CONCLUDING
REMARKS
CHAPTER VI

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In the present study, investigations in Palynology with special reference to pollination ecology and floral biology of some economically important papilionaceous plants, have been carried out during the period 1992-96. The family Papilionaceae i.e. Faboideae (Thorne, 1992) includes the plants producing pulses, vegetables, oil, fibres, fodder, medicine and natural fertilizers. There are about 105 species of cultivated and wild members of Papilionaceae (Fabaceae) occurring in the Amravati District of Maharashtra (Dhore, 1988). The group of legumes is an important group of plants showing an incredible variety of pollination mechanisms (Menon and Bagla, 1990). Floral biology and pollination ecology of some Papilionaceae plants have been studied by Free (1966), Rahman and Patil (1986), Patil and Rath (1987).

The ecological significance of plant animal relations is unparalleled and the understanding of these interactions is of vital importance in the conservation of plants and cultivation practices. Emphasis on pollination biology in the tropics is justified for several reasons. There has been no detailed study made on the floral characters of each plant species and family associated with pollinator attraction, preference and consistency for particular blossoms (Solomon Raju and Subba Reddi, 1987). Therefore, the economically important plant Crotalaria sericea Retz. (Agrawal, 1986; Chopra et al. 1986) and two colour morphs of Clitoria ternatea Linn. (Kapoor, 1990; Duke, 1986) i.e. C. ternatea (A) with white flowers and C. ternatea (B) with blue flowers were investigated during the period 1992-96 for the following aspects.
1. **Blooming Phenological Data**

   Environmental factors have been known to influence several events in the reproduction process. Ecological factors greatly influence the growth and seasonal flowering of plants and also the availability of flower foragers including pollinators (Opler et al, 1976).

   Blooming phenological data was collected from different seven natural and cultivated sites (A to G) for four consecutive years of the investigation period. In *C. sericea*, it starts blooming from the second week of October and full bloom is observed during November. In *C. ternatea* (A) and *C. ternatea* (B) flowering starts during the second week of July and the peak period is August to September. Bertin (1989) stated that the phenology or temporal pattern of flowering influences plant fitness and has consequences at the community level.

2. **Flower Dynamics and Daily Periodicity**

   The plants were observed for types of inflorescence developed, and for flower orientation. It has been found to be terminal or axillary racemes in *C. sericea* and solitary axillary in *C. ternatea* colour morphs. Copious inflorescence or gregarious flowering is important in establishing relationship with insects (Percival, 1965; Faegri and Pijl, 1971). The flower opening time was found to be in the morning hours between 6 a.m. to 8 a.m. Flower bud development was observed by tagging the buds to know the floral biology and its significance in the pollination mechanism starting from the early development of buds. The number of inflorescence and flowers developed were noted. The flowering time of individual plant species is largely determined by intrinsic factors. Anther dehiscence was also observed in plants under investigation. Maximum flower life time was noted in *C. sericea* and minimum in *C. ternatea* (A) and *C. ternatea* (B) both.
3. **Pollen Productivity**

Pollen production varies from species to species (Snyder and Clausen, 1973). Pollen productivity was done by a simple method (Nair and Rastogi, 1963). It was found to be more in *C. sericea* wild plants i.e. $277686.33 \pm 5575.68$ at the natural site and $150720 \pm 1768.19$ under cultivation. *C. ternatea* (A) and *C. ternatea* (B) pollen production was $4655.83 \pm 339.73$ and $5686.83 \pm 695.70$ per flower. Variation in pollen production was noted within two colour morphs of *C. ternatea* under investigation. There are many evidences to show that pollen production per flower has been known to vary within and among plants in population.

4. **Pollen Ovule Ratio**

Pollen-ovule ratio was found to be a much better indicator of the breeding system (Cruden, 1977). It was found higher in *C. sericea* at the natural site i.e. $13223.14$ than in the cultivated plants which was found to be $8373.33$ In *C. ternatea* (A) and *C. ternatea* (B) pollen ovule ratio was $517.22$ and $568.60$ respectively.

5. **Pollen Viability**

To determine the pollen viability *in vitro*, tetrazolium test method (Lakon, 1942) was adopted. Maximum pollen viability was found to be $98.46\%$ in *C. ternatea* (A) and it was minimum $92.77$ in *C. sericea* pollen from globose long filamentous anthers. However, in *C. sericea* the pollen from elongated short filamentous anthers it was $96.05\%$ and $98.29\%$ in *C. ternatea* (B). Higher pollen viability shows more reproductive success in plants. *In-vivo* pollen viability was expressed in terms of natural fruit set extent. It was found to be $88.75\%$ in *C. sericea*, $94.37\%$ in *C. ternatea* (A) and $90.00\%$ in *C. ternatea* (B).
6. **Stigma Receptivity**

Stigma become receptive after the anthesis in all the plants under investigation. The receptive stigma plays an important role in successful completion of post-pollination events. It remains receptive for two days in all the plants studied. Gori (1983) discussed the stigma receptivity in relation to change in flower colour and closing of the flower. Stigma receptivity coincides with flower colour change and withering of the flower. Period of receptivity was found to be influenced by environmental factors. After the loss of receptivity stigma becomes blackish in colour. Stigma receptivity in some shrubs was also observed by Lamont (1985).

7. **Flower Life Time**

Flower life time was maximum in *C. sericea*. Standard and alae start to change colour from yellow to reddish from second day of opening and withered subsequently after third day. In *C. ternatea* (A) and *C. ternatea* (B) flowers remain open only during the day of flower opening. It withered on second day and dried subsequently.

8. **Nectar Production and Monitoring**

Nectar is found to be most common reward for pollinators (Faegri and Pijl, 1971; Kevan and Baker, 1983), secreted by floral nectaries. Percival (1965) and the reports of several other investigations in floral biology and pollination ecology reviewed the significance of nectar.

In all the studied plants, nectar secretion was observed on flower opening day i.e. after dehiscence of anthers. Nectar quantity per flower was measured between morning hours (9.00 a.m. to 10.00 a.m.) and evening hours
(5.00 to 6.00 p.m.) on flower opening day. It was 2.56 µl, 8.90 µl, 17.22 µl during morning hours and 0.56 µl, 4.80 µl and 22.65 µl during evening hours in C. sericea, C. ternatea (A) and C. ternatea (B) respectively. Flowers on second day of opening did not show any nectar.

Nectar production was highest during pollinator activity (Willson and Bertin, 1979). Sugar concentration was observed with the help of refractometer. Generally the sugar concentration of nectar varies between 25 and 75 percent with varying proportions of glucose, fructose and saccharose (Percival, 1961).

Total glucose present was estimated by GOD-POD method (Trinder, 1969). It was found to be 736 mg/dl, 440 mg/dl and 565 mg/dl in C. sericea, C. ternatea (A) and C. ternatea (B) flower nectar respectively.

9. **Dominant Mode of Reproduction**

Plants under investigation were tested for apomixis, autogamy, allogamy and insect pollination. From the experimental breeding programme, all the plants were found to be primarily self-pollinated though the flowers offer several rewards to attract the pollinator. The out crossing rate is likely to result from interaction of plant traits and local pollination ecology (Karoly, 1994). Out crossing was 5-10% in C. sericea and C. ternatea (B) however, it was found to be nil in C. ternatea (A). Plant showed the absence of apomixis. Self-pollinated papilionaceous plants are frequently pollinated by insect visitors (Free, 1966). Open pollination showed high fecundity.

10. **Natural Fruitset**

The number of fruits available on any plant in a given year is influenced
by many parameters including plant size, pollination success, pre-ripening predation etc. (Abrahamson, 1989). Natural fruit set percentage was found to be 90-100%, 85-100% and 100% in *C. sericea*, *C. ternatea* (A) and *C. ternatea* (B). The average number of seeds per fruit was 21, 9 and 10 respectively in *C. sericea*, *C. ternatea* (A) and *C. ternatea* (B).

11. **Flower Visitors Dynamics, Census and Activity**:

A number of insect species visited the flowers of Papilionaceae in the locality. A blossom-visitor relationship is established by means of an attractant (Faegri and pijl, 1971). The ultimate reason why most pollinators visit flowers, however, is to obtain a reward (Armbruster, 1995).

Bright yellow coloured flowers aggregated in raceme attract the pollinator mainly due to blossom type, colour, pollen and nectar in *C. sericea*. In *C. ternatea* (B) blue coloured flower are preferably visited by bees than *C. ternatea* (A). Both the colour morphs secretes abundant nectar i.e. maximum upto 8.50 μl in *C. ternatea* (A) and 22.65 μl in *C. ternatea* (B). The flowers were found visited by bees, butterflies, grass hoppers, beetles, thrips and ants. Bees were taken as principal pollinators. Deodikar and Suryanarayana (1977) also stated that in fodder and grain legumes, bees are good pollinators. Flower visitors census was made at different study sites and their period of activity was noted. To enhance the productivity pollinators can be managed to the target crop (Savoor, 1998).

12. **Behaviour of Foragers, Flower Visited and Time Spent**:

A number of investigators have observed the behaviour of foragers in some plants of Papilionaceae. Pollinators use different techniques to feed with the greatest efficiency from different kinds of flowers (Heinrich, 1979a). Colour vision is well developed in bees (Frisch, 1950).
Insects developed a foraging pattern by continuous visits. Insect activity synchronizes with availability of pollen, nectar and flower age. The bees maintained constancy of species but the butterflies also visited other species. *Apis* species visited the flowers mainly to collect pollen and nectar. They enter inside the glued petals and collect the pollens in *C. sericea*. *Xylocopa* sp. thrust its mouth towards nectaries with force and the stigma touches the abdomen of the insect along with pollen. Among the butterflies *Papilio demoleus*, *Tetias hectarata*, *Calo-chrysops shabo*, *Danais chrysippus* are found visiting flowers. The role of thrips in pollination of Fabaceae has been reviewed by Ananthakrishnan (1993). In *C. ternatea* (A) and *C. ternatea* (B) flower was found to be rarely visited by butterflies.

The timing of forager visit, time spent on visited flower, forage type, number of flowers visited per trip was noted.

13. **Pollen Pick-up by Forager:**

Pollinators can both deposit and pick-up pollen in a single visit (Abrahamson, 1989). Among the pollinators, bees carried most of the pollen load. Maximum pollen load was found to be 3864 pollen per bee in *C. sericea*. *A. florea* carried 1226 pollen from *C. sericea* flower. In *C. ternatea* (B) pollen pick-up by bee was 2453 pollen, however it was found 112 pollen in *C. ternatea* (A).

14. **Pollen Depletion:**

Maximum pollen depletion was observed on the day of flower opening. It increases during the activity of insect visitors. Early arrival of pollen on a stigma generally increases its likelihood of success. Number of pollen depleted was 345, 327 and 224 pollen per stigma in *C. sericea*, *C. ternatea* (A) and
C. ternatea (B) on flower opening day, however, it was 187, 511 and 187 pollen per stigma on second day of flower opening. Number of pollen retained by anther was found to be very less.

15. *In-vivo Pollen Germination*:

The stigmas of pollinated flowers were observed at 5.00 pm on the day of flower opening and pollen germinated was noted out of stigmatic load. It was observed to be 16.25%, 18.78% and 10.83% in *C. sericea*, *C. ternatea* (A) and *C. ternatea* (B) respectively. On second day of flower opening it was found to be 20.55%, 32.04% and 36.34%. It indicates maximum % of pollen germination required for average number of seeds per fruit after successful pollination.

16. *Pollen Morphology*:

Light microscopic studies have been carried out as per the method of Nair (1960). Accordingly pollen preparation, staining and mounting was done. A study of pollen morphology was made both with optical and scanning electron microscope (LM and SEM). Pollen grains are trizonocolporate, oblate spheroidal, reticulate, 23.07 μm x 23.90 μm and 24.15 μm x 25.56 μm in *C. sericea*. Trizonocolpate, prolate spheroidal, punctate, 64.74 μm x 59.04 μm in *C. ternatea* (A) and trizonocolpate, subprolate, punctate and 65.40 μm x 56.44 μm in *C. ternatea* (B).

Studies in the field of pollination ecology and floral biology in tropical regions has gained importance during the later part of 20th century, since it is a profitable aspect of palynology. Despite the immense theoretical and practical importance it has received little attention. It provides vital data for conservation biology, higher seed set and fruit set, insect plant interactions and the role of such
interactions in the evolution of biota and ecology. Papilionaceae includes several economically important plants, cultivated and wild. Therefore, the present work gives a broad outline for an increased production of such economically important plants in this region and it can provide information about biotic interactions.

Observations on the floral biology and pollination ecology showed that the cross pollination appears to be an intricate problem because of the closed structure of the papilionaceous flower though it offers different floral rewards. However, from the present observations and the previous reports regarding the insect pollination of papilionaceous plants, the general conclusions can be drawn that the bees are the insects which frequently visit and cross pollinate these plants. Nevertheless, it is suggested that such an investigation needs more evidence which are still awaited in a number of plant species and that it will foster further various lines of investigations for welfare of man and new researchers.