ECOLOGY OF POLLINATION IN TWO CAT-MINT SPECIES[1]

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The herbaceous perennials, *Anisomeles malabarica* and *A. indica* grow from perennating root stock and seed. *A. indica* produces flowering episodes in correspondence with water-saturation of the soil while *Anisomeles malabarica* does not. The floral morphology and pollination mechanism of the two species are similar. The plants resort to self -pollination shortly before flowers turn disfunctional in the absence of pollinators. Both plants are nototribically pollinated by some species of carpenter bees and sunbirds during probing for floral forage. The pollinators by their forage collecting behaviour coupled with territorial and traplining behaviour greatly augment cross-pollination in the plants. The data presented in the paper are valuable for commercial breeding.

INTRODUCTION

The Asian-Australian genus *Anisomeles* belongs to the tribe Lamieae of the subfamily Lamiodeae (Abu-Asab and Cantino 1987) and is taxonomically characterised by glandular-hairy floral parts, and upper pair of stamens with 1-celled anthers and a lower pair with 2-celled anthers. The essential floral parts always extend dorsally in the corolla tube, proximate to or along the upper corolla lip, and not along the lower lip as in the subfamily Ocimoideae. Except for a small note on the flower morphology and foragers of *Anisomeles indica* by Burkill (1916), there is no information on the details of ecological aspects of pollination in the genus *Anisomeles*. The pollination biology data are required to understand sexual reproduction and perpetuation of weedy species.

The paper describes ecological aspects of pollination in *Anisomeles indica* and *Anisomeles malabarica* in India. The investigation was made with a view to provide information on pollination of the plants for extensive commercial uses.

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OBSERVATIONS

1. Plant and flowering phenology

Anisomeles malabarica grows in disturbed and undisturbed areas with soils saturated and unsaturated, while *Anisomeles indica* is confined to undisturbed areas with only water-saturated soils on foot hills of Nallamalai range near Turimella (15°10' and 16°18' N, 78°45' and 79°34' E) of Prakasam district of Andhra Pradesh, India. The two species are herbaceous perennials and grow from perennating root stock and seed. The perennial root stock produces rapidly growing and early flowering plants, while plants that develop from seed appear later and flower later. *Anisomeles malabarica* starts vegetative growth with the first rains of the monsoon and continues until flowering is initiated. The plant can extend vegetative growth beyond flowering. The plant commences vegetative growth in July, flowers in mid-October and disappears in January.

Anisomeles indica primarily inhabiting stream edges does not show vegetative growth following first rains. Streams in this area are rain-fed and used for irrigating local farmlands through regulation of water flow by diverting excess water into reservoirs. The plant begins

vegetative growth only when the soil is water-saturated. The water-saturation of the soil of the area depends on water flow in streams. The vegetative growth and flowering of the plant fall during the period from October to mid-January. The plant exhibits flowering episodes in response to the water content of the soil where it grows.

2. The Flower

The flower details of the two *Anisomeles* species are similar to each other. The purple and fragrant flowers are borne in verticils on the stem. Within a verticil the flowers are arranged in rings. New flowers open daily from each verticil and each flower lasts 2 days. The flowers are gullet type and distinctly bilabiate with a small upper lip and a broad expanded lower lip. They have a basal corolla tube containing a good amount of nectar (1.6-1.8 µl) having 32-48% sugar concentration and protected from unwelcome foragers by a ring of hairs from the base of the flowertube at the point where the stamens are inserted. The anthers which dehisce prior to anthesis are oriented downward at the upper lip of the corolla, thereby brushing pollen onto the anterior dorsal part of the flower. The bilobed stigma protrudes little beyond the anthers. The spreading lower lip acts as landing place for the insect foragers.

The sugar composition of the two *Anisomeles* species nectar determined by paper chromatography indicated presence of glucose, sucrose and fructose.

3. Pollination

Anisomeles malabarica antheses during the night from 0100 to 0500 hr and *Anisomeles indica* in the early morning from 0530 to 0730 hr, the flowers of both are available for day-time foragers. The flowers are foraged by day-flying bees, wasps, ants, thrips, butterflies and sunbirds. The foragers seem attracted to the purple colour of the flowers with sweet fragrance, ample pollen and copious nectar. Of these, only carpenter bees and sunbirds are regular and perform effective and efficient pollination. The other foragers occasionally visit the flowers and some of them deplete floral forage by probing from the side of the flowers bypassing the pollination apparatus. The carpenter bees after landing on the strong lower lip probe flowers nototribically in upright position for nectar during which the stigma situated near the tip of the upper lip contacts the residual pollen in the dorsal cervical crevice of the bees.

The bees exhibit territorial foraging behaviour defending selected plant populations of *Anisomeles* from intruders depleting floral forage by remembering space constellations and images of the region. The bees also display trap-lining behaviour by foraging on discontinuously stretched flowering *Anisomeles* in a selected region visited on their regular rounds. The dual foraging behaviour displayed by carpenter bees greatly profit the plants in outcrossing.

Sunbirds are as regular and effective as carpenter bees in performing the pollination in *Anisomeles* species. They forage for nectar in the flowers from the front in vertical position. Their foraging for the hidden nectar through the protective ring of floral hairs near the staminal base results in the contact of the bilobed stigma and the anthers with the bill and forehead of the birds. The *Anisomeles* species are used as feeding stations by the birds throughout the winter season. There are no other species of flowers and the birds totally rely on *Anisomeles* flowers for food source.

The flowers of both species resort to self-pollination by reflecting the stigmatic lobes striking the powdery pollen in the anthers below.

This physiological movement of the stigma occurs shortly before the stigma turns brown and becomes dry. The auto-pollination occurs only in those flowers which have not been visited by foragers of any kind.

Discussion

Since the two *Anisomeles* species are herbaceous perennials, they reproduce asexually from perennating root stock and sexually by seed. Sexual reproduction of the plants involves seasonal or timely production of flowers coinciding the availability of pollinators. Flowering in *Anisomeles malabarica* is independent of water-saturation of the soil after the plant's vegetative growth. In contrast, the flowering on *Anisomeles indica* seems regulated by water quantity of the soil which causes flowering episodes. Attempts to test this phenomenon in a green house by growing this plant experimentally have been made without success. Seeds of this plant did not germinate in different treatments, and it appears that there are unknown barriers for breaking dormancy and subsequent germination (Aluri unpubl. data; Cantino pers. comm.).

The two *Anisomeles* species have a personate floral form with stamens and style extending beyond the upper lip and resulting in the classical gullet type blossom credited for precision and economy in pollen transfer by nototriby. The purple colour of the flowers appears to act as the main attractant coupled with flower density, amplified by patchy distribution of the plants. The purple flowers seem to reflect blue component which the insect foragers can see. Experimental evidence for this phenomenon has been repeatedly shown in the purple flowered *Pedicularis* species which reflect blue component and ultraviolet light and are pollinated by bumble bees (Macior 1968, 1982, 1986a, b, c).

Recorded observations on the foragers of the two *Anisomeles* species suggest that only the carpenter bees and sunbirds are suitable and functional pollinators which orderly and precisely effect pollination by manipulation of the floral mechanism (Proctor and Yeo 1972, Faegri and Van der Pijl 1979). Burkill (1916) also observed carpenter bees as appropriate pollinators of *Anisomeles indica.* Other foragers by their occasional and intra-floral behaviour mainly deplete the floral forage thereby influencing the intensity of foraging visits of the functional pollinators.

The flower form with sexual organs positioned near the upper lip and with the spreading strong lower lip facilitates adequate landing place for the large bodied carpenter bees (*Xylocopa latipes and X. pubescens*). The bees nototribically pollinate the flowers by their probing in upright position dorsally contacting in the cervical crevice region and the anteriorly placed anthers and stigma near the upper lip. Since the plants resort to self-pollination extending the stigmatic lobes into the pollen-laden anthers shortly before the stigma becomes dry and brown in the absence of pollinators, the plants appear to have a preference for cross-pollination. The carpenter bees by their nototribic foraging behaviour and inter-plant and patch movement cross-pollinate the flower. The latter movement of the bees is exhibited in territorial and trap-lining behaviour, both of which are instrumental for effective cross-pollination. Such behaviour of the bees on different plants has been documented by several workers (Pijl 1954, Janzen 1964, Frankie 1976, Barrows 1980, Frankie *et al.* 1983).

The sunbirds also probe the flowers nototribically by landing on internodes of the inflorescence, inserting their bill and forehead into the flower mouth leading to the nectary and

contacting the bifid stigma with their pollen-laden posterior edge of the bill and anterior edge of the forehead. The birds do not employ foraging methods exhibited by carpenter bees. They, however, use flowering *Anisomeles* populations as feeding stations and daily forage on the flowers by having nests nearby in the branches of *Euphorbia antiquorum*. The carpenter bees also use the plants of some species for nest-making in the *Anisomeles* growing area. The birds also contribute to active pollen flow for cross-pollination by their regular and effective foraging on the plants within and between patches. Both carpenter bees (*Xylocopa latipes* and *X. pubescens*) and sunbirds (*Nectarinia asiatica* and *N. zeylonica*) are thus equally important for pollen transfer in the two *Anisomeles* species.

The two *Anisomeles* species occupy the same geographic area but separated by habitat. This habitat separation is not instrumental in preventing natural inter-breeding between the two plant species since carpenter bees and sunbirds are long distance flyers and make foraging movements between the two plant species. Such alternate foraging of the pollinators is likely to result in inter-breeding provided that the genomes of the plants are compatible for crossing.

Field surveys in the study area indicate that one plant resembles in the vegetative and floral features of both *Anisomeles indica* and *Anisomeles malabarica*. Extensive study is needed to understand how this plant has resulted. Attempts are being made to test this by hybridization raising the plants from the seeds fed with its natural soil in a green house. If the results indicate viable and vigorous hybrids, the data would then form a basis for further studies on commercial lines.

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