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# Distribution, Present Situation and Conservation Strategy of the Genus *Phacellaria*

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**Abstract:** There are eight species in the genus *Phacellaria*, six of which are distributed in tropical and subtropical mountain areas of South and Southwest China. The species belonging to this genus are obligate hemiparasites on plants in Loranthaceae and *Dendrotrophe* (Santalaceae). Based on previously collected specimens, documents and field investigation, we found that *Phacellaria* is becoming more and more vulnerable, and is well on its way to becoming endangered in the near future. The main factors contributing to the growing vulnerability of *Phacellaria* species are: (1) deforestation resulting in a dramatic decline in the population density of the hosts of *Phacellaria*, and (2) the decrease in number of *Dicaeum* spp., the small birds that disperse seeds of *Phacellaria*, due to habitat loss and capture for the pet trade. We suggest two solutions to this dilemma. The first is to recover the previously damaged ecosystems of *Phacellaria* and *Dicaeum* spp., and the second is to enhance research on the biological characters of *Phacellaria* species.
**Key words:** *Phacellaria*, parasitic plant, geological distributional, present situation, conservation

The genus *Phacellaria* belongs to the family Santalaceae. They are a very special hemiparasites of Loranthaceae but occasionally occur on *Dendrotrophe* (Tao, 1986; Tan, 1988). This genus has 8 species occurring only in the south of China and southeast Asia and there are 6 species in China. Because of the limited distribution, studies on this special parasitic plant are very limited and much information is still unknown. By collecting specimens and reviewing previous publications, we found that most of the species in this genus are endangered or are almost extinct. This article focused on the current research on this genus, their current distribution and the cause of their limited distribution. We also discuss the possible protection policy so that we can protect and provide more information on this rare parasitic plant.

## 1. Current Research

So far the majority of research on this genus focused on the following areas:

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## 1.1 Systematics

In 1880 British scientist Bentham created the genus based on samples from two specimens from India and Myanmar: *Phacellaria rigidula* and *P. compressa*. *Phacellaria rigidula* is the type for this genus. Afterwards botanists named six more species: *P. wattii, P. caulescens, P tonkinensis, P. fargesii, P. ferruginea*, and *P. malayana*. Danser (1939) reworked the taxonomy by lumping *P. compressa, P. wattii, P. ferruginea* into *P. compressa*, and also named a new species *P. gracilis*. By the end of 1980s, Tao (1987) named a new species, *P. glomerata,* when he was organizing specimens at the Chinese Academy of Science in Kunming Botanic Garden. Now we have 8 species in the genus.

Kuijt (1968) suggested that Olacaceae is the most primitive family and is the ancestor of Loranthaceae, Myzodendraceae, Opiliaceae, Santalaceae, Eremolepidaceae, and Viscaceae. Among these, Loranthaceae, Myzodendraceae, Eremolepidaceae, and Santalaceae are directly related to Olacaceae and Viscaceae is derived from Santalaceae. Therefore, Viscaceae is the most derived group in the order. Liu and Qiu (1993) came to the same conclusion when they studied the pollen morphology of 45 members of Loranthaceae and some Santalaceae.

## 1.2 Hosts and Distribution of Loranthaceae

Loranthaceae is limited to the south of China and southeast Asia. It continues from Chongqing (32°N) to the Malaysian peninsula (Selangor 3°N) and west from east India to Fujian province of China. The whole region includes Malaysia, Singapore, Thailand, Myanmar, Cambodia, Viet Nam, east India, Yunnan, Hainan, Tibet, Guangxi, Guangdong, Fujian, Guixhou, Sichuan, Chongqing, and Hubei. The elevational range is from 900–2300 m in the subtropical and tropical mountain forests (Table 1).

There direct hosts include several species. Most hosts belong to Loranthaceae except *P. compressa* which can be found occasionally on *Dendrotrophe polyneura*. We reviewed publications and inspected specimens from the Chinese Academy of Science in Kunming Botanical Garden and Southeast Garden of Chinese Academy of Science. We found the following host genera: *Macrosolen, Taxillus, Scurrula, Helixanthera, Dendrophthoe, Korthalsella*, and *Loranthus*. *Taxillus* is the major host. Among Loranthaceae hosts, most of them are distributed in south China and tropical and subtropical regions of southeast Asia, except for *Korthalsella* which can be found in parts of Africa and Australia.

Indirect hosts of this genus include Fagaceae, Lauraceae, Theaceae, and Rosaceae which are important economically. The relationship of *Phacellaria* and their direct and indirect hosts is illustrated in Fig. 1.

## 1.3 Seed Dispersal

Like Loranthaceae, the genus *Phacellaria*, such as *P. rigidula* and *P. tonkinensis*, are bird dispersed. Ripe fruits are small in this genus and they are ovoid in shape, 5-8 mm long and 2-3 mm wide, with a leathery pericarp and a fleshy mesocarp and hard endocarp. The pericarp is light yellow to brown and can be bright red when exposed to sunlight. Bright coloration can attract birds. The hard endocarp is formed with sclerified cells that are difficult to digest, therefore the seeds inside are intact after passing through the bird's digestive system. At the interface of the mesocarp and endocarp there is a layer of viscous material that can stick to the host plant after

**Table 1 Species, distribution, direct and indirect host plants of the genus *Phacellaria***

| Species | Distribution | Direct host plants | Indirect host plants* |
|---|---|---|---|
| *P. caulescens* | In China: Mengla, Jinghong, Xichou, Dali and Tengchong in Yunnan In South East Asia: Burma | *Macrosolen cochinchinensis* | 1, 2, 3, 4, 5, 6 |
| *P. compressa* | In China: Puer, Jinghong, Menghai, Yangbi in Yunnan; Leye in Guangxi; Motuo in Tibet. In South East Asia: Burma, Tailand, Vietnam | *Taxillus chinensis*<br>*Dendrotrophe polyneura* | 7, 8, 9, 10, 11,12, 13, 14, 15, 2, 16, 17, 18, 4 |
| *P. fargesii* | In China: Leshan, Chengkou in Sichuan; Xianfeng in Hubei; Guizhou; Guangxi; Longyan, Nanjing, Liancheng in Fujian | *Taxillus levinei*<br><br>*T. sutchuenensis* | 15, 19, 20<br><br>7, 21, 11, 22, 15, 23 24, 25, 26, 27, 28, 29, 30 |
| *P. gracilis* | Vietnam | *Scurrula parasitica* | 31, 32, 33, 34, 10, 21, 35, 36, 5, 37, 38, 39, 40 |
| *P. malayana* | In South East Asia: Malay Peninsula | *Dendrophthoe pentandra* | 41, 42, 2, 43, 34, 16, 9 |
| *P. rigidula* | In China: Damiaoshan in Guangxi; Tonghai, Mengla, Jinghong, Deqin, Xichou, Luchun in Yunnan; Emei in Sichuan; Guangdong In South East Asia: Burma, India | *Korthalsella japonica*<br>*Taxillus caloreas var. fargesii*<br>*Scurrula parasitica* var. *graciliflora*<br>*Taxillus thibetensis*<br>*T. limprichtii*<br><br>*Macrosolen bibracteolatus* | 4, 5, 44, 45, 46, 47<br>35, 48, 49<br><br>10, 21 50, 51, 52, 53, 54<br>21, 11, 55, 20, 26<br>56, 1, 57, 2, 58, 20, 19, 53, 59<br>60, 61, 62, 63 |
| *P. glomerata* | Jingdong, Yunnan | *Loranthus delavayi* | 4, 35, 21 |
| *P. tonkinensis* | In China: Fengkai, Lianshan in Guangdong; Sanya in Hainan; Qujing, Jinping, Pingbian in Yunnan; Longyan, Shanghang, Nanjing in Fujian. In South East Asia: Vietnam | *Helixanthera parasitica*<br><br>*Taxillus chinensis*<br><br>*T. levinei*<br>*Loranthus delavayi*<br>*Macrosolen bibracteolatus*<br>*Scurrula parasitica* var. *graciliflora* | 64, 2, 65, 66, 27, 60, 67<br>7, 8, 9, 10, 11, 12, 13, 14, 15, 2, 16, 17, 18<br>15, 19, 20<br>4, 35, 21<br>60, 61, 62, 63<br><br>10, 21, 50, 51, 52, 53, 54 |

* 1, *Liquidambar formosana*; 2, *Vernicia fordii*; 3, *Cunninghamia*; 4, Fagaceae; 5, Theaceae; 6, Moraceae; 7, *Morus alba*; 8, *Ficus elestica;* 9, *F. microcarpa*; 10, *Prunus persica*; 11, *P. salicina*; 12, *Dimocarpus longan*; 13, *Litchi chinensis*; 14, *Averrhoa carambola*; 15, *Camellia oleifera*; 16, *Bombax malabaricum*; 17, *Pinus massoniana*; 18, *Glyptostrobus pensilis*; 19, *Cinnamomum camphora*; 20, *Castanea mollissima*; 21, *Pyrus* spp.; 22, *Prunus mume*; 23, *Ternstroemia gymnanthera*; 24, *Toxicodendron verniciflum*; 25, *Juglans regia*; 26, *Quercus*; 27, *Lithocarpus*; 28, *Fagus*; 29, *Betula*; 30, *Corylus*; 31, *Citrus grandis*; 32, *C. reticulata*; 33, *C. limon*; 34, *Clausena lansium*; 35, *Keteleeria evelyniana*; 36, *Cupressus duclouxiana*; 37, Ulmaceae; 38, Euphorbiaceae; 39, Apocynaceae; 40, Sapindaceae; 41, *Canarium pimela*; 42, *C. album*; 43, *Mangifera indica*; 44, Lauraceae; 45, Myrtaceae; 46, Symplocaceae; 47, Oleaceae; 48, *Pinus yunnanensis*; 49, *Picea*; 50, *Prunus armeniaca*; 51, *Punica granatum*; 52, *Camellia sinensis* var. *assamica*; 53, *Castanopsis henryi*; 54, *Pinus*; 55, *Diospyros kaki*; 56, *Michelia chapensis*; 57, *Loropetalum chinense* var. *rubrum*; 58, *Firmiana platanifolia*; 59, *Lindera communis*; 60, *Cinnamomum*; 61, *Camellia*; 62, *Antidesma*; 63, *Symplocos*; 64, *Schima superba*; 65, *Melia azedarach*; 66, *Castanopsis*; 67, *Ficus*


Fig. 1. A diagram showing the relationship between plants in the genus *Phacellaria* and their direct and indirect host plants. A, *Taxillus caloreas* var. *fargesii* (direct host of *Phacellaria*) growing on *Keteleeria evelyniana* (indirect host of *Phacellaria*); B, *Phacellaria rigidula* growing on *Taxillus caloreas* var. *fargesii*; C, Flowering branch of *Taxillus caloreas* var. *fargesii*; D, Fruits of *Phacellaria rigidula*.

dispersal, and can germinate when the conditions are right. All of these characteristics of the fruits are adaptations to their parasitic lifestyle and bird dispersal.

We found that *Dicaeum* spp. are the main dispersing vectors for *P. fargesii*. These birds are small, light, with long sharp beaks and claws. Their stomach is small and thin-walled and have limited digestive ability which corresponds to the fruit structure of *P. fargesii* and therefore there is a coevolutionary relationship between the two. These birds are mainly distributed on the Indian subcontinent, Pacific islands, southeast Asia and parts of southern China (Zheng 2002). Their distribution coincides with the genus *Phacellaria* and the family Loranthaceae, which again emphasizes the coevolution between the three groups.

## 2. *Phacellaria*, Distribution and Cause of Rarity in China

### 2.1. Current Distribution in China

We inspected specimens from Botanic Garden Museum of Chinese Academy of Science and Kunming Botanical Garden Museum, Southeast Botanical Garden Museum of the Chinese Academy of Science and we found that all specimens were collected in the 20th century and most were very early collections. [Summary of specimens from these three museums]

At the Botanical Garden Museum of Chinese Academy of Science there are only 11 specimens of the genus *Phacellaria*. The earliest sample was *P. compressa* collected in Maoshang, Sichuan Province in 1930. The newest collection of *P. compressa* was from Motuo in Tibet in 1974. Most of the specimens were collected between the 1930s and 1950s. At the Kunming Botanical Garden Museum they had 21 specimens and the earliest one was collected in Maoshang, Sichuan Province in 1930 [same specimen number as above]. The latest specimen of *P. rigidula* was collected from Luechun Huanlianshan in Hunan province in 1995. Most of the collections are from the 1950s and 1980s, some are from the 1930s and 1990s. From the Southeast Botanical Garden Museum there were 23 specimens, the earliest collection of *P. compressa* was from Puer in Yunnan province in 1933. The latest collection of *P. tonkinensis* was from Lianshan in Guangdong province in 1985. Most of the specimens are from the 1970s and 1950s.

Xiao and Pu (1988) investigated *Phacellaria* in Xi Shuang Ban Na and found that they prefer sunny habitats mostly along roadsides, riverbanks, around fields and outskirts of villages, forest openings and regenerating forests. These habitats are very sunny, facilitating photosynthesis in these hemiparasitic plants. We found similar results in the present study: both *Taxillus caloreas* var. *fargesii* and *Scurrula parasitica* var. *graciliflora* are mainly found on sunny cliffs, roadsides, and forest openings as well as sunny areas in regenerating forests. Besides the benefit from higher photosynthesis in sunny areas, this also allows birds to more easily discover and disperse their seeds. This could be more evidence for coevolution between the parasite, host, and birds.

These plants are easy to discover in forests due to their bushy growth form, 10-30 cm high, their yellow pigment, and the bright red color on surfaces exposed to sun. Based on descriptions from museum specimens, personal communications with experts, and a literature review, we tried to collect new specimens from original localities, including Ba Wang Ling and Jian Feng Ling in Hainan province, Hei Shi Ding Natural Reserve in Feng Kai, Guangdong province, Cai Yang He Natural Reserve in Si Mao in Yunan province, Tong Hai and Cang Shan. The results from these collection attempts were as follows: no specimen was found in Ba Wang Ling and Jian Feng Ling in Hainan province; one clump of *Phacellaria tonkinensis* was collected from Hei Shi Ding Natural Reserve (from the Huanan Botanical Garden museum three samples of *P. tonkinensis* and one sample of *P. fargesii* were collected at different times and locations in Hei Shi Ding); two samples *P. compressa* from Cang Shan (Kunming Botanical Garden museum collected two specimens of *P. compressa* from Cang Shan Natural reserve and one *P. rigidula* from different times and locations); and in Cai Yang He Natural Reserve one dying clump of *P. compressa*; very few *P. rigidula* in Tong Hai, Yunan province.

Based on specimens and field collections, we found that in the original habitats of *Phacellaria* it is becoming increasingly difficult to collect these parasitic plants. They are becoming endangered or almost extinct in these habitats.

### 2.2 Cause of Rarity in China

These are the following reasons for the rarity of this plant in China:

(1) Deforestation. This is the main cause of the decline of *Phacellaria* and their host plants because both prefer sunny habitats such as forest edges, riverbanks and roadsides. Secondary hosts are mainly Pinaceae, Moraceae, Euphorbiaceae, and Rutaceae which contain economically important members that are commonly harvested.

In Hei Shi Ding Natural Reserve, the host plants for *P. tonkinensis* are *Taxillus levinei* and *Loranthus delavayi*. These two host mistletoe species mainly grow on roadside plants in the above families, therefore it is common to see the mistletoe on these hosts. As the roadside host trees and host mistletoes are cleared, *P. tonkinensis* disappears.

In Tong Hai, the main host for *P. rigidula* is *Taxillus caloreas* var. *fargesii* which in turn grows on *Keteleeria evelyniana*, which is a common timber species in regenerating forests in this area. This tree produces high quality timber, is rot resistant, and is the top choice for levee construction. As this species becomes rare along roadsides and openings, *P. rigidula* is also becoming rare.

(2) Death of Primary Host [mistletoe]. There are two main causes for host mistletoe death, natural and anthropogenic. Natural death refers to the disappearance of the parasitic relationship between host and parasite. This is not a mutual relationship, hence the more growth of the parasite, the more is taken from the host. When this unbalanced relationship progresses to the point where the host plant dies, so does the parasite. To survive, *Phacellaria* must continuously take nutrients from its Loranthaceae and *Dendrotrophe* hosts, which in turn take nutrients from their hosts. When these two host mistletoes die, the *Phacellaria* also dies.

Human disturbance is another important cause for the decline of *Phacellaria*. Because the Loranthaceae and *Dendrotrophe* hosts grow on tea, fruit and timber trees, they cause economic loss and as a result they are listed as pests. People eradicate them by pruning, clearing, and herbicide spraying which is the main cause of the decline of *Phacellaria* in the walnut region of Yang Bi. Moreover, many Loranthaceae are used for traditional medicine which leads to their decline and subsequent loss of *Phacellaria*.

(3) Reduced Number of Bird Dispersers. The disperser for *Phacellaria* seeds are small-bodied flowerpeckers that can only fly short distances, which leads to a patchy distribution in a region. For example, in Tong Hai Yunan province, the closest distance between two mountains is ca. 800 m. The dominant vegetation is *Keteleeria evelyniana* and the forest edges have abundant host mistletoes [*Taxillus* and *Scurrula*], however, one mountain has abundant *Phacellaria rigidula* while the other has none. It is probable that forest cutting has lead to fragmentation of the flowerpecker habitat which in turn affected *Phacellaria* seed dispersal.

Moreover, flowerpeckers have bright plumage and feed on *Phacellaria* seeds as well as nectar and worms and are commonly kept as pets. The use of pesticides is another factor in flowerpecker decline. In summary, flowerpecker habitat loss and decline in population size affected the expansion and distribution of *Phacellaria*.

## 3. Conservation Policy

Currently species under protection can belong to the following: 1) extremely rare and limited in distribution; 2) of significant economic, scientific and cultural value; 3) wildtypes and sister groups for important crops; 4) becoming rare through exploitation.

So far *Phacellaria* is not considered economically important; however, as a unique plant group, they have a distinct function in the ecosystem: 1) rapidly produce abundant fruit over a long period of time providing important seed source for flowerpeckers, 2) poses a threat to the primary mistletoe hosts [Loranthaceae and *Dendrotrophe*] and can cause their death which in turn limits the damage to the host tree and maintains a dynamic balance among these species. Throughout its life history, *Phacellaria* forms a complex relationship with Loranthaceae, *Dendrotrophe*, flowerpeckers, and pollen vectors, and other organisms and is an important component of biodiversity. If *Phacellaria* is not protected it could disappear in the near future and the disappearance of one species could mean the loss of many more species. Maybe this is one of the reasons that earth's biodiversity is declining every year at the rate of 0.1 to 1.1% (World Conservation Monitoring Centre, 1992). Therefore, we think it is very necessary to protect *Phacellaria*. The policies that we propose are

(1) Protect Natural Habitat. Compared to generalist parasitic plants, specialists such as *Phacellaria* have very limited distributions, grow in less favorable environments with a complex yet fragile life histories, and any interruption in a particular life cycle stage can greatly threaten their survival. Habitat destruction due to deforestation not only threatens the survival of *Phacellaria* but also causes irreversible damage to biodiversity.

(2) Protect Flowerpeckers and Provide Corridors. Besides dispersing *Phacellaria* seeds, flowerpeckers also move between Loranthaceae and feed on their fruits, seeds, and insects (Xiao et al. 1994). In Xi Shuang Ban Na, Wong et al. (2000, 2002) observed that *Dicaeum cruentatum* [scarlet backed flowerpecker] sometimes randomly feeds on the fruits of *Choerospondias axillaris* and *Trema orientalis*. Therefore, flowerpeckers are important pollen and seed dispersers in the tropics and subtropics. People should be educated as to their legal and scientific protection and prohibited from capturing them for pets; educate farmers to use less damaging pesticides in their habitat to minimize toxicity in their food and water sources. Habitat fragmentation effects seed dispersal of *Phacellaria*, therefore, reforestation would provide a corridor for flowerpeckers and allow expansion of *Phacellaria* populations.

(3) Increase Basic Research. *Phacellaria* not only has limited distribution but is also present in remote regions where basic scientific research on it is poor. As such a unique genus over long evolutionary periods, why did *Phacellaria* choose Loranthaceae as their host? What is the mechanism for its seeds germinating on the host branch? What is the recognition signal involved in this process? What are the pollen vectors? What are the details of the seed dispersal process?

From 1990s until now, scientists have studied the systematics of parasitic plants using molecular techniques. However, the phylogenetic relationships within Santalales remains unclear. Nickrent and Malécot (2001) chose 54 out of 155 genera in the order Santalales and used 58 species for nuclear SSU rDNA and chloroplast *rbcL* sequences. They found Olacaceae is at the base of the tree and upwards are Loranthaceae, Opiliaceae, Santalaceae, Eremolepidaceae and Viscaceae. This finding differs from those of Kuijt (1968), Wiens and Barlow (1971), Bhatnagar and Johri (1983) in the position of the families within this order.

It is noteworthy that Opiliaceae, Loranthaceae, and Viscaceae are monophyletic and Olacaceae and Santalaceae are paraphyletic. *Choretrum* and *Dendrotrophe* in Santalaceae are more closely related to Viscaceae. Because of the limited availability of specimens, the systematics and phylogeny of *Phacellaria* is still not available. Nickrent et al. (2002) suggested that increased sampling, including *Phacellaria*, will improve the tree topology because this group of plants represent the independent evolution [of aerial parasitism]. Therefore, the conservation of *Phacellaria* is important for systematic research.

Sequencing results found chloroplast DNA of parasitic plants lack many photosynthetic genes (Wimpee et al. 1991) and 18S RNA gene sequences have 2.5 time higher substitution rates compared to nonparasitic plants (Nickrent and Starr 1994). Are these common phenomena found in parasitic plants also present in *Phacellaria*? This is a question that warrants further research.

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