

## New insights into the diversity of the Flora of Vietnam

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REGALADO, JR., J.C., NGUYEN, TIEN HIEP, PHAN KE LOC, AVERYANOV, L. & HARDER, D.K. 2005. New insights into the diversity of the Flora of Vietnam. *Biol. Skr.* **55**: 189-197. ISSN 0366-3612. ISBN 87-7304-304-4.

The flora of Vietnam has an estimated 12,000 vascular plant species, of which 10,000 have already been identified and cataloged. The proportion of endemics has been variously reported between 30% nationwide to as high as 50% in northern Vietnam. The centers of plant diversity are the Hoang Lien Son Range, the Truong Son Range (Annamites), and the Tay Nguyen Plateaus (Central Highlands). The high level of biodiversity can be attributed to a high degree of environmental heterogeneity for climate, soil, landscape and topography. Great progress in botanical explorations and scientific investigations in Vietnam during the past few years have brought new insights into the diversity and patterns of complexity of the flora of Vietnam. After the sweeping economic reforms that ended the country's isolation, Vietnamese botanists have sought foreign technical assistance and have actively collaborated with colleagues abroad in the study of Vietnam's flora, which has resulted in numerous and exciting plant discoveries. In the past decade alone (1993-2003), more than 200 new taxa, including 13 genera, of vascular plants have been described. At least 100 records of plants new to Vietnam have been similarly documented. These findings accounted for a remarkable 3% increase in the known flora. Significant increases in numbers of known new taxa were made in the Orchidaceae, Myrsinaceae, Araceae, and Euphorbiaceae.

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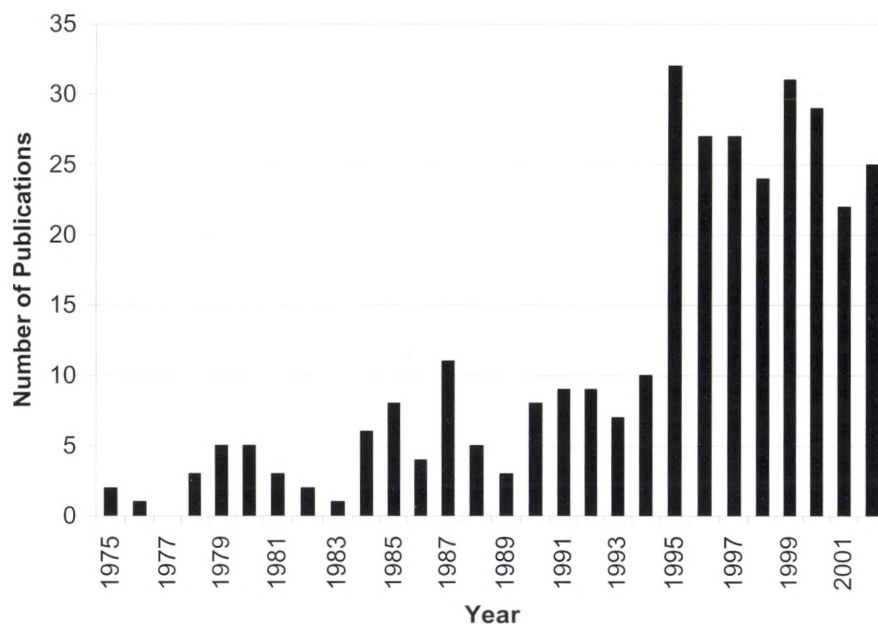
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## Introduction

Vietnam is considered as one of the most biologically diverse countries in the world and it is widely recognized that the country has a globally significant proportion of rare and endemic species of plants and animals. In the past decade, Vietnam stunned the world with the discovery of three previously unknown large mammals: the small dark muntjac (*Muntiacus truongsongensis*), giant muntjac (*Megamuntiacus vuquangensis*) and saola (*Pseudoryx nghetinhensis*). A number of preliminary estimates (Tolmachev 1974; Nguyen Tien Hiep 1997; Phan Ke Loc 1998) offer figures of about 9600 indigenous species of vascular plants in Vietnam. In addition, about 750 naturalized, introduced and cultivated species occur in Vietnam. An estimated 2400 additional species are expected to be discovered and added to the flora. The total number of species of vascular plants known in Vietnam for the time being is about 10,350 species in 2,256 genera and 305 families (Phan Ke Loc 1998). This is a remark-

ably diverse flora for a relatively small country like Vietnam. The ten largest families in this flora are Orchidaceae (897 species), Fabaceae (557 species), Poaceae (467 species), Euphorbiaceae (416 species), Rubiaceae (395 species), Cyperaceae (304 species), Asteraceae (291 species), Lauraceae (245 species), Fagaceae (211 species) and Acanthaceae (177 species).

The flora of Vietnam is not only large, but also rich in endemic species, adding to its significance. The proportion of endemics has been variously recorded, ranging from 20% (Pocs 1965) to as high as 50% (Thai Van Trung 2000). A more conservative estimate (Vo Quy 1995) suggests that about 10% of species and 3% of genera are endemic to Vietnam. Among 305 vascular plant families reported for Vietnam, the highest levels of endemism are observed in the Acanthaceae, Anacardiaceae, Annonaceae, Apocynaceae, Araceae, Arecaceae, Asclepiadaceae, Celastraceae, Ericaceae, Euphorbiaceae, Fagaceae, Myrsinaceae, Rubiaceae, Sapindaceae, Sapotaceae, Theaceae and Zingiberaceae (Schmid 1974;



**Fig. 1.** Rate of publications on Vietnam flora from 1975-2002.

**Table 1.** New genera for Vietnam described from 1993-2003.

Family	Genus	Place of Publication
Orchidaceae	<i>Zeuxinella</i> Aver.	Averyanov & Averyanova, Updated Checklist of the Orchids of Vietnam, p. 96 (2003)
Orchidaceae	<i>Vietorchis</i> Aver. & Averyanova	Averyanov & Averyanova, Updated Checklist of the Orchids of Vietnam, p. 92 (2003)
Polypodiaceae	<i>Caobangia</i> A.R. Sm. & X.C. Zhang	Smith & Zhang, Novon 12: 546-550 (2002)
Cupressaceae	<i>Xanthocypris</i> A. Farjon & T.H. Nguyen	Farjon <i>et al.</i> , Novon 12: 179-189 (2002)
Araliaceae	<i>Metapanax</i> J. Wen & D.G. Frodin	Wen & Frodin, Brittonia 53: 117 (2001)
Rubiaceae	<i>Rubovietnamia</i> D.D. Tirvengadam	Tirvengadam, Biogeographica 74: 166 (1998)
Rubiaceae	<i>Vidalasia</i> D.D. Tirvengadam	Tirvengadam, Biogeographica 74: 164 (1998)
Rubiaceae	<i>Fosbergia</i> D.D. Tirvengadam & C. Sastre	Tirvengadam & Sastre, Biogeographica 73: 88 (1997)
Zingiberaceae	<i>Distichochlamys</i> M.F. Newman	Newman, Edinburgh J. Bot. 52: 65 (1995)
Araliaceae	<i>Grushvitzkya</i> N.T. Skvortsova & L.V. Averyanov	Skvortsova & Averyanov, Bot. Zhurn. (Moscow & Leningrad) 79(7): 108 (1994)
Asclepiadaceae	<i>Vietnamia</i> P.T. Li	Li, Journal of South China Agricultural University 15(4): 72 (1994)
Poaceae	<i>Vietnamochloa</i> J.F. Veldkamp & R. Nowack	Veldkamp & Nowack, Bull. Mus. Natl. Hist. Nat., B, Adansonia 16(2-4): 214 (1995)
Orchidaceae	<i>Christensonia</i> J.R. Haager	Haager, Orchid Digest 57: 40 (1993)

Takhtajan 1986; Rundel 1999). A recent inventory of the orchid species in Vietnam showed that endemism of the family is 20% (Averyanov & Averyanova 2003).

### Causal factors of plant diversity

**Geography.** Vietnam is situated on the eastern seaboard of Southeast Asia, bordered by China in the north, Laos and Cambodia in the west, the Gulf of Thailand in the south, and the South China Sea in the east. The country has an area of 329,566 km<sup>2</sup>, its territory spreads more than 2,000 km from north to south, between latitudes 8°30'N and 23°25'N. The country has an elongated S-shape with broad deltas of the Song Hong (Red) River in the north and the Mekong River in the south, linked by a narrow central section. The coun-

try is predominantly mountainous. Three quarters of the country consists of hills, plateaus and mountains that extend up to 3,000 m above sea level. The Truong Son (Annamite) mountain ranges form the natural boundary with Laos and Cambodia. The mountains in the northern border with China are extensions of the mountain systems of southeast Yunnan and Guangxi (Averyanov 1990; Rundel 1999).

**Topography.** The mountain areas fall superficially into three distinct regions: 1) the mountains of northeastern Vietnam, 2) the Hoang Lien Son Range of northwestern Vietnam, which represents a southern extension of the Himalayas, and 3) the long Truong Son (Annamite) Range which forms the backbone of Southeast Asia along the western border of Vietnam (Schzeglova 1957; Rundel 1999). In



the northwest of the country are the largest mountain formations of the Indochina peninsula with the highest peaks in the region – Fan Si Pan (3143 m), Ta Giang Pinh (3096 m), Si Lung (3076 m), Luong (2985 m), Phuong Chang (2825 m), Lang Kung (2817 m) and a number of others. The central mountain chain is dissected by relatively level plateaus, where average elevations are mostly from 500 to 1500 m above sea level. The Dak Lak and Plei Ku Plateaus, along with the Lam Vien (Dalat) Plateau, are sometimes collectively referred to as the Tay Nguyen Plateau (Central Highlands). The UNEP World Conservation Monitoring Centre (United Kingdom) considers the Hoang Lien Son Range, the Truong Son Range (Annamites) and the Tay Nguyen Plateau (Central Highlands) as the centers of plant diversity in Vietnam.

Other distinctive geomorphologic areas of the country are coastal plains and wide alluvial valleys of the Mekong and Red Rivers. Irregular coastal flat plains with minimal elevations above sea level connect the fertile river valleys of northern and southern Vietnam by a narrow belt coming along the coast line. The two largest rivers of Southeast Asia, namely the Song Hong (Red) and Mekong Rivers, create wide alluvial delta regions in Vietnam. Both these regions represent large flat delta plains covered by alluvial deposits of Quaternary age. The Song Hong River delta has an area of more than 15,000 km<sup>2</sup> while that of the Mekong extends over 40,500 km<sup>2</sup> covering much of the lowlands of southern Vietnam. Rich alluvial soils in each of the delta regions have enabled these areas to evolve as major population centres based on their agricultural productivity. More than 80% of the population live in territories of coastal and delta plains, while the mountain regions still have a very sparse human population.

**Climate.** North and northeast winds dominate in the region from October to March, due

to high pressure regularly occurring during winter in the centre of Asia over the plains of Mongolia. Basically these winds are cold and dry. Precipitation is low during this period. Monsoon winds from the south and southwest dominate in Southeast Asia from April to September. These winds come from the Indian and Pacific oceans where high pressure areas are formed during summer. Basically monsoon winds are warm and wet. They bring to the continent hot and rainy weather (Schzeglova 1957; Fridland 1961; Phan Ngoc Toan & Phan Tat Dac 1993). At the same time the complicated orography and specific configuration of the coast line of Vietnam locally shift direction of monsoon winds, change times of dry and rainy seasons and influence the amount of precipitation. This results in incredibly diverse climatic patterns in the country.

Six main basic types of climate are defined for Vietnam in recent climatologic studies (Nguyen Khanh Van *et al.* 2000). These types are classified as: 1. Monsoon tropical climate with cold winter, summer rains; 2. Monsoon tropical climate with cool winter, summer-autumn-winter rains; 3. Monsoon tropical climate with summer rains; 4. Monsoon tropical climate with autumn-winter rains; 5. Monsoon sub-equatorial climate with summer rains; and 6. Monsoon tropical climate associated with mountains.

**Geology.** Generally mountain systems in Vietnam are composed of silicate rocks, mainly granite, gneiss, rhyolite or quartzite, which were formed by extensive magmatic intrusions in the late Paleozoic and Mesozoic (Dovzikiv *et al.* 1965a, b). Tertiary tectonic movements uplifted these mountain terrains to current elevations and subsequent erosions formed modern characteristic rocky landscape (Schzeglova 1957; Rundel 1999). Ancient highly metamorphosed limestone from which developed karst is typical and widely distributed in the northern part of the country. To the east the mountains gradually give way to vast allu-

vial plains. For excellent reviews of the geological history of Vietnam and the Indochina region, refer to the following literature: Schzeglova (1957), Fridland (1961), Dovzikiv *et al.* (1965b) and Rundel (1999).

**Historical Biogeography.** The uplifting of the Himalayas over the last 10MY formed an effective barrier to the exchange of species between Palearctic and Indo-Malayan realms. This barrier, reinforced by increased climatic cooling after the Miocene, isolated Indo-Malaya and created conditions for species divergence. Recent relatively stable equatorial conditions combined with dynamic geological changes allowed isolated populations to diverge further, thus contributing to the enormous species richness and high levels of endemism that now characterize the region (MacKinnon & MacKinnon 1986).

Vietnam lies on the crossroad of interchange between the floristic elements of the southeastern Himalayas and Indo-Malaysia. The Hoang Lien Son mountains in the northwest of the country form an extension of the Hengduan mountains of China and are floristically related to southwest China. The mountains to the east of the Red River are connected to the limestone ranges of Guangxi and show close affinities to the flora of southern China (Nguyen Nghia Thin & Harder 1996). In the west, the Truong Son Range forms a partial barrier between the moist uplands of Vietnam and the drier monsoon forests of Laos, and it traverses the transition zone between the tropical monsoon climate with cool winters in the north and the tropical Indo-Malayan south.

## Vegetation

Tropical monsoon forests are the most common kind of vegetation in Vietnam. Wet closed evergreen broad-leaved, mixed or coniferous forests are found in mountain regions. At the same time in some hilly lowland and valley

areas with more arid conditions these forests give way to open, semi-deciduous and deciduous broad-leaved savanna-like woodlands. Along semi-desert coastal plains and on arid sea slopes of southern Vietnam woodlands develop their shrubby derivatives, which often appear as a more or less dense sclerophyll scrub. Swampy grass-sedge communities and mangrove thickets are common on flat coastal plains especially in deltas of large rivers. All types of native primary vegetation have been destroyed in many parts of the country. Secondary forests, shrubs and grasslands, bamboo thickets, tree plantations, pastures, crop and vegetable fields, and different weed communities have replaced most native vegetation in Vietnam.

The eight main types of plant cover are: 1. Evergreen broad-leaved forests on alkaline soils; 2. Evergreen and semi-deciduous broad-leaved, mixed and coniferous limestone mountain forests; 3. Evergreen lowland forests on silicate rocks at 0 – 1000 m elevation; 4. Evergreen montane and highland forests on silicate rocks at 1000 – 3000 m elevation; 5. Semi-deciduous dry lowland forests; 6. Deciduous dry lowland forests and savanna-like woodlands; 7. Coastal vegetation, lowland wetlands and mangrove thickets; 8. Secondary, weed and agricultural plant communities, wood and industrial plantations (Averyanov *et al.* 2003).

## Phytogeographic units

Up until recently, available data on geology, climate, flora and vegetation of Vietnam were rather poor for even preliminary phytogeographic generalizations in the eastern part of Indochina. As a result, only highly schematic and abstract floristic divisions of the area were proposed in consideration of modern phytogeography of mainland Southeast Asia (Good 1964; Takhtajan 1978, 1986; Wu & Wu 1998). Recent botanical explorations in Vietnam dur-



ing the last ten years have revealed considerable new knowledge on this area. The analysis of modern literature and recent data on geology, geomorphology, climate, flora and vegetation give possible preliminary delineation of main phytogeographic units in the eastern part of Indochina.

Six floristic units may be outlined on the territory of Vietnam and adjacent areas of the eastern part of Indochina. Some preliminary borders of these areas as floristic province were outlined in the general floristic division of Takhtajan (1978, 1986). The six defined floristic provinces with more or less defined borders are: 1. Sikang-Yunnan Province; 2. South Chinese Province; 3. North Indochinese Province; 4. Central Annamese Province; 5. South Annamese Province; 6. South Indochinese Province (Averyanov *et al.* 2003).

### Studies on the Flora of Vietnam

Our understanding of the flora of Vietnam, albeit incomplete, is attributed to several fundamental taxonomic publications, such as *Flora Cochinchinensis* (Loureiro 1790, 1793), *Flore Générale de l'Indo-Chine* (Lecomte & Humbert 1907-1951), *Flore du Cambodge, du Laos et du Vietnam* (Aubréville *et al.* 1960-2001), *An illustrated flora of Vietnam* (Pham Hoang Ho 1991-1993), *Vascular plant synopsis of Vietnamese flora* (Averyanov *et al.* 1990, 1996) and a number of large recent floristic and taxonomic studies. Analyses of the systematic structure of the flora have been done by Phan Ke Loc (1998) and Le Tran Chan (1999).

The flora of Vietnam is being written, in French, as part of the regional flora *Flore du Cambodge, du Laos et du Vietnam*, but the progress has been slow. From 1960-2001, 74 families have been published, which comprise only 26% of the total number of families in Vietnam. Most major groups have not been revised, including Acanthaceae, Asteraceae,

Cyperaceae, Euphorbiaceae, Ericaceae, Fagaceae, Lamiaceae, Lauraceae, Moraceae, Orchidaceae, Poaceae, Pteridophyta, Rubiaceae, Urticaceae, and Zingiberaceae. Recently Vietnamese botanists have started writing the *Flora of Vietnam* in their own language. The first four volumes: Annonaceae (Nguyen Tien Ban 2000), Lamiaceae (Vu Xuan Phuong 2000), Cyperaceae (Nguyen Khue Khoi 2002), and Myrsinaceae (Tran Thi Kim Lien 2002) have already been published.

Our incomplete understanding of the flora of Vietnam is based on older, unverifiable data and a paucity of research collections supporting adequate biogeographic and taxonomic studies. A large number of forest inventories and checklists have been produced based on field observations and literature alone. This methodology typically overlooks many species, especially in taxonomically difficult or unpublished groups, and as a result there are no reliable estimates of the numbers of threatened species or total number of species in the country. All credible botanical inventories must rely on high-quality, fully documented vouchers of all vascular and non-vascular plants.

Perhaps Loureiro gathered the first collections of herbarium specimens in Vietnam before 1790. Mostly French collectors, such as Balansa, Chevalier, Eberhardt, Harmand, Pételot, Pierre, Schmid, Thorel, Vidal, and especially Poilane, collected a majority of the extant specimens during the first four decades of the past century. Estimates of the number of collections made by these botanists is around 75,000 with a majority of the specimens deposited in the herbarium at the Laboratoire de Phanérogamie, Muséum National d'Histoire Naturelle in Paris (P) and several thousands duplicates kept in the Herbaria of the Institute of Tropical Biology in Ho Chi Minh City (HM) and the Department of Botany of Vietnam National University in Hanoi (HNU). After 1945, Vietnam was racked by warfare for

many years, with little botanical exploration in the country since French colonial times. After the sweeping economic reforms in the 1990s that ended Vietnam's isolation from the world since 1975, Vietnamese botanists have sought foreign technical assistance and have actively collaborated with their colleagues abroad in the study of Vietnam's flora. International cooperative agreements were made with the following institutions: Missouri Botanical Garden (U.S.A.), Komarov Botanical Institute (Russia), Royal Botanic Gardens, Kew (U.K.), National Herbarium of New South Wales (Australia), Singapore Botanic Gardens (Singapore), Kunming Botanical Institute (China), and with international conservation organizations working in Vietnam, namely, world Conservation Union (IUCN), World Wildlife Fund (WWF), and Fauna and Flora International (FFI). These research initiatives have resulted in additional specimens using modern collection methods and have contributed significantly to our knowledge of the rich flora of Vietnam. Over the past ten years, international botanical teams have conducted surveys in 22 provinces. More than 15,700 collection numbers with 78,500 duplicate specimens were collected. Duplicates were distributed to AAU, K, L, MO and P.

### Recent discoveries

A survey of the botanical literature, using the online version of the Kew Records of Taxonomic Literature (<http://www.rbgekew.org.uk/kr/KRHomeExt.html>), showed a dramatic increase in the number of publications on the Vietnam flora in mid-1990's when the international cooperative activities were initiated (Figure 1). These collaborative efforts have resulted in numerous and exciting plant discoveries. Thirteen new genera (Table 1) and 229 new species and infraspecific taxa were described from 1993-2003, including 77 new

records for the flora of Vietnam. These discoveries added 306 species to the flora of Vietnam, contributing to a 3% increase in the known flora (Table 2). Significant gains in numbers of new taxa were made in the Orchidaceae (63 species), Myrsinaceae (34 species), Araceae (27 species) and Euphorbiaceae (15 species).

The most spectacular findings are the new genera and species of a cupressoid conifer, *Xanthocypris vietnamensis* (Farjon *et al.* 2002) and the polypodiaceous fern, *Caobangia squamata* (Smith & Zhang 2002). The Vietnam Golden Cypress (*Xanthocypris vietnamensis*) is the fourth new conifer described since 1948, after *Metasequoia*, *Cathaya* and *Wollemia*. The unusual species bears both juvenile needles and mature scale leaves on the same branches of mature trees. This species closely resembles the Nootka Cypress (*Chamaecypris nootkatensis* = *Xanthocypris nootkatensis*) of western North America, reflecting ancient links between eastern Asia and western North America. On the other hand, *Caobangia* is one of two fern genera recently described. The discovery of a new genus of ferns based on new collections is an uncommon event. In 2001 a new fern genus was described from Korea but previous to that, the last such new genera were described in the late 1960's.

Table 2. Summary of discoveries for Vietnam flora from 1993-2003.

Plant Groups	New species & infraspecific taxa	New species records
Ferns	1	10
Cycads	10	8
Conifers	5	5
Dicots	106	12
Monocots	107	42
<b>Total:</b>	<b>229</b>	<b>77</b>



## Acknowledgments

Field work and laboratory studies that resulted in a number of exciting botanical discoveries which are summarized in this paper were funded by various grants from the following sources for which we give thanks: U.S. National Geographic Society (grants #5094-93, 5803-96, 6300-98, 6383-98, 6733-00), U.S. National Science Foundation (grant # DEB-9870231), Fauna and Flora International, American Orchid Society, San Diego County Orchid Society Conservation Committee, the Henry Luce Foundation, and the Basic Research in Natural Sciences Program (grant # 6.110.01).

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