

Sex-ratio variations in *Acalypha fruticosa* Frosk along plant height and altitude

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Abstract. The ratio of male to female flowers per inflorescence in *Acalypha fruticosa* increases from bottom to top inflorescence of the plant and also along the altitudinal gradient. The increase is due to increase in male flower number per inflorescence. We explain these facultative changes in sex-ratio as fitness optimising strategies of the plant in response to altered success of males from the bottom to the top of the plant and along altitude which is primarily due to changes in pollen donation pattern.

Keywords. *Acalypha fruticosa*; sex-ratio variations along altitude; plant height; pollen donation ability.

1. Introduction

Variations in the male and female flower ratios in monoecious species across gradients like moisture, canopy conditions, age, resource status etc have been reported earlier (Charnov and Bull 1977; Abul and Bazzaz 1979; Freeman *et al* 1981; Uma Shaanker and Ganeshaiyah 1984). While most of these workers only document the changes, few offer explanations based on some proximate factors like resource and nutrient availability (Freeman *et al* 1981; Policansky 1982). Recently, the facultative changes in sex-ratios have been explained as adaptive responses to differential success of male and female sexes in maximising the individual fitness in varied environments (Willson 1979; Maynard Smith 1978; Charnov *et al* 1981; Bawa and Beach 1981; Bull 1981; Uma Shaanker and Ganeshaiyah 1984). In this paper, we report variations in the ratio of male to female flowers between the bottom and top inflorescence of a monoecious species, *Acalypha fruticosa*. The differences between the bottom and top of the plant as influenced by an altitudinal gradient are also presented. We explain these changes in sex-ratio as an optimising strategy of plants to the altered successes of male and female sexes from the bottom to the top of the plant and along the altitude.

2. Materials and methods

A. fruticosa is a monoecious shrub and bears flowers in a racemose inflorescence of 8–15 mm long; female flowers are borne at the bottom and males at the top of the inflorescence. The floral features of the plant are strongly indicative of the anemophilous nature of pollination. The flowers are small, light coloured and do not

possess any rewards such as nectar. The stigma is highly branched and exposed to sieve the wind carrying pollen grains. Further, no insects or birds were found to visit the flowers, thus precluding the possibility of their involvement in pollination. *A. fruticosa* occurs abundantly as a natural colonizer along the hilly ranges of the study site. It was distributed over a wide range of altitude in the area and hence rendered itself as a good material for the study.

The study was conducted on the hilly ranges along Cauvery river at Sangam, Kanakapura, Bangalore, during July–October, 1984. Four hills of approximately 500 m (above mean sea level) were chosen and each of them divided into 3 altitudinal zones, viz hill bottom (400–410 m), middle (450–460 m) and top (490–500 m).

Data was collected from randomly selected plants of approximately 150 cm height at these 3 altitudes for inflorescences borne on the lower half of the plant (plant bottom) and the upper half of the plant (plant top). Plants were censused for the male to female flower ratio per inflorescence, fruit and seed set percentage. The number of pollen grains deposited on the stigma was estimated by excising the stigma and staining in 1% acetocarmine; the pollen grains were then counted under a microscope.

Gene flow and pollen grain dynamics is generally studied either by dyeing the pollen grains or by using pollen grain mimicking colloidal dyes (Schaal 1980; Nicholls 1985; Bos *et al* 1986). We used turmeric and vermilion powder of suitable grade which closely simulated the *Acalypha* pollen in size for estimating the pollen dispersal pattern from flowers at different plant heights. Cotton swabs saturated with vermilion and turmeric powder were fastened to plant bottom and top respectively in a few plants. Glass slides with cellophane tapes as traps were exposed in 8 directions around these plants at various distances and at 3 different heights. The slides were collected after 3 h and examined under a microscope for the deposition of the vermilion and turmeric powder. The vermilion indicated the dispersal from plant bottom and turmeric powder from plant top.

3. Results

The ratio of male to female flowers per inflorescence was significantly greater in plant top compared to plant bottom (table 1). The male-biased ratio in the top inflorescence was primarily due to the increased number of male flowers per axil as there was negligible difference in the female flower number between the bottom and the top. These differences were maintained at all altitudes.

The sex-ratio also increased with increase in the altitude. The differences were not marked between the hill bottom and middle, but these two altitudes differed significantly from hill top. The differences were again due to an increase in the absolute male flower number per axil (table 1).

Associated with the increase in sex-ratio from the plant bottom to top, there was also an increase in the number of pollen grains deposited on the stigma (table 2). However, this pattern was not clear along the altitudinal gradient.

The fruit set percentage was significantly higher at plant top than at plant bottom (table 1). However, the data for the per cent seed set was quite contrary. There was a greater seed set for fruits in plant bottom compared to plant top. The differences in fruit and seed set percentages between bottom and top of the plant remained almost constant along the altitude.

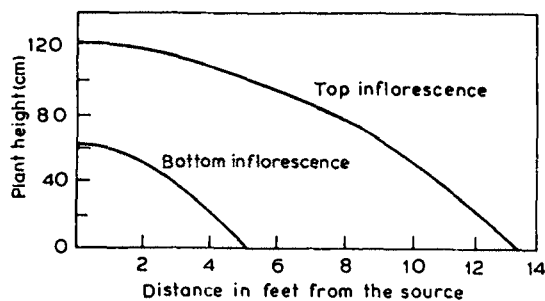
Table 1. Male and female flower number per inflorescence, sex-ratio, fruit and seed set percentage in *Acalypha* along plant height and altitude.

		Male flower No./axil		Female flower No./axil		Sex-ratio		Fruit set (%)		Seed set (%)	
		Plant bottom	Plant top	Plant bottom	Plant top	Plant bottom	Plant top	Plant bottom	Plant top	Plant bottom	Plant top
Hill bottom (400-410 m)	N	21	39	28	43					19	41
	\bar{X}	91.3 ^a	186.3 ^a	1.04 ^a	1.37 ^a	87.8 ^a	135.9 ^a	37.2 ^a	51.0 ^a	76.4 ^a	56.1 ^a
	SE \pm	4.95	12.90	0.07	0.05			2.39	6.63	2.00	4.08
Hill middle (450-460 m)	N	20	31	37	21					40	24
	\bar{X}	84.5 ^a	161.3 ^b	1.33 ^{b*}	1.53 ^{**}	63.53 ^a	105.5 ^b	43.2 ^a	42.6 ^a	64.8 ^b	46.4 ^a
	SE \pm	18.90	8.88	0.10	0.07			3.37	2.05	2.47	6.36
Hill top (490-500 m)	N	26	32	41	64					62.8 ^b	55.0 ^a
	\bar{X}	193.1 ^b	255.6 ^c	1.36 ^b	1.56 ^b	141.9 ^b	163.8 ^c	46.0 ^b	66.5 ^b	62.8 ^b	55.0 ^a
	SE \pm	8.65	15.81	0.07	0.04			28.11	1.38	1.53	3.71

All the parameters showed significant differences between plant top and bottom except where indicated by asterisk. ^{a,b,c}All the values under a column for a parameter differ significantly if their superscripts are different.

Table 2. Pollen grain number per stigma in *Acalypha*.

		Hill bottom (400-410 m)	Hill middle (450-460 m)	Hill top (490-500 m)
Plant bottom	N	25	25	25
	\bar{X}	11.66	4.67	8.75
Plant top	N	25	25	25
	\bar{X}	18.00	24.00	19.00

**Figure 1.** Pattern of pollen dispersal from top and bottom inflorescence of *A. fruticosa*.

The pollen dispersal pattern as indicated by the vermilion and turmeric powder distribution is given in figure 1. On an average, dispersal occurred over larger distances from sources at plant top than those from plant bottom. While the distribution of powder from the bottom source was limited to the bottom stratum only, the top source contributed to all the strata.

4. Discussion

The fitness of an individual is maximized by an optimal resource allocation to the male and female sexes in proportion to their relative fitness contribution (Charnov

and Bull 1977; Charnov 1982). In plants, pollen donation (male success) and pollen reception (female success) are probably the two main processes through which they realise their reproductive success (Willson 1979; Bawa 1980). Thus, sex ratio adjustments can be expected to occur in response to variation in the pollen dispersal and receiving ability of a plant in its habitat. In this context, the observed variations in the sex-ratio in *Acalypha* may be regarded as optimal strategies to maximise their fitness in its habitat. The data on pollen grain per stigma and the pollen distribution pattern (figure 1) show that the pollen dispersal ability of flowers at the plant top is more compared to the flowers at the plant bottom. This is probably due to the restricted wind movement and poor exposure of flowers at the bottom of the plant while flowers at the top are better displayed to the unhindered wind movements (Willson 1979). Such increased pollen dispersal ability of the flowers at the top enhances their outcrossing ability. Under such situations of good pollen flow between plants, an intense competition would be set in among the plants to represent a greater proportion of the population pollen by their own as it is relatively inexpensive to accrue the reproductive success through males than females (Bateman 1948; Willson 1979). In *Acalypha*, this competition appears to have caused a male specialised inflorescence at the top of the plant.

Due to the increased outcrossing and the consequent advantages accrued through the flowers at the plant top, the male forms a strong competitor at the top for reproductive resources. This probably explains the reduced seed set percentage at the top of the plant despite the increase in the pollen grains deposited on the stigma of these flowers. On the other hand, as the poor pollen flow at the bottom strata intensifies the inbreeding, a female biased resource allocation would be favoured at the bottom of the plants. This is reflected in the decreased sex-ratio at the bottom of the plant. Thus *Acalypha* functions as a male specialist in the top and female specialist in the bottom of the plant.

Similar advantages accrued through unhindered wind movement at the hill top compared to the hill bottom may be responsible in increasing the sex-ratio in plants from bottom to the top of the hill. Though experimental evidence of such differential gains through male and female are lacking, there are reports for instance in a dioecious species, *Populus tremeloides* that sex-ratio changes from female biased to male biased at higher altitudes (Grant and Mitton 1979). The unsuccessful pollen donation under thick canopy due to hindered wind movements have been suggested for the female biased sex-ratio in two monoecious species (Abul Fatih and Bazzaz 1979; Freeman et al 1981). For instance, in *Ambrosia trifida*, the sex-ratio was biased towards females under thick canopy compared to peripheral zones where it was male biased (Abul Fatih and Bazzaz 1979).

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