

## Towards inventory of non-photosynthetic plants in Vietnam: a progress report

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*Summary:* The paper summarizes results of investigations of non-green plants carried out in the Russian-Vietnamese Tropical Center during the years 2009–2018. The checklist is provided which includes 29 species in seven families. Among them, holoparasites are represented only by the family Balanophoraceae (4 spp.), while the mycoheterotrophs comprise Ericaceae (1 sp.), Petrosaviaceae (1 sp.), Orchidaceae (16 spp.), Burmanniaceae (1 sp.), Thismiaceae (3 spp.) and Triuridaceae (4 spp.). Four species new to science and several new species records for Vietnam were published during this study. The highest diversity of non-photosynthetic plants was found in Central Highlands and especially in Thach Nham protected forest and Chu Yang Sin National Park. The obtained specimens are currently employed in morphological, phylogenetic and genomic studies of several groups of heterotrophic plants.

*Keywords:* flora of Vietnam, protected areas, achlorophyllous plants, mycoheterotrophy, parasitism

Non-photosynthetic, or holo-heterotrophic, plants represent a noteworthy group of organisms. They do not produce chlorophyll (or produce it in extremely small amounts), and therefore they are not capable of photosynthesis and lack green coloration in all parts of the plant. For this reason, they are readily distinguished from all the autotrophic plants in natural habitats.

In the respect of organic nutrition, the non-photosynthetic plants, being fully heterotrophic, are more similar to animals and fungi than to the green plants. They can be divided into two distinct groups by the mode of carbon obtaining. The first group comprises obligate parasites of the other plants; they use specialized roots (haustoria) to suck the nutrients from roots or stems of the host plants. The second group are fully mycoheterotrophic plants which obtain carbon from mycorrhizal fungi. Their roots form an association with fungal mycelium which is similar to true mycorrhiza differing from the latter by the direction of nutrient flow (from fungi to plant) and thus being more close to exploitative than to cooperative interaction. It is sometimes assumed that mycoheterotrophic plants are widely involved into a tripartite association: a heterotrophic plant, a fungus and a photosynthetic plant, where the fungus obtains carbon from the green plant through a true mycorrhiza. In this case, the heterotrophic plant appears to act as an epiparasite of the green plant with employment of the common mycorrhizal association as a transmitter (MERCCKX 2013).

Non-photosynthetic taxa occur in numerous lineages of higher plants including liverworts (Marchantiophyta), clubmosses and ferns (Lycopodiopsida and Polypodiopsida; gametophytes only), gymnosperms and angiosperms. Among the angiosperms, most of the parasites belong to dicots, while the majority of mycoheterotrophs are monocots. Besides, the geographical distribution of these groups is unequal: mycoheterotrophs are found mainly in the tropical regions, and parasites are also diverse in temperate and subtropical areas.

In this paper, we summarize the data on diversity and distribution of non-photosynthetic plants obtained during our long-term field investigations of Vietnamese flora. We do not treat clubmosses and ferns here as they always possess green sporophytes. We also exclude the genus *Cuscuta* (Convolvulaceae) from this review since it is shown to be chlorophyllous, especially at the stage of seedling.

## Materials and methods

The material collection was performed in 2009–2018 during expeditions of the Russian-Vietnamese Tropical Center in the following provinces of Vietnam (listed from North to South and from East to West): Lao Cai (Bat Xat Nature Reserve, Hoang Lien National Park), Cao Bang (Phia Oac-Phia Den National Park), Phu Tho (Xuan Son National Park), Thanh Hoa (Xuan Lien Nature Reserve), Nghe An (Pu Hoat Nature Reserve, Pu Mat National Park), Kon Tum (Chu Mom Ray National Park, Thach Nham protected forest), Gia Lai (Kon Ka Kinh National Park, Kon Chu Rang Nature Reserve), Dak Lak (Chu Yang Sin National Park), Lam Dong (Bidoup Nui Ba National Park, Bao Loc forest).

The plants were collected as spirit and/or herbarium material and deposited at MW (also LE for Orchidaceae). Each collection is accompanied by a series of photographs of a living plant.

## Results and discussion

Our collection of non-photosynthetic plants numbers 29 species from seven families of which only four species of Balanophoraceae are parasites and the others are mycoheterotrophs. Their representatives are shown in Fig. 1.

Below we provide the list of the collected specimens with localities of our findings and references to published details of these records. The name(s) of the collector(s) are omitted to keep the list short; all the numbers belong to *Nuraliev* or *Nuraliev et al.* We also discuss distribution and taxonomy of our most significant findings.

### List of non-photosynthetic angiosperms collected during expeditions of the Russian-Vietnamese Tropical Center

#### Parasitic plants

##### Balanophoraceae

*Balanophora fungosa* subsp. *indica* (Arn.) B. Hansen. Hoang Lien: *s.n.*, Xuan Son: 1166, Chu Yang Sin: 514 (VISLOBOKOV & GALINSKAYA 2018)

*Balanophora harlandii* Hook. f. Hoang Lien: *s.n.*, Xuan Son: 1167 (VISLOBOKOV & GALINSKAYA 2018)

*Balanophora laxiflora* Hemsl. Bat Xat: 2282, Hoang Lien: *s.n.*, Phia Oac-Phia Den: 2334, Xuan Lien: 1178

*Rhopalocnemis phalloides* Jungh. Pu Hoat: 2194, Thach Nham: 1378, 1384, Chu Yang Sin: 1002 (SCHELKUNOV et al. 2019)

#### Mycoheterotrophic plants

##### Ericaceae

*Monotropastrum humile* (D. Don) Hara. Pu Hoat: 2221a (photo), Thach Nham: 1379, 1397, 1656

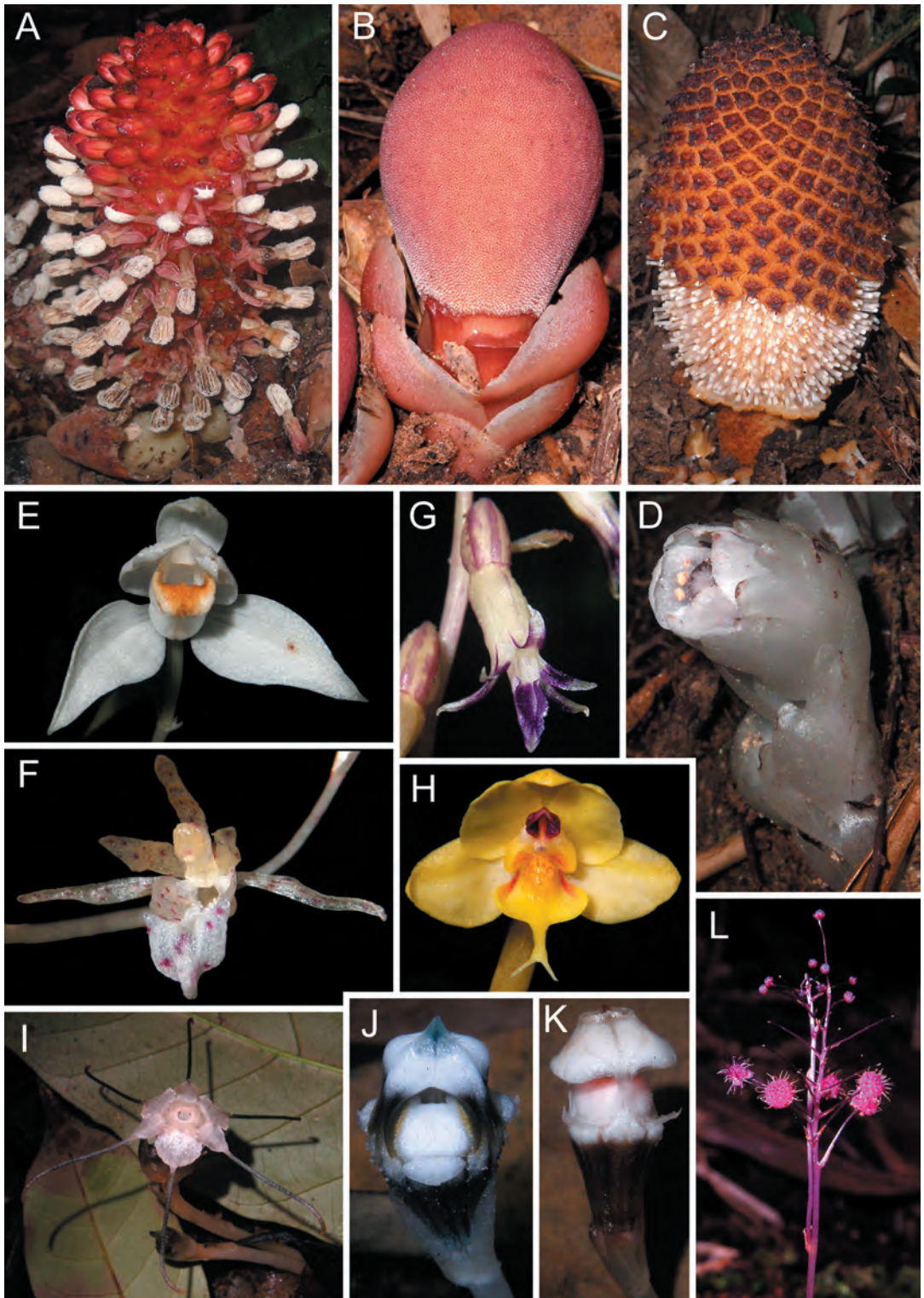


Figure 1. A, B – *Balanophora fungosa* subsp. *indica* (male and female individuals); C – *Rhopalocnemis phalloides*; D – *Monotropastrum humile*; E – *Cephalanthera exigua*; F – *Epipogium roseum*; G – *Stereosandra javanica*; H – *Viororchis furcata*; I – *Thismia annamensis*; J – *Thismia mucronata*; K – *Thismia puberula*; L – *Sciaphila nana*. All photos by M. Nuraliev.

Petrosaviaceae

*Petrosavia stellaris* Becc. Thach Nham: 1381, 1668, Chu Yang Sin: 486, 681, 946 (LOGACHEVA et al. 2014; REMIZOWA et al. 2017)

Orchidaceae

*Aphyllorchis evrardii* Gagnep. Bidoup Nui Ba: 244

*Cephalanthera exigua* Seidenf. Bao Loc: 820 (NURALIEV et al. 2014b)

*Cyrtosia faberi* (Rolfe) Aver. Hoang Lien: s.n., Pu Hoat: 2211

*Cyrtosia lindleyana* Hook. f. & Thomson. Pu Hoat: 2179

*Didymoplexiella ornata* (Ridl.) Garay. Kon Ka Kinh: 1781

*Didymoplexiella siamensis* (Rolfe ex Downie) Seidenf. Bao Loc: 586 (AVERYANOV 2013)

*Didymoplexiopsis khiriwongensis* Seidenf. Pu Mat: 2107

*Didymoplexis holochelia* Aver. & Nuraliev. Pu Hoat: 2171 (holotype) (AVERYANOV et al. 2019)

*Didymoplexis pallens* Griff. Bao Loc: 644

*Epipogium roseum* (D. Don) Lindl. Pu Hoat: 2151, Pu Mat: 2127, Chu Mom Ray: 1203, Thach Nham: 1645, Kon Ka Kinh: 1472, 1725, 1829, Kon Chu Rang: 1601, Chu Yang Sin: 717, Bao Loc: 834, 843 (SCHELKUNOV et al. 2015)

*Galeola nudifolia* Lour. Pu Mat: 2076

*Gastrodia theana* Aver. Kon Ka Kinh: 1529

*Lecanorchis nigricans* Honda. Thach Nham: 1686

*Stereosandra javanica* Blume. Chu Mom Ray: 1235, 1279

*Vietorchis furcata* Aver. & Nuraliev. Chu Yang Sin: 518 (holotype), 747 (paratype), 998, Bao Loc: 810 (paratype) (AVERYANOV 2013; AVERYANOV et al. 2013)

Burmanniaceae

*Burmannia lutescens* Becc. Thach Nham: 1657 (NURALIEV et al. 2018)

Thismiaceae

*Thismia annamensis* K. Larsen & Aver. Thach Nham: 1644, Kon Chu Rang: 1562, Chu Yang Sin: 999

*Thismia mucronata* Nuraliev. Chu Yang Sin: 1009, Bao Loc: 813 (holotype) (NURALIEV et al. 2014a)

*Thismia puberula* Nuraliev. Chu Yang Sin: 1000 (holotype) (NURALIEV et al. 2015)

Triuridaceae

*Sciaphila densiflora* Schltr. Thach Nham: 1670

*Sciaphila nana* Blume. Thach Nham: 1380a, 1669, Chu Yang Sin: 498, 947, 972

*Sciaphila stellata* Aver. Thach Nham: 1380b

*Sciaphila* sp. Kon Chu Rang: 1616

**The genus *Balanophora***

The species delimitation within this genus is known to be difficult, and there is still no consensus on its species number in the flora of Vietnam and worldwide. For this reason, a number of our collections including those from Xuan Lien Nature Reserve are still not identified and not listed in this paper. *Balanophora harlandii* is among the morphologically distinct species of this genus. It is remarkable that this species was only provisionally listed for Vietnam by HANSEN (1973) and

no records were published till recently. Our two findings from Lao Cai and Phu Tho provinces (see also VISLOBOKOV & GALINSKAYA 2018) together with the collection by BUI et al. (2018) from Lai Chau province thus represent the first reports of *B. harlandii* from this country.

Investigations by VISLOBOKOV & GALINSKAYA (2018) in Xuan Son have revealed considerable differences in pollination of two species of *Balanophora* growing close to each other: *B. harlandii* is pollinated mainly by wasps while *B. fungosa* by drosophilid flies. Both of them produce abundant nectar to attract the insects.

### The genus *Petrosavia*

This genus comprises two species, *P. stellaris* and *P. sakurarii* (Makino) J.J. Sm. ex Steenis. For a long time, only the latter species was listed for Vietnam and exclusively near the border with China. The other species, *P. stellaris*, was believed to be restricted to Malaysia and Indonesia. During our revision of *Petrosavia* in Vietnam, we have shown that this genus is rather widespread across its territory with several populations of *P. sakurarii* in the North (the southernmost of them in Nghe An province) and *P. stellaris* inhabiting a number of mountain areas in Central Highlands (see details in REMIZOWA et al. 2017).

### The genus *Cephalanthera*

*Cephalanthera* comprises about 15 species of which about a half are non-photosynthetic. Most of its non-photosynthetic representatives are rare tropical plants. *Cephalanthera exigua* was described from Laos and later also found in two populations in Northern Thailand. Our finding of this species in Southern Vietnam (NURALIEV et al. 2014) appeared to be its fourth known locality and the first record of the whole genus in this country.

### The genus *Vietorchis*

This genus was described as recently as in 2003 together with a single species, *V. aurea* Aver. & Averyanova, restricted to a single locality in Northern Vietnam. Our collections from Central Highlands brought the second species of this genus, *V. furcata* (AVERYANOV et al. 2013). The genus *Vietorchis* possesses an uncertain placement in the system of the family Orchidaceae due to its intriguing morphology: the structural details of gynostemium and pollinaria resemble those of Orchidoideae while the rhizome is more typical for Epidendroideae. *Vietorchis* is currently treated along with *Silvorchis* in the recently segregated subtribe Vietorchidinae of the tribe Orchideae (subfamily Orchidoideae). We continue clarification of this question with employment of molecular phylogenetic studies.

### The genus *Thismia*

In the early 2000s, *Thismia* was known to be represented in Vietnam by a single species, *T. javanica* J.J. Sm. Two more species, *T. annamensis* and *T. tentaculata* K. Larsen & Aver., were described in 2007. Then, *T. okhaensis* Luu, Tich, G. Tran & Dinh was added in 2014. After our investigations, which have resulted in discovery of *T. mucronata* and *T. puberula* (NURALIEV et al. 2014, 2015) the genus *Thismia* numbers six species in Vietnam. We expect continuation of such findings in the nearest future. It is important that some of these recently discovered species appear to be rather widespread: *T. tentaculata* originally described from Quang Tri province in Central Vietnam is now known from Hong Kong (Ho et al. 2009); *T. annamensis* described from Dak Nong province seems to be distributed across the Central Highlands; *T. mucronata* from Lam Dong province was later found in the neighboring Dak Lak province.



Figure 2. Map of Vietnam with localities of our collections. Figures in brackets represent number of collected non-photosynthetic plant species.

### Patterns of distribution of non-photosynthetic species in Vietnam (Fig. 2)

According to our collections, non-photosynthetic plants are most diverse within Vietnam in mountainous areas of Central Highlands, particularly in Thach Nham (also known as Kon Plong district) and Chu Yang Sin. This is most likely a consequence of diverse conditions found at these sites: at both of them, we have explored a wide range of elevations, i.e. 1000–1750 m and 700–2050 m a.s.l., respectively. The relatively high diversity found in Bao Loc is remarkable, as this area is entirely located at middle elevations (450–1300 m a.s.l.).

Our findings perfectly illustrate the well-known ability of mycoheterotrophic plants to co-occur with each other (e.g. MERCKX 2013). For instance, in Thach Nham, *Monotropastrum humile*, *Burmannia lutescens* and three species of *Sciaphila* were recorded along a trail 500 m long, some of

them scattered among the others. In Chu Yang Sin, a 300 m distance along a river bank was found to be inhabited by *Epipogium roseum*, *Vietorchis furcata*, *Thismia annamensis* and *T. puberula* (and also the parasitic *Rhopalocnemis phalloides*).

The number of species listed here for Bidoup Nui Ba and Xuan Lien is obviously underestimated, as it resulted from short observation fieldtrips.

Among the areas unexplored by our team, the most promising for further exploration, on our opinion, are several localities around the hotspots revealed here (e.g. Ngoc Linh and Hon Ba) as well as the northern provinces Ha Giang and Cao Bang along the border with China.

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