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Pollination ecology and breeding system in *Dalbergia latifolia* and *D. sissoides*

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ABSTRACT

Dalbergia latifolia and *D.sissoides* are very closely related and considered as two precious timber species of India; the former distributed in various parts of India, while the latter is restricted to the Western Ghats. *D. latifolia* is categorized as "Vulnerable" in the Red Data Book of IUCN. Both the species exhibited wide variation in the phenological features; *D. latifolia* flowered during August/ September and produced fruits from October onwards. In *D. sissoides*, flowering started in the second week of March and continued till the end of the month, for a very short period; the fruiting occurred in April. The flowers of both the species produced copious nectar having high sugar concentration and sticky pollen grains, which are adaptations for pollination by insects and birds. The tree species were found to be highly self incompatible and cross pollinated mainly by honey bees, butterflies and birds. The natural fruit setting recorded in *D. latifolia* was 5.24 percent and in *D. sissoides* the fruiting was 8 percent. Certain insect pests and flower feeding birds caused considerable damage to the flowers. The population of these tree species have been dwindling in the forest areas, due to various reasons and reproductive constraints could be one of those factors. In this context, there is urgent need for conserving the genetic resources of these species, both *in-situ* and *ex-situ*, for ensuring their survival.

Key words: *Dalbergia latifolia, D. sissoides, Phenology, Pollination, Conservation, Breeding system.*

Introduction

The genus *Dalbergia* comes under the family, Fabaceae and the constituent species are distributed in Tropical Asia, Africa, America and Australia. There are 30 species of Dalbergias reported from India, among which 10 are tree species and 20 are shrubs or climbing shrubs. *Dalbergia latifolia* and *D.sissoides* are considered as two precious timber species of India. *D. latifolia* is naturally distributed in the Indo-Malaysian region. In India, it occurs in the sub-Himalayan tract from Oudh eastwards to Sikkim, Bihar, Orissa, Central, Western and Southern India. *D. sissoides* is a closely allied species of *D. latifolia* and is distributed in the Western Ghats, from the hills of Karnataka southwards to Pulneys and Kerala. Of late, the populations of these species have been dwindling considerably in the forest areas. Thus, *D. latifolia* has been categorized as "Vulnerable" in the Red Data Book published by IUCN. Understanding reproductive processes is a pre-requisite for genetic amelioration, conservation and rational management of genetic resources (Congdon and Herbohn, 1993; Aronson *et al.*, 1994). Information on reproductive biology and breeding systems of these species has been scanty and hence the present study was undertaken.

There have been several studies on pollination ecology of forest trees in India. The pollination ecological studies of Red Sanders, *Pterocarpus santalinus*, an endemic and endangered tree species were made by Rao and Solomon Raju (2002). They

noticed that, *Apis* spp. were the only flower visitors pollinating this tree, under moon light. Rickson *et al.* (2003) found that, the bee *Braunsapis* sp. inhabited the stem domatia of *Humboldtia brunonis*, a leguminous tree species of India. Devy and Davidar (2003) studied the pollination modes of 59 tree species occurring in Kakachi area of the Western Ghats and found that 50 species of anthophilous insects in addition to vertebrate pollinators are involved in pollination. The insect pollinators, including bees, visiting flowers of *Tamarindus indica* and *Tectona grandis* were enumerated and it was noticed that, many species of wild bees play an important role in pollination of these tree species (Sasidharan *et al.* 2000 & 2003). Mishra *et al.* (2004) studied the intensity and diversity of flower visiting insects, including bees, in relation to plant density of *Ziziphus mauritiana* Lamk. in Rewa area of Madhya Pradesh, India.

Nayak and Davidar (2010a) studied the pollination and breeding systems of woody plant species in tropical dry evergreen forests of Southern India and it revealed that, there is a predominance of outcrossing in these plant species and a generalized pollination system in this forest type, wherein the constituent species received visits from diverse insects such as social bees, solitary bees, wasps, moths and flies. Nayak and Davidar (2010b) also highlighted the pollination limitation and the effect of breeding systems on plant reproduction in forest fragments in 10 species of woody plants in natural and restored forest fragments in the Puducherry region. The studies revealed that the low reproductive output in self-incompatible species might lead to lower population sizes.

The papilionaceous type of flower shows adaptations with specific and highly efficient pollination mechanisms that have relationship with biotic pollen vectors. In Fabaceae, different pollination mechanisms adapted to different biotic vectors such as bees and birds have been reported (Rangaiah *et al.* 2004; Solomon Raju and Rao, 2004). Arthur van Dulmen (2001) investigated the pollination and phenology of flowers in the canopy of two contrasting rain forest types in Amazonia, Colombia and observed that, small bees were the pollinating agent for *Dalbergia riedelii* (Benth.) Sandw. Sundarapandian *et al.* (2005) worked on the vegetative and reproductive phenology of 42 tree species, including that of *Dalbergia latifolia*, in the forest areas in Kodayar area of the Western Ghats, in Tamil Nadu. Singh and Kushwaha (2006) investigated the diversity of flowering and fruiting phenology of trees, including *Dalbergia latifolia* and *D. sissoo* in a Tropical Deciduous Forest area in Uttar Pradesh State of India.

Materials and Methods

Flowering phenology, floral structural and functional aspects

The flowering phenology and floral structural and functional aspects were examined following the methods of Dafni *et al.* (2005). Twenty five trees of each species were studied for leaf flushing and flowering season events, by making periodical field trips to the study areas. The flowering process and duration were noted at the level of individual trees by following five selected trees, from the starting to cessation of flowering. Ten inflorescences selected at random from different trees were tagged before the initiation of flowering and followed them daily until they ceased flowering to note the number of open flowers. The open flowers were then removed to avoid recounting on the next day. Twenty five flowers were used to note floral characteristics. Pollen grain number/ anther per flower were determined from twenty flowers distributed over five different individuals, following the procedures followed by Solomon Raju and Reddi (1994). The time of anthesis and anther dehiscence were recorded by observing marked mature buds. The nectar sugar concentration was measured using a Hand Sugar Refractometer.

Pollination ecology, plant-pollinator interaction and breeding behaviour

The flower behaviour during the entire period of its life was carefully observed with reference to pollination. Flower visitors were also observed with respect to their mode of approach, landing, probing behaviour, forage collected and contact with sex organs to effect pollination and inter-tree foraging activity. Foraging visits made by major pollinators were recorded on selected inflorescences. Fixed number of flowers from different inflorescences were bagged/tagged and followed further, to study whether the pollination is vector dependant and to understand the flower abortion rate. Another set of flowers were used for experiments on Apomixis, Self-pollination and Cross-pollination experiments

and data collected to understand the breeding behaviour.

Results

Pollination ecology and breeding system

Dalbergia latifolia

i) Flowering phenology

Usually flowering starts in *D. latifolia* in the month of January and it continues up to March. But, rarely flowering also occurs in August-October, as it was noticed in our study location in Chelakode area of Thrissur Forest Division. Fruiting is from November to February and occasionally it happens in June.

ii) Floral biology

The inflorescence is axillary or extra-axillary, lax, divaricate, corymbose panicles, 5-15cm long, usually produced from the axils of fallen leaves; bracts minute; bracteoles membraneous, cauducous. Flowers white or slightly yellowish, scented, 0.4 to 0.7 cm long; pedicels 0.2-0.5cm long, filiform; calyx 0.3-0.5cm long, campanulate, slightly puberulous when young, 5-lobed with the upper two lobes subconnate; corolla with 5 distinctly clawed petals; vexillum 0.4-0.6 cm long, sub-orbicular, reflexed, emarginate at apex, reticulate-veined; wings 0.4-0.5 cm long, auricled, reticulate-veined, acute at apex with often reflexed margins; keels 0.4-0.6 cm long, auricled, reticulate-veined, subconnate at apex; stamens 9, monadelphous, staminal column 0.5-0.5 cm long, longitudinally split above filaments; pollen grains range from 270 to 300; pistil 0.2-0.4cm long, glabrous; ovary 3-5 or up to 7 ovuled, stipitate; style slender, stigma capitate.

In *D.latifolia*, the number of flowers in an inflorescence varied from 23 to 74. The anthesis happened from 5.00 hrs to 8.00 hrs and anther dehiscence from 7.00 to 9.00 hrs; pollen grains are sticky. The flowers produce copious nectar and nectar secretion started from 9.00 hrs and continued up to 12.00hrs. The mean sugar concentration of the nectar was 6.49 percent. The nectar feeders include sunbird, honey bees and butterflies (Table 1). They also effect pollination during flower visits.

iii) Breeding system

Studies carried out on breeding system have shown that under open pollination, 5.24 percent of flowers set fruits in *D.latifolia.* Under autogamy (self pollination) the fruit set observed was 2 percent. No fruiting was obtained when two separate flowers of the same tree was crossed (Geitanogamy) as well as in the case of apomixis. Under xenogeny (cross pollination) 4 percent of the flowers set fruits (Table 2).

Dalbergia sissoides

i) Flowering phenology

In *D.sissoides,* flowering starts in the month of December and it continues up to April. The fruiting period is from March to August. In our study area located at Sholayur Forest Range in Mannarkad Forest Division of Kerala, the flowering started in the second week of March and continued till the end of the month, for a very short period. The fruiting was noticed in April.

ii) Floral biology

It has inflorescence in large panicles of 10-20cm long, arising from the axils of leaves towards the ends of branches. Flowers are milky white, fragrant, 0.6- 0.9cm long; pedicels 0.2-0.5cm long; bracts minute; bracteoles membranous and cauducous; calyx 0.3-0.4cm long, campanulate, 5-lobed, the upper two subconnate, lower three sub-equal; corolla has 5 petals, slenderly clawed except the vexillum; vexillum 0.4-0.6 cm long, cuneate, reflexed, reticu-

Table 1.Nectar feeders / flower visitors recorded on *D.latifolia*

S.No.	Scientific name	Common name
1	*Nectarinia minima* Sykes	Crimson-backed Sunbird
2	*Neptis hylas* L.	Common sailer (Butterfly)
3	*Euploea klugii* Moore & Horsfield	Common crow (Butterfly)
4	*Hypolimnas misippus* L.	Danaid eggfly (Butterfly)
5	*Prosotas nora* Felder	Common lineblue (Butterfly)
6	*Rapala manea* Hewitson	Slate Flash (Butterfly)
7	*Apis cerana indica* Fabricius	Indian honey bee

lately veined, wavy along the margins; wings 0.4-0.5cm long, obovate, clawed, reticulate veined, rounded at tip; keel petals 0.3-0.4 cm long, auricled, reticulate veined, oblique or blunt at apex; stamens 9 or rarely 10, monadelphous; staminal column 0.4-0.6 cm long, split along the upper side; filaments free in their upper third, subequal, anthers blunt or cleft at apex; pistil upto 0.6cm long, glabrous; ovary long stipitate, glabrous, 1-4 ovuled; styles slender, narrowed into the ovary; stigma capitate.

The number of flowers per inflorescence varied from 30 to 163 depending on the size of the inflorescence. The time of anthesis was from 3.30 hrs – 9.00 hrs. Anther dehiscence happened from 5.00 hrs – 8.00 hrs. The flowers produced copious nectar; nectar secretion started around 11.00 hrs and continued up to 14.00 hrs. The mean sugar concentration of the nectar was 13.87 percent. The nectar feeders include honey bees and butterflies. They also effect pollination during flower visits.

iii) Breeding system

Under open pollination, 8 percent of the flowers set fruits. In the case of autogamy (self pollination) no fruit set was observed, while under Geitanogamy (when two separate flowers of the same tree were crossed), the fruit setting was 4 percent. Under cross pollination (Xenogamy) the fruit setting noticed was 6 percent. There was no fruit setting during apomixis (Table 3).

Flower pests

Many species of birds and insects were found to cause destruction to flowers of Dalbergias. The birds which fed on flowers of *D.latifolia* include Small Green Barbet *(Megalaima viridis* Boddaert*),* Plum headed Parakeet (*Psittacula cyanocephala* L.) and Red vented Bulbul (*Pycnonotus cafer* L.). The caterpillars of the butterfly Slate Flash (*Rapala manea* Hewitson) devoured the flower buds and open flowers of *D.latifolia*. The jassids, which are sap sucking pests infest the inflorescence of both *D.latifolia* and *D.sissoides* leading to premature falling of flower buds and open flowers. The jassids produce honey like substance, which attract secondary infection by moulds and it in turn leads to withering of total inflorescence and falling of flower buds and open flowers. The entire affected inflorescence turns blackish and dries up. The flower pests thus adversely affect the reproductive success of both the Dalbergia species.

Discussion

Information on phenology, floral characteristics and pollination are important in understanding breeding systems. The papilionaceous type of flowers exhibit adaptations with specific and highly efficient pollination mechanisms that have relationship with pollen vectors. In Fabaceae, different pollination

Table 2. Fruit set during crossing experiments in *Dalbergia latifolia*

Treatments	No. of flowers observed/ crossed	No. of Flowers set fruit	% of Fruit set
Autogamy	50	1	2
Geitanogamy	50	0	0
Xenogamy	50	2	4
Apomixis	50	0	0
Open pollination	916	48	5.24

Note:-Observations made on 25 Trees

Table 3. Fruit set during crossing experiments in *Dalbergia sissoides*

Treatments	No. of flowers observed/ crossed	No. of Flowers set fruit	% of Fruit set
Autogamy	50	0	0
Geitanogamy	50	2	4
Xenogamy	50	3	6
Apomixis	50	0	0
Open pollination	1104	88	8

Note:-Observations made on 25 Trees

mechanisms adapted to different biotic vectors such as bees and birds have been reported. In the present study, in both the species of Dalbergia, the activity of honey bees and butterflies commenced with the opening of the flower and showed diurnal rhythm as observed in *Dalbergia sissoo* (Vasudeva and Sareen, 2011). They have also reported that the most effective and vigorous pollinators of *D.sissoo* was honey bees. The honey bees were noticed as the most common pollinators in the present case also. Such a synergistic phenological behaviour showing diurnal insect activity accompanied by diurnal anthesis and anther dehiscence appears to be an adaptation which ensures maximum pollination.

In *D.latifolia* and *D.sissoides*, the fruit set noticed under open pollination was 5.24 percent and 8 percent respectively. Even though *D.latifolia* produced 2 percent fruits under selfing, the fruits fell off prematurely, indicating an obligate xenogamous syndrome. *D.sissoides* did not produce fruits under selfing. Under cross pollination, *D.latifolia* and *D.sissoides* produced 4 percent and 6 percent fruits respectively. Almost a similar trend was noticed in *D.sissoo*, except for higher percentage of fruiting as a result of cross pollination (Vasudeva and Sareen, 2011). Cruden (1977) has documented presence of self incompatibility leading to outcrossing in many facultative xenogamous species. Pias and Guitian (2006) found that, in *Sorbus aucuparia* L., a masting tree species, there is marked self-incompatibility, so that the fruit setting is strongly dependent on pollinator service. Ganeshaiah and Uma Shankar (1988) based on experimentation reported that flower and fruit abortions in *D.sissoo* are due to post-zygotic factors. Gibbs and Sassaki (1998) indicated that apparent self-incompatibility in *Dalbergia miscolobium* was due to post-zygotic rejection and coupled with Bawa's suggestion inferred that such a mechanism occurs more widely in the genus Dalbergia. Nayak and Davidar (2010b) highlighted the pollination limitation and the effect of breeding systems on plant reproduction and concluded that low reproductive output in self-incompatible species might lead to lower population sizes.

Conclusion

Our studies on *D.latifolia* and *D.sissoides* in the States of Kerala and Tamil Nadu have revealed that the populations of these tree species are skewed towards old trees and the number of younger trees is drastically dwindling in the forest areas. Similarly, there is severe impairment of natural regeneration owing to various factors, the prominent one could be the reproductive constraints exhibited by these tree species due to self incompatibility and lesser recruitment. In this context, there is urgent need for conserving the genetic resources of these species, both *in-situ* and *ex-situ*, for ensuring their survival.

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