Ecology and population structure of a terrestrial mycoheterotrophic orchid, *Aphyllorchis montana* Rchb.f. (Orchidaceae) in Soppinabetta forests of the Western Ghats, India

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The Western Ghats is a mega-biodiversity hotspot in India, and one among the 34 global Biodiversity Hotspots (Mittermeier et al. 2004). The 1,60,000km^2 hill stretch inhabits at least 1,500 endemic plant species that includes many rare, endangered and threatened plants (Ahamedullah & Nayar 1986). During our ongoing research in an unprotected, farmer-managed Soppinabetta forest (Sinu et al. 2011, 2012) of Western Ghats, we came across several populations of a data-deficient mycoheterotrophic terrestrial orchid species, *Aphyllorchis montana* Rchb. f.. Here we report the population structure and ecology of the species, and discuss the possible reasons for the locally rare status of the species in the Western Ghats.

Aphyllorchis montana is a terrestrial mycoheterotrophic (McKendrick et al. 2002) orchid species that grows in low and midland broadleaved forests of India, Sri Lanka, Malaysia, Borneo, the Philippines, southern Japan, southern China, Vietnam and Taiwan (Boufford et al. 2003). *Aphyllorchis montana* is categorized as a data deficient orchid of conservation concern in India, and is enlisted in the RET plant list of India (Mohanan et al. 1982; Santhan & Rajasekaran 1993; Nayar et al. 2006). A total of 30 species (Xinqi & Gale 2009) belonging to the genus *Aphyllorchis* Blume are known to exist in various parts of the world of which three species have been reported from India, namely, *Aphyllorchis alpina* King & Pantl., *Aphyllorchis gollanii* Duthie and *Aphyllorchis montana* Rchb.f. The ecology and breeding system of the species and the possible causes for its rarity are not known. The non-chlorophyllous, non-leafy single erect orchid shoot grows to a height of 20–60 cm, and bears laxly arranged flowers in raceme (Image 1).

Materials and Methods

The study was conducted in Soppinabetta forests of Sringeri area 12^{0}55'–13^{0}54'N and 75^{0}01'–75^{0}22'E, average 725m above sea level) of central Western Ghats in Karnataka State of India. The sparsely populated Sringeri Taluk is largely under the forest cover of two types, reserve forests (owned by the forest department) and Soppinabetta forests (leased to local farmers by the forest department as a source of organic manure; hereafter, "SBF") (Sinu et al. 2012). The forests of Sringeri adjoin pristine evergreen forests of Kudremukh National Park and Agumbe rain forests. The mean annual rainfall at Sringeri varies between 4,000 and 6,500 mm (Pascal 1988). Most of the rainfall happens during the southwest monsoon (June–September). Mean daily maximum temperatures vary between 22.8^{0}C (July) and 35.1^{0}C (April). However, the mean daily minimum temperature varies between 13.2^{0}C (January) and 19.8^{0}C (May).

SBF are managed semi-evergreen forest patches (area ca. 1–4 ha) and can be ascribed as *Hopea ponga-*

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Image 1. Morphology of *Aphyllorchis montana*. © P.A. Sinu
A - a clump of the orchid; B - a single flower; C - terminal part of an inflorescence with mature capsules.

Memecylon umbellatum-Dimocarpus longan-Vateria indica-Syzigium spp. type (P.A. Sinu pers. obs. 2006–2007). However, the dominance of the tree species varies between forest patches. *Vateria indica* L., *Hopea ponga* (Dennst.) Mabb. and *Hopea parviflora* Bedd. (Dipterocarpaceae) are some of the canopy tree species that have clear dominance in some SBFs.

Fourteen different SBFs were surveyed to study the distribution and population structure of *A. montana* (Table 1). The study was undertaken in the monsoon months (July–September) of 2007 and 2008. All the selected forest fragments were less than 4ha in size; hence, the survey was conducted on the entire forest floor. Vegetation structure and tree composition, however, was estimated using two belt transects of 100×10 m in each forest patch. Once the orchid was detected, a fine-scale leaf litter study was made in the vicinity of the orchids. Leaf litter of 30×30 cm^2 quadrate that surrounds the orchid clump was studied; the number of leaves (fresh and old) in the litter bed was checked by inserting a fine knife; litter depth was checked using a measuring gradient scale; and the tree species of the leaves was recorded. Canopy cover was visually ranked from six random points in each of the forest patches. The clump size, length of the shoots, number of flowers, and number of fruit capsules were recorded for every recorded orchid clump. The distance between two orchid clumps was measured in each of the forest fragments.

The differences in the number of orchid clumps

Table 1. A general overview of 14 Soppinabetta forest patches (study sites) selected for the study in Sringeri area of central Western Ghats, India.

Serial No.	Study site Co-ordinates	Altitude (m)	Soil pH	Canopy cover (%)	Litter depth (cm)*	Percentage of dipterocarpacean plant leaves in leaf litter	Dominant tree species
1**	13°30.664'N 75°10.643'E	675	4.7	67	2.5	61	Hp-Dl-Ci
2**	13°21.232'N 75°18.612'E	692	4.8	57	1.3	85	Hp-Mu
3**	13°28.566'N 75°09.122'E	712	4.4	80	1.4	100[$]	Vi
4**	13°29.439'N 75°12.038'E	728	5.0	70	3	81.5	Hp-Mu
5**	13°29.467'N 75°20.664'E	738	4.7	80	3	35	Hp-Al
6	13°29.332'N 75°11.891'E	654	4.8	80	3.5	0	Al-Mu
7	13°22.104'N 75°13.356'E	757	4.9	80	2.5	0	Ah-Dl
8	13°29.309'N 75°10.436'E	712	5.1	65	1	77.5	Hp
9	13°29.309'N 75°10.436'E	694	5.1	70	1	0	Dl-Mu-Gm
10	13°30.087'N 75°11.841'E	790	4.9	65	0.5	88	Hp
11	13°27.112'N 75°13.538'E	690	4.8	65	1	54.4	Hp-Al
12	13°26.548'N 75°13.330'E	761	4.8	75	1.5	12.4	Lw-Mu-Hp
13	13°25.056'N 75°12.321'E	758	5.0	75	1.5	0	Dl-Mu
14	13°23.221'N 75°18.112'E	722	5.1	65	1	68.5	Hp-Al

* - recorded during the Orchid survey; ** - SBFs having *Aphyllorchis montana* populations; [$] - *Vateria indica* leaves
Abbreviations of plant species: Hp - *Hopea ponga*; Dl - *Dimocarpus longan*; Ci - *Calophyllum inophyllum*; Me - *Mimusops elengi*; Vi - *Vateria indica*; Al - *Aporusa lindleyana*; Mu - *Memecylon umbellatum*; Ah - *Artocarpus heterophyllus*; Gm - *Garcinia morella*; Lw - *Lophopetalum whitianum*

between years and forest fragments were compared using Mann-Whitney U test and Kruskal Wallis rank ANOVA test, respectively.

Results

The flowering *A. montana* shoots were seen by the onset of southwest monsoon in June. The flowering of the orchid continued until mid September. Fruit development occurred until mid October. Although the orchid was found growing with a single shoot in some fragments, most of them were found in clumps (Image 1) of up to 13 shoots (average 3.83 shoots/clump (± 3.21 SD; N=70). The length of the erect shoots varied between 16cm and 78cm (av. 40.86±12.70 SD; N=268). The number of flowers per shoot varied between five and 24 (av. 11.47±3.65 SD; N=149). The fruit set ranged between 0% and 64.7% per shoot (N=214) of the flowers set fruits. Orchid distribution tends to be cluttered; the inter-clump distance ranged between four and 21 m in a forest fragment (av. 9.8±3.9 m SD; N=30). The voucher specimens are deposited in the Sringeri field station of ATREE (17.viii.2007, 4 nos, Soppinabetta Kumbarakodu: SRINGERI, Collection no. 315).

The orchid clumps were located only in five SBF fragments that were separated by 6–20 km. The SBFs having the orchid populations were dipterocarp species dominated (*H. ponga*, *H. parviflora* and *V. indica*). The orchid clumps were seen under the thick canopy (>80% canopy cover) of forests. Overall, 286 orchid shoots of 72 clumps were recorded in both the years. Most of these clumps were present during 2007 and 2008. However, two additional clumps were located, and some of the previously located clumps were enriched by additional shoots in 2008 survey (Fig. 1). The difference in the number of orchid shoots between years was not significant (Mann-Whitney U test: U=463.5, P=0.08; Fig. 1). The difference in the number of orchid shoots between five SBFs was also not significant (Kruskal-Wallis test: H=3.99, d.f.=4, P=0.40; Fig. 1).

Discussion

Terrestrial orchids are in need of species-specific fungi for seed germination and growth (Warcup 1973; Clements et al. 1986); however, the relationship is obligate in mycoheterotrophic orchids (McCormick et al. 2004). As the vegetative growth of the terrestrial mycoheterotrophic orchid is absolutely an underground mechanism, it is a challenge to locate them in vegetative conditions (Rasmussen & Whigham 1998). Although the present study does not go in depth to identify the ectomycorrhizal fungi associated with the *A. montana*, the study assumes that the fungi is also associated with dipterocarp plants (Tho et al. 2007).

The study initiated with the assumption that *A. montana* occurs in dipterocarp plant dominated forests. Tho et al. (2007) reported *A. montana* populations in *Shorea guiso* and *Vatica odorata* (Dipterocarpaceae) dominated forests in Vietnam. The results supported our assumption as we found four *A. montana* populations in the *H. ponga* dominated SBFs, and the fifth population in a *V. indica* dominated SBF. It is also previously reported that leaf litter quantity and quality has an effect on some symbiotic associations, such as mycorrhiza-plant associations in tropical forests (Rasmussen & Whigham 1998; Batty et al. 2001; Bergman et al. 2006). Meanwhile, some SBFs having *H. ponga* as a co-dominant species had no *A. montana* in it (Table 1), indicates the effects of other environmental features on the population ecology of *A. montana*.

A. montana distributed in a cluttered manner in forest fragments indicates that the germination happens in the vicinity of fruiting orchids (Bergman et al. 2006). In some fragments, the overall orchid distribution was limited within a 30m radius. The study also showed that the orchid grows in clumps of 2–13 shoots. Both these findings indicate that the patchy distribution of associated fungi primarily determines the terrestrial mycoheterotrophic orchid growth and colonization. The reports that germination in

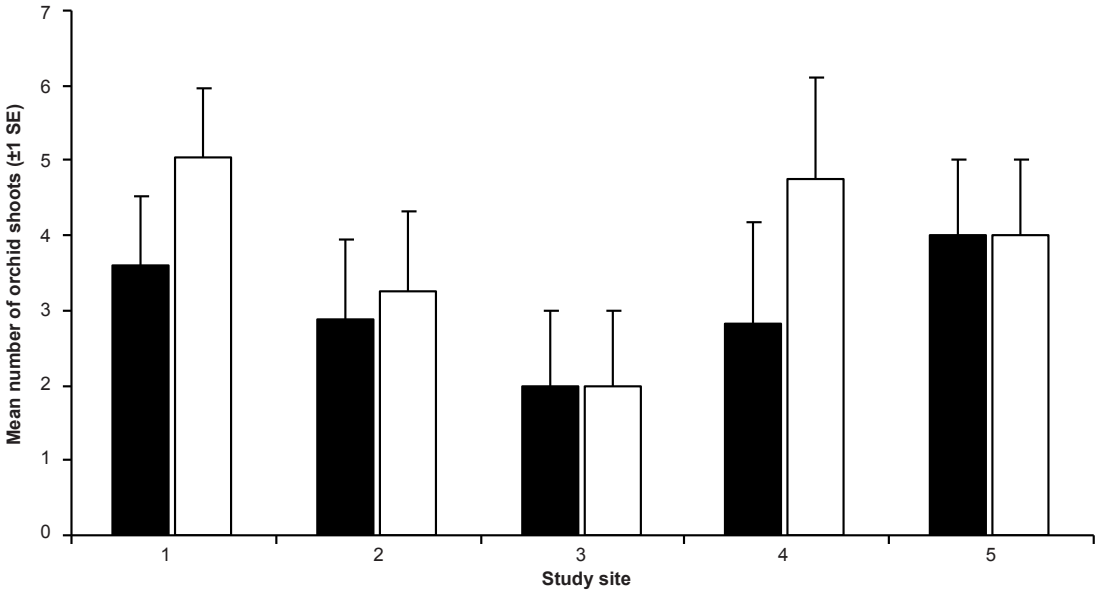

Figure 1. Number of *Aphyllorchis montana* shoots per clump in the year 2007 (closed bars) and 2008 (open bars) in Soppinabetta forest patches. Refer Table 1 for study site information

terrestrial orchids increases in the vicinity of the adult orchid (Rasmussen & Whigham 1998) also would have been a reason behind the clumpy growth of the species, but this is required to be studied in more detail. Large numbers of fruit capsules indicate that there are no reproductive barriers in the species. However, it is worth undertaking a study on the pollination system in the species. Although we did not extend our study further, we could collect 42 muscid flies (Muscidae: Diptera) from a fruit capsule. This indicates that the seed predation by some agents, either the muscid fly itself or some lepidopteran caterpillar that was parasitized by the fly, exists in the species. This may be a reason why seeds do not disperse to a great distance.

The data deficiency status of the species in India might be due to the sampling artifact (Rao 1998). Like many other mycoheterotrophic terrestrial orchids, the above ground stage of the orchid is visible only in a narrow window of time during peak monsoon in India, a period of few botanical expeditions. The present inventory of *A. montana* populations in SBFs of Sringeri point out that unprotected human-influenced forests of Western Ghats are also significant in the conservation of rare and endangered flora and fauna (Sinu et al. 2011). Based on the present and some previous studies, it is imperative that conservation practitioners identify various 'potentially-unprotected forests' in the Western Ghats, while designating ecologically sensitive areas (Gadgil et al. 2011).

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