POLLINATION AND FRUITING BEHAVIOUR OF ACACIA SINUATA (LOUR.) MERR. OF FABACAEAE

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Abstract: Morphologically, Fabaceae is characterized by simple to compound leaves (pinnate, rarely palmate, or bipinnate), unifoliate, trifoliate (Trifolium, Medicago), sometimes phyllodic (most of Acacia species), or reduced to a tendril (Lathyrus), arranged spirally with stipules present that are sometimes large and leaf-like (eg: Pisum) or developed into spines (Prosopis, Robinia).

Introduction: Morphologically, Fabaceae is characterized by simple to compound leaves (pinnate, rarely palmate, or bipinnate), unifoliate, trifoliate (Trifolium, Medicago), sometimes phyllodic (most of Acacia species), or reduced to a tendril (Lathyrus), arranged spirally with stipules present that are sometimes large and leaf-like (eg: Pisum) or developed into spines (Prosopis, Robinia).

Systemic position of *Acacia sinuata*:
Kingdom:Plantae
Subkingdom: Tracheobionta
Super division: Spermatophyta
Division:Magnoliophyta
Class:Magnoliopsida
Subclass: Rosidae
Order: Fabales
Family: Fabaceae
Sub family:Mimosaceae
Genus:*Acacia*
Species: *sinuata*
Common Names: Chikaka, Shikakai, Banritha, Reetha, Kochi, Ritha, Sige, Shikai, Shikaya
Habitat: Throughout India, grows wildly in forests especially in Peninsular region.
Useful Parts: Leaves and Fruits Pods
Description: Shikakai is a climbing, most well-known for the natural shampoo derived from its fruit. Thorny branches have brown smooth stripes - thorns are short, broad-based, flattened. Leaves with caducous stipules are not thorn-like. Leaf stalks are 1-1.5 cm long with a prominent gland about the middle. Leaves are double-pinnate, with 5-7 pairs of pinnae, the primary rachis being thorny, velvety. Each pinnae has 12-18 pairs of leaflets, which are oblong-lance shaped, 3-10 mm long, pointed, obliquely rounded at base. Inflorescence is a cluster of 2 or 3 stalked rounded flower-heads in axils of upper reduced leaves, appearing paniculate. Stalk carrying the cluster is 1-2.5 cm long, velvety. Flowers measure about 1 cm in diameter when mature. Flowers are pink, without or with reduced subtending bracts. Pods are thick, somewhat flattened, stalked, 8 cm long, 1.5-1.8 cm wide.

The flowers are hermaphroditic and monostylous, offering both pollen and nectar as floral rewards. Foragers included bees, wasps, flies, butterflies and thrips. Additionally, sunbirds made occasional visits for feeding on extra-floral nectaries located at the base of leaf petioles. The pod-set rate was 2% only. The low pod-set rate is attributed to a variety of factors. The study suggests that pod and seed yields may be enhanced by introducing manageable bees together with their nesting requirements. The forests in India yield a large number of products which play an important role in the economy of the country. Among these, timber and firewood are known as major forest products.

***Fig: 1 Acacia sinuata*(Lour.) merr.Plant**

The minor forest products may not be of great economic importance individually, but collectively their value is immense. Large quantities of these products are consumed locally. They support a large number of indigenous industries besides finding their way into external trade. There are a number of other forest products which have not come into the market so far; but are likely to gain economic importance, if properlyexploited. The exploitation of these minor forest products is usually made without considering their renewal on a perennial basis. Their renewability and yield aspects are directly related to their reproductive ecology. It is in this context that the subject of reproductive ecology assumes great importance.

The genus Acacia is often cited as a classical example for ant–plant mutualism in which the plant provides the ants with food and domicile, while the ants protect the plant from herbivores by stinging and from invading vegetation by biting it off.

About 22 indigenous Acacia species occur in India, of which only *Acacia sinuata*, a woody shrub, is valued for its pods. It is commonly known as 'Shikakai , and grows in tropical jungles of South India, at high altitudes. The pods of this plant are rich in saponins and are used for washing hair, promoting hair growth and also as an expectorant, emetic and purgative14. This is a highly valued non-timber forest product and there is great demand for pods in the market. Tribals, Girijan Co-operative Corporation of Government of Andhra Pradesh and traders get good returns through merchandise. Keeping in view this commercial importance, we studied the details of reproductive features, breeding system and pollinators of A. sinuata. Populations of *A. sinuata* (= *Acacia concinna* DC.) were studied in the forest areas of Lambasingi (Latitude 17°52¢N and Longitude 82°21¢E) located at an elevation of 900 m in Visakhapatnam District, Andhra Pradesh, during 1999–2001. These areas comprise open forest and woodland, with a mixture of tree populations composing the canopy. The area is subjected to constant human pressure. Therefore, the forest is in a denuded state. Although *A. sinuata* is a woody shrub, it reaches the canopy of the forest and shades other trees.

Flowering pattern was observed at plant and inflorescence level. For the latter, 10 inflorescences, selected at random from different individuals were tagged before the initiation of flowering. These individuals were followed daily and the number of open flowers was recorded. The open inflorescences were then removed to avoid recounting on the next day. The tagged inflorescences were followed until they ceased flowering. Fifty flowers were sampled to record flower morphometrics and pollen characters. The time of daily anthesis, anther dehiscence and nectar production was recorded. Pollen grain number (polyads)/anther per flower was determined from 30 flowers distributed over different individuals following the procedure in Aluri and Subba Reddi15. Stigma receptivity was tested with H_2O_2 according to Dafni. Seven hundred and fourteen globose inflorescences on different plants were tagged and followed until fruit development to observe the rate of natural fruit production. Insects were observed when they were seen foraging for pollen and nectar on the inflorescences. The foraging insects at work were recorded using a video camera and were also observed with binoculars. Flower handling behaviour was observed to determine the role of insects as pollinators. Visitation pattern was determined by recording the time and the frequency of insect visitors.

The flowering occurs from mid-February to mid-April. The inflorescence is a globose head and consists of 48 flowers (Figure 1 a). The flowers are small, odourless and bisexual. The ovary consists of 11 ovules on average (range 10–14). The inflorescences appear purple before anthesis (Figure 1 b). Their buds mature and open simultaneously in one day (Figure 1 c). The flowers open from 0630 to 0730 h. Colour of the floral parts remains unchanged during the life of the flower. The flowers secrete nectar in trace amount. The microspores remain together in groups, generally referred to as polyads. The mean number of polyads per anther is 48 and per flower is 3840. The ratio of polyad to ovule number is 349:1. In newly opened flowers, the style and stigma protrude beyond the level of anthers. The stigma is receptive to pollen for about three days after anthesis. The stamens gradually curl downward making the stigma more prominent; 3- and 4-day-old flowers show the stigma much more prominent from the withering stamens down below with puff-like appearance. This is a clear indication of dichogamy. The floral parts, i.e. sepals, petals and stamens remain as vestiges for about two months in fruited flowers.

The hand-pollination tests indicated 96% pod-set through xenogamy, with no pod-set with other modes of pollination (Table 1). Each fruited flower matured without abortion. The fruit development is very slow and takes nine months gestation period to reach maturity. Fruit maturity is almost immediately followed by the initiation of flowering in the following year. Of the total flower production, only 2% set fruits. The fruited inflorescences showed 1 to 5 pods (Figure 1 e, h). A sample of 714 inflorescences (34,272 flowers) selected at random on different individuals of *A. Sinuate* was used for estimating pod-set rate. Of these, 79% were podded and the remaining bore no pods (Table 1). About 50% of inflorescences set single pods (Figure 2). Eight-seeded pods were more, while one- and thirteen-seeded pods were rare (Table 2). A sample of 231 inflorescences consisting of 11,088 flowers with 121,968 ovules selected at random at flower stage was used for estimating seed set and fecundity. Of these, 270 flowers set pods with 1886 seeds. Seed set was 63.5%. Fecundity was 1.5% which was expressed in terms of total number of seeds producedagainst the total number of ovules in sampled inflorescences. The flowering globose heads were found infected with an unknown insect. The infected heads developed 'mounds' (solid mass; Figure 1 d) and thus flowers and even growing fruits dropped off during the flowering phase. This was recorded on almost all individuals of A. sinuata occurring in widely different forest sites in the Eastern Ghats. The infection rate was estimated from a sample of 500 inflorescences randomly collected fromTable 1. Pod-set rate in controlled and open-pollination treatment in *A. sinuata* No. of flowers No. of flowers Percentage Treatment pollinated per pod of pod-set Autogamy 50 0 0Geitonogamy 50 0 0 Xenogamy 50 48 96 Open-pollination 34,272 833 2.4 (inflorescences tagged and followed for pod-set) different individuals.

The flowers were visited by different insects from 0800 to 1600 h. The visits included bees, wasps, flies, butterflies and thrips. Two species of thrips, namely Thripshawaiiensis and Scirothripsdorsalis visited the flowers. They were observed staying on the plant and coming for pollen and nectar consistently. Within the bee group, *Pithitisbinghami* constituted 49%, *Apisceranaindica* 25%, *Ceratinasimillima* 16% and *Amegilla* sp. 10% (Table 3). Among butterflies, *Euploea core* constituted 38%, *Danauschrysippus* 30%, and the other three butterfly species together made 32%. Within the wasp category, Vespa constituted 61% of the total visits, while the remaining were made by Delta conoideus. All fly visits were made exclusively by *Eristalisarvorum*. The hourly visits made by these insect groups show that their foraging activity is largely concentrated during 1000– 1300 h. Further, the hourly foraging visits made by eachbee species are presented in Figure 3. All insects in general were less in number.

The fly, *E. arvorum* and also butterflies collected nectar very slowly when compared to other insects. The open flowers offer both pollen (polyads) and nectar. The foraging insects gathered pollen and/or nectar. All the bee species visited for both floral rewards, while the other insects visited for nectar only. The bees probed the flowers in an upright position by landing on the top of the flowers, which were massed into heads. The bees were commonly found to collect pollen and nectar of most of the flowers in a globose inflorescence during a single visit. Sometimes, they collected either pollen or nectar during a visit. Wasps, flies and butterflies also used the same posture that the bees employed for collecting nectar. They fed on nectar and pollen. Flower-probing behaviour by pollen-collecting bees showed no discrimination between the anthers and the stigmas. All insects visited one- and two-day-old anthesed inflorescences and avoided visiting three- and four-day-old ones. Of all the insects, Amegilla, wasps and butterflies moved frequently among conspecific plants compared to other bees and flies. The breeding system indicates that the plant is self-incompatible; only interplant foraging activity of insects facilitates cross-pollination. Bees, wasps and thrips moved quickly among flowering inflorescences than flies and butterflies. *Amegilla* and wasps were swift fliers and collected floral rewards very quickly compared to other insects.

All insects were pollen carriers and contacted the stigmas while collecting floral rewards. The probing behaviour of all insects, except thrips facilitates crosspollination as they visited the flowering inflorescences of different conspecific plants in succession. Sunbirds, *Nectarinia asiatica* and *N. zeylonica* were found to feed occasionally on extra-floral nectaries located at the base of leaf petioles. As they removed nectar, their heads, shoulders and feathers contacted the flowering inflorescences in the leaf axils. Their probing for extra-floral nectar on individual plants by hopping from branch to branch, provided further contact with flowering inflorescences. Such a foraging behaviour inadvertently facilitated cross-pollination. The extra-floral nectaries occurred year-round and were produced along with the leaf flushing from new branches, which largely takes place during rainy season.

The predominant reproductive strategy in tropical ecosystems is obligate out-breeding, either through self-incompatibillity mechanisms, dioecy or various forms of functional dioecy6 . Several acacias in the tropics havebeen found to be self-incompatible and out-crossing. Self-incompatibility in some acacias is coupled with dichogamous flowering which also promotes out-crossing 3,5. Some acacias are partially self-compatible through hermaphroditism4,7. In the present study, *A. sinuata* is a monostylous hermaphrodite. The hand pollination tests and natural fruit-set rate indicate that it is a self-incompatible, obligate out-crosser. This breeding system is functional only when the conspecifics bloom simultaneously and occur nearby, and requires vectors to mediate pollen among conspecific plants. *A. sinuata* exhibits synchronous blooming at population level, thereby facilitating pollen transfer among conspecifics by vectors. The deposition of a single compatible and viable polyad on the receptive stigma seems to be sufficient to fertilize all ovules of the ovary. About 30 polyads are produced for each ovule. The polyad condition is imperative for *A. sinuata* to maximize seed set and to overcome low pod-set rate.

Moran et al. documented the acacias in Australia to be pollinated by bees. Burkill recorded butterfly-pollination in Acacia farnesiana, Acacia modesta and *Acacia arabica* in India. Subramanya and Radhamani and Thangaraja et al. showed that *Acacia nilotica* was pollinated by insects and birds. Ganesh Kumar et al. recorded a wide array of insects on A. mellifera in Coimbatore, South India. In *Acacia sinuata*, the globose inflorescences provide easy access to the foragers for probing floral rewards. Consequently, the flowers were visited by an array of insects, including bees, wasps, flies, butterflies and thrips. Sunbirdsalso contributed to cross-pollination, but were unreliable. *A. sinuata* shows profuse flowering daily and the entire flowering season lasts for about eight weeks only. In consequence, the floral rewards were abundant and available daily. Despite the richness of floral rewards and easily accessible unspecialized flowers, there was insufficient number of foraging visits by different insects. The individuals of insect species were also small in number. In effect, most of the flowers remained unvisited and unpollinated. The location of *A. sinuata* at forest margins and its flowering during dry season appear to be disadvantageous, because insects tend to migrate to the interiors of the forest during dry period. The insects were found in considerable numbers in the interiors of the forests in the valley where they were found to take shelter and obtain food from a variety of other flowering plants that thrive in cool and shady habitats during dry season. With dry-season flowering *A. sinuata* is deprived of insect visits and pollination.

Many factors could affect low fruit set in *A. sinuata*. First, the foraging activity of insects in small numbers, the intensive pollen-collecting behaviour of attending bees, and their tendency to confine to the same plant that they first foraged may result in more self-pollen transfer. Secondly, infection to flowering heads and probably, availability of low maternal energy investment during dry period may be attributed to the low pod-set rate recorded in *A. sinuata*. However, the small pod crop appears to have been compensated by large seed crop. During dry season under water stress, the delay in pod growth and seed production of *A. sinuata* appears to be inevitable. Therefore, it is the energy resource environment in the plant that influences the timing of maturation of crop. As *A. sinuata* is valued for its pods, enhancement of pod yields is imperative, which may be achieved within the potential of the plant by managing bee colonies, especially honey bees and stingless bees, and by studying remedial measures to combat infection to flowering inflorescences.

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