apex; bracteoles usually absent or very reduced on most pedicels; calyx tube 0.5–0.8 mm long; calyx lobes triangular, apices shortly-toothed or acute, their bases not overlapping; corolla tube 5–15 mm long; corolla lobes elliptic-oblong, 2–5 × 1–3 mm, apices acute or slightly acuminate; filaments ca. 1 mm long, anthers 2–3 mm long; style exserted from corolla tube for 4–5 mm, stigmatic lobes 0.5–0.8 mm long, spreading. Fruits globose, 4–7 × 5–7.5 mm, with persistent calyx, red when ripe; fruit wall 0.5–1 mm thick; pyrenes 3–6 × 2.5–4 mm, seeds 1–2.5 × 1–2 mm.

Habitat:—Forests, on slopes or on high canopy or streamside forests, with ultramafic soil; elevation 50–650 m.

Distribution:—In the provinces of north, central and southern Luzon (Fig. 17).

Phenology:—Flowers: January–May, December; fruits: January, March–June, November–December.

Notes:— *Ixora ebracteolata* is strongly characterized by its bracts and bracteoles that are reduced or entirely absent.

Additional specimens examined:— PHILIPPINES. Luzon: **Cagayan:** *s.loc.*, April 1910, *Bernardo 15480* (P); **Camarines Norte:** Mt. Kadig, 18 June 1959, *Edaño 40473* (PNH); **Isabela:** Palanan Bay, June 1913, *Escritor 21132* (US); *Escritor 21166* (K, P, US); Diguyo, 24 April 1991, *Ridsdale et al. 136* (A, K, L); Dimapnat, Palanan, 13 April 1992, *Ridsdale et al. 513* (K); Digallorin, Divinisa camp site, 8 April 1992, *Ridsdale et al.* (A, CAHUP, L, P); **Pangasinan:** Mt. San Isidoro Labrador, November 1917, *Fenix 30002* (P); **Quezon:** Guinayangan, Tayabas, March–April 1913, *Escritor 20712 & 20773* (US); **Romblon:** Mt. Giting-giting, Magallanes, Sibuyan Island, April 1910, *Elmer 12335* (K, L, NY, US); 10 December, *Reynoso et al. 21579* (K, L); **Zambales:** Pamiraogan, Masinloc, March 1977, *dela Cruz & Fernando 123523* (PNH); Mt. Canaynayan, Castillejos, December 1916, *Edaño 26831* (P); Botolan, May 1903, *Merrill 2953* (US); June 1903, *Merrill 2985* (K. NY, US); Subic and vicinity, April 1903, *Merrill 2080* (US); *s.loc.*, November–December 1907, *Ramos 4798 & 5038* (US); Mt. Tapulao, November–December 1924, *Ramos & Edaño*

FIGURE 21. *Ixora ebracteolata (Curran 5845)* (US, lectotype).

44749 (NY, P); Masinloc, Coto Mines, Coral, 5 February 1992, *Reynoso et al. 4224* (K, L);Acoje Mine concession area Sta Cruz, 23 May 1986, *Ridsdale 1443* (A, L); 22 May 1988, *Ridsdale 1387* (A, L); 1965, *Rojo 19* (L); 22 July 1964, *Valbuena & Lopez 91890* (PNH); Infanta, March 1986, *Vidal 3034* (K); Sta. Cruz, March 1884, *Vidal 1619* (K); *s.loc.*, March 1886, *Vidal 3034* (K).

12. *Ixora filipes* Valeton (1913: 359) (Fig. 22).

Type:—INDONESIA. Celebes: Monte Lolomboelan prope Pakoe-oere, February 1895, *Koorders 18710* (lectotype L!, **here designated**).

Remaining syntypes of *I. filipes***:—**INDONESIA. Celebes: Monte Lolomboelan prope Pakoe-oere, February 1895, *Koorders 18715 & 18668* (not seen).

= *Ixora tenuipedunculata* Merrill (1921a: 321). **Type:—**PHILIPPINES. Mindanao: Surigao: *s.loc.*, 30 April 1919, *Ramos & Pascasio 34475* (holotype PNH, destroyed; lectotype US!, **here designated**; isolectotype A!), *syn.nov.*

= Ixora gracilipes Merr. *nom. illeg.* (ICN Art. 53) **Type:—**PHILIPPINES. Luzon: Quezon: Mt. Cadig, Guinayangan, March 1913, *Escritor 20723* (holotype PNH, destroyed; lectotype K!, **here designated**).

= Ixora oligantha Merrill. non. Schltr. & K.Krause *nom. nud.* (ICN Art. 38).

Shrub or small tree 2–5(–8) m tall; young internodes olivaceous, terete, older internodes brown; all external parts glabrous. Stipules subpersistent, sheath broad, subtruncate, 1–1.5 mm long, awn 3–5 mm long. Leaves with petioles 0.2–0.5 cm long; blades oblong, lanceolate or oblanceolate, 6–13 × 1.8–3.5 cm, chartaceous to coriaceous, drying brown above, paler brown below; apex obtuse, acute or slightly acuminate (acumen 0.3–0.5 cm long); base acute to cuneate; secondary veins 7–13(–20) each side, spreading at nearly right angles, obscure, the reticulations lax. Inflorescences terminal or axillary, uniflorous or more often 3(–9) flowered, erect, articulate throughout, lax; modified inflorescence-supporting leaves usually absent (seen once and then less than 1 cm long); peduncle 5–6 cm long, very slender; central first order axis 1.2–1.5 cm long, lateral first order axes 1.2–2.5 cm long; first order bracts with stipular parts absent and foliar parts narrowly triangular, up to 1 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular, up to 0.8 mm long. Ultimate flower triads with flowers pedicellate; pedicels 2–10 mm long, pedicels of central flower either as long as or shorter than the pedicels of the lateral ones. Flowers with corolla pink; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular, apices acute, 0.5–1 mm long, reaching the middle of the ovary; calyx tube 0.2–0.8 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube 10–25 mm long; corolla lobes linear-lanceolate, 8–10 × 1–2 mm, apices acute; filaments ca. 1 mm long, anthers 1.5–2 mm long; style exserted from corolla tube for 0.5–1 mm, stigmatic lobes 1–1.5 mm long, erect or spreading. Fruits globose, 7–8.5 × 6–10 mm, with persistent calyx, red when ripe; mature seeds unknown.

Habitat:—Forests on slopes or ridges; elevation 80–1066 m.

Distribution:—North Sulawesi to Philippines particularly in the eastern provinces, Camarines Norte and Quezon in Luzon, Eastern Samar and Western Samar in Visayas, Agusan del Norte and Surigao del Norte in Mindanao (Fig. 23).

Phenology:—Flowers: February–May; fruits: March–May, November–December.

Notes:—*Ixora filipes* is strongly characterized by its uniflorous or 3(–9) flowered inflorescences that are terminal or axillary and the very slender peduncles.

Additional specimens examined:—PHILIPPINES. Luzon: **Camarines Norte:** Paracale, November–December 1918, *Ramos & Edaño 33644* (A); **Quezon:** Mapatong, Tagkauayan, 21 May 1959, *Lagrimas 39428* (A, PNH); Malbog, Tayabas, January 1929, *Oro 30686* (NY); Alabat Island, September–October 1926, *Ramos & Edaño 47984* (NY); Visayas: **Eastern Samar:** Western Samar: Mt. Sohoton, 1970, *Gutierrez et al. 117594* (L); Samar: *s.loc.,* April 1914, *Ramos 1699* (A, NY, P); So. Kansulabau, Concord, 14 May 1948, *Sulit et al. 6371* (A, BR, PNH); Mindanao: **Agusan del Norte:** Mt. Hilong-hilong Cabadbaran, 13 April 1949, *Mendoza & Convocar 10743* (PNH); **Surigao del Norte:** Sukailang, 2 March 1949, *Mendoza & Convocar 10241* (A, PNH); 26 February 1949, *Mendoza & Convocar 10259* (A, L, PNH, SAN).

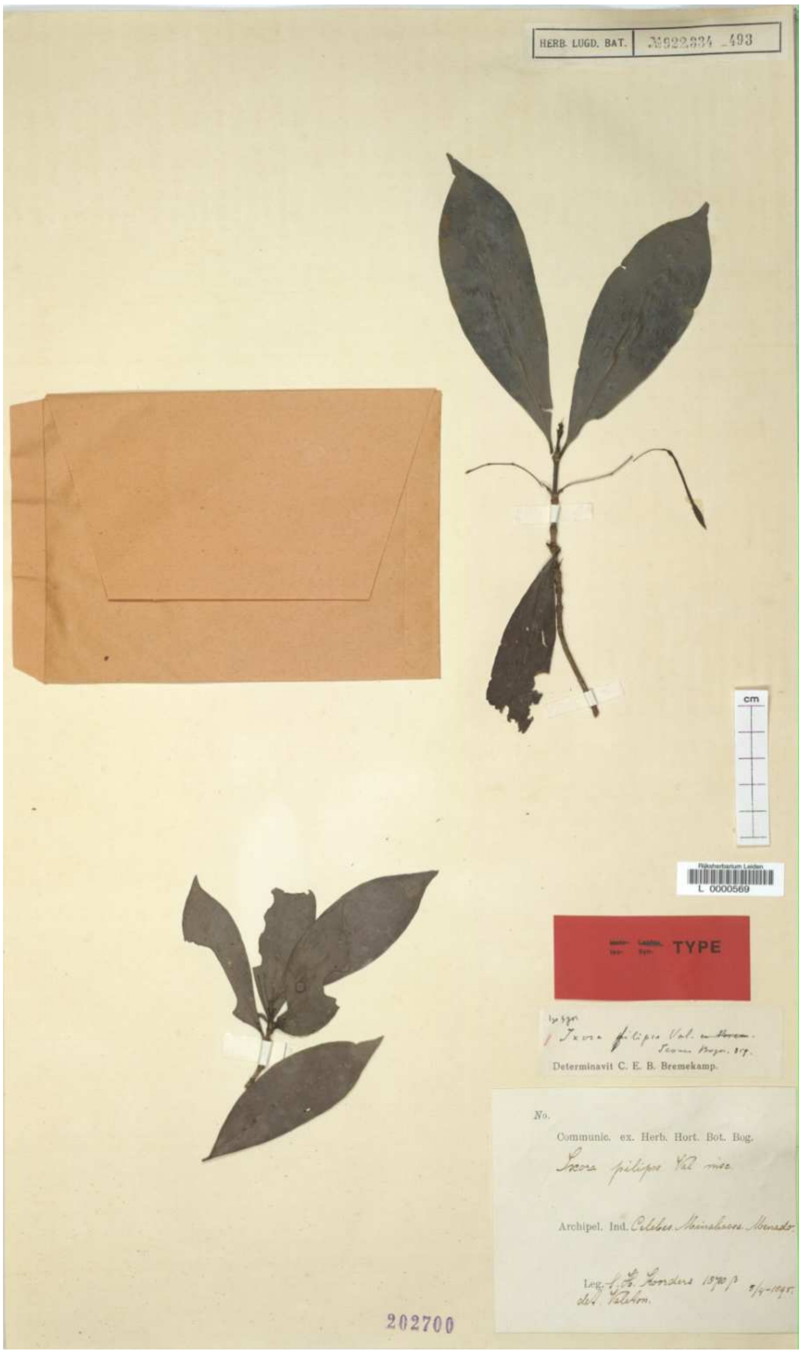

FIGURE 22. *Ixora filipes (Koorders 18710)* (L, isotype).

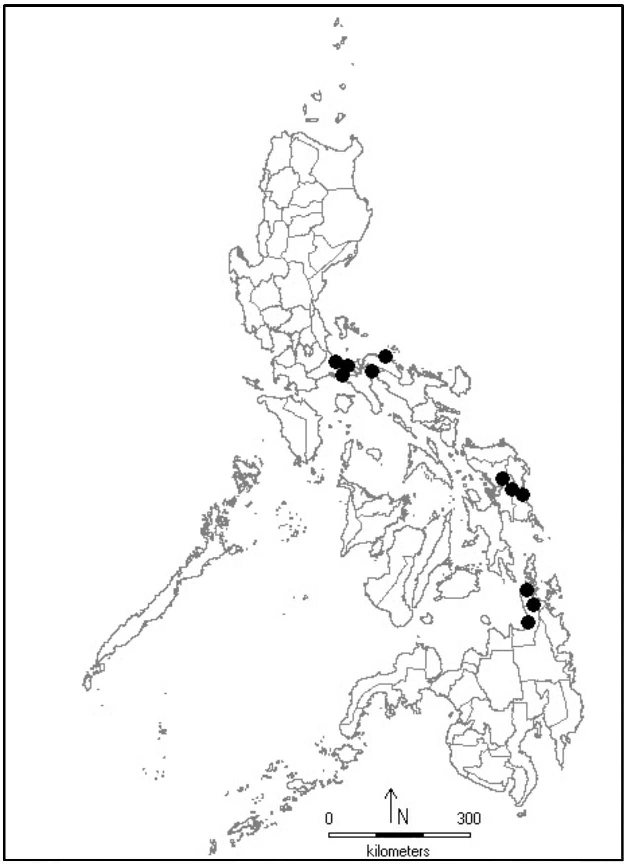

FIGURE 23. Distribution of *I. filipes*.

13. *Ixora gigantifolia* Elmer (1913: 1864) (Fig. 24).

Type:—PHILIPPINES. Mindanao: Agusan del Norte: Mt Urdaneta, Cabadbaran, October 1912, *Elmer 14206* (holotype PNH, destroyed; lectotype US!, **here designated**; isolectotype A!, K!, L!, MO, NY!, P!).
= *Ixora platyphylla* Merrill (1915: 120). **Type:—**PHILIPPINES. Mindanao: Sarangani: Glan, June 1912, *Miranda 18250* (not traced).

Shrub or small tree 2.5–7 m tall; young internodes brown or grayish white, terete, older internodes grayish or fawn; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas moderately to densely covered with very short erect trichomes. Stipules caducous. Leaves with petioles 1.5–2 cm long; blades oblong, 17–30 × 6.5–14 cm, chartaceous or subcoriaceous, drying reddish brown above, paler brown below; apex rounded or obtuse; base rounded; secondary veins ca. 10 each side, prominent on the lower side only. Inflorescence terminal, subsessile or shortly pedunculate, divaricately branching, non-articulate throughout, lax to moderately compact, 4–6 × 5–10 cm; modified inflorescence-supporting leaves absent; peduncle 1–5 cm long, yellowish green; central first order axis 1.5–9 cm long, lateral first order axes 1.5–8.5 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and foliar parts forming small leaves; higher order bracts with stipular parts reduced or absent and foliar parts triangular and vaulted. Ultimate flower triads with flowers pedicellate; pedicels 1–1.5 mm long, pedicels of the central flower as long as or shorter than the pedicels of lateral ones. Flowers with corolla white; flower bud with acute apex; bracteoles usually absent on most pedicels if present then opposite at the base of the ovary or on pedicels, narrowly triangular to filiform, apices acute to acuminate, ca. $\leq$ 1 mm long, reaching at most the base of the ovary; calyx tube 0.5–0.8 mm long; calyx lobes ovate, apices rounded, their bases sometimes overlapping; corolla tube 4–10 mm long; corolla lobes elliptic, 4–5 × 1–2 mm, apices acute; filaments ca. 1 mm long, anthers 4–5 mm long; style covered with long spreading trichomes, exserted from corolla tube for 1–2 mm, stigmatic lobes 3–3.5 mm long, spreading. Fruits subglobose, 4–7 × 5–8 mm, with persistent calyx, red when ripe; fruit wall ca. 1 mm thick; mature seeds unknown.

Habitat:—In dry or well drained soil along the forested ridge; elevation 80–1100 m.

Distribution:—Restricted in Mindanao in Basilan, Dinagat Island and Surigao del Norte (Fig. 25).

Phenology:—Flowers: February–May; fruits: March–May, November–December.

Notes:— *Ixora gigantifolia* is similar to *I. bartlingii* in the shape and texture of the leaves but strongly differs in the inflorescences which are shortly pedunculate or subsessile, first order bracts with stipular and foliar parts present and the latter forming small leaves. Another species with comparatively large leaves and similar characters of the first order bracts is *I. crassifolia* but this species can be distinguished from *I. gigantifolia* in having rigidly coriaceous leaves and higher order bracts being absent.

Additional specimens examined:—PHILIPPINES. Mindanao: **Basilan:** UP Land Grant, Isabela, 28 October 1953, *Britton 19713* (PNH); **Dinagat Island**: *s.loc.*, June 1931, *Ramos & Convocar 84048* (A); **Surigao del Norte:** Siargao Island, June 1919, *Ramos & Pascasio 35007* (A, K, P, US).

FIGURE 24. *Ixora gigantifolia (Elmer 14206)* (US, lectotype).

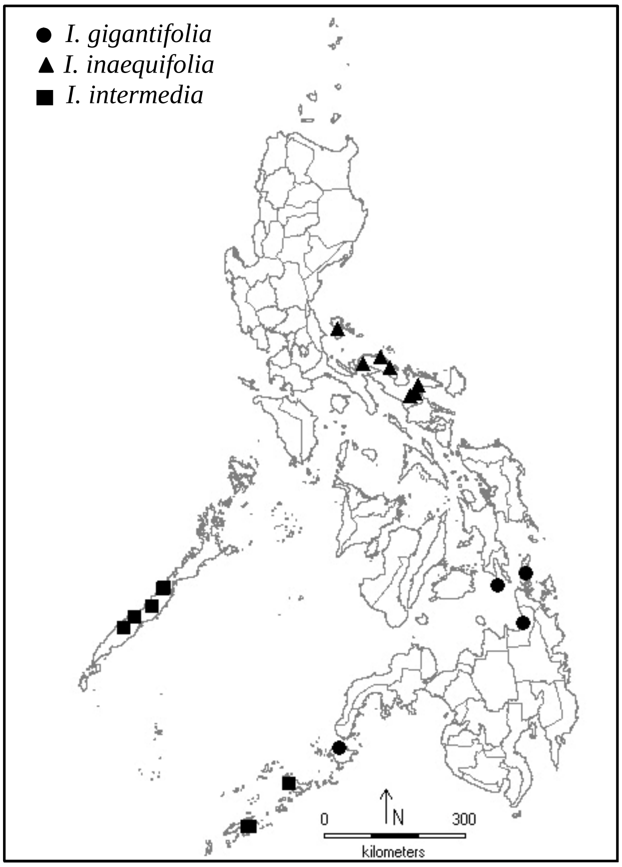

FIGURE 25. Distribution of *I. gigantifolia*, *I. inaequifolia* and *I. intermedia.*

14. *Ixora inaequifolia* Robinson (1911: 222) (Fig. 26).

Type:—PHILIPPINES. Luzon: Quezon, Polillo Island, *s.d.*, *MacGregor BS 10216* (holotype PNH, destroyed). —PHILIPPINES. Luzon: Camarines Sur: Panagan River, December 1928, *Edaño76461* (neotype NY!, **here designated**).

Shrub 1–3 m tall; young internodes flattened, brown, older internodes subterete, brown to grayish-brown; all external parts glabrous. Stipules persistent, sheath subtruncate, 1–1.5 mm long, awn 1.5–2 mm long. Leaves sessile; blades oblanceolate or oblong, 12.5–25 × 3–6.5 cm, chartaceous to subcoriaceous, drying drown above, paler brown below; apex acuminate (acumen 5–8 mm long); base auricled or cordate; secondary veins 15–20 each side. Inflorescences terminal, pendulous or shortly pedunculate, trichotomously branched, articulate throughout, lax, 3–8 × 5–7 cm; one pair of modified inforescence-supporting leaves present, subsessile, blades elliptic to ovate, 7–8 × 3–3.5 cm, apices acute, base cordate; peduncle 1–8 cm long; central first order axis 0.8–1.5 cm long, lateral first order axes 0.5–1.8

cm long; first order bracts with stipular parts and foliar parts narrowly triangular, up to 2 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular or linear, up to 5 mm long. Ultimate flower triads with flowers pedicellate; pedicels 2–4 mm long, pedicels of the central flower as long as or shorter than the pedicels of the lateral ones. Flowers with ovary and calyx reddish, corolla white; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular, apices acute, 1–1.5 mm long, reaching the middle of the ovary or base of the calyx tube; calyx tube 0.5–1 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube 3–10 mm long; corolla lobes lanceolate, 4–4.5 × 1–2 mm, apices acute. Fruits subglobose, 6–7.5 × 8–9 mm, with long persistent calyx up to 5 mm long, white to pink when ripe; fruit wall ca. 1 mm thick; pyrenes 4–6 × 3–4 mm, seeds 3–4 × 2–3 mm.

Habitat:—On slopes in secondary or mossy forests; elevation 50–2300 m.

Distribution:—In southern Luzon particularly in the provinces of Camarines Sur, Camarines Norte and Quezon (Fig. 25).

Phenology:—Flowers: June, November, December; fruits: October–December.

Notes:— *Ixora inaequifolia* has much similarity with *I. auriculata* but differs strikingly by the presence of the smaller leaves that are oblanceolate, bracts and bracteoles narrowly triangular with acute tip and with the stipular parts of the first order bracts absent. One specimen (*Castro & Annonuevo 6507*) was collected from Pollilo Island, the same area where the original and lost type specimen of *I. inaequifolia* was collected. However it is sterile and cannot serve as the neotype. Instead, *Edaño76461* collected from Camarines Sur was selected as the neotype since it contains mature fruits showing the unusual long persistent calyx. All, other specimens studied are sterile or have immature flowers, thus the description of the flowers is incomplete and are only based on collector's notes.

Additional specimens examined:—PHILIPPINES. Luzon: **Camarines Norte:** Mt. Kadig, 17 June 1959, *Edaño 40191* (PNH); Paracale, November–December 1918, *Ramos & Edaño 33704* (P); Basud Tuaca, Mt. Nilisan, 11 November 1991, *Reynoso et al. 1358* (A, K, L); Bicol National Park, 21 November 1991, *Reynososo et al. 3678* (A); **Camarines Sur:** Mt. Potianay, November 1928, *Edaño 75966 & 75982* (NY); Sarapan, October 1928, *Edaño 76173* (NY); **Quezon**: Anibawan, Polillo Island, 4 December 1958, *Castro & Anonuevo 6507*.

FIGURE 26. *Ixora inaequifolia (Edaño 76461)* (NY, neotype).

15. *Ixora intermedia* Elmer (1912: 1336) (Fig. 27).

Type:—PHILIPPINES. Luzon: Palawan: Mt. Pulgar, Puerto Princesa, April 1911, *Elmer 12957* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotypes A!, K!, L!, MO, US!).
= *Ixora brachyantha* Merr. **Type:—**MALAYSIA. Sabah: Tawao, Elphinstone Province, British North Borneo, March 1923, *Elmer 21012* (holotype (not traced); isotypes A!, BR!, K!, L!, NY!, P!) *syn. nov.*

Shrub 2.5–4 m tall or tree 5–14 m tall; young internodes grayish; all external parts glabrous except for the inflorescence axes and pedicels moderately to densely covered with very short erect trichomes. Stipule caducous. Leaves with petioles 0.7–1 cm long; blades elliptic, widely elliptic or oblong elliptic, 11–23 × 4–10.5 cm, chartaceous to subcoriaceous, pale olivaceous, shining above, paler below, drying brown or dark brown above, paler brown below; apex obtuse or acuminate (acumen 0.5–1 cm long); base acute or acuminate, rarely obtuse; secondary veins 10–12 each side. Inflorescences terminal, multiflorous, sessile or pedunculate, divaricately spreading; non-articulate throughout, lax to moderately compact, (2–)10–15 × (4–6)18–20 cm; modified inflorescence-supporting leaves absent; peduncle 5–8 cm long; central first order axis 1–9 cm long, lateral first order axes 1–8 cm long; first order bracts with stipular parts absent and the foliar parts forming small leaves; higher order bracts with stipular parts absent and foliar parts triangular and vaulted. Ultimate flower triads with flowers subsesile or shortly pedicellate; pedicels of lateral flowers 0.5–1 mm long, central flower sessile or with pedicels $\leq$ 0.5 mm long. Flowers with ovary and calyx red sometimes green, corolla white, corolla tube white sometimes reddish, style, stigma, filaments and anthers white; flower bud with rounded to acute apex; bracteoles present on most pedicels, sub-opposite at the base of the ovary, apices acuminate, narrowly triangular to filiform, 1–2 mm long, reaching the middle of the ovary; calyx tube 0.5–1 mm long; calyx lobes triangular to ovate, apices acute or rounded rarely subtruncate, their bases sometimes overlapping; corolla tube 5–7(–10) mm long; corolla lobes elliptic or oblong, 1.5–3.5(–5) × 2.8–3.5 mm, apices acute or rounded; filaments ca. 1 mm long, anthers 1–2 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 0.5–1.5 mm long, spreading. Fruits subglobose, 8–8.5 × 7–10 mm, with persistent calyx, green turning light pink to red when ripe; fruit wall ca. 1.5 mm thick; pyrenes 6–6.5 × 5–8 mm, seeds 3–4 × 2.5–4 mm.

Habitat:—In dense dry forests at low and medium altitudes; elevation 50–700 m.

Distribution:— Restricted to the Philippines to the islands of Palawan and Tawi-tawi (Fig. 25). Also growing in Malaysia and Indonesia.

Phenology:—Flowers: March, August–December; fruits: March, April, July, August.

Notes:—*Ixora intermedia* is only recorded to be present in Palawan from Luzon and Tawi-tawi from Mindanao, this is not surprising as these two islands are very close to Sabah, Malaysia, where this species probably has its origin. *Ixora brachyantha*, here treated as synonym of *I. intermedia*, was described by Merrill (1929) based from a specimen collected from Sabah, but also cited in the protologue specimens collected from Balabac Island, Palawan. According to Merrill, this species is characterized by its unusually short flowers, reflexed corolla lobes being about one-half as long as the tube.

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Brgy. Simpocan, Puerto Princesa, 1992, *Horgen 23 & 405* (L); Brgy. Bundog, Quezon, 1996, *Pipoly et al. 38087, 38185, 38187* (L), *38095* (A, K, L, NY) *& 38184* (K, L); Balabac Island, November 1927, *Ramos & Edaño 49685* (BR!, NY!); Brgy. Underground, Quezon, March 1964, *Reynoso 87849* (L, PNH); Sitio Ladayon, Brgy. Saurigan, Quezon, 30 May 1995, *Soejarto et al. 9196* (A, L); Mindanao: **Sulu:** Siasi, Jolo, 5 February 1957, *Kondo & Edaño 38945* (A, PNH); **Tawi-tawi:** Birad-dali (Angel), Languyan, 27 May 1992, *Gaerlan & Sagcal 10132* (K, L); Seratang Languyan, 30 May 1992, *Gaerlan & Sagcal 10220* (K, L); *s.loc.*, January–February 1957, *Kondo & Edaño 38901* (A, PNH); Tarawakan, 15 November 1961, *Olsen 779* (C).

—INDONESIA. W. Koetai, bij hikam Batoe Bong, 28 July 1925, *Endert 2261* (NY), 10 August 1925, *Endert 2451* (NY); S. Kahayan, 20 April 1988, *Burley et al. 735* (NY); Membakut, August 1928, *Tahir 1180* (NY).

—MALAYSIA. Sabah: Sandakan, 28 April 1928, *Allen 623* (NY); Sandakan, Myburgh Province, October–December 1921, *Elmer 20093* (NY!); Tawao, Elphinstone Province, *s.d.*, *Elmer 20411* (NY); Tawao, Elphinstone Province, October–March 1923, *Elmer 20941* (L!, NY!).

.

FIGURE 27. *Ixora intermedia (Elmer 12957)* (NY, lectotype).

16. *Ixora leucocarpa* Elmer (1912: 1337) (Fig. 28).

Type:—PHILIPPINES. Luzon: Palawan: Mt. Pulgar Puerto Princesa, March 1911, *Elmer 12894* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotypes A!, K!, L!, MO, US!).

Shrub 1–3 m tall; young internodes brown, terete, older internodes grayish; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas sparsely covered with very short erect trichomes. Stipules persistent, sheath subtruncate, 1–1.5 mm long, awn 2–4 mm long. Leaves with petioles 0.5–1.5 cm long; blades obovate, ovate or the smaller ones oblong or oblanceolate, 8–23 × 4–8 cm, coriaceous, deep green above, much paler beneath, unequally dull brown when dry; apex acute or roundly obtuse; base cuneate or obtuse; secondary veins 5–9 each side. Inflorescences terminal, pedunculate, trichotomously branched, non-articulate throughout, moderately compact, 1–2 × 1.5–2 cm; one pair of modified inflorescence-supporting leaves present preceeded by a shorter internode, subsessile, blades elliptic, 0.6–1.5 × 0.2–0.5 cm; peduncle 2–5 cm long; central first order axis 2–3 mm long, lateral first order axes 1.5–3 mm long; first order bracts with stipular parts absent and foliar filiform or narrowly triangular, 1 mm long or less; higher order bracts with stipular parts absent and foliar parts filiform, 1 mm long or less. Ultimate flower triads with flowers subsessile or shortly pedicellate; pedicels 0.5–2 mm long. Flowers with corolla white; flower bud with rounded apex; bracteoles usually absent, if present then on pedicels, filiform, 1 mm long or less, reaching the base of the ovary; calyx tube 0.5–1 mm long; calyx lobes widely triangular or ovate, apices obtuse, their bases not overlapping; corolla tube 10–15 mm long; corolla lobes rounded to ovate, 3–4.5 × 3.5–4 mm, apices rounded; filaments ca. 1 mm long, anthers 3–3.5 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 1–1.5 mm long, erect or spreading. Fruits subglobose, 5.5–7.5 × 7.5–8.5 mm, with persistent calyx, whitish when ripe; mature seeds unknown.

Habitat:—In secondary forests along rivers or streams; elevation 70–300 m.

Distribution:— Known only from Palawan (Fig. 29).

Phenology:—Flowers: March; fruits: February, March, May.

Notes:—According to Elmer (1912) *Ixora leucocarpa* is related to *I. crassifolia*. *Ixora leucocarpa* differs from *I. crassifolia* in having subtruncate stipules, smaller corolla lobes and absence of the stipular parts on first and higher order bracts.

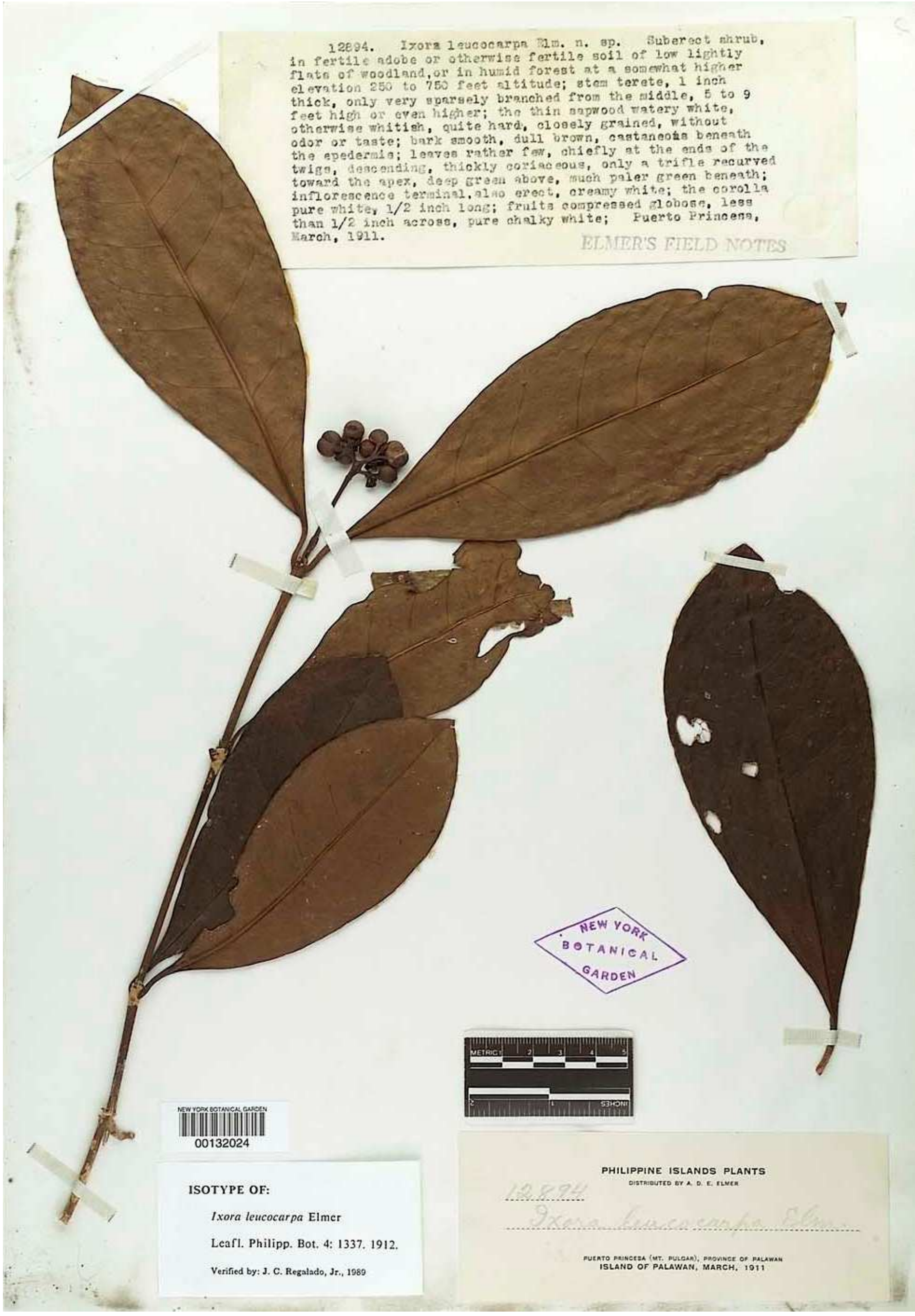

FIGURE 28. *Ixora leucocarpa (Elmer 12894)* (NY, lectotype).

Additional specimens examined:—PHILIPPINES: Luzon: **Palawan:** Lapu-lapu River, Iwahig, Puerto Princesa, May 2011, *Banag I010* (USTH); Bindoyan, Puerto Princesa, 4–8 March 1940, *Ebalo 605* (A, PNH); Lapu-lapu River, Iwahig, Puerto Princesa, 3 March 1947, *Edaño 273 & 301* (PNH); 4 March 1947, *Edaño 323* (A, PNH); 5 March 1947, *Edaño 283* (PNH); Iwahig River, Puerto Princesa, 18 February 1903, *Merrill 738* (NY, US); Montible Penal Colony Iwahig, Puerto Princesa, August 1976, *Vendivil & Reynoso 123003* (PNH).

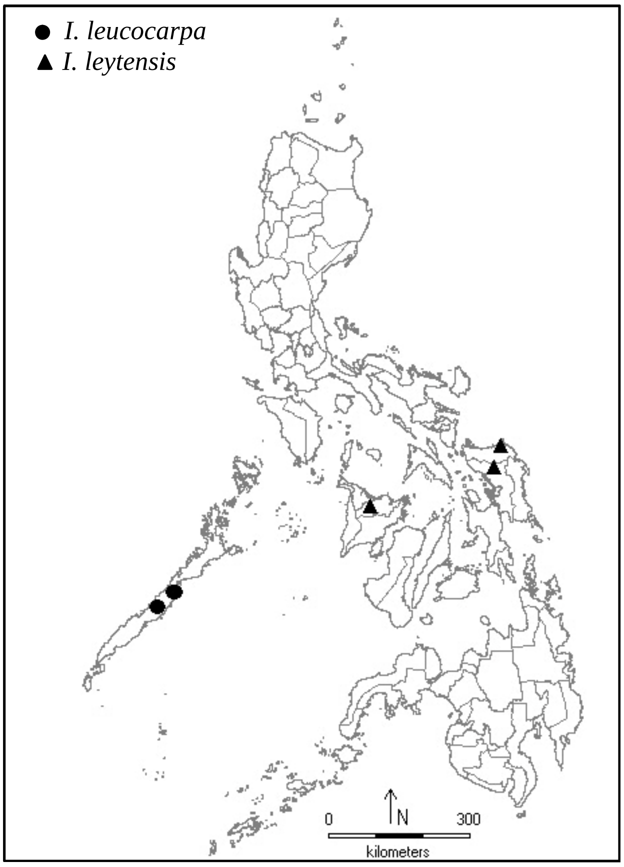

FIGURE 29. Distribution of *I. leucocarpa* and *I. leytensis.*

17. *Ixora leytensis* Elmer (1906: 69) (Fig. 30).

Type:—PHILIPPINES. Visayas: Leyte: Palo, January 1906, *Elmer 7044* (holotype PNH, destroyed).—PHILIPPINES. Visayas: Samar: Mt. Sarawag, 4 December 1951, *Edaño 15287* (neotype PNH!, **here designated**; isoneotype A!, L!).

Shrub 3–4 m tall; young internodes grayish; young twigs, lower surface of the leaves, petioles, peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas moderately to densely covered with short trichomes. Stipules caducous; sheath triangular, 1–1.5 mm long, awn 8–10 mm long (visible only on young stipule pairs). Leaves with petioles 1–2 cm long; blades oblong, elliptic, the smaller ones obovate , 9–24 × 2–7(–9.5) cm, membranous to chartaceous, drying brown above, paler brown below; apex obtuse, acute or shortly acuminate; base narrowed obtuse or acute; secondary veins 10–15 each side. Inflorescences terminal, shortly pedunculate, trichotomously branched, the branches spreading at right angles, articulate throughout, lax, 1.5–2.5 × 2.5–7 cm; one pair of modified inflorescence supporting leaves present, subsessile (petioles $\leq$ 0.5 cm); peduncle 2–9 cm long; central first order axis 0.3–1.5 cm long, lateral first order axes 2–3 cm long; first order bracts with stipular parts absent and foliar parts widely triangular, 3–3.5 mm long; higher order bracts with stipular parts absent and foliar triangular, 2–2.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 2–5 mm long, central flower with pedicels as long or as shorter than the pedicels of the lateral ones. Flowers corolla white tinged with pink; flower bud with rounded apex; bracteoles present on most pedicels, opposite at the base of the ovary, triangular, apices acute, 1 mm long or less, reaching the base of the ovary; calyx tube ca. 0.5 mm long; calyx lobes shortly apiculate to truncate, their bases not overlapping; corolla tube 3–10 mm long; corolla lobes ovate, 3–4 × 1.5–2 mm long, apices rounded; filaments ca. 1 mm long, anthers 3–3.5 mm long; style exserted from corolla tube for 2–2.5 mm, stigmatic lobes 2–3 mm long, spreading. Fruits subglobose, 9–10 × 7–8 mm, with persistent calyx, red when ripe; fruit wall ca. 1 mm thick; pyrenes 6–7 × 4–4.5 mm; seeds 5–6 × 3–3.5 mm.

Habitat:—Ravines or along forested ridges; elevation ca. 100–500 m.

Distribution:—In Visayas, Capiz, Leyte and Samar (Fig. 29).

Phenology:—Flowers: February–March, December; fruits: April–May.

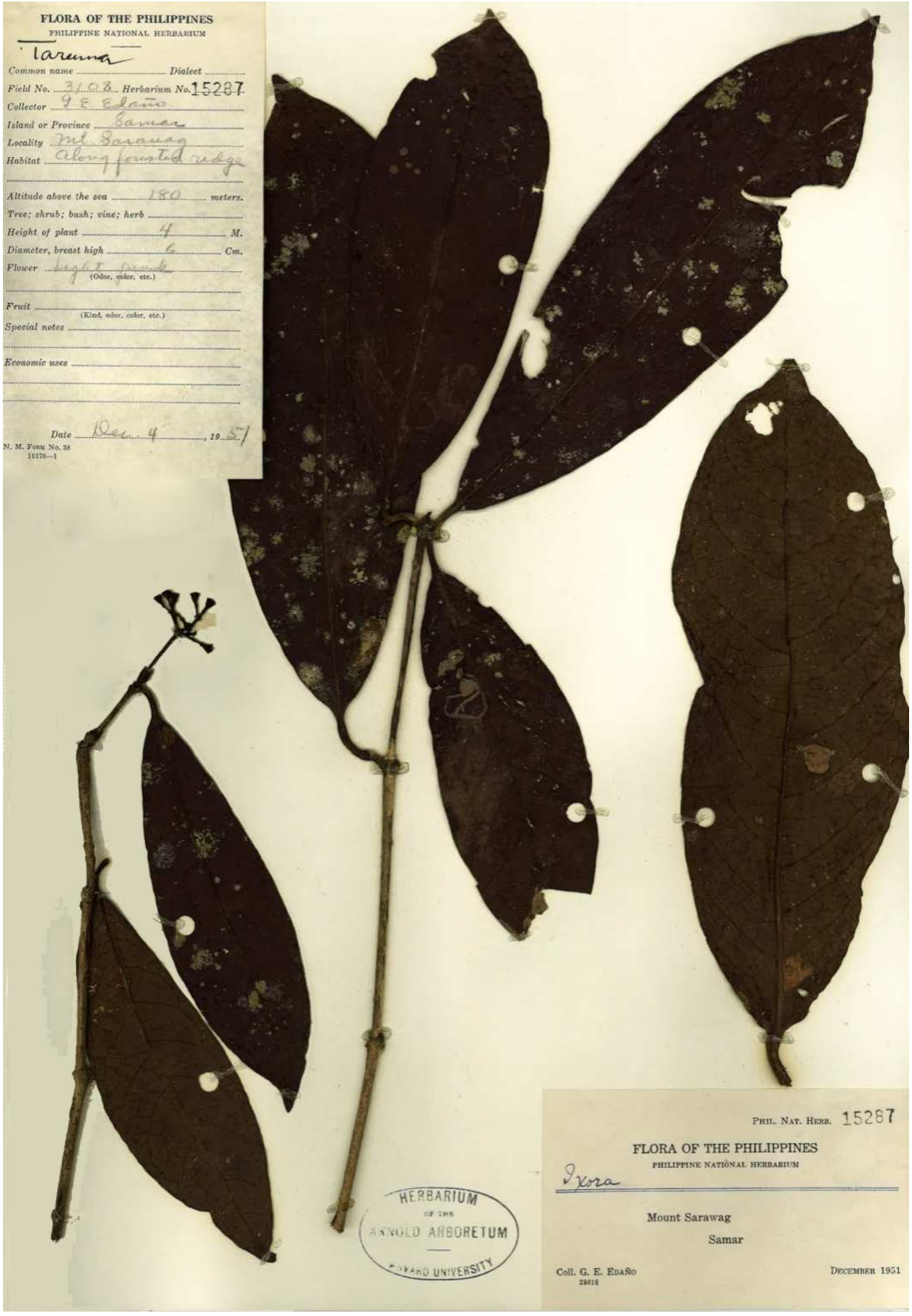

FIGURE 30. *Ixora leytensis* (*Edaño 15287*) (A, isoneotype).

Notes:—*Ixora leytensis* differs from all other Philippine *Ixora* species in its pubescence particularly the puberulent young stem, petioles and underside of the leaves. The holotype of *I. leytensis* was destroyed in PNH during the World War II and no isotypes can be traced, however the protologue perfectly matches one specimen (*Edaño 15287*) collected from Samar and is designated as the neotype of *I. leytensis.* This species is very similar with *I. bartlingii* but differs in the pubesence of the internodes, leaves and petioles, caducous stipules with sheath triangular, ovate corolla lobes, and higher order bracts with stipular parts absent.

Additional specimens examined:—PHILIPPINES. Visayas: **Capiz:** Jamindan, April–May 1918, *Ramos & Edaño 31021* (A); **Northern Samar:** Catubig River, February–March 1916, *Ramos 24212*.

18. *Ixora longifolia* Smith (1811:3) (Fig. 31).

Type:—INDONESIA. Island of Honimoa, 1797, *Smith s.n.* (lectotype LINN [microfiche], designated by Turner (2013); isolectotype BM).
=Ixora fulgens Roxburgh (1814:10). **Type:—**INDONESIA. Amboina, *s.d., s.coll., s.n.* (lectotype Rumphius, Herb. Amboin. 4: t. 46. 1743 [icon], designated by Merrill (1917b). —Basionym:—*Pavetta fulgens* (Roxb.) Miquel (1857:204).

Shrub 1–4(–6) m tall; young internodes brown; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries and calyces which are puberulent to hirtellous. Stipules persistent, sheath widely triangular, 2–3 mm long, awn 3–5 mm long. Leaves with petioles 1–1.8 cm long; blades usually lanceolate, sometimes oblong-lanceolate, elliptic, or narrowly elliptic, (9–)15–22 × (2–)3–4 cm, coriaceous, drying dark brown above, paler brown below; apex acute to long acuminate (acumen 1–1.5 mm long); base cuneate to obtuse; secondary veins 8–10 each side. Inflorescence terminal, shortly pedunculate, trichotomouly branched, articulate throughout, compact, 2.5–2 × 3–6 cm; modified inflorescence supporting leaves absent; peduncle 0.2–0.3 cm long; central first order axis 0.5–3 cm long, lateral first order axes 0.3–3.5 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and foliar parts widely triangular and vaulted; higher order bracts with stipular parts absent and foliar parts triangular and vaulted. Ultimate flower triads with flowers subsessile; pedicels ≤ 1 mm long. Flowers with ovary and calyx green, corolla bright red, style, stigma, filaments and anthers pale red to yellow; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, triangular, up to 1 mm long, reaching the base of the ovary; calyx tube ca 0.5 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube 25–30(–40) mm long; corolla lobes broadly ovate, lanceolate or elliptic, 10–12 × 2–3 mm, apices acute; filaments ca. 1 mm long, anthers 2–3 mm long; style exserted from corolla tube for 1–2.5 mm, stigmatic lobes 2–3 mm long, spreading. Fruits globose to subglobose, 5–6 × 7–10 mm, with persistent calyx, purple when ripe; fruit wall 0.5–1 mm thick; pyrenes 4–5 × 3.5–5 mm, seeds 3–4 × 2.5–4 mm.

Habitat:—In primary or secondary forests; elevation 200–800 m.

Distribution:—Mostly distributed in provinces of Visayas and Mindanao, and Palawan (Fig. 32). Also occuring in China, India, Mayanmar, Indonesia, Malaysia and Vietnam.

Phenology:—Flowers: February–March, June–August, October, December; fruits: January, March, August, October–November.

Notes:— *Ixora longifolia* and *I. salicifolia* are closely related as their flowers are comparable in size and color. However there are still differences present between the two, e.g. in *I. fulgens* leaves are usually lanceolate and never linear, bracts and bracteoles widely triangular and vaulted, flowers of ultimate flower triad shortly pedicellate (pedicels $\leq$ 1 mm long) and the bases of the calyx lobes not overlapping. In *I. salicifolia,* leaves are always linear, bracts and bracteoles narrowly triangular, pedicels of ultimate flower triad up to 4 mm long and the bases of the calyx lobes are overlapping.

Additional specimens examined:—PHILIPPINES. Luzon: **Masbate:** Brgy. Tugbo, *s.d., Barbon et al. 12527* (K, L); **Palawan:** Mt. St. Paul, Sabang, May 2012, *Alejandro et al. 12438* (USTH); Mt. Pulgar, May 2011, *Banag et al. I008* (USTH); Panalingajan River, March 1929, *Edaño 77374 & 77391* (A); Rizal, Ransang, Cabinbin, 1994, *Gaerlan et al. 13299* (L); Brgy. Bundog near Suminda River, Quezon, 1996, *Pipoly et al. 38109* (A), *38136, 38212 & 38312* (L); Visayas: **Antique:** Mt. Poras, Imparayan, Sibalom, 1995, *Reynoso et al. 21053* (L); **Bohol:** *s.loc.*, August–October 1923, *Ramos 43098* (A, P); **Capiz:** Jamindan, April–May 1918, *Ramos & Edaño 30938* (A, P); **Cebu:** Poblacion Alcoy, Argao, 1997, *Gaerlan & Reynoso 20196* (L); camp 7 (lower), Minglanilla (ERDS), 14 June 1997, *Gaerlan & Reynoso 20383* (K, L); Cantipla Forest, 2011, *Paraguison & Chavez L010* (USTH); **Leyte:** Dagami, 27 July 1957, *Frohne 35690* (PNH); Baybay, 11 July 1961, *Gutierrez 119981*

FIGURE 31. *Ixora longifolia* (*Robinson 169*) (NY, type).

(PNH); Palo, 1 March 1963, *Pancho 10779* (CAHUP); **Western Samar:** Sitio Kapinyahan, Brgy. Lokilokon, Paranas, 1992, *Reynoso et al. 7433* (L); Loquilocon, Wright, April–May 1948, *Sulit 6145* (A); Mindanao: **Dinagat Island:** *s.loc.*, May–July 1931, *Ramos & Convocar 83798* (A); **Lanao del Sur:** vicinity of Dansalan, 6 October 1938, *Lynn Zwickey 263 & 270* (A); **South Cotabato:** Mt. Matutum, April 1932, *Ramos & Edaño 85010* (A); **Sulu:** Jolo, September 1924, *Ramos & Edaño 44408, 44442 & 44448* (NY); **Surigao:** *s.loc.*, June 1919, *Ramos & Edaño 34719* (A); **Zamboanga del Norte:** Nipaan, 19 November 1957, *Frake 36303* (PNH); Dikus, 7 September 1957, *Frake & Frake 35990* (PNH); **Zamboanga Sibugay:** Malangas, Octobe–November 1919, *Ramos & Edaño 36858, 36867* (A) *& 37082* (NY).

—INDONESIA. Amboina, July–November 1913, *Robinson 169* (NY); Sumatra: Bandas, Poeloeh, Asahan, *s.d.*, *Yates 1772* (NY); Djaroem-djaroem, March–May 1932, *Si Torres 2168 & 3815* (NY); Marbau, Bilah, near Bilah Pertama, February–March, *Si Torres 108* (NY); Natoras to Kopas, Asahan, 5 October 1928, *Si Torres & Hamel 1456* (NY).

—MALAYSIA. Mt. Kinabalu, 5 December 1933, *Clemens s.n.* (NY); Mt. Kinabalu, *s.d.*, *Clemens 50530* (NY).

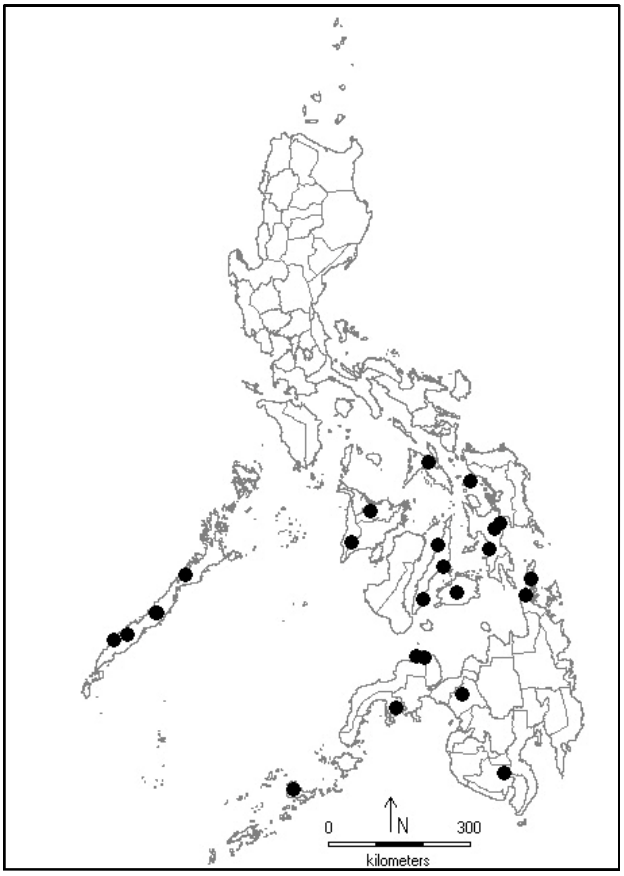

FIGURE 32. Distribution of *I. longifolia*.

19. *Ixora longistipula* Merrill (1910: 236) (Fig. 33).

Type:—PHILIPPINES. Visayas: Negros Occidental: Mt. Marapara, September 1909, *Curran & Foxworthy 13625* (holotype PNH, destroyed; lectotype US!, **here designated**).

Shrub 1.5–3 m tall; young internodes reddish-brown, terete; all external parts glabrous. Stipules persistent, sheath triangular, 1–1.5 mm long, awn 4–8 mm long. Leaves with petioles 0.5–1 cm long; blades elliptic or oblong-lanceolate, 8–20 × 2.5–3.5 cm, chartaceous, drying brown and often somewhat glossy above, paler brown below; apex sharply acuminate (acumen 0.5–10 mm long); base acute; secondary veins 10–13 each side. Inflorescence terminal, pendulous, with flowers forming simple, dense head, 1–1.5 × 2–2.5 cm; one pair of modified inflorescence supporting leaves present, subsessile, blades similar in shape to vegetative leaves or ovate but smaller, 1–3 × 1.5–2.5 cm, base cordate, acute or rounded; peduncle slender, 9–15 cm long; central and lateral first order axes hardly distinguishable; bracts filiform, 1–2 mm long. Ultimate flower triads with flowers sessile. Flowers with ovary and calyx red, corolla pink, greenish in bud stage, corolla tube reddish at the base, style, stigma, filaments and anthers yellowish to white; flower bud with rounded apex; bracteoles present, opposite at the base of the ovary, narrowly triangular to filiform, apices acute, 0.5–1 mm long, reaching the base of the ovary; calyx tube 0.5–0.8 mm long; calyx lobes triangular, their bases not overlapping; corolla tube 13–20 mm long; corolla lobes widely elliptic, 3–5 × 1.5–2 mm, apices obtuse; filaments ca. 1 mm long, anthers 2.5–3 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 1–1.5 mm long, spreading. Fruits subglobose, 7–9 × 8–10 mm, with persistent calyx, pink when ripe; fruit wall 0.5–1 mm thick; pyrenes 6–8 × 4–5 mm, seeds 5–7 × 3–4 mm.

Habitat:—Lower montane forests; elevation 500–700 m.

Distribution:—Ilocos Norte, Occidental and Oriental Mindoro in Luzon, Aklan, Atique, Capiz and Negros Occidental in Visayas (Fig. 34).

Phenology:—Flowers: March–April, September; fruits: February–March, May, November–December.

Notes:—*Ixora longistipula* differs from other Philippine Ixoras in having capitate inflorescences.

Additional specimens examined:—PHILIPPINES. Luzon: **Ilocos Norte:** Burgos, July 1918, *Ramos 32729* (P); **Occidental Mindoro:** Paluan, 1921, *Ramos 39570* (L, P); **Oriental Mindoro:** Busay, Naujan, 2 October 1947, *Celestino & Castro 1948* (L, PNH); Mt.

Yagaw (S slope), 4 August 1953, *Conklin 18632* (L, PNH); Malasimbo, Puerto Galera, March 1910, *Griffith 217* (A); Puerto Galera, November–December 1925, *Ramos 46355* (NY); Mt. Halcon, 1922, *Ramos & Edaño 40602* (L); Sibuang River Camp, San Teodoro, 1985, *Ridsdale 984* (L); Visayas: **Aklan:** Libacao, May–June 1919, *Marcelino & Edaño 35534* (P); **Antique:** Mt. Purga Libertad, 2 May 2012, *Abad et al. 12150, Chavez et al. 12092*, *12093*, *12096* (USTH); **Capiz:** Panay, October–November 1925, *Edaño 46158* (NY); May–August 1918, *McGregor 32319* (P); **Negros Occidental:** Kinabkaban River, 25 March 1954, *Edaño 21856* (L, PNH); **Negros:** *s.loc.*, September 1909, *Curran 13694* (K, NY).

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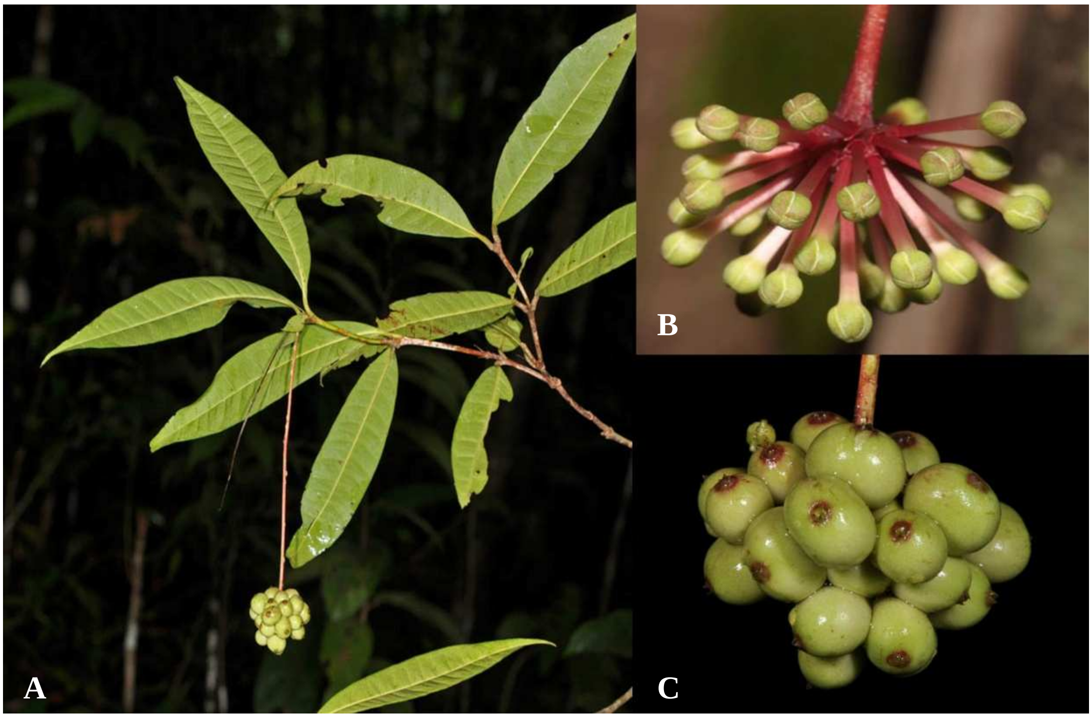

FIGURE 33. *Ixora longistipula*. A—fruiting branch, B—inflroescence, C—infructescence. Locality of A & B: vicinity of Sibaliw field station, Brgy. Tagusip, Buruanga, Aklan; C: Northwest Panay Peninsula. Credit: P.B. Pelser & J.F. Barcelona (A & B); R. A. Bustamante (C).

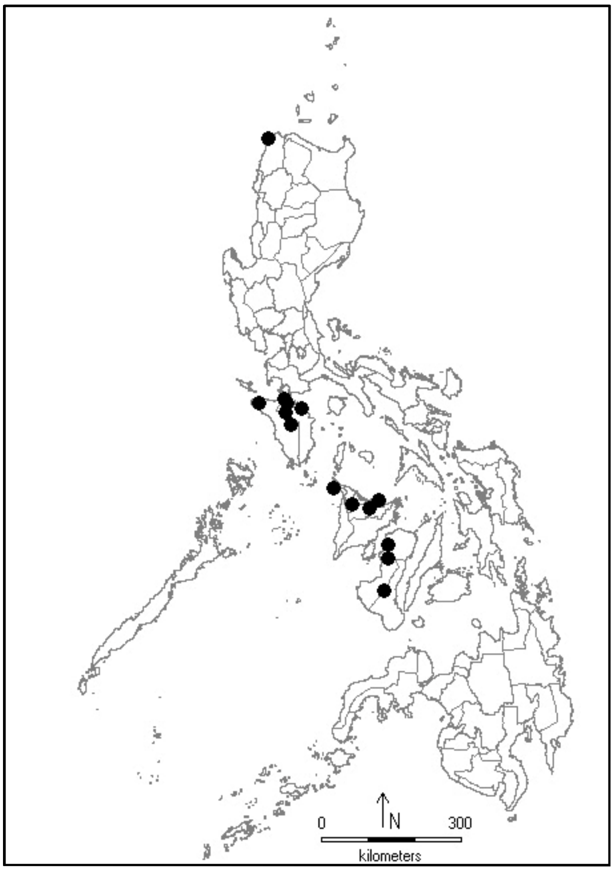

FIGURE 34. Distribution of *I. longistipula*.

20. *Ixora luzoniensis* Merrill (1921b: 434) (Fig. 35).

Type:—PHILIPPINES. Luzon: Pangasinan: Mt. San Isidro Labrador, 4 November 1917, *Fenix 29956* (holotype PNH, destroyed; lectotype US, **here designated**; isolectotypes K, P).
= Ixora capitulata Merrill *nom. inval.* (ICN Art. 29).
= Ixora zambalensis Merrill *nom. inval.* (ICN Art. 29).

Shrub 1–3 m tall; young internodes grayish-brown; all external parts glabrous. Stipules persistent, sheath triangular, 1–2 mm long, awn 4–10 mm long. Leaves with petioles 0.1–0.2 cm long; blades lanceolate to oblong lanceolate, 11–19 × 1.5–5 cm, chartaceous, drying pale brown and often somewhat glossy on both sides; apex shortly acuminate; base acute; secondary veins ca. 15 each side. Inflorescence terminal, subsessile or shortly pedunculate (peduncle 0.5–0.8 cm long), articulate throughout, lax, 4–4.5 × 3–3.5 cm; one pair of modified inflorescence supporting leaves present, subsessile, blades similar in shape with vegetative leaves but smaller, 1–1.5 × 0.3–0.5 cm; central first order axis 0.5–1.5 cm long, lateral first order axes 0.8–1.5 cm long; first and higher order bracts with stipular parts absent and foliar parts narrowly triangular and vaulted, 1.5–2 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 5–8 mm long, central flower with pedicels 5–7 mm long. Flowers with ovary and calyx green turning red, corolla, style, stigma, filaments and anthers white; flower bud with acute to rounded apex; bracteoles present on most pedicels, opposite at the base of the ovary or rarely on the pedicels, triangular, apices acute, 1–1.3 mm long, reaching the base of the ovary; calyx tube 1–2 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube 5–15 mm long; corolla lobes elliptic, 6–7 × 3–4 mm, apices acute or rounded; filaments ca. 1 mm long, anthers 3–4 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 2–2.5 mm long, spreading. Fruits subglobose, 5–6 × 6–8 mm, with persistent calyx, red when ripe; fruit wall 0.5–1 mm thick; pyrenes 4–5 × 3–4 mm, seeds 3–4 × 2–3 mm.

Habitat:—In forests at low altitude; elevation 100–500 m.

Distribution:— In northern to central Luzon (Fig. 36).

Phenology:—Flowers: May–June; fruits: February–April, November.

Notes:—*Ixora luzoniensis* is similar with *I. longistipula* in terms of vegetative structures like the shape of the leaves and in having stipules with awn reaching up to 8–10 mm in length. The best distinguishing characters between the two are the inflorescences, that are pendulous and capitate in *I. longistipula* but shortly pedunculate and lax in *I. luzoniensis.*

Additional specimens examined:—PHILIPPINES. Luzon: **Cagayan:** Sitio Quiddao, Brgy. Balatubat, Calayan, Camiguin Island, 1996, *Fuentes & Fernando 37079* (L); Brgy. Pagippit, Calayan, Camiguin Island, 12 March 1996, *Fuentes & Fernando 37150* (L); Brgy. Kilkiling, Taggat Watershed Area, Claveria, 8 May 1995, *Garcia et al. 18348* (K, L); Pamplona, March 1909, *Ramos 7420* (NY, P); **Catanduanes:** *s.loc.,* 14 November–11 December 1917, *Ramos 30520* (P); **Ilocos Norte:** Mt. Darna, 22 March 1953, *Edaño 18131* (K, L, PNH); **Oriental Mindoro:** Bongabon & Pinamalayan, February–April 1941, *Maliwanag 305* (PNH); **Zambales:** Panuraogan, Sta. Rita, Masinloc, 2 June 2011, *Banag et al. MA008* (USTH); *s.loc.*, October 1919, *Elgincolin 27813* (US); *s.loc.*, December 1907, *Ramos 5045* (NY, P); Mt. Marayep, December 1924, *Ramos & Edaño 44780* (P).

FIGURE 35. *Ixora luzoniensis* (*Fenix 29956*) (US, lectotype).

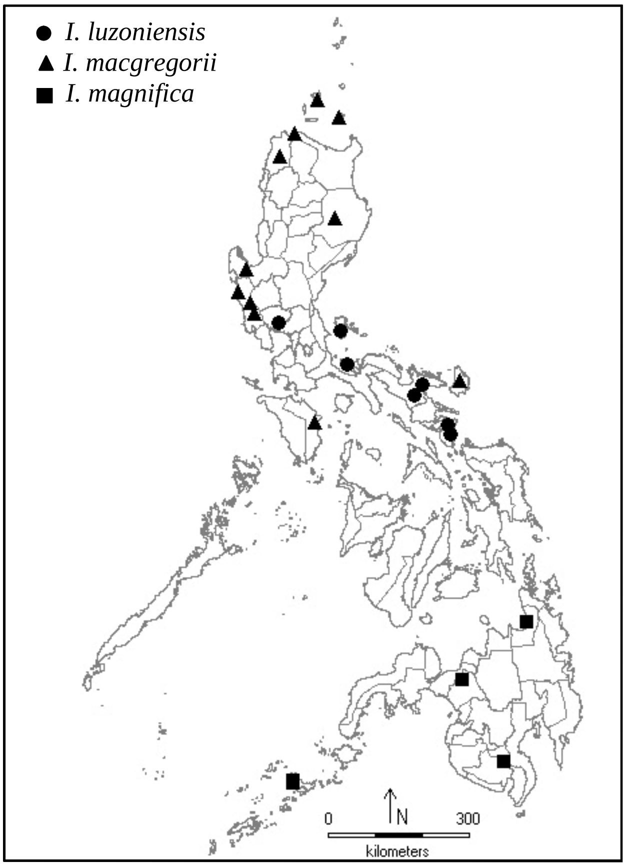

FIGURE 36. Distribution of *I. luzoniensis*, *I. macgregorii* and *I. magnifica.*

21. ***Ixora macgregorii*** Robinson (1911: 223) (Fig. 37).

Type:—PHILIPPINES. Luzon: Quezon: Polillo Island, October–November 1909, *McGregor 10219* (holotype PNH, destroyed; lectotype US!, **here designated**; isolectotypes K!, L!, NY!).
=*Ixora irosinensis* Elmer (1934: 3251). **Type:—**PHILIPPINES. Luzon: Sorsogon: Mt. Bulusan, Irosin, September 1916, *Elmer 17301* (lectotype NY!, **here designated**; isotypes C!, L!, P!, US!) *syn. nov.*

Shrub 1–3 m tall; young internodes brown, terete, older internodes grayish; all external parts glabrous except for peduncle, inflorescence axes, pedicels sparsely covered with very short erect trichomes. Stipules persistent, sheath triangular, 1–1.5 mm long, awn 4–5 mm long. Leaves with petioles 0.4–0.8 cm long; blades lanceolate or oblong lanceolate, 10–23 × 3–7 cm, membranceous to chartaceous, drying similarly brown on both surfaces; apex acute to shortly acuminate; base rounded or sometimes abruptly narrowed; secondary veins 9–25 each side, conspicous, reticulations quite evident. Inflorescence terminal, pedunculate, trichotomously branched, articulate throughout, moderately compact, 2–2.5 × 3–4 cm; one pair of modified inflorescence supporting leaves present, subsessile, blades lanceolate, 1–5 × 0.3–1 cm; peduncle 2–4 cm long; central first order axis 0.4–1 cm long, lateral first order axes 0.3–0.7 cm long; first order bracts with stipular parts absent and foliar parts narrowly triangular up to 4 mm long; higher order bracts with stipular parts absent and foliar parts linear or triangular, up to 2 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 2–3 mm long, central flower sessile or with pedicels 0.5–1 mm long. Flowers with ovary and calyx green, corolla white; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular to filiform, apices acute, 1–2 mm long, reaching the middle of the calyx lobes; calyx tube 0.2– 0.5 mm long; calyx lobes triangular, apices acute, their bases not overlapping; corolla tube 5–20 mm long; corolla lobes lanceolate, 6–10 × 2–4 mm, apices acute; filaments 1–2 mm long, anthers 5–7(–10) mm long; style filiform, exserted from corolla tube for 3–4 mm, stigmatic lobes 2–3.5 mm long, recurving. Fruits subglobose, 6–8 × 7–9 mm, with persistent calyx, pink when ripe; fruit wall 0.5–1 mm thick; pyrenes 5–7.5 × 4–5 mm, stony; seeds 4–5 × 2–3 mm.

Habitat:—In lowland dipterocarp forests; elevation 300–450 m.

Distribution:—Provinces of Camarines Sur, Quezon and Sorgsogon in Luzon (Fig. 36).

Phenology:—Flowers: February, September–November; fruits: April, September–December.

Notes:— *Ixora irosinensis* is here treated as synonym of *I. macgregorii*. The type material of *I. irosinensis* was collected from Mt. Bulusan Irosin, Sorsogon and was distributed by Elmer at different herbaria under the name of *I. luzoniensis.* However, after studying the specimens and the protologue, it perfectly matches the description of *I. macgregorii* except for the size of the leaves. *Ixora macgregorii* differs from *I. luzoniensis* in having very slender style and stigmatic lobes that are recurving and central flower of the ultimate flower triad sessile or with pedicels 0.5–1 mm long.

FIGURE 37. *Ixora macgregorii* (*McGregor 10219*) (US, lectotype).

Additional specimens examined:—PHILIPPINES. Luzon: **Camarines Sur:** Agosais, 24 October 1928, *Edaño 76112* (NY); Kinaclan, 7 November 1928, *Edaño 76333* (NY); **Quezon:** Alabat Island, 21–30 December 1916, *Merrill 10434* (K, NY, P, US); September–October 1926, *Ramos & Edaño 48341* (A, NY); **Sorsogon:** Mt. Pocdol, Boc-man Geothermal Plant, Bacon, 18 April 2013, *Chavez et al. 13336* (USTH); Bulusan Lake, Brgy. San Roque, 15 April 2013, *Chavez et al. 13315* (USTH); Mt. Bulusan, Irosin, June 1916, *Elmer 16480* (K, NY, US); Mt. Bulusan, Irosin, 1996, *Garcia et al. 22891* (L); Mt. Bulusan, Irosin, 3 November 1996, *Garcia & Fernando 22951* (A, L).

22. ***Ixora macrophylla*** De Candolle (1830: 487) (Fig. 38).

Type: —PHILIPPINES. Luzon: Manila, *s.d.*, *Haenke s.n.* (unknown).
—PHILIPPINES. Laguna, Pangil, 27 May 1959, *Ramos s.n.* (neotype PNH, designated by Banag & Tandang (2014: submitted); isoneotype L!).

Tree (2–)5–6 m tall; young internodes grayish-brown; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas moderately to densely covered with very short erect trichomes. Stipules persistent, sheath widely triangular or ovate, 2–3 mm long, awn 1–2 mm long. Leaves with petioles 0.4–1.5 cm long; blades very variable in shapes elliptic, lanceolate or oblanceolate sometimes ovate or obovate, (3–)7–20(–25) × 3.5–7.5(–9.5) cm, coriaceous, drying brown above, paler brown below; apex acute or shortly acuminate; base cuneate or attenuate rarely obtuse; secondary veins 9–13 each side. Inflorescence cauliflorous or ramiflorous, multiflorous, pendulous, non-articulate throughout, compact, 5–5.5 × 2.5–3 cm; modified inflorescence supporting leaves absent; peduncle 7–23 cm long; central first order axis 1–3 cm long, lateral first order axes 1.5–4 cm long; first and higher order bracts with stipular parts absent and the foliar parts absent or more often reduced to filiform, up to 1.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 1–3 mm long, central flower (sub)sessile or with pedicels 0.5–1 mm long. Flowers with ovary and calyx red, corolla white tinged with pink, style, stigma, filaments and anthers white; flower bud with rounded apex; bracteoles often absent, if present then subopposite on the pedicels, narrowly triangular or filiform, 1–1.5 mm long, reaching at most the base of the ovary; calyx tube ca 0.5 mm long; calyx lobes triangular or shortly apiculate to dentate, apices acute, their bases not overlapping; corolla tube 10–20 mm long; corolla lobes oblong, 3–5 × 1.5–3 mm, apices obtuse; filaments 1–1.5 mm long, anthers 2–3.5 mm long; style exserted from corolla tube for 1–3 mm, stigmatic lobes 1–2.5 mm long, spreading. Fruits subglobose, 8–11 × 9–14 mm, with persistent calyx, light pink to pale purple when ripe; fruit wall 1–2 mm thick; pyrenes 6–9 × 5–7 mm, seeds 4–6 × 2–4 mm.

Habitat:—In forests at low and medium altitude; elevation 50 – 800 m.

Distribution:—Widely distributed, in most islands or provinces of Luzon, Visayas and Mindanao (Fig. 39).

Phenology:—Flowers: January–December; fruits: January–December.

Notes:—*Ixora macrophylla* can be easily distinguished from other species of Philippine *Ixora* by its cauliflorous sometimes ramiflorous inflorescences–a very rare feature for *Ixora* taxa, whose inflorescences are usually terminal.

Additional specimens examined:—PHILIPPINES. Luzon: **Aurora:** Brgy. Zabali, Baler, 30 April 2011, *Banag et al. 11053* (USTH); Brgy. Diteki, San Luis, 1996, *Fuentes & Fernando 37468* (L); Sierra Madre Mountains, NNE of Dingalan, 15 March 1968, *Jacobs 104361* (PNH); 1968, *Jacobs 7755* (L); Baler, 2 April 1947, *Quisumbing 2290* (A, PNH); Minola, Baler, 27 February 1949, *Quisumbing 8067* (A, K, PNH); **Bataan:** Lamao River, Mt. Mariveles, April 1904, *Borden 613* (K, NY); Lamao, November 1947, *Edaño 4166* (A, L, PNH); Lamao River, Mt. Mariveles, 11–14 June 1903, *Merrill* 2503 (K, NY); Lamao River, Mt. Mariveles, February 1905, *Meyer 2611* (K, NY); Lamao River, Mt. Mariveles, April 1904, *Whitford 54* (K, NY, P); Lamao River, Mt. Mariveles, 28 November 1903, *Williams 259* (A, NY); **Bulacan:** Angat Watershed Area Brgy. San Lorenzo, Norzagaray, 1994, *Garcia et al. 15152 & 15200* (L); Mt. Biak na Bato, San Miguel, 1994, *Garcia et al. 15047* (L); Biak na Bato, San Miguel, 27 November 1976, *Payawal 658* (CAHUP); *s.loc.*, September 1913, *Ramos 1511* (A, NY); Angat, February 1919, *Ramos & Edaño 34157* (A, K); Angat, August 1959, *Vidal 408bis* (A); **Cagayan:** Lagum, vicinity of Peñablanca, 4 May 1917, *Adduru 250* (A); Bagio Cove, Cagayan, 1981, *Allen 14381 & 160216* (L); Brgy. San Vicente, Palaui Island, Sta. Ana, 11 December 1995, *Barbon et al. 18834* (A, L) *& 18872* (L); Camiguin Volcano, Camiguin Island, Babuyanes, March 1930, *Edaño 79183* (A); Pagikpik, May 1930, *Edaño 79479* (A); Calayan Island, Brgy. Cabudadan Centro 2, 1997, *Fuentes & dela Rosa 38869* (L); Brgy. Balatubat, Calayan, Camiguin Island, 1996, *Fuentes & Fernando 37024* (L); Brgy. Kilkiling, Taggat Watershed Area, 1995, *Garcia et al. 18156* (L); Peñablanca, March–May 1929, *Ramos 76817* (A, K); Peñablanca, April 1926,

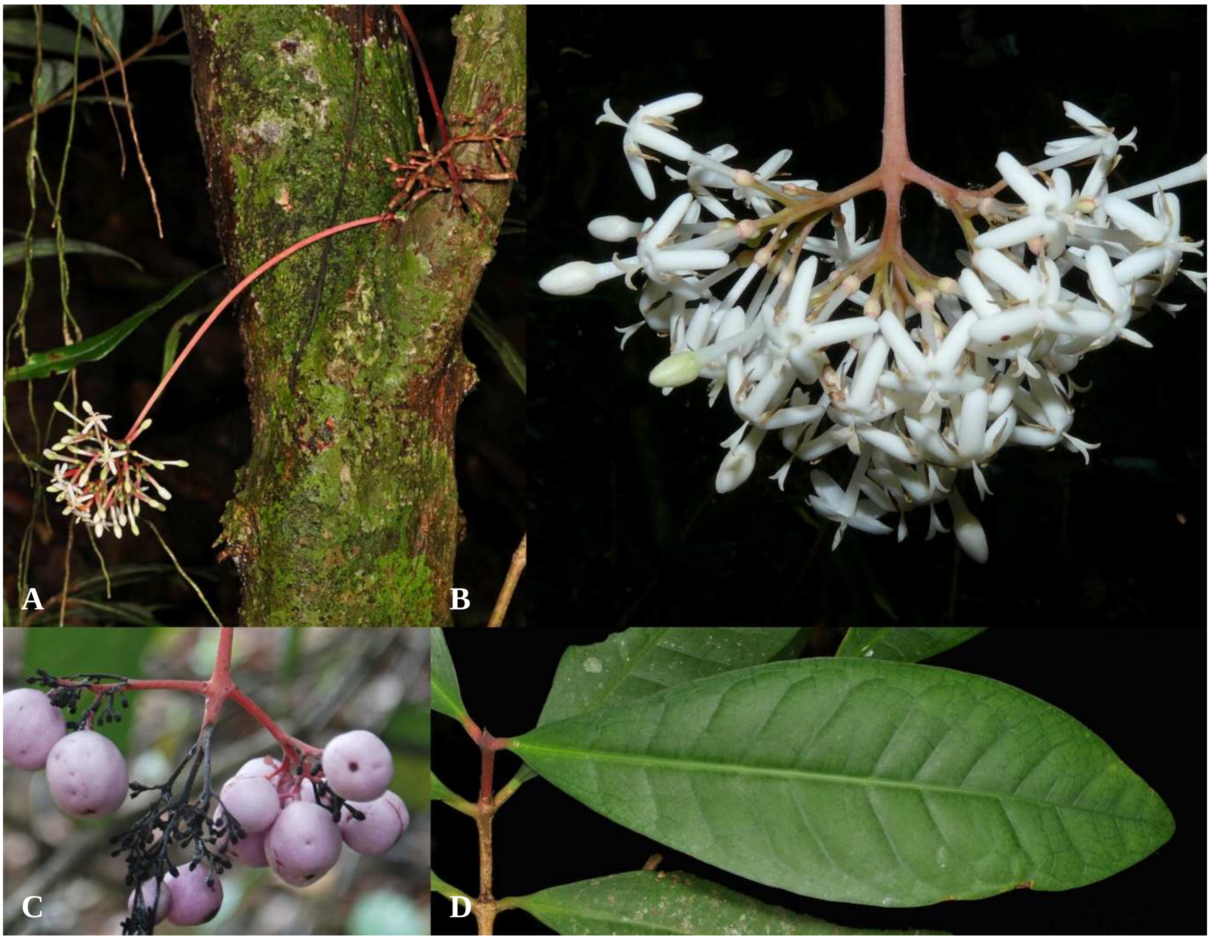

FIGURE 38. *Ixora macrophylla*. A—flowering branch, B— inflorescence, C—infructescence, D—adaxial side of the leaf. Locality of A: vicinity of Sibaliw field station, Brgy. Tagusip, Buruanga, Panay, Antique; B: Puerto Galera, Oriental Mindoro; C: Baler, Aurora; D: Brgy. Aningalan, San Remegio, Panay, Antique. Credit: P.B. Pelser & J.F. Barcelona (A,C,D); G.J.D Alejandro (B).

Ramos & Edaño 46568 (NY); Claveria Kilkiling, Mt. Taggat, 1994, *Reynoso et al. 11951* (L); **Camarines Norte:** Daet, 23 September 1981, *Croat 29121* (CAHUP); Bicol National Park, 7 June 1969, *Hernaez 17888* (CAHUP); Bicol National Park, 16–20 May 1991, *Hernaez & Cajano 56451 & 56452* (CAHUP); Bicol National Park, 8 October 1978, *Pancho 27340 & 27341* (CAHUP); Mt. Bagacay, November–December 1918, *Ramos & Edaño 33918* (A); *s.loc.*, September 1921, *Simeon 28737* (A); **Camarines Sur:** Gatbo, Ocampo, 23–28 November 1998, *Cajano & Mandia 172066* (PNH); Carambola, Pili, 5 May 1947, *Convocar 2951* (A, L, PNH); Mt. Isarog National Park, Ocampo, 1994, *Delprete 6447* (NY); Pacolagu River, May 1929, *Quisumbing 76635* (NY); Brgy. Ipil, Buhi, 3 October 1983, *Regalado 39774* (CAHUP); **Catanduanes:** Mt. Nagpakdil, July–September, *Ramos & Edaño 75341* (NY); **Ilocos Norte:** Mt. Palemlem, April 2013, *Alejandro et al. 13023* (USTH); Mt. Quebrada, 27 February 1953, *Edaño 17850* (A, L, PNH) *& 17879* (PNH); Darna, Pagudpud, 1992, *Gaerlan 9987* (L); Bo. Gawwa, Bangui, August 1930, *Paraiso 31263* (K, NY); **Isabela:** Sierra Madre Mtn. Range (E foothills), Brgy. San Isidro, Sitio Diago, Palanan, 7 May 1991, *Co 3422* (A, L); Sierra Madre Mtn. Range (E foothills), Brgy. San Isidro, hill N of Sitio Diago, 11 May 1991, *Co 3445* (A, L); Sierra Madre Mtn. Range (E foothills), Brgy. San Isidro, hill NW of Sitio Diago ca. 1.5 km of Palanan Point, 21 May 1991, *Co 3514* (A, L, PNH); Palanan Dikatkotan, 1991, *Gaerlan et al. 2945* (L); Sierra Madre Mountains, Bo. Disulap, San Mariano, 26 April 1961, *Gutierrez 78069* (A, K, L); Dipaguidin (Nr. Palanan Point), Palanan, 16 April 1991, *Ridsdale et al. 36* (A, CAHUP, L); Dipaguidin (Nr. Palanan Point), Palanan, 16 April 1991, *Ridsdale & Dejan 61316* (CAHUP); **Laguna:** c.n. Tagpo, Laguna, September–October 1958, *Vidal 385d* (A, K); **Marinduque:** Hawillian, So. Maulawin, Brgy. Dampula, Torrijos, 1996, *Romero & Chavez 29072* (L); **Masbate:** 7-R Ranch, Sitio Kalunukan, Brgy. Matipuron, Milagros, 1994, *Barbon et al. 12708* (L); **Nueva Ecija:** Mt. Umingan, August–September 1916, *Ramos & Edaño 26435* (A); **Occidental Mindoro:** Paluan, April 1921, *Ramos 39808* (A); **Oriental Mindoro:** Puting Bato, Puerto Galera, 5 May 1935, *Bartlett 13734* (A, NY, PNH); E. Mindoro, N. Slope of Mt. Alinyaban, 5 km SW of Puerto Galera, 1987, *Burley 142* (L); Mt. Yagaw (Eastern Slope), Mansalay, 16 March 1953, *Conklin 17442* (A, L, PNH); Baco River, Aril 1903, *Merrill 1781* (A, K, NY); Baco River, March 1905, *Merrill 4059* (K, NY); Subaan River inland from San Teodoro, North Coast Mindoro, 21 April 1986, *Ridsdale et al. 5456* (A, L, PNH); Mt. Yagaw (Eastern Slope), Mansalay, 13 December 1952, *Sulit & Conklin 16959* (A, L, PNH); **Pangasinan:** Mt. San Isidro Labrador, November 1917, *Fenix 30011* (A); **Quezon:** Quezon National Park, 1996, *Castro et al. 22261* (L); Lukutan, Polillo Island, 12 December 1948, *Castro & Anonuevo 6544* (A, BR, PNH); Karlagan, Polillo Island, January–February 1949, *Fox 9135* (A, PNH); Mt. Camagon Brgy. Bacung, Alabat Island, 1996, *Gaerlan & Romero 23335* (L); Quezon National Park, Malikboy, Pagbilao, Pantayen to Silo River trail, 1996, *Gaerlan & Romero 23683* (L); Malbog, Tayabas, 11 February 1929, *Ladia 30813* (NY); Lagumanon, Tayabas, November 1903, *Merrill 3359* (K, NY, P); Malbog, Tayabas, 26 January 1929, *Oro 30715* (NY); Bo. Palale, Tayabas, June 1977, *Vendivil & Reynoso 124358* (PNH); Atimonan, August–September, *Whitford 633* (P); Tayabas, August–September, *Whitford 715* (P); Mt. Cadig, Tayabas, December 1916, *Yates 25400 & 25550* (A); **Rizal:** Antipolo, April 1904, *Ahern 468* (K, NY); Tayabas, Brgy. San Jose, Antipolo, 29 May 2012, *Banag et al. AN001* (USTH); Tanay, Antipolo, 1 May 2012, *Diesmos ACD001* (USTH), San Andales, December 1926, *Edaño 48837* (NY, P); Montalban, March 1906, *Merrill 5049* (K, L, NY, P); Mt. Irid, November 1926, *Ramos & Edaño 48440* (C); San Mateo, November–December 1958, *Vidal*

408 (A, L); **Romblon:** So. Barikwang, Brgy Marigondon Sur, San Andres, 1996, *Reynoso & Fuentes 24576* (L); Looc I, Tablas, September–October 1958, *Vidal 358f* (A); **Sorsogon:** Road to Brgy. San Francisco, Bulusan, 16 April 2013, *Chavez 13320* (USTH); Mt. Bulusan, Irosin, November 1915, *Elmer 15202* (A, C, K, L, NY, P, PNH) *;* Mt. Bulusan, Irosin, December 1915, *Elmer 15475* (A, K, L, NY, P, PNH)*;* Mt. Bulusan National Park, Brgy. Inlagadian, Casiguran, 1996, *Garcia & Fernando 22744* (L); Mt. Bulusan Kapungkaya Hill, 16 August 1947, *Sulit 2694* (A, L, PNH); **Zambales:** Mt. Aglao, San Marcelino, December 1916, *Edaño 26800* (P); Mt. Pinatubo, Yamtok, June–July 1948, *Fox 4825* (A, PNH); Subic vicinity of Zambales, April 1903, *Merrill 2071* (K, NY); Visayas: **Antique:** Lower portion of Mt. Baloy, Brgy. San Agustin, Valderama, 1995, *Garcia & Romero 15738 & 15787* (L); Mt. Poras, Imparayan, Sibalom, 1995, *Reynoso et al. 21058* (L); **Biliran:** *s.loc.*, Jun 1914, *McGregor 18573 & 18605* (A); **Bohol:** *s.loc.*, August–October 1923, *Ramos 42631* (A); Logarita, Bilar, 1993, *Reynoso et al. 7787 & 7844* (L); **Capiz:** Mt. Bulilao, Panay, June 1919, *Martelino & Edaño 35658* (A, P); **Cebu:** Cantipla Forest, 2011, *Paraguison & Chavez L009* (USTH); **Eastern Samar:** Kadapnan Bo. Bantayan, Oras, 4 May 1948, *Castro 5667* (A, BR, PNH); Kadapnan Bo. Bantayan, Oras, 2 May 1945, *Castro & Anonuevo 5675* (A, PNH); Mt. Concord, May 1969, *Gutierrez et al. 117002* (L, PNH); **Iloilo:** Brgy. Manaripay, Calinog, 1995, *Garcia & Romero 18072* (L); Maasin Falls, La Rido Hill, Lambunao, 24 July 1995, *Reynoso et al. 17965* (A, L); **Leyte:** Palo, January 1906, *Elmer 7053* (A, K, NY); Abuyog, 12 September 1929, *Fontanoza 31127* (NY); N. Palo, near Palo River, 16 August 1945, *Glassman 788* (A); Balinsasayao Forest Reserve, Abuyog, July 1961, *Gutierrez 119898* (PNH); Cabalian, December 1922, *Ramos 41499* (A); *s.loc.*, 10 March 1913, *Wenzel 25* (A, L); **Negros Occidental:** *s.loc.*, April 1908, *Everett 11206* (NY); **Negros Oriental:** Sibulan Kabalinan, L. Balinsasayao, 1991, *Reynoso et al. 932* (L); Mt. Talinis Cuernos, 1991, *Reynoso et al. 1165* (L); **Northern Samar:** Catubig River, February–March 1916, *Edaño 24855* (A); Mt. Purog, 22 December 1951, *Gatchalian 15460* (PNH); Catubig River, February–March 1916, *Ramos 24137* (A, K); **Western Samar:** Daku River, Mt. Sohoton, April 1970, *Gutierrez 117723* (K, L); Mt. Sohoton, Pamamayaon, April 1970, *Madulid et al. 117793* (L, PNH); Catbalogan, 29 April 1911, *Piper 373* (P); Paranas Campo Uno, 1996, *Reynoso & Majaducon 21910* (L); Mindanao: **Agusan del Norte:** Tungao, So. San Mateo, Bo. Butuan, 12 June 1961, *Mendoza 42257* (PNH); Mt. Hilong-hilong, Cabdaran, 13 April 1949, *Mendoza & Convocar 10744* (PNH); *s.loc.*, September 1915, *Miras et al. 24428 & 24431* (A); Jabonga, April–May 1931, *Ramos & Convocar 83640 & 83641* (A); **Davao:** *s.loc.*, March–April 1949, *Edaño 11454* (A, L, PNH); **Dinagat Island:** *s.loc.*, May–July

1931, *Ramos & Convocar 83830* (A); *s.loc.*, June 1931, *Ramos & Convocar 84033* (A); **Maguindanao:** Bugasan, Parang Cotabato, 5 December 1946, *Edaño 1491* (A, L, PNH); **Surigao del Norte:** Brgy. Jaboy, So. Paghungawan, Siargao Island, 11 September 2011, *Banag SU006A* (USTH); Sitio Tiktikan, Bucas Grande, Socorro, Siargao Island, September 2011, *Banag SU006B* (USTH); del Carmen Siargao Island, 24 September 2011, *Banag SU006C* (USTH); Tapian, Mainit, 13 March 1949, *Mendoza & Convocar 10366* (A); Mt. Kabatuan, Bacuag, 26 March 1949, *Mendoza & Convocar 10591* (A, L, PNH, SAN); Lake Mainit, March–April 1931, *Ramos & Convocar 83393* (A); Siargao Island, June 1919, *Ramos & Pascasio 34964* (A); *s.loc.*, April 1919, *Ramos & Pascasio 34386* (A, K); Poneas Island, Sitio Dabo, Sunkoi Hill, Siargao Island, 1993, *Stone et al. 9437* (L); *s.loc.*, 15 May 1928, *Wenzel 3332* (A, BR, K, NY); **Tawi-tawi:** Tarawacan, 12 February 1957, *Kondo & Edaño 38855* (PNH); **Zamboanga del Norte:** Siuya, 2 January 1958, *Frake 38040* (A, L); Pulalu, 9 January 1958, *Frake 38074* (A, PNH); Muyu, 15 February, *Frake 38333* (A, L); Balentinawan, 22 June 1958, *Frake 38189* (PNH); **Zamboanga Sibugay:** Suluoan Mountain, near Kabasalan, 10 December 1940, *Ebalo 764* (A).

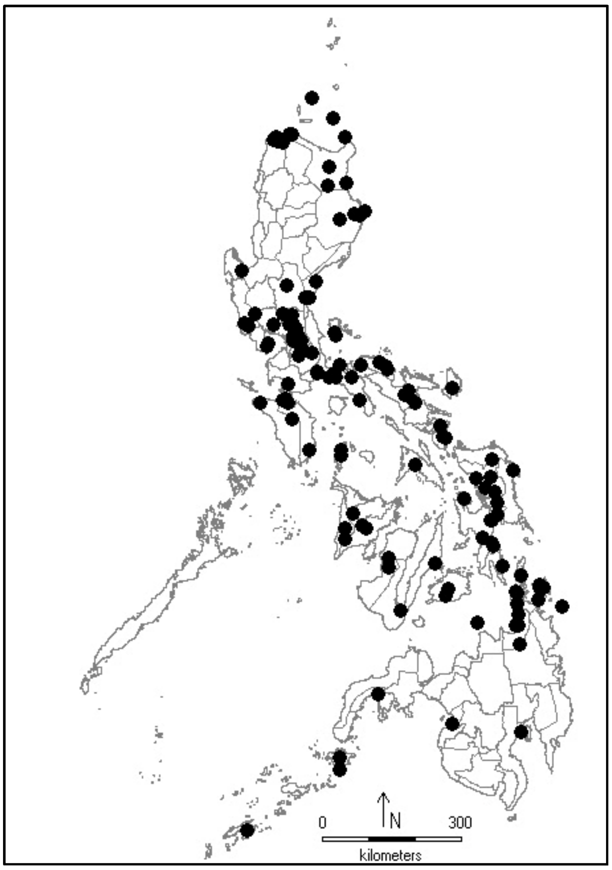

FIGURE 39. Distribution of *I. macrophylla*.

23. *Ixora magnifica* Elmer (1913: 1865) (Fig. 40).

Type:—PHILIPPINES. Mindanao: Agusan del Norte: Mt. Urdaneta, Cabadbaran, August 1912, *Elmer 13424* (holotype PNH destroyed; lectotype US!, **here designated;** isolectotypes A!, C!, L!, MO, NY!, P!).

Shrub 1–4 m tall; young internodes blackish-brown, terete; all external parts glabrous except the inflorescence axes and pedicels sparsely covered with very short erect trichomes. Stipules subpersistent, sheath triangular, 1–2 mm long, awn 3–4 mm long. Leaves with petioles 0.5–2 cm long, canaliculate; blades broadly oblong or the smaller ones elliptically oblong, 20–25.5 × 4.5–7 cm, chartaceous, drying greenish brown on both sides; apex obtusely rounded or occasionally shortly acute; base broadly obtuse; secondary veins 9–10 each side. Inflorescence terminal, shortly pedunculate, trichotomously branched, articulate throughout, compact, 3.5–5 × 3–7 cm; modified inflorescence supporting leaves absent; peduncle 0.5–3 cm long; central first order axis 0.5–2 cm long, lateral first order axes 1–2 cm long; first (and sometimes also second) order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular an vaulted or sometimes forming small leaves, 2.5–5 mm long; higher order bracts with stipular parts absent and foliar parts triangular and vaulted, 2–4.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers up to 2 mm long, central flower sessile or with pedicels up to 0.5 mm long. Flowers with ovary and calyx red or green, corolla red or sometimes orange or yellow in the same inflorescence, style, stigma, filaments and anthers yellowish; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, triangular, apices acute, 1–1.5 mm long, reaching the base of the calyx tube; calyx tube ca. 0.5 mm long; calyx lobes triangular, apices sharply acute, their bases sometimes overlapping; corolla tube 40–50 mm long; corolla lobes elliptic, 8–10 × 4–5 mm, apices acute; filaments 1 mm long or less, anthers 3–3.5 mm long; style exserted from corolla tube for ca. 2 mm, stigmatic lobes 1.5–2 mm long, spreading. Fruits unknown.

Habitat:—In moist fertile ground covered with humus in dense woods or forests; elevation 30–450 m.

Distribution:—In the provinces of Agusan del Norte, Lanao del Sur and Sulu in Mindanao (Fig. 36).

Phenology:—Flowers: February, April–June, August, October; fruits: unknown.

FIGURE 40. *Ixora magnifica* (*Elmer 13424*) (US, lectotype).

Notes:—The inflorescence axes and pedicels of *I. magnifica* are puberulent and not glabrous as described in the protologue. At first glance *I. magnifica* is very similar to *I. javanica* particularly in the shape of the leaves and color of the corolla. However, the two species differ in the following characters: calyx lobes and apices (triangular with sharply acute apices in *I. magnifica*, ovate with rounded apices in *I. javanica*); length of bracts and bracteoles (up to 3mm long for *I. magnifica*; up to 2 mm long for *I. javanica*) and shape of corolla lobes (elliptic with acute to shorty acuminate apex for *I. magnica;* ovate with rounded apex for *I. javanica*). All specimens observed for *I. magnifica* are either sterile or in flowering stage, no specimens are in fruiting stage, thus no information about the fruits was given.

Additional specimens examined:—PHILIPPINES. Mindanao: **Lanao del Sur**: Sacred Mt. Dansalan, 1 October 1953, *Britton 19614* (PNH); **South Cotabato**: Mt. Matutum, April 1932, *Ramos & Edaño 85010* (A); **Sulu**: Gorro, Siasi, Jolo, 4 February 1957, *Kondo & Edaño 38910* (PNH); Jolo, September 1924, *Ramos & Edaño 44408 & 44448* (NY); *s.loc.,* 1889, *Warburg 14599* (A).

24. *Ixora mindanaensis* Merrill (1910: 237) (Fig. 41).

Type:—PHILIPPINES. Mindanao: Zamboanga del Sur: Port Banga, 29 November 1907, *Whitford & Hutchinson 9010* (holotype PNH, destroyed). —PHILIPPINES. Mindanao: Zamboanga del Sur: Sax River, 14 February 1905, *Williams 2192* (lectotype NY!, **here designated**; isolectotype A!, NY!).

Shrub 2–5 m tall or tree 10–15 tall; young internodes light gray, terete and slender, older internodes grayish or fawn, somewhat corky; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas sparsely to moderately covered with very short erect trichomes. Stipules subpersistent, sheath ovate to oblong-ovate, 1–1.5 mm long, awn 3–5 mm long. Leaves with petioles 0.5–1 cm long; blades lanceolate, oblong lanceolate or oblong-oblanceolate, 8–21 × 3–8 cm, coriaceous or subcoriaceous, drying brown above, paler brown below and somewhat glossy on both sides; apex sharply acuminate (acumen 5–10 mm long); base acute or somewhat acuminate; secondary veins 8–10 each side, usually brown, anastomosing, reticulation very lax, often nearly obsolete. Inflorescence terminal, sessile or shortly pedunculate (peduncle $\leq$ 1 cm), trichotomously branched, those with sessile inflorescences non-articulate branching throughout, for the pedunculate ones articulate and opposite branching restricted to the lower part of the inflorescence (first order axis), moderately compact, 2–3 × 3–4 cm; modified inflorescence supporting leaves absent; central first order axis 1–1.3 cm long, lateral first order axes 0.5–1 cm long; first (and sometimes also second) order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular and vaulted, up to 1 mm long; higher order bracts with stipular parts absent and foliar parts usually filiform rarely triangular, 1–2 mm long, sub-opposite. Ultimate flower triads with flowers pedicellate; pedicels up to 2 mm long, the pedicel of the central flower usually shorter than the pedicels of the lateral ones. Flowers with corolla white or pinkish; flower bud with acute apex; bracteoles present on most pedicels, subopposite at the base of the ovary, narrowly triangular or filiform, up to 1 mm long, apices acute, reaching at most the middle of the ovary; calyx tube ca. 5 mm long; calyx lobes ovate or triangular, apices rounded or acute, their bases somewhat overlapping; corolla tube 1–10 mm long; corolla lobes elliptic ovate, 2–5 × 1–2 mm, apices acute; filaments ca. 1 mm long, anthers 2–3.5 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes ca. 2 mm long, spreading. Fruits subglobose, 5–10 × 4–9 mm, with persistent calyx and often also with remnants of dried flowers, red when ripe; fruit wall ca. 1 mm thick; seeds unknown.

Habitat:—In primary forests; elevation 0–800 m.

Distribution:—Restricted in Mindanao provinces of Lanao del Sur, Misamis Occidental Tawi-tawi and Zamboanga del Sur (Fig. 42).

Phenology:—Flowers: February, May, November; fruits: February, October–November.

Notes:—*Ixora mindanaensis* can be distinguished from other Philippine *Ixora* species by its sharply acuminate leaves (acumen 5–10 mm long), branching of inflorescences non-articulate throughout or articulate and opposite branching restricted to the lower part of the inflorescence (first axis), higher order bracts and bracteoles narrowly triangular to filiform and fruits often with persistent dried flower remnants.

FIGURE 41. *Ixora mindanaensis* (*Williams 2192*) (US, lectotype).

Additional specimens examined:—PHILIPPINES. Mindanao: **Lanao del Sur:** *s.loc.*, 18 October 1938, *Lyn Zwickey 417* (NY, PNH); 3 November 1938, *Lyn Zwickey 633* (NY, PNH); **Misamis Occidental:** Malabug River, trail to Mt. Malindang, May 1906, *Mearns & Hutchinson 4773* (NY!); **Tawi-tawi:** Lapid-lapid, 20 Novmber 1961, *Olsen 817* (C); Tarawakan, 23 October 1961, *Olsen 626* (C, L); 13 November 1961, *Olsen 1961* (C); **Zamboanga del Sur:** Mt. Tubuan, October 1919, *Ramos & Edaño 36556* (A, P).

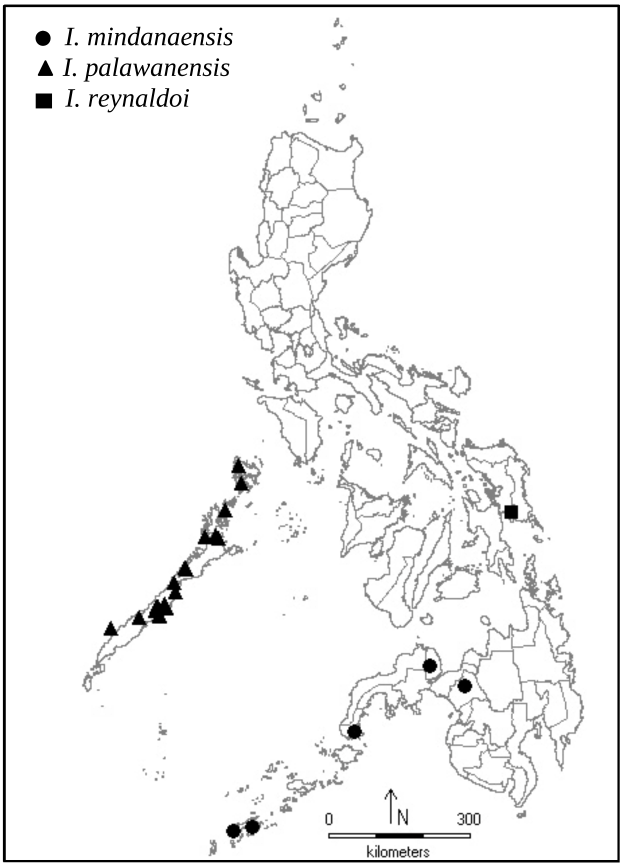

FIGURE 42. Distribution of *I. mindanaensis*, *I. palawanensis* and *I. reynaldoi.*

25. ***Ixora palawanensis*** Merrill (1910: 238) (Fig. 43).

Type:—PHILIPPINES. Luzon: Palawan: Iwahig, Puerto Princesa, 22 April 1906, *Foxworthy 793* (holotype PNH, destroyed; lectotype US!, **here designated**).

Shrub 1–3 m tall or tree 5–10 m tall; young internodes reddish-brown, terete; all external parts glabrous. Stipules persistent, sheath triangular, 1–1.5 mm long, awn 2.5–3.5 mm long. Leaves with petioles 0.4–0.5 cm long; blades lanceolate to linear, rarely oblanceolate, 7–13(–

17) × 1.5–4.5(–6), membranceous or subcoriaceous, drying brown above, paler brown below and somewhat glossy on both sides; apex sharply acuminate; base acute or acuminate; secondary veins 12–15 each side. Inflorescence terminal, multiflorous, shortly pedunculate, trichotomously branched, articulate throughout, compact, 5–6 × 3–4 cm; modified inflorescence supporting leaves absent; peduncle 0.5–1 cm long; central first order axis 0.3–0.5 cm long, lateral first order axes 0.5–1 cm long; first order bracts with stipular parts present fused to an ovate blade with a central awn and the foliar parts triangular to narrowly triangular and vaulted; higher order bracts with stipular parts absent and foliar parts triangular and vaulted. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers 2–3 mm long, central flower sessile or with pedicels up to 2 mm long. Flowers with ovary, calyx, style, stigma, filaments and anthers red, corolla orange to red; flower bud with rounded or acute apex; bracteoles present on most pedicels, opposite at the base of the ovary or on the pedicel, ovate or triangular, apices acute or rounded, 1–1.5 mm long, reaching at most the middle of the ovary; calyx tube 0.5–0.8 mm long; calyx lobes ovate, apices obtuse or rounded, their bases overlapping; corolla tube 30–35 mm long; corolla lobes elliptic or ovate, 10–13 × 3–8 mm, apices acute or rounded; filaments ca. 1 mm long, anthers 3–3.5 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 1–2 mm long, spreading or recurving. Fruits globose or subglobose, 7–9 × 8–10 mm, with persistent calyx, red when ripe; fruit wall ca. 1 mm thick; pyrenes 6–8 × 4–5 mm, seeds 5.5–6 × 3–4 mm.

Habitat:—In secondary forest along streams; elevation 30–600 m.

Distribution:—Restricted to the island of Palawan (Fig. 42).

Phenology:—Flowers: January–May, September, December; fruits: January, March, May, July, September.

Notes:—According to Merrill (1910), *I. palawanensis* is closely allied to *I. congesta* Roxburgh (1820: 397) but with relatively narrrower, smaller leaves which are sharply acuminate and the veins not prominent. In addition to this, the two species differs strikingly in the foliar part of the first order bracts (triangular to narrowly triangular and vaulted for *I. palawanensis*; forming small ovate leaves for *I. congesta*).

FIGURE 43. *Ixora palawanensis* (*Foxworthy 793*) (US, lectotype).

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Mt. St. Paul, Sabang, May 2012, *Alejandro et al. 12403* (USTH); *s.loc.*, April 2010, *Arriola P001* (USTH); Lake Manguao, Taytay, July, 2011, *Banag et al. LM002* (USTH); Sabang, Km. 25 marker Sta. Lucia, Iwahigm Puerto Princesa, July 2011, *Banag & Majaducon LM 023* (USTH); Sagpangan, Aborlan, 5 May 1955, *Celestino & Ramos 22997* (PNH); Mt. Ibusi, 3 August 1947, *Ebalo 1214* (PNH); Babuyan, Puerto Princesa, 15 March 1947, *Edaño 253* (PNH) *& 259* (K, PNH); Bacungan, Puerto Princesa, 23 March 1947, *Edaño 299* (PNH); Bacungan, Puerto Princesa, 28 March 1947, *Edaño 386* (PNH); Lapu-lapu River, Iwahig, Puerto Princesa, 6 March 1947, *Edaño 306* (PNH); Tarateon River, Aborlan, 4 March 1951, *Edaño 14147* (PNH); Victoria Mountain, 18 March 1951, *Edaño 14231* (K, L, PNH); Mt. Pulgar, Puerto Princesa, March 1911, *Elmer 12821* (NY, PNH); Culion, 22 April 1931, *Herre 1032 & 1055* (NY); Puerto Princesa, 22 March 1957, *Kondo 36570* (PNH); Busuanga, September 1922, *Lopez 41376* (P); El Nido, 2011, *Medecillo MPM471 & MPM472* (USTH); Taytay, May 1913, *Merrill 1362* (A, NY, P); Tagimbung, 13 September 1961, *Olsen 252* (C, L); *s.loc.*, 11 February 1963, *Pancho 11868 & 11877* (CAHUP); Brgy. Poblacion, Narra, May 2011, *Pineda et al. RTJ009 &RTJ010* (USTH); near Sumindap River, Brgy. Bundog, Quezon, 21 Ausgust 1996, *Pipoly et al. 38108* (K, L); Culion Island, October 1922, *Ramos 41300* (P); Busuanga Island, September 1922, *Ramos 41182* (P); Bungalon, Quezon, 3 December 1964, *Reynoso 87789* (PNH); Mt. Capoas, Bambanan, Taytay, 6 June 1993, *Reynoso et al. 11139* (K, L); Irawan R valley head, north side, Puerto Princesa, 21 March 1984, *Ridsdale 174* (K, L, PNH); Mt. Beaufort, NNW spur, east side , 13 March 1984, *Ridsdale 40* (K, L, PNH); Takdua zigzag, 35-40 km. from Puerto Princesa, 30 July 1988, *Soejarto & Reynoso 6248* (A); Lake Manguao, Taytay, 19 January 1991, *Stone et al. 300* (K, L); La Estrella, Narra, 22 January 1991, *Stone et al. 107* (A, K, L); La Estrella, Narra, 23 January 1991, *Stone et al. 112* (A); Victoria Mountains, Panacan, Aborlan, 13 May 1950, *Sulit 12366* (PNH).

26. *Ixora philippinensis* Merrill (1910: 238) (Fig. 44).

Type:—PHILIPPINES. Luzon: Bataan: Lamao River, Mt. Mariveles, December 1904, *Meyer 2299* (holotype PNH, destroyed; lectotype NY!, **here designated**; isolectotype US!).
=*Ixora filmeri* Elmer (1912: 1338). Type:—PHILIPPINES. Luzon: Palawan: Addison Peak, Brooke's Point, March 1911, *Ramos 12719* (holotype, PNH!; isotypes A!, L!, MO, NY!, P!).

=*Ixora philippinensis* var. *brevituba* Merr. Type:—PHILIPPINES. Luzon: Ilocos Norte: Pasuquin, 3 November 1908, *Merritt & Darling 15501* (holotype PNH, destroyed; lectotype US!, **here designated**) *syn. nov.*
=*Ixora littoralis* Merr. Type:—PHILIPPINES. Visayas: Bohol: Tagbilaran, July 1906, *McGregor 1274* (holotype PNH, destroyed) *syn. nov.*

Shrub or small tree 2–7 m tall; young internodes, grayish to reddish-brown, terete; all external parts glabrous except the petioles sometimes puberulent, the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas entirely glabrous or sparsely to densely covered with short erect trichomes. Stipules caducous, sheath lanceolate or ovate lanceolate, 1–1.5 mm long, awn 3–5 mm long (only visible in youngest stipule pair). Leaves sessile or with short petioles 0.1–0.2 cm long; blades oblong-ovate to ellipitic-ovate or ovate, 6–15 × 2–6 cm, coriaceous, drying brown or dark brown above; apex shortly and broadly acuminate, acute or rarely obtuse; base broadly rounded, usually distinctly cordate; secondary veins ca. 11 each side. Inflorescence terminal or on short lateral banches, with (3–)6–18(–30) flowers, sessile or pedunculate, non-articulate throughout, lax to moderately compact, 0.5–1 × 1–1.5 cm; one pair of modified inflorescence supporting leaves present, (sub)sessile, blades ovate, 1.5–2.5 × 1.5–2 cm, base cordate; peduncle 0.1–5 cm long; central first order axis 0.1–0.5 cm long, lateral first order axes 0.2–0.5 cm long; first order bracts with stipular parts absent and the foliar parts filiform, 1–2 mm long; higher order bracts with stipular parts absent and foliar parts filiform, up to 1 mm long. Ultimate flower triads with flowers subsessile or shortly pedicellate; pedicels of lateral flowers 1–2 mm long, central flower sessile or with pedicels 0.5–2 mm long. Flowers with ovary and calyx red sometimes green, corolla white (tinged with pink at bud stage), style, stigma white, filaments and anthers yellow; flower bud with acute or rounded apex; bracteoles present or absent on most pedicels, sub-opposite on the pedicel, narrowly triangular to filiform, apices acute, $\leq$ 0.5 mm long, never reaching ovary; calyx tube ca. 0.5 mm long; calyx lobes shortly apiculate or truncate, their bases not overlapping; corolla tube 10–20 mm long; corolla lobes elliptic oblong, 5–7 × 3–3.5 mm, apices obtuse or rounded; filaments ca. 1 mm long, anthers 3–3.5 mm long; style exserted from corolla tube for 1–2 mm, stigmatic lobes 1.5–2 mm long, erect or spreading. Fruits globose, 7.5–11 × 9–13 mm, with persistent calyx, light pink to pale purple rarely whitish when ripe; fruit wall 1–1.5 mm thick; pyrenes 6.5–9.5 × 4–6 mm, seeds 5–8 × 3–5 mm.

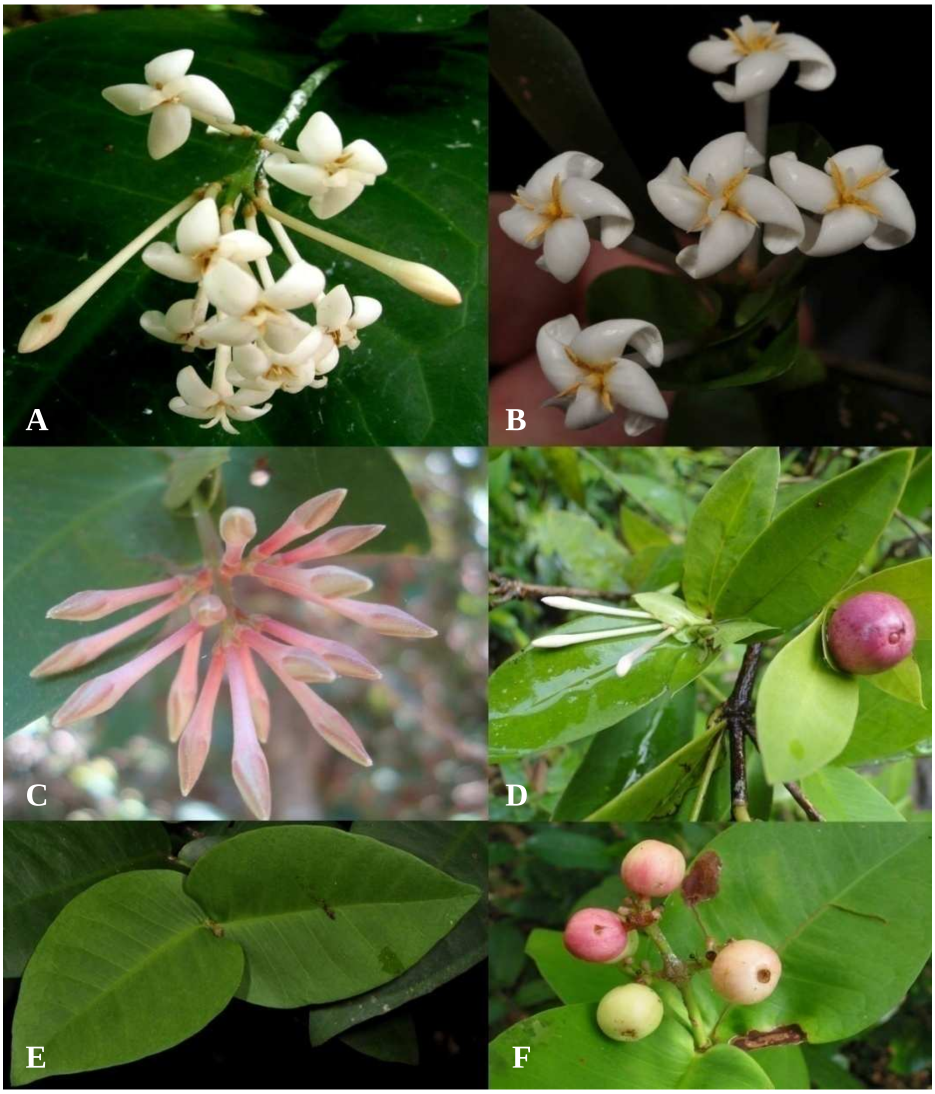

FIGURE 44. *Ixora philippinensis*. A-C—inflorescences, B—flowering and fruiting branch, C—sessile leaves with cordate bases, D—infructescence. Localities: (A & F) Puerto Princesa Subterranean River Natural Park, Palawan; (B & E) Mamburao , Occidental Mindoro; (C) Palpalookada, Poblacion, Burgos, Ilocos Norte; (D). Mt. Redondo, Dinagat Island. Credit: P.B. Pelser (A, B, E & F); C. Banag (C) and G.J.D. Alejandro (D).

Habitat:—In primary or secondary forest, in shaded or moist places, near streams; elevation 0–750 m.

Distribution:—Widely distributed throughout the country (Fig. 45). Also growing in China, Malaysia and Taiwan.

Phenology:—Flowers: January–December; fruits: January–December.

Notes:—Two variants of *I. philippinensis* can be distinguished. However many intermediates are found and the recognition of formal taxa would be difficult. A first variant is entirely glabrous and characterized by leaves shortly petiolate with acute or rounded bases and inflorescences with longer peduncles (up to 5 cm). It is mainly found in Palawan (Fig. 44A & 44F). The second variant has sessile leaves with cordate bases and inflorescences sessile to shortly pedunculate. The inflorescence axes, calyces and corollas are puberulent to densely pubescent (covered with short erect trichomes). The distribution of the second variant is found in northern Luzon and Mindanao (Fig. 44C & 44D). The intermediate type is characterized by the petiolate leaves of the first variant and pubescence of the second variant. Its distribution area falls in central Luzon to Visayas and within Palawan. The type of *I. littoralis* was not seen, however the description in the protologue leaves no doubt that this is *I. philippinensis.* The criteria used by Merrill to segregate var. *brevituba* (sessile or very shortly pedunculate inflorescences, corolla tube barely 1.5 cm) in no way justify an infraspecific division of *I. philippinensis.*

Additional specimens examined:—PHILIPPINES. *s.loc., s.d., s.coll.* (NY); Luzon: **Bataan:** Lamao River, Mt. Mariveles, July–August 1904, *Ahern 1463* (NY, US); Tarak Ridge, Mt. Mariveles, April 2012, *Banag et al. TA006* (USTH); Lamao River, Mt. Mariveles, September–December 1904, *Borden 2024* (NY, US); Mt. Natib, So. Ulingan, Brgy. Banawang, Bagac, 20 December 1996, *Fuentes & dela Rosa 38789* (A, L); Mt. Mariveles, July 1904, *Leiberg 6118* (K); Napot, 12 May 1976, *Nojadera 123829* (PNH); Mt. Natib, 1995, *Reynoso et al. 17326* (L); Lamao River, Mt. Mariveles, May 1905, *Whitford 1270* (NY, US); Lamao River, Mt. Mariveles, 25 December 1903, *Williams 378*, (NY, US);

Batanes: Mt. Matarem, Brgy. San Vicente, 23 April 1996, *Madulid et al. 23755* (A, L); **Batangas:** Calatagan, 16 June 1949, *Quisumbing 6573* (BR, PNH); Wawa Beach, January 1954, *Steiner 454* (US); **Bulacan:** Polo, 2 December 1946, *Mendoza 3084* (BR, PNH); **Cagayan:** Dalupiri Island, Babuyan Group, 31 October 1935, *Bartlett 15052* (PNH); Camiguin Island, Babuyanes, June–July 1907, *Fenix 4096* (US); Brgy. Cabudahan, Calayan Island, 1997, *Fuentes & dela Rosa 38945 & 38959* (US); Brgy. Pagippit, Calayan, Camiguin Island, 10 March 1996, *Fuentes & Fernando 37095* (K, L); Fuga Island, 29–30 May 1907, *Mearns 3246* (NY, US); Calayan Island, Babuyanes, May 1917, *Penas 26711* (US); **Ilocos Norte:** Ka-angrian Falls, Brgy. Agaga, Burgos, 12 May 2012, *Banag BU006* (USTH); Palapalookada, Poblacion, Burgos, 12 May 2012, *Banag BU002, BU003, BU004 & BU005* (USTH); Mt. Quebrada, 28 February 1953, *Edaño 17908* (PNH); Mt. Pico de Loro, 8 March 1953, *Edaño 17999* (PNH); Kalaw, 24 August 1992, *Gaerlan et al. 9872* (K, L); Mt. Pico de Loro, Brgy. Dampig, Pagudpud, 6 February 1997, *Garcia & Edaño 25141 & 25190* (K, L); Piddig, November 1923, *McGregor 43635* (US); Burgos, February–March 1917, *Ramos 27250* (P); Burgos, July 1918, *Ramos 32768* (P); Sungadan, Paoay, April–May 1984, *Vendivil & Fernando 160433* (PNH); **Laguna:** University of the Philippines Los Baños, 25 July 1983, *Calo 39805* (CAHUP); **Metro Manila:** Malabon, *s.d.*, *Loher 1455* (US); Caloocan, 25 November 1903, *Merrill s.n.* (NY); *s.loc.*, October–November 1903, *Merrill 3428* (NY, US); **Masbate:** Ticao Island, 31 March 1957, *Kondo & Edaño 36864* (PNH); **Occidental Mindoro:** Golo, Lubang Island, 3 April 1957, *Kondo & Edaño 36739* (PNH); Lubang Island, April 1903, *Merrill 975* (NY); Polo, May 1903, *Merrill 2249* (US); Mt. Gonting, Lubang Island, 29 June 1996, *Romero & Fuentes 37579* (K, L); Mt. Ambil, Sitio Tabao, 7 July 1996, *Romero & Fuentes 37621* (A, L); **Oriental Mindoro:** vicinity of Puerto Galera, 15 April 1935, *Bartlett 13514* (A); Puerto Galera, *s.d.*, *Chavez GN023* (USTH); Mt. Yagaw (SE Slope), 5 August 1953, *Conklin 18622* (A, L); Calapan, 1 July 1913, *Escritor 21265* (P, US); Baco, January 1903, *Merrill 1199* (NY); Bulalacao, April 1903, *Merrill 930* (NY); *s.loc.*, January 1908, *Merritt 8657* (US); Mahabang Parang Cove, Puerto Galera Bay, 1952, *Santos 5166* (L); Puerto Galera, 20 April 1952, *Santos 5195* (L, US); Bo. Manaul, Mansalay, 29 December 1952, *Sulit 17151* (A, L, PNH); **Palawan:** Mt. St. Paul, Sabang, May 2012, *Alejandro et al. 12400* (USTH); Sitio Lapu-lapu, Narra, July 2011, *Banag & Majaducon LM022* (USTH); Iwahig Penal Farm, Puerto Princesa, May 2011, *Banag et al. I002* (USTH); *s.loc.*, December 1905, *Bermejos 251* (NY, US); Bo. Tamlang, Brooke's Point, 16 October 1990; *Cajano 54153* (CAHUP); Sagpangan, Aborlan, 6 May 1955, *Celestino & Ramos 23000* (L, PNH); Mt. Sorsogon, vicinity of Puerto Princesa, 5 February 1940, *Ebalo 417* (PNH); Canigaran, Puerto Princesa, 8 April 1947, *Edaño 296* (PNH); Brooke's Point, 26 April 1947, *Edaño 230* (PNH); Culion, August 1913, *Escritor 21656* (NY); *s.loc.*, August 1913, *Escritor 21565* (NY, P, US); *s.loc.*, May 1914, *Fernandez 21499* (P, US); Limestone Hill, Lipuun Point, Quezon, 1963, *Gutierrez & Espiritu 80741* (L); Banwangdaan, Coron Island, 27 September 1993, *Madulid et al. 11514* (K, L); Apulit Island, Taytay, 1995, *Madulid et al. 18550* (L); Pangolacion Island, El Nido Town, 28 April 1997, *Madulid et al. 27588* (K); Taglomot Quezon, 21 April 1964, *Mendoza & Espiritu 91176* (PNH); Magangas Island, 25 April 1964, *Mendoza & Espiritu 91292* (PNH); Balabac Island, 16 October 1906, *Merrill 5377* (NY, US, P); *s.loc.*, May 1913, *Merrill 1370* (P); Balabac Island, 5 October 1961, *Olsen 538* (C, L); Balabac Island, Dalawan Bay, 12 October 1961, *Olsen 611* (C); Balabac Island, Dalawan Bay, 8–12 December 1961, *Olsen 477 & 610* (C); Brgy. Polacion, Narra, May 2011, *Pineda et al. RTJ005 & RTJ006* (USTH); Mt. Gantung, Mantalingajan Mt. Range, District of Tindogan, 16 August 1996, *Pipoly et al. 37742* (K, L); Balabac Island, November 1927, *Ramos & Edaño 49687* (NY); Subsubon, Quezon, 2 December 1963, *Reynoso et al. 87777* (PNH, SAN); Sidanao Island, Quezon, 9 December 1963, *Reynoso*

87840 (PNH, SAN); mid-point between Calauag and Saldem point, near 32 m spot height, Taytay, 1984, *Ridsdale 420* (L); Langen (Malapakan) Island, Malapakan Cove, 16 April 1984, *Ridsdale 455* (K, L, PNH); St. Paul's Bay Underground River National Park, bay east of Tuturingen Point, 9 May 1984, *Ridsdale 1660* (K, L, PNH); concession area Trident Mining Company, Victoria Peaks, Narra, 24 May 1984, *Ridsdale 1853* (K, L); Pulot, Massin River, 12 Km. north Brooke's Point, 1985, *Ridsdale 1020* (L); Tabon Island, Quezon, 1994, *Soejarto et al. 8450 & 8505* (L); Olympic Mines, north of Bivouac Point, 26 January 1991, *Stone 226* (K, L); Victoria Mountains Panacan, Aborlan, 8 May 1950, *Sulit 12291* (L, PNH); Iraan Mountains, Aborlan, 27 May 1950, *Sulit 12468* (A, L, PNH, SAN); **Pangasinan:** Manluluwag, Mangatarem, February 1974, *Madulid & dela Cruz 120888* (PNH); Hundred Islands, Alaminos, 12 March 1960, *Mendoza & Pancho 40735* (PNH); Alaminos, 12 March 1960, *Pancho 10535* (CAHUP); **Quezon:** Pagbilao Grande Island, Tayabas Bay, Bo. Lipata, 22 September 1978, *Fernando 27217* (CAHUP); Katimo, Tagkawayan, 9 June 1965, *Mendoza 97808* (PNH); Lagumanoc River, Tayabas, November 1903, *Merrill 3358* (NY, US); Dalahican Beach, Lucena, 26 December 1953, *Sulit 18861* (L, PNH); **Rizal:** *s.loc.*, November 1914, *Ramos 2011* (P); **Romblon:** Brgy. Bonbon, Sibuyan, 27 February 1994, *Reynoso et al. 14218* (K, L); **Zambales:** Masinloc Mine, 13 November 1999, *Argent et al. 99249* (A, L); Mt. Pinatubo, 21 May 1948, *Fox 4572* (PNH); Anuling, November–December 1924, *Ramos & Edaño 44653* (C); Visayas: **Antique:** Brgy. Bagacay, Culasi, Antique, Panay, 17 February 1992, *Gaerlan & Fernando 5100* (K, L); Balawarte, Brgy. Semirara Island, Caluya, 1997, *Romero & Majaducon 29466 & 29493* (L); Libo/Sigayan/Balibago, Brgy. Semirara Island, Caluya, 1997, *Romero & Majaducon 29551 & 29561* (L); **Leyte:** Gigantangan, 25 March 1957, *Kondo & Edaño 36771* (PNH); **Cebu:** Sitio Poo, Brgy. Sta. Rosa, Olango, Lapu-lapu City, 21 May 1993, *Madulid et al. 7659* (K, L); *s.loc.*, March 1912, *Ramos 11100* (C); Tuyom, Carcar, 18 January 1964, *s.coll. 92091* (PNH); **Guimaras:** Buenavista Bo. Salvacion, March 1950, *Sulit 11762* (PNH) *& 11767* (L); Buenavista Bo. Salvacion, 25 February 1958, *Sulit 11695* (PNH); Buenavista, 1955, *Taleon 33925* (L); Mindanao: *s.loc.*, September–October 1907, *Clemens 1197* (US); **Basilan:** *s.loc.*, September 1912, *Reillo 16296* (US); **Camiguin:** Brgy. Catabac, Brgy. Bonbon, Catarman, 1995, *Gaerlan et al. 23059* (L); **Davao del Sur:** Tibunco, August 1933, *Kaehira 2602* (NY); Sta. Maria, *s.d.*, *Lemana BL006* (USTH); **Davao Occidental:** Lawayon, Malita, 5 November 1950, *McVittie & Curran 13836* (PNH); **Davao Oriental:** Baguan River, 8 March 1949, *Edaño 11315* (PNH); Pujada Island, 29 April 1949, *Edaño 11662* (A); Mt. Hamiguitan, 8 August 1949, *Edaño 10994* (PNH); Mati, January 1931, *Ondrada 31352* (NY); **Dinagat**

Island: Mt. Redondo, 2011, *Alejandro et al. 11102* (USTH); **South Cotabato:** Klaja Hill, Barrio Konel, 13 September 1950, *Anonuevo 13596* (L, PNH); *s.loc.,* March 1906, *Hutchinson 3934* (NY, US); *s.loc.,* April 1912, *Whitford 14230* (P); **Sulu:** Tarawakan Beach, Jolo, 18 February 1957, *Kondo & Edaño 36870* (PNH); Cagayan de Sulu, 27 February 1957, *Kondo & Edaño 39017* (L, PNH, US); Cagayan de Sulu, 25 February 1904, *Mearns s.n.* (US); Cagayan Sulu Island, December 1927, *Ramos & Edaño 49929* (NY); **Tawi-tawi:** Sibutu Island, 13 October 1906, *Merrill 5298* (NY); **Zamboanga del Sur:** *s.loc.*, 1901, *Ahern s.n.* (US); *s.loc.,* 1902, *Ahern 650* (NY); Sta. Maria, September–October 1912, *Reillo 16378* (K, P); Port Banga, July 1910, *Robinson 11827* (P); Sax River, 26 February 1905, *Williams 2312* (NY, US).

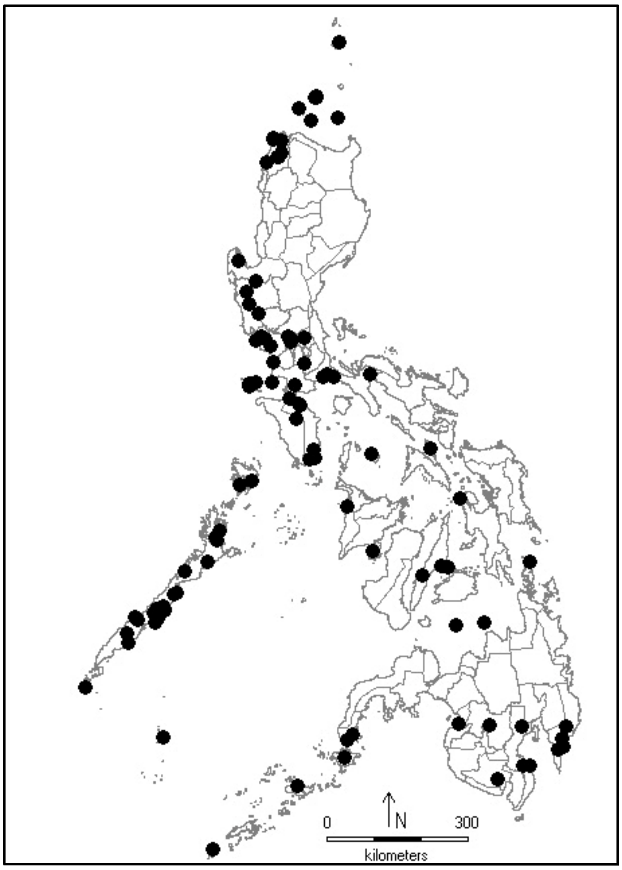

FIGURE 45. Distribution of *I. philippinensis*.

27. *Ixora reynaldoi* Banag (2014: submitted) (Fig. 46).

Type:—PHILIPPINES. Visayas, Eastern Samar: Maydolong, Borongan, 28 August 2011, *Banag et al. SA004* (holotype PNH 254887!, isotypes USTH!, K!, US!).

Shrub 1–2 m tall; young intermodes brown, terete, older internodes grayish to brown, corky; all external parts glabrous. Stipules persistent, sheath 1–2 mm long, awn 4–6 mm long. Leaves with petioles 0.5–1 mm long, canaliculate; blades elliptic to obovate, 8–15 × 1–3 cm, coriaceous, dyring olivaceous above, paler below; apex narrowly acute to acuminate; base acute to rounded; secondary veins 10–15 each side. Inflorescences terminal, sessile, consisting of one small head of up to 15 flowers; modified inflorescence-supporting leaves absent; bracts triangular, 5–6 mm long, apices narrowly acute. Flowers with ovary and calyx red, corolla and style white, stigma, filaments and anthers cream; flower bud with acute apex; bracteoles present, opposite at the base of the ovary, linear or narrowly triangular, keeled, apices acuminate, up to 8 mm long, reaching half of the calyx lobes; calyx tube 2–5 mm long; calyx lobes triangular or foliaceous, keeled, apices acute or shortly acuminate, 8–10 mm long, their bases not overlapping; corolla tube 20–22.5 mm long; corolla lobes elliptic to ovate, 5.5–6.5 × 2–3.5 mm, apices acuminate; filaments 0.5–1.0 mm long; anthers 5–7 mm long; ovary 1.2–2.3 mm long; style exserted from corolla tube for 2–2.4 mm long, stigmatic lobes 1.5–2.5 mm long, spreading. Fruits and seeds unknown.

Habitat:—Thrives in secondary forests; elevation 200–400 m.

Distribution:—Only known from the type locality (Fig. 42).

Phenology:—Flowering from May to August.

Notes: — *Ixora reynaldoi* differs from the other species of the genus by its shortly petiolate or subsessile leaves, a pseudanthium type of inflorescence and very long bracteoles and calyx lobes (up to 10 mm). *Ixora reynaldoi* has very long bracteoles and calyx lobes, a very rare feature in Philippine *Ixora* and the genus as a whole, only known in *I. amplexicaulis* Gillespie (1930:30) from Fiji (bracteoles about 9 mm long, calyx lobes narrowly triangular, 7–8 mm long).

Additional specimens examined:—

FIGURE 46. *Ixora reynaldoi.* A—stipules, B—foliaceous calyces. Locality: Maydolong, Borongan, Eastern Samar (*Banag et al. SA004*).

28. ***Ixora salicifolia*** (Blume) De Candolle (1830: 487) **(**Fig. 47).

Basionyms:—*Pavetta salicifolia* Blume (1826: 951); *Ixora fulgens* var. *salicifolia* (Blume) Kuntze (1892: 286). **Type:**— INDONESIA. Java, *s.d.,Reinwardt s.n.* (holotype L).

=*Ixora longissima* Merr. **Type:—**PHILIPPINES. Visayas: Leyte: without definite locality, *Rosenbluth s.n.,* March 1909 (lectotype HUH!, designated by Banag *et al.* (2014).

Shrub 1–3 m tall; young internodes pale-brown, terete; all external parts glabrous except the peduncle, inflorescence axes, pedicels, bracts and bracteoles, ovaries, calyces and corollas sparsely to moerately covered with very short erect trichomes. Stipules persistent, sheath connate, 1–1.5 mm long, awn 3–5 mm long. Leaves with petioles 1–1.5 cm long; blades linear or sometimes lanceolate, (10–)25–40 × (1.5–)3.5–5.5 cm, submembranaceous or chartaceous, drying brown above, paler brown below and somewhat glossy on both sides; apex narrowly acute; base acute; secondary veins ca. 23 each side. Inflorescence terminal, shortly pedunculate, trichotomously branched, articulate throughout, compact, 1.5–4.5 × 3–10 cm; modified inflorescence supporting leaves absent; peduncle 1–1.5 mm long; central first order axis 3–5 cm long, lateral first order axes 4–6 cm long; first (and sometimes second) order bracts with stipular parts present fused to an ovate blade with a central awn and foliar parts narrowly triangular, 3–4 mm long; higher order bracts with stipular parts absent and foliar parts narrowly triangular, 3–4 mm long. Ultimate flower triads with flowers subsessile or pedicellate; pedicels of lateral flowers (0.5–)2–4 mm long and the central flowers (sub)sessile or with pedicels up to 1.5 mm long. Flowers with ovary, calyx and corolla red, style, stigma, filaments and anthers pale red to yellow; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, triangular, 1–1.5 mm long, reaching the middle of the ovary; calyx tube ca. 0.5 mm long; calyx lobes triangular to ovate, apices acute to obtuse, their bases overlapping; corolla tube 30–40 mm long; corolla lobes elliptic, 8–10 × 3–3.5 mm, apices acute; filaments 1–1.5 mm long, anthers 3–4 mm long; style exserted from corolla tube for 2–2.5 mm, stigmatic lobes 1–2 mm long, spreading. Fruits subglobose, 5–7 × 7–10 mm, with persistent calyx, red when ripe; fruit wall 0.5–1 mm thick; pyrenes 4–6 × 3–5 mm, seeds 4–5 × 2–4 mm.

Habitat:—In secondary forest, along ridges or near streams; elevation 50–900 m.

FIGURE 47. *Ixora salicifolia*. A—flowering branch (inset showing stipules), B—infructescence, C—inflorescence. Locality: (A) Brgy Tina, San Miguel, Surigao del Sur (*Banag SU002*); (B) Brgy. Catmon (*Banag et al. 12026*), St. Bernard, Leyte; (C) Siargao Island, Surigao del Norte. Credit: C. Banag & D. Tandang.

Distribution:—Widely distributed in Visayas and Mindanao, in Luzon only known from Palawan and Masbate (Fig. 48).

Phenology:—Flowers: January–December; fruits: January, April, June–July, October–November.

Notes:—*Ixora salicifolia* can be immediately recognized by its long linear leaves (up to 40 cm). It is closely related to *I. longifolia* but with striking differences (see discussion under *I. longifolia*).

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Mt. Gantung, May 1929, *Edaño 77599* (A); Baraki, 30 November 1950, *Fox 13340* (A); Iwahig River, Puerto Princesa, 18 February 1903, *Merrill 751* (NY); Lake Manguao (Danao), Taytay, 5 April 1984, *Ridsdale 316* (A, L, PNH, SAN); *s.loc.*, 1957, *Wintermitz 36342* (L); **Masbate:** *s.loc.*, May–June 1904, *Clark 1868* (NY); Visayas: **Biliran:** Mt. Suiro (Northern Slope), 30 April 1954, *Sulit 21577* (L, PNH); **Leyte:** San Juan, Sogod, 26 November 2011, *Banag & Asis SJ005* (USTH); Brgy. Catmon, St. Bernard, 12 April 2012, *Banag et al. 12026* (USTH); Libtong, Naval, Biliran, 1992, *Barbon et al. 8582* (L); Antilao River, Ormoc, 12 March 1950, *Edaño 11858* (A, PNH); Palo, January 1906, *Elmer 7052* (NY); *s.loc.*, 24 July 1945, *Glassman 697* (A); *s.loc.*, 23 February 1913, *Wenzel 286* (A); **Western Samar:** Loquilocon, Wright, 17 April 1948, *Sulit 6138* (PNH); Rawis, Sohoton National Park, 1971, *s.coll. 193* (L); Mindanao: **Agusan del Norte:** Tungao, 2 October 1966, *Coloma 98385* (PNH); Mt. Urdaneta, Cabadbaran, August 1912, *Elmer 13527* (L, NY); Asiga River, April–May 1931, *Ramos & Convocar 83675* (A); **Davao del Sur:** Todaya, Mt. Apo, July 1909, *Elmer 11182* (L, NY); **Davao Oriental:** Mt. Kampalili, 23 March 1949, *Edaño 11572* (A, L, PNH); Mt. Mayo, April–May 1927, *Ramos & Edaño 49405* (NY); *s.loc.*, August1933, *Kanehira 2578* (NY); **Dinagat Island:** *s.loc.*, June 1931, *Ramos & Convocar 84013* (A); **Lanao del Sur:** Sacred Mountain, Dansalan, 1953, *Britton 388* (L); **Surigao del Norte:** Brgy. Malinaw, General Luna, Siargao Island, 10 September 2011, *Banag SU009* (USTH); Sitio Tiktikan, Bucas Grande, Socorro, 22 September 2011, *Banag SU020* (USTH); Sukailang, February–March 1949, *Mendoza & Convocar 10240* (A, PNH) *& 10262* (A, L, PNH); Siargao Island, June 1919, *Ramos & Pascasio 34943* (NY); **Surigao del Sur:** Brgy. Tina, San Miguel, 11 September 2011, *Banag & Dolojan SU002A & SU002B* (USTH); Tandag, October 2012, *Blasco et al. 12558* (USTH); **Surigao:** *s.loc.*, April 1919, *Ramos & Pascasio 34459* (P) *& 34506* (A); *s.loc.*, 30 June 1927, *Wenzel 2896* (A, BR, NY).

—INDONESIA. Java, 22 Jun. 1918, *Bünnemeÿer 3204* (P); West Kalimantan, Kabupaten Sanggau, 17 November 1994, *de Jong 886* (NY); Lenkong, West Java, 9 March 1977, *Raynal 18916* (P); Java, Bogor, *s.d., Schuurman 136H* (P); Java, Passir Madang in Urwalda, 13 August 1843, *s.coll. 1843* (P).

—MALAYSIA. Kinabatangan, 23 August 1929, *Evangelista 941* (NY); *s.loc.*, September 1894, *Haviland 2978* (P).

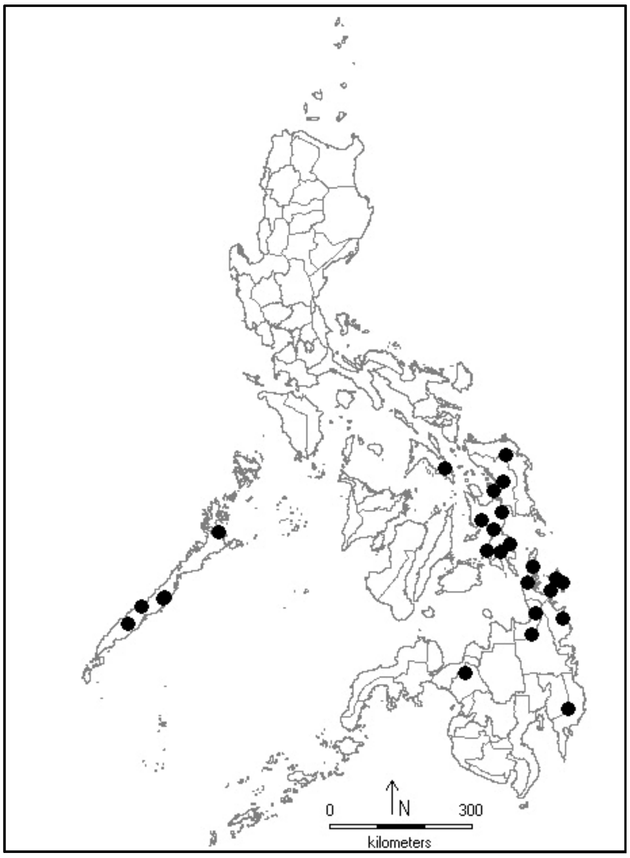

FIGURE 48. Distribution of *I. salicifolia*.

29. *Ixora silagoensis* Manalastas *et al.* (Banag *et al.* 2014: submitted) (Fig. 49).

Type:—PHILIPPINES. Visayas: Leyte: Silago, Brgy. Catmon, Mt. Mumpung, 11 April 2012, *Banag et al. 12037* (holotype: USTH 5857!; isotypes: USTH!, PNH!).

Shrub ca. 1 m tall; young internodes brown, terete, older internodes grayish, somewhat corky; all external parts glabrous. Stipules persistent, sheath 1.5–2.5 mm long; awn 1.5–2 mm long. Leaves sessile; blades linear, 6–19 × 1–1.5 cm, rigidly coriaceous, drying brown above, paler brown below; apex narrowly acute; base cordate; secondary veins 10–15 each side, midvein prominent on both sides, intersecondaries reticulate but visible with difficulty. Inflorescences terminal, subsessile or pendulous, trichotomously branched, articulate throughout, lax, 1–2.5 × 1.5–4 cm; one pair of modified inflorescence-supporting leaves present, subsessile, blades similar in shape to vegetative leaves but smaller, 1–4 × 0.3–1 cm; peduncle 1–10 cm long, red; central and lateral first order axes 0.5–2 cm long; first and higher order bracts with stipular parts absent, foliar parts triangular or anvil-like, vaulted, 3–4 mm long. Ultimate flower triads with flowers pedicellate; pedicels 5–6 mm long, the pedicel of the central flower as long as or shorter than the pedicels of the lateral ones. Flowers with ovary and calyx green to red, corolla white (tinged with pink at bud stage), style white, stigma, filaments and anthers yellow or cream; flower bud with acute apex; bracteoles present on most pedicels, opposite at the base of the ovary, narrowly triangular and vaulted, apices acute to acuminate, 2–3 mm long, reaching the middle of the calyx lobes; calyx tube ca 0.5 mm long; calyx lobes narrowly triangular, their bases not overlapping, 0.5–2 mm long, apices acute; corolla tube 5–25 mm long; corolla lobes elliptic to ovate, 5–6 × 1.8–2.5 mm, apices sub-acute to rounded; filaments 0.5–1 mm long; anthers ca. 4 mm long; ovary 1–1.5 mm long; style exserted from corolla tube for 2–3 mm; stigmatic lobes 2–3 mm long, spreading. Fruits subglobose, 4–10 × 3–15 mm, with persistent calyx, red when ripe; fruit wall 1–2 mm thick; pyrenes 2.5–6.8 × 2–4.8 mm; seeds 2–6.3 × 1.5–4.3 mm.

Habitat:— In secondary forests; elevation ca. 600 m.

Distribution:—Restricted in Leyte and Samar from the Visayas (Fig. 50).

Phenology:—Flowers: October–November and Fruits: May

Notes:—*Ixora silagoensis* was believed to be known only from the type locality. However, a few specimens deposited at PNH which are mostly in fruiting stage clearly belong to *I. silagoensis* as well. These were collected in Samar, a neighboring province of Leyte in Visayas. The populations of *I. silagoensis* collected from Samar, differs from the specimens collected from Leyte in having pendulous inflorescences. Since correlation with other characters can not be found, such variation in peduncle length is presumed to have no taxonomic value. In addition, it has been noted in some *Ixora* species that a sessile inflorescence becomes pedunculate or pendulous in the fruiting stage (De Block 1998).

Additional specimens examined:—PHILIPPINES. Visayas: **Leyte:** San Juan Sogod, 26 November 2011, *Banag & Asis SJ021* (USTH); **Eastern Samar**: Mt. Concord, 1969, *Gutierrez et al. 117168* (L); Bagacay, Concord, April–May 1948, *Sulit 6246 & 9373* (PNH); Mt. Caligba, Taft, 18 May 1948, *Sulit 6425* (K, PNH).

Figure 49. *Ixora silagoensis*. A—inflorescence B—infructescence. Drawn from 5857 (USTH). Locality: Mt. Mumpung, Brgy. Catmon, Silago, Leyte *(Banag et al. 12037*). Credit: J. dela Bajan

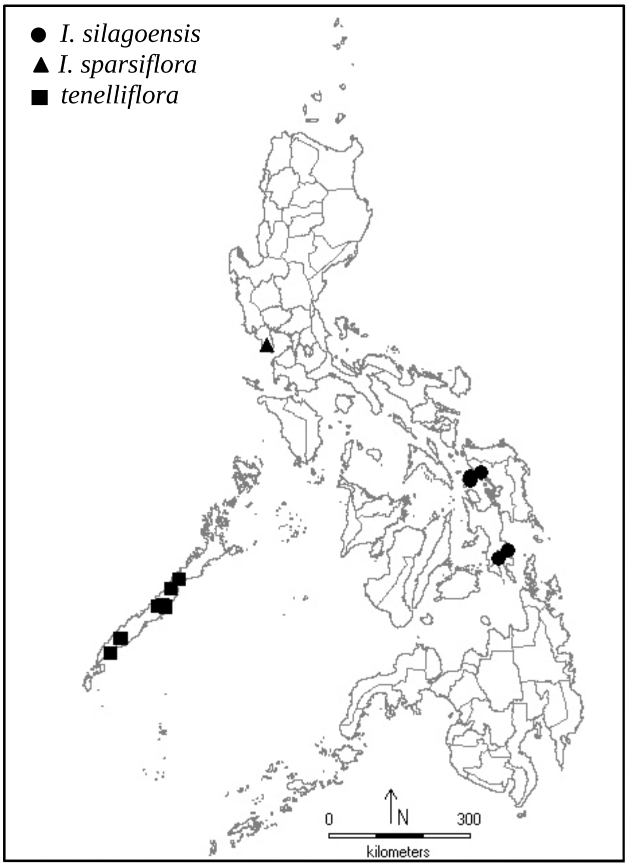

FIGURE 50. Distribution of *I. silagoensis, I. sparsiflora* and *I. tenelliflora.*

30. *Ixora sparsiflora* Elmer (1906: 8) (Fig. 51).

Type:—PHILIPPINES. Luzon: Bataan: Mt. Mariveles, November 1904, *Elmer 6641* (holotype PNH, destroyed; lectotype NY, **here designated**; isolectotype K).

Shrub ca. 3 m tall; young internodes grayish; all external parts glabrous. Stipules caducous, sheath triangular, 1–1.5 mm long, awn up to 8 mm long (only visible in young stipule pairs). Leaves sessile; blades triangularly acuminate, 5–8 × 2–3 cm, submembranous, drying brown above, paler brown below; apex narrowly acute; base subemarginate; secondary veins 15–18 each side. Inflorescences terminal, sessile or subsessile (peduncle $\leq$ 1 mm), trichotomously branched, articulate throughout, lax, 1–2 × 2–2.5 cm; one pair of modified inflorescence supporting leaves present, subsessile, blades linear, 0.8–1 × 0.1–0.2 cm; central and lateral first order axes 0.5–1 cm long; first and higher order bracts with stipular parts absent and the foliar parts narrowly triangular and vaulted, 2–2.5 mm long. Ultimate flower triads with flowers pedicellate; pedicels ca. 10 mm in fruiting stage; bracteoles present on most pedicels, opposite at the base of the ovary, triangular, 0.5–1 mm long. Fruits subglobose, 7–8 × 5–6 mm, with persistent calyx. Flowers unknown.

Habitat:—No information, probably in forest.

Distribution:—Known only from the type locality (Fig. 50).

Phenology:—Fruits: November

Notes:—This species is only known fom the type. As a result the description may need to be updated when more material becomes available. *Ixora sparsiflora* is very close to *I. luzoniensis* but differs in having sessile leaves that are triangularly acuminate with subemarginate bases. The lack of information about the flowers of *I. sparsiflora* does not allow to resolve its relationships with *I. luzoniensis.* Survey and collecting efforts should be done in the distribution area of this species to ascertain its conservation status.

Additional specimens examined:—

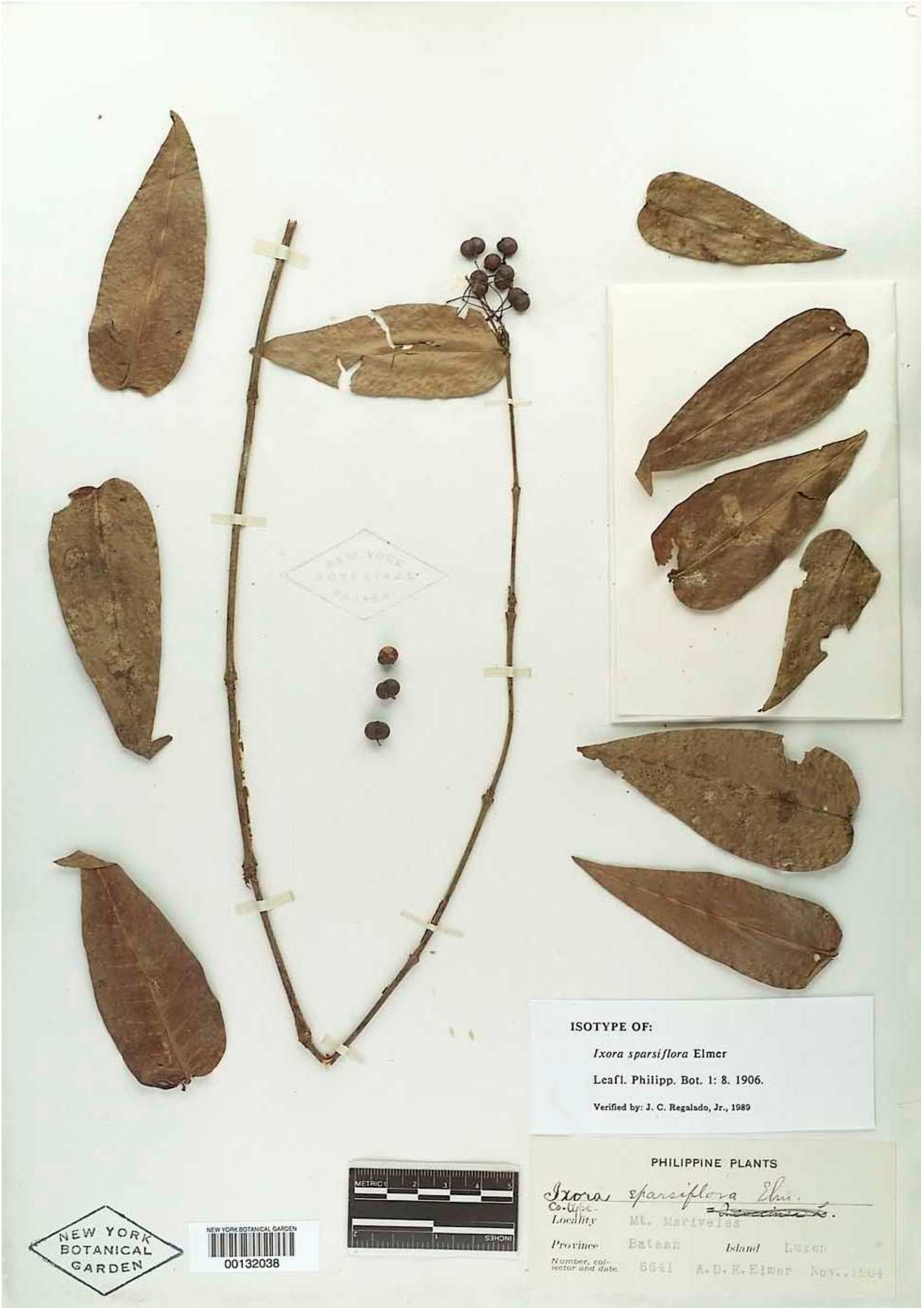

FIGURE 51. *Ixora sparsiflora* (*Elmer 6641*) (NY, lectotype).

31. *Ixora tenelliflora* Merrill (1926: 423) (Fig. 52).

Type:—MALAYSIA. Banguey Island, 1 August 1923, *Castro & Melegrito 1384* (holotype UC; isotypes A!, K!).

Tree 5–8 m all; young internodes; young internodes, subterete; all external parts glabrous except the peduncle, inflorescence axes, bracts and bracteoles, pedicels and calyces sparsely or moderately covered with very short erect trichomes. Stipules subpersistent, sheath widely triangular or ovate, 2–3 mm long, awn ca. 3 mm long. Leaves with petioles 0.2–0.4 cm long; blades oblong-oblanceolate to oblong-obovate, 15–23 × 6–8.5 cm, membranaceous, drying olivaceous above, paler below; apex rounded sometimes shortly acuminate; base obtuse to acute; secondary veins 10–13 each side. Inflorescence terminal, pendulous, the opposite clusters of flowers along the central axis congested, non-articulate throughout, (2.5–)7–16 × (2.5–)5–10.5 cm; one pair of modified inflorescence supporting leaves present, subsessile or shortly petiolate, similar in shape and size with vegetative leaves; peduncle (1–)7–10 cm long; central first order axis (0.5–)9–12 cm long, lateral first order axes (0.5–)3–5 cm long; first order bracts with stipular parts fused to an ovate blade with central awn and foliar parts forming small leaves; higher order bracts with stipular parts absent and foliar parts triangular, 2–8 mm long. Ultimate flower triads with flowers pedicellate; pedicels of lateral flowers up to 2.5 mm long, central flower sessile or with pedicels up to 1.5 mm long. Flowers with ovary and calyx red, corolla, style, stigma, filaments and anthers white; flower bud with acute apex; bracteoles present on most pedicels, sub-opposite at the middle portion of the pedicels, triangular, apices acute, 0.5–1 mm long, never reaching the ovary; calyx tube 0.2– 0.5 mm long; calyx lobes ovate to triangular, apices rounded or acute, their bases sometimes overlapping; corolla tube 30–45 mm long; corolla lobes elliptic, 5–7 × 3.5–4 mm, apices acute; filaments 1–2 mm long, anthers 3–3.5 mm long; style exserted from corolla tube for 2–3 mm, stigmatic lobes 1–1.5 mm long, erect. Fruits globose, 7–8 × 7–9 mm, with persistent calyx, red when ripe; fruit wall ca. 1 mm thick; pyrenes 6–7 × 3.5–4 mm; seeds 5–6 × 2.5–3 mm.

Habitat:—In forests along creeks or streams; 50–850 m.

Distribution:—In the Philippines it is only known from Palawan (Fig. 50), but is also growing in Malaysia.

FIGURE 52. *Ixora tenelliflora* (*Castro & Melegrito 1384*) (K, isotype).

Phenology:—Flowers: February–May, August, October–November; fruits: March, May, November.

Notes:—*Ixora tenelliflora* is strongly characterized by its pendulous inflorescence with the opposite clusters of flowers along the central axis congested and first order bracts with stipular parts fused to an ovate blade with central awn which is typical for species with sessile or shortly pedunculate inflorescences.

Additional specimens examined:—PHILIPPINES. Luzon: **Palawan:** Sagpangan, Aborlan, 13 May 1955, *Celestino & Ramos 23045* (A, L, PNH); *s.loc.*, August–September 1925, *Cenabre 80089* (NY); Mt. Tagbarungis vicinity of Puerto Princesa, 14 February 1940, *Ebalo 496* (A, PNH); Mt. Langogan vicinity of Puerto Princesa, 23 February 1940, *Ebalo 560* (A, PNH); Imolnod, March 1929, *Edaño 77353* (A); Tigpalan River, April 1929, *Edaño 77660* (A); Mt. Matalingahan, Brooke's Point, 5 May 1947, *Edaño 281* (PNH) *& 291* (A, PNH); April 1929, *Edaño 77499* (A); Tarateon River, Aborlan, March–April 1951, *Edaño 13993* (K, L, PNH); Baraki, 23 November 1950, *Fox 13360* (A); 24 November 1950, *Fox 13366* (A, L, PNH, SAN); Sitio Impapay, Brgy. Irawan, Puerto Princesa, 5 October 1993, *Madulid & Majaducon 8105* (A); trail to Thumb Peak Balsaban river, Iwahig Prison Colony, Puerto Princesa, 1995, *Soejarto et al. 9128* (L).

POTENTIAL NEW SPECIES

The following specimens may well represent additional new species however insufficient material prevents the formal description of these taxa.

Ixora sp. "Batanes"

Habitat:—In forest; elevation ca. 500 m.

Distribution:—Only known from one specimen (*Tandang DT588*) from Mt. Matarem, Batanes Island.

Phenology:—Fruits: November.

Notes:— *Ixora sp.* "Batanes" is similar to *I. philippinensis* on the basis of its cordate and sessile leaves but differs in having first order bracts with stipular parts and the foliar parts forming small leaves. Recent molecular study on Philippine *Ixora* (Banag *et al.* submitted) also revealed that this species is not closely related with *I. philippinensis*. However it is only known from one fruiting specimen and lack of good flowering material prevents the formal description of *Ixora sp.* "Batanes".

***Ixora sp.* "Lanao"**

Habitat:—Probably in forest; elevation ca. 600 m.

Distribution:—Only known from one specimen (*Lyn Zwickey 189*) from Lanao del Sur.

Phenology:—Flowers: September.

Notes:—*Ixora sp.* "Lanao" is similar to *I. bartlingii* in having terminal and pendulous inflorescences with branches spreading at right angles and shortly triangular calyx lobes. However it differs from *I. bartlingii* in having obovate leaves (vs. oblong), first order bracts with stipular parts present (vs. first order bracts with stipular parts fused to an ovate blade with central awn), and central flower of the ultimate flower triad sessile (vs. pedicellate flowers in ultimate flower triad). *Ixora sp.* "Lanao" is only known from one specimen in bud stage.

***Ixora sp.* "Palawan"**

Habitat:—In forest; elevation ca. 600 m.

Distribution:—Only known from one specimen (*Alejandro et al. 12-406*) from Palawan.

Phenology:—Flowers: May.

Notes: *Ixora sp.* "Palawan" can not be matched with any other native species of Philippine *Ixora* on the basis of its orange flowers. The only species of *Ixora* known in the Philippines with orange flowers is *I. javanica*, which is only known as an introduced and cultivated plant.

***Ixora sp.* "Dinagat"**

Habitat:—In secondary forest; elevation ca. 600 m.

Distribution:—Only known from one specimen (*Alejandro et al. 11-068*) from Mt. Redondo, Dinagat Island.

Phenology:—Flowers: May.

Notes:—*Ixora sp.* "Dinagat" is similar to *Ixora sp.* "Palawan" in having orange flowers and can not be matched with the other recognized Philippines species. It differs however from the *Ixora sp.* "Palawan" in having elliptic, very coriaceous leaves with very prominent tertiary venation. Further material is required to ascertain whether the two specimens cited here are conspecific.

Cultivated species:

Other Asian *Ixora* species have been introduced in the Philippines as ornamentals. They are commonly used as hedge because of their very attractive flowers. *Ixora coccinea, I. chinensis* and *I. finlaysoniana* may be considered as the three most widespread cultivated Ixoras in the Philippines followed by *I. javanica* and *I. macrothryrsa.* The native species of Philippine *Ixora* are only rarely cultivated. However they certainly do have ornamental potential, especially the shrubs with pendulous inflorescences e.g. *I. bartlingii* and *I. macrophylla*. The cultivated species of *Ixora* in the Philippines were not described or treated taxonomically in detailed here. However some Philippine species were previously tranferred as synonyms to some of these cultivated species.

Key to the commonly cultivated species of *Ixora* in the Philippines.

1a. Calyx lobes up to 5 mm long; flowers white, very fragrant..........................*I. finlaysoniana*

1b. Calyx lobes 0.1–1.5 mm long; flowers red, orange, yellow, sometimes white,
usually not fragrant...2

2a. Style pubescent; leaves distinctly petiolate, petioles 4–10 mm long.......................3

3a. Corolla tube glabrous; leaf blade linear-lanceolate
or ovate..*I. macrothyrsa*

3b. Corolla tube pubescent; leaf blade elliptic, ovate-oblong
or obovate...*I. javanica*

2b. Style glabrous; leaves sessile or shortly petiolate, petioles 3.5 mm long or less.....4

4a. Leaf base cuneate or subobtuse; stipules and abaxial
leaf surfaces pubescent in young twigs, corolla
lobes obovate with obtuse to rounded apices...........*I. chinensis*

4b. Leaf base cordate to obtuse; stipules and abaxial
leaf surfaces glabrous; corolla lobes lanceolate
or rhomboidal with acute to acuminate apices............*I. coccinea*

Insufficiently known species:

The descriptions of the following species are based on material destroyed in PNH. No duplicates of type specimens could be traced for this revision. The relatively vague descriptions in the protologues do not permit to relate *I. mearnsii, I. pilosa* and *I. propinqua* with sufficient certainty with other species.

Ixora mearnsii Merrill (1910: 236).

Type:—PHILIPPINES. Luzon: Quezon: Casiguran, Tayabas, 1 June 1907, *Mearns 2999* (holotype PNH, destroyed).

According to Merrill, this species is allied to *Ixora congesta,* but with thinner, fewer-nerved leaves, and more lax inflorescences.

Ixora pilosa Merrill (1913: 39).

Type:—PHILIPPINES. Luzon: Quezon: Tagacauayan, Tayabas, March 1911, *Ramos 13371* (holotype PNH, destroyed).

This taxon is distinguished by Merrill from other Philippine species of *Ixora* in its pubescence especially its ciliate corolla lobe, however, this characters also agree with those of *I. leytensis* but differs in the shape of the calyx lobes (oblong-lanceolate in *I. pilosa*; shortly apiculate to truncate in *I. leytensis*).

Ixora propinqua Merrill (1913: 39)

Type:—PHILIPPINES. Mindanao: Zamboanga del Sur: Sax River Mountains, November 1911, *Merrill 8254* (holotyped PNH, destroyed).

According to Merrill, *I. propinqua* is similar with *I. longifolia* but differs in that the leaves are not shining, not at all acuminate but blunt or at most acute, and the stipules have short not elongate point.

Excluded species:

The following Philippine taxa were excluded from *Ixora:*

Canthium glandulosum Merrill (1928: 8)

= *Ixora glandulosa* Blanco (1837: 61)

Tarenna meyeri Elmer (1913: 1898)

= Ixora meyeri Elmer (1906: 68)

Scyphiphora hydrophylacea Gaertner (1806: 91)

= *Ixora manila* Blanco (1837: 60)

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References:

Adams, L.G., Bridson, D.M. & Robbrecht, E. (1987) The identity of *Lasianthus graciliflorus* Bailey (Rubiaceae). *Kew Bulletin* 42: 209–214.

Alejandro, G.J.D. (2007) The current status of the Philippine Rubiaceae. *Philippine Journal of Systematic Biology* 1: 47–60.

Andrews, H. (1799) Botanist's Repository, for new, and rare plants. *T. Bensley, London* 78 pp.

Arénes, J. (1960) A propos de quelques genres Malgaches de Rubiacées. *Notulae Systematicae (Paris)* 16: 6–19.

Batugal, P.A., Kanniah, J., Young, L.S. & Oliver, J.T. (eds) (2004) Medicinal Plants Research in Asia, Volume 1: The Framework and Project Workplan International Plant Genetic Resources Institute–Regional Office for Asia, the Pacific and Oceania (IPGRI-APO). *Serdang, Selangor, DE, Malaysia.*

Backer, C.A. (1936) Verklarend woordenboek der wetenschappelijke van de in Nederland en Nederlandsch Indië in het wild groeiende en in tuinen en parken gekweekte varens en hogere planten. *Groningen, Noordhoff,* 664 pp.

Baker, J.G. (1890) Flora of Madagascar. *Journal of the Linnean Society, Botany* 25: 320–321.

Beddome, R.H. (1873) The Flora Sylvatica for Southern India. *Gantz Brothers, Madras,* 327 pp.

Blanco, F.M. (1837) Flora de Filipinas. *En la imprenta de Sto. Tomás por D. Candido Lopez, Manila.*

Blanco, F.M. (1845) Flora de Filipinas ed 2. *Imprenta de D. Miguel Sanchez. Manila.*

Blume, C.L. (1826) Bijdragen tot de flora van Nederlandsch Indie. *Ter Lands Drukkerij, Batavia,* 327 pp.

Blume, C.L. (1827) Bijdragen tot de flora van Nederlandsch Indie. *Ter Lands Drukkerij, Batavia,* 1007 pp.

Bremekamp (1937) The Malesian species of the genus *Ixora* (Rub.) *Bulletin du Jardin Botanique ser. 3,* 14: 197–367.

Bridson, D.M. & Adams, L.G. (1987) Studies in African Rubiceae-Vanguerieae: a new circumscription of *Pyrostria* and a new subgenus, *Canthium* subgenus Bullockia. *Kew Bulletin* 43: 611–639.

Brown, N.E. (1883) The Gardeners' Chronicle, new series 20. Bradbury, Agnew & Co. *London,* 472 pp.

Dave, Y. & Thomas, V. (1991) Anatomy and histochemistry of stipular colleters in *Ixora coccinea* L. *Journal of Indian Botanical Society* 70: 51–54.

Davis, A.P., Govaerts, R., Bridson, D.M., Ruhsam, M. & Moat, J. (2009) A global assessment of distribution, diversity, endemism, and taxonomic effort in the Rubiaceae. *Annals of the Missouri Bototanical Garden* 96: 68–78.

De Block, P. (1998) The African species of *Ixora* (Rubiaceae–Pavetteae). *Opera Botanica Belgica* 9: 1–217.

De Block, P. (2007) Three new Madagascan *Ixora* species (Rubiaceae) with flowers up to 23 cm long. *Nordic Journal of Botany* 25: 78–84.

De Block, P. (2014a) A synopsis of the multilocular species of *Ixora* (Rubiaceae) from Madagascar. *Phytotaxa* 162: 121–133.

De Block, P. (2014b) Eight new species of *Ixora* (Ixoreae-Rubiaceae) from Madagascar. *Plant Ecology and Evolution* 147: 237–255.

De Candolle, A.P. (1830) Rubiaceae. in De Candolle, A.P. (ed.). *Prodromus systematis naturalis regni vegetabilis,* 487 pp.

De Wildeman (1907: 177) Études de systematique et de géographie botaniques sur la flore de Bas- et du Moyen-Congo 2. *Paris,* 177 pp.

Decaisne (1834) Nouvelles Annales du Museum d'Histoire Naturelle 3. *Paris,* 418 pp.

Elmer, A.D. (1906) Philippine Rubiaceae. *Leaflets of Philippine Botany* 1: 8–9.

Elmer, A.D. (1910) Additional New Species of Rubiaceae. *Leaflets of Philippine Botany* 1:69–70.

Elmer, A. D. (1911) New and noteworthy Rubiaceae. *Leaflets of Philippine Botany* 3: 1020–1021.

Elmer, A.D. (1912) Palawan Rubiaceae. *Leaflets of Philippine Botany* 4:1338–1339.

Elmer, A.D. (1913) Rubiaceae from Mt. Urdaneta. *Leaflets of Philippine Botany* 5: 16–23.

Elmer, A.D. (1934) New Urticaceae and Rubiaceae. *Leaflets of Philippine Botany* 9: 3251–3252.

Fagerlind, F. (1937) Embryologische, Zytologische und Bestäubungsexperimentelle Studien in der Familie Rubiaceae nebst Bemerkungen über einige Polyploiditätsprobleme. *Acta Horti Bergiani* 11: 195–470.

Gaertner, C.F. (1806) Supplementum Carpologiae: seu continuati operis Josephi Gaertner De fructibus et seminibus plantarum. *Leipzig*, 91 pp.

Gillespie, J.W. (1930) New Plants from Fiji. *Bernice P. Bishop Museum Bulletin* 74:30.

Guillamin, A. (1937) Bulletin du Muséum d'Histoire Naturelle 9. *Paris,* 290 pp.

Hallé, N. (1973) *Captaincookia*, genre nouveau monotypique néocalédonien de Rubiaceae—Ixoreae. *Adansonia*, série 2,13: 195–202.

Horner, H.T. & Lersten, N.R. (1968) Development, structure and function of secretory trichomes in Psychotria bacteriophila (Rubiaceae). *American Journal of Botany* 55: 1089–1099.

Husain, T. & Paul, S.R. (1984) A New Species of *Ixora* (Rubiaceae) from the Andaman & Nicobar Islands. *Blumea* 30(1):153–156.

Husain, T. & Paul, S.R. (1989) Taxonomic studies on Indian species of the genus *Ixora* L. (Rubiaceae). *Scientific Publishers, Jodhpur, India*, 205 pp.

Jussieu, A.L. de (1789) Genera Plantarum secundum ordines naturales disposita. Herissant & Barrois, *Paris,* 498 pp.

Klein, D.E., Gomes, V.M., Neto, S.J.S. & Da Cunha, M. (2004) The structure of colleters in several species of *Simira* (Rubiaceae). *Annals of Botany* **94**, 733–740.

Kuntze, O. (1892) Revisio Generum Plantarum 1. *Leipzig,* 286 pp.

Kurz, W.S. (1872) New Barmese Plants. *Journal of the Asiatic Society of Bengal. Part 2. Natural History* 41: 317.

Lamarck J.-B. de (1792) Tableau encyclopédique et méthodique des trois règnes de la nature. Botanique, tome 1. *Panckoucke, Paris,* iii–xvi + 496 pp.

Lersten, N.R. (1974a) Morphology and distribution of colleters and crystals in relation to the taxonomy and bacterial leaf nodules in *Psychotria* (Rubiaceae). *American Journal of Botany* 61: 973–981.

Lersten, N.R. (1974b) Colleter morphology in *Pavetta, Neorosea* and *Tricalysia* (Rubiaceae) and its relationship to the bacterial leaf nodule symbiosis. *Botanical Journal of Linnean Society* 69: 125–136.

Lersten, N.R. (1975) Colleter types in Rubiaceae, especially in relation to the bacterial leaf nodule symbiosis. *Botanical Journal of the Linnean Sociaty* 71: 311–319.

Linnaeus, C. (1753) Species Plantarum. Stockholm p. 110.

Lorence, D.H., Wagner, W.R., Mouly, A. & Florence, J. (2007) Revision of *Ixora* (Rubiaceae) from the Marquesas Islands (French Polynesia). *Botanical Journal of the Linnean Society* 155: 581–597 .

Madulid, D.A. (2001) A dictionary of Philippine plant names. 2 vols. Manila: Bookmark, Inc.

Merrill, E.D. (1910) New and noteworthy Philippine Plants. *Philippine Journal of Science* 5: 233–240.

Merrill, E.D. (1913) New and noteworthy Philippine Plants. *Philippine Journal of Science* 8: 39–40.

Merrill, E.D. (1915) Studies on Philippine Rubiaceae, II. *Philippine Journal of Science* 10: 119–121.

Merrill, E.D. (1917a) Studies on Philippine Rubiaceae, III. *Philippine Journal of Science* 12: 168–169.

Merrill, E.D. (1917b) An Interpretation of Rumphiu's Herbarium Amboinense. *Bureau of Science Manila.*

Merrill, E.D. (1918) Species Blanconae: A critical revision of the Philippine species of plants described by Blanco and by Llanos. *Manila Bureau of Printing.*

Merrill, E.D. (1921a) New or noteworthy Philippine Plants. *Philippine Journal of Science* 17: 320–322.

Merrill, E.D. (1921b) Studies on Philippine Rubiaceae, IV. *Philippine Journal of Science* 17: 434–435.

Merrill, E.D. (1922) New or noteworthy Philippine Plants. *Philippine Journal of Science* 20(4):461–462.

Merrill, E.D. (1923) An enumeration of Philippine Flowering Plants. *Manila Bureau of Printing* 2: 492–576.

Merrill, E.D. (1926) The Flora of Banguey Island. *Philippine Journal of Science* 29(3):423.

Merrill, E.D. (1929) Plantae Elmerianae Borneenses. *University of California Press* 15, 315 pp.

Merrill, E.D. (1942) Records of Indo-Chinese Plants, III. *Journal of the Arnold Arboretum* 23(2): 194.

Merrill, E.D. & Perry, L.M. (1945) Plantae Papuanae Archboldianae, XVI. *Journal of the Arnold Arboretum* 26(3): 257.

Miquel, F.A.W. (1857) Flora Indiae Batavae. *Flora van Nederlandsch Indië* 2: 204.

Montrouzier, X. & Baker, E.G. (1921) Plants from New Caledonia. *Journal of the Linnean Society, Botany* 45: 333.

Moore, T. (1878) New Anthuriums. *Florist and Pomologist* 31: 76.

Mouly, A. (2008) Systématique de la tribu des Ixoreae A. Gray (Rubiaceae): phylogénie, biogéographie et taxinomie. *Acta Botanica Gallica* 155(3): 457–464.

Mouly, A.P. & Bremer, B. (2009) in Mouly, A., S.G. Razafimandimbison, A. Khodabandeh & B. Bremer. (2009). Phylogeny and classification of the giant pantropical showy genus Ixora (Rubiaceae-Ixoreae) with indications of geographical monophyletic units and hybrids. *American Journal of Botany* 96: 686–706.

Mouly, A. & Florence, J. (2007) in Lorence, D.H., Wagner, W.R., Mouly, A. & Florence, J. (2007) Revision of *Ixora* (Rubiaceae) from the Marquesas Islands (French Polynesia). *Botanical Journal of the Linnean Society* 155: 581–597 .

Mouly, A, Razafimandimbison S, Florence J, Jeremie J, Bremer B. (2009) Paraphyly of *Ixora* and new tribal delimitation of Ixoreae (Rubiaceae): inference from combined chloroplast (*rps16*, *rbc*l, and *trn*T-F) sequence data. *Annals of Missouri Botanic Garden* 96: 146–160.

Nadeaud, J. (1899) Plantes nouvelles des Iles de la Société. *Journal de Botanique (Morot)* 13: 1–8.

Naves, A. & Ferández-Villar, C. (1883). Novissima appendix ad Floram Philippinarum Emmanuëlis Blanco: seu, Enumeratio contracta plantarum philippinensium cum synonymiis PP. Blanco, Llanos, Mercado et aliorum auctorum. *in Blanco, Manuel. Flora de Filipinas. Manila, 1877–1883.*

Nilson, L.A., Rabakonandrianina, E., Petterson, B. & Ranaivo, J. (1990) "Ixoroid" secondary pollen presentation and pollination by small moths in the malagasy treelet *Ixora platythyrsa* (Rubiaceae). *Plant Systematics and Evolution* 170: 161–165.

Oliver, D. (1892) Icones Plantarum. Dulao & Co., *London,* 2236 pp.

Pelser, P.B., Barcelona, J.F. & Nickrent, D.L. (eds.). 2011 onwards. Co's Digital Flora of the Philippines. www.philippineplants.org

Pradeep, A.K. (1997) *I. sivarajiana*, a new species of Rubiaceae from India. *Nordic Journal of Botany* 17: 315–317.

Puff, C., Robbrecht, E., Buchner, R. & De Block, P. (1996) A survey of secondary pollen presentation in the Rubiaceae. *Opera Botanica Belgica* 7: 369–402.

Reynolds, S.T. & Forster, P.I. (2006) A taxonomic revision of *Ixora* L. (Rubiaceae: Ixoroideae) in Australia. *Austrobaileya* 7: 253–278.

Robbrecht, E. (1988) Tropical woody Rubiaceae: Characteristic features and progressions. Contributions to a new subfamilial classification. *Opera Botanica Belgica* 1: 1–271.

Robbrecht, E. & Lejoly, J. (1982) Bulletin van de Nationale Plantentuin van Belgiee 52. *Belgium* 487 pp.

Robinson, C.B. (1911) Botanical notes upon the island of Polillo. *Philippine Journals of Science* 6: 222–224.

Roxburgh, W. (1814) Hortus Bengalensis, or a Catalogue of the Plants Growing in the Hounourable East India Company's Botanical Garden at Calcutta. *Serampore*, 10 pp.

Roxburgh, W. (1820) Descriptions of Indian Plants. *Flora Indica* 1:381–382.

Schlechter, R. & Krause, K. (1908) in Schlechter, R. (ed.) Beiträge zur Kenntnis der Asclepiadaceen des Monsun-Gebietes. Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 40 (Beibl. 92): 39.

Schumann, K.M. & Lauterbach, C. (1900) Die Flora der Deutschen Schutzgebiete in der Südsee. *Gebrüder Borntraeger*, *Leipzig,* 572 pp.

Schumann, K.M. (1903) Rubiaceae africanae. Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 33: 333–384.

Sharma, K.A. & Chatterjee, T. (1960) Chromosome studies in *Ixora*. *Genetica* 31: 421–447.

Smith, A.C. & Darwin, S.P. (1988) Family 168. Rubiaceae. *Flora Vitiensis Nova* 4: 143–362.

Sohmer, S.H. & Davis, A.P. (2007) The genus *Psychotria* (Rubiaceae) in the Philippine Archipelago. *Botanical Research Institute of Texas*, 247 pp.

Standley, P.C. (1931) Publications of the Field Museum of Natural History, Botanical Series 7, 296 pp.

Tao, C. & Taylor, C.M. (2011) Ixora. *Flora of China* 19: 177–182.

Thiers, B. (2013) *Index Herbarorium: A global directory of public herbaria and associated staff.* New York Botanical Garden's Virtual Herbarium. Available from http://sweetgum.nybg.org/ih/ (Accessed 8 January 2014).

Thomas, V. (1991) Structural, functional and phylogenetic aspects of the colleter. *Annals of Botany* 68: 287–305.

Thomas, V. & Dave, Y. (1990) Structure and necrosis of stipular colleter in *Mitragyna parvifolia* (Rubiaceae). *Belgian Journal of Botany* 123: 67–72.

Tosh, J., Dessein, S., Buerki, S., Groeninckx, I., Mouly, A., Bremer, B., Smets, E.F. & De Block, P. (2013) Evolutionary history of the Afro-Madagascan Ixora species

(Rubiaceae): species diversification and distribution of key morphological traits inferred from dated molecular phylogenies. *Annals of Botany* 112: 1723–1742.

Turner, I.M. (2013) Robinson a century on: the nomenclatural relevance of Roxburgh's Hortus Bengalensis. *Taxon* 62(1): 158.

Valeton, T. (1911) Rubiaceae. in H.A. Lorenz (ed.), Résultats del' expédition scientifique néerlandaise à la Nouvelle-Guinée en 1907 et 1909, vol. 8, Botanique, 437–519 + illustr. Librairie et Imprimerie Ci-Devant E.J. Brill, Leiden, Netherlands.

Valeton, T. (1913) Icones Bogorienses 4: 189–190.

Verdcourt, B. (1983) Notes on Mascarene Rubiaceae. *Kew Bulletin* 37: 521–574.

Vidal, S.S. (1885) Phanerogamae Cumingianae Philippinarum. *Establecimiento Tipo-Litográfico de M. Pérez hijo, San Jacinto.* Binondo, Manila.

Vogel, S. (1954) Blütenökologische Typen als Elemente der Sippengliederung dargestellt anhand Flora Südafrikas. Rubiaceae. *Botanische Studien* (Jena, Fischer) 1: 1–338.

Wallich, N. (1820) Flora Indica or Descriptions of Indian Plants 1: 398. Serampore, India.

Wallich, N. & Don, G. (1834) *A General History of the Dichlamydeous Plants 3. London,* 572 pp.

Williams, R.F., Metcalf, R.A. & Gust, L.W. (1982) The genesis of form in oleander (*Nerium oleander* L.). *Australian Journal of Botany* 30: 677–687.

Zollinger, H. & Moritzi, A. (1855) in Zollinger, H. ed. *Systematisches Verzeichniss der im indischen Archipel in den Jahren 1842–1848 gesammelten sowie der aus Japan empfangenen Pflanzen 3: 65.* Kiesling, Zürich.

Appendix I. Vernacular names of Philippine *Ixora* gathered from literature and labels of the herbarium specimens used in this study. Accepted species appear in **bold**. The Philippine dialects in parentheses are the standard abreviations (Madulid 2001).

	Species	Common Names
1.	***Ixora angustilimba*** Merr.	–
2.	***Ixora auriculata*** Elmer	puropunta (Neg.)
3.	***Ixora bartlingii*** Elmer	arukoramit (Neg.); bukel-todok (Tas.); dila-dila (Tag.); Hantungan (Mbo.); kayo-mahagid bunga (Tas.); lantuig (Tag.); matang-hipon (Tag.); tipurus (Sml.)
4.	***Ixora bibracteata*** Elmer	pasagi (Tag.);
5.	*Ixora brachyantha* Merr.	–
6.	***Ixora capitulifera*** Merr.	–
7.	***Ixora chartacea*** Elmer	matigandang (Mbo.); Bitajoyan (Mbo.)
	var. membranacea Elmer	bagobodon (Mbo.).
8.	***Ixora chinensis*** Lam.	santan (Tag., Bik.); santan-pula (Tag.); santa ana (Tag.)
9.	***Ixora coccinea*** L.	santan (Tag.); santan pula (Tag.); tangpupo (Bis.)
10.	***Ixora confertiflora*** Merr.	–
11.	***Ixora crassifolia*** Merr.	mangopong (Sub.); paginugun (Sub.)
12.	***Ixora cumingiana*** Vidal	agundalagap (Ilk.); bago-bago (Bis.); bakir (Ilk.); bantana (Bik.); barokbok (Ilk.) ; kabar (Tagb.) ; kahan (Tag.); maglado (Bag.); con (S. L. Bis.); sablut (Ilk.); salpadun (Ting.); talab (Tag.); Luat (C.Bis.); Butul manukdir'it (Mang.); Lagpan (Pal.); dugo-adung (Tagb.); tiga puran polu (Pal); antap-antap (Tagb.); sungkudit-biyankunan (Tag.)
13.	***Ixora ebracteolata*** Merr.	dagumirang (Ibn.); pamutun (Sbl.); pilis (Sbl.); opeg (Neg.); talab (Sbl.); tatanik (Tag.)
14.	***Ixora finlaysoniana*** Wall & G. Don	santan (Tag., Bik.); santan-puti (Tag.)
15.	*Ixora fulgens* Roxb.	siki-manatad (Sul.)

16.	***Ixora gigantifolia*** Elmer	–
17.	*Ixora gracilipes* Merr	–
18.	*Ixora ilocana* Merr	–
19.	***Ixora inaequifolia*** C.B. Rob.	–
20.	***Ixora intermedia*** Elmer	ali-alemat (Tagb.)
21.	*Ixora irosinensis* Elmer	–
22.	***Ixora leucocarpa*** Elmer	bitelis (Tagb.)
23.	***Ixora leytensis*** Elmer	malatabulian (S. L. Bis.).
24.	*Ixora littoralis* Merr.	–
25.	***Ixora longissima*** Merr.	–
26.	***Ixora longistipula*** Merr.	mayanman (P. Bis.)
27.	***Ixora luzoniensis*** Merr.	–
28.	***Ixora macgregorii*** C.B. Rob.	–
29.	***Ixora macrophylla*** Bartl. ex DC.	asas (Tag); bagotambis (Mbo.); bilibid (Mbo.); dingin (Sbl.); hagoko (C. Bis.); hilakan-manatad (C. Bis.); kintasin (Bik.); ligad (Mbo.); malasantan (Tag.); mali-mali (Sul.); parauitas (Neg.); panaguyambi (Mang.); paan labuyo bagbag (Pint. Sbl.); bubutigan (S.L.Bis.); daromal (S.L.Bis); bulian (Sub.); malpa (Sub.); pintad (Sub.); nonuk (Sub.)
30.	***Ixora magnifica*** Elmer	bonog-bonog (Mbo.)
31.	*Ixora mearnsii* Merr.	–
32.	***Ixora mindanaensis*** Merr.	–
33.	*Ixora myriantha* Merr.	–
	Ixora oblongifolia Elmer	–
34.	***Ixora palawanensis*** Merr.	sugbokbit biyangunan (Tagb.)
35.	***Ixora philippinensis*** Merr.	gintinanik (Ilk.); kamingi (Tag.); kayomkom (Tag.); lulumboi (Kuy.); lumoi-manok (Pang.); makomakopahan (Tag.); oon (P. Bis.); talapulukit (Mag.); tintinani (Ilk.); tulang-tulang (Ilk.); bua-ungit (Pint Sbl.); santan gubat (Tag.); payuput kayu (Mang.); udok-udok

		(Tagb.)
	var. brevituba Merr.	–
36.	*Ixora pilosa* Merr.	–
37.	*Ixora platyphylla* Merr.	–
38.	*Ixora propinqua* Merr.	–
39.	***Ixora salicifolia*** DC.	bulalakau (Tag.); lauihan (P. Bis.); pamayugsukon (C. Bis.); pilat-pilat (Mbo.) ; suding (C. Bis.); udang-udang (Bag.); songkod it biyangunan (Tagb.)
40.	*Ixora samarensis* Merr.	–
41.	***Ixora sparsiflora*** Elmer	–
42.	***Ixora tenelliflora*** Merr.	amje (Tagb.); kanumpas (Tagb.)
43.	*Ixora tenuipedunculata* Merr.	–

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