

more in straw than in grain. It has been reported by Tulin *et al.*⁶ from a study in soils contaminated due to Chernobyl accident that the increasing levels of potassium fertilization reduce the absorption of ¹³⁷Cs from soil by oats. Similar observations were reported by Orlovius and Sattler⁷. Although in the present investigation the crop was fertilized with 40 kg K₂O ha⁻¹ and has illite as the dominating clay mineral, the contamination level did not show a decline in soil to plant transfer of ¹³⁷Cs in both pearl millet and sorghum.

The results reported here indicate that release of considerable amounts of radionuclides from nuclear facilities resulting in contamination of soils, may find their way into crops in the tropical regions and eventually into the food chain of man.

1. International Atomic Energy Agency, *Handbook of parameter values for the prediction of radionuclide transfer in temperate environments*. Technical Reports Series No. 364, IAEA, Vienna, 1994, p. 74.
2. International Atomic Energy Agency, *Measurements of Radionuclides in Food and Environment – A guidebook*, Technical Reports Series No. 295, IAEA, Vienna, 1989, p. 169.
3. Gerzabek, M. H., Mohammad, S. A. and Muck, K., *Commun. Soil Sci. Plant Anal.*, 1992, **23**, 321–330.
4. McCee, E. J., Keatinge, M. J., Synnot, H. J. and Colgan, P. A., *Health Phys.*, 1995, **68**, 320–326.
5. D'Souza, T. J. and Mistry, K. B., *Plant Soil*, 1980, **55**, 189–198.
6. Tulin, S., Stavrova, N. and Korovyakovskaya, S., *Int. Fertil. Correspondent*, 1994, **35**, 4–5.
7. Orlovius, K. and Sattler, E. L., *VDLUFA-Schriftenreihe*, 1988, no. 23, 731–741.

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Stylar length variation in *Caesalpinia pulcherrima* (Caesalpinaceae) – Basic patterns

R. Loksha, R. Vasudeva*, B. S. Sarala,
P. Palakonda Reddy and S. N. Nayak

Department of Genetics and Plant Breeding, College of Agriculture,
P. B. No. 24, Raichur 584 101, India

*Forestry Degree Programme, Sirsi 581 401, India

Caesalpinia pulcherrima (Caesalpinaceae) produces four categories of morphologically distinguishable flowers within the same inflorescence, viz. flowers with long, medium, short and rudimentary styles. The stylar length variation within an inflorescence was found to be discontinuous. The long-styled flowers were functionally hermaphroditic and are produced towards the basal region of inflorescences whereas medium, short and rudimentary styled flowers were essentially males and are produced towards top region. The adaptive significance of this variation has been discussed in the light of stochastic events of resource availability and plant–pollinator interaction.

STYLE lengths of flowers borne on different individuals vary notably among species exhibiting di and tri-stylous condition^{1,2}. Among andromonoecious species, male plants bear flowers with rudimentary styles while flowers of hermaphrodite plants possess normal styles^{3–5}. However, among angiosperms, perfect flowers borne on a plant or even within an inflorescence also exhibit subtle differences in floral morphology and/or function. For instance, flowers of *Callonia grandiflora* (Polemoniaceae) exhibit intra-individual differences with respect to style length, pollen tube growth rate and

morphology of stigmatic papillae⁶. Cruden and Hermann–Parker⁷ have shown that *Caesalpinia pulcherrima* produces two types of flowers within an inflorescence: hermaphroditic flowers with abundant nectar and normal style; male flowers with rudimentary style and poor nectar.

Of late, floral variations within an inflorescence have been viewed as a result of dynamic interaction among plants and their pollinators. In a recent study Ganeshaiah *et al.*⁸ have shown that figs guard their flowers against depredation from agonid wasps by varying the stylar length among flowers within a synconium. Stochastic events of fruit set and availability of resources to developing young buds within an inflorescence may also determine the extent of variation in floral features. Hence intra-inflorescence variation in floral features may be more common in flowering plants and might also represent an important mechanism to increase pollination efficiency. However, studies documenting such variations are scanty.

We have attempted to assess variation in stylar length within inflorescences in *Caesalpinia pulcherrima* (Caesalpinaceae), its association with floral functioning and also the possible adaptive significance of such variations.

The experiment was undertaken at College of Agriculture, Raichur (16°15'N, 77°20'E; 389 m above MSL), Karnataka, India.

Caesalpinia pulcherrima (Caesalpinaceae) is a perennial woody shrub of Indo-Malayan origin⁹. Plants bear either bright red or yellow flowers throughout the year. The flowers exhibit psychophilic syndrome and hence are pollinated by butterflies and moths⁷. In *Caesalpinia*, the inflorescence is a compound raceme with primary, secondary, tertiary and quaternary inflorescences emerging from a common axis and blooming occurs in

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an acropetal succession (basal floral buds bloom first and proceed in upward direction). The flowers anthesis around 8.00 am and are retained on the inflorescence for well over two days. The older flowers change their colour to deeper shades. Generally fruit set is maximum in primary inflorescences followed by secondary inflorescences. In most cases tertiary and quaternary inflorescences fail to produce fruits.

During 1993 in each of the 18 plants found growing in the campus (nine with yellow and nine with red flowers), six randomly chosen inflorescences were tagged before blooming. The flowers were observed for the stylar character (length) throughout the blooming period and grouped into four categories, viz. long (if the style length was > 4 cm, extend above or at the same height of the anthers), medium (if the style length was between 3 and 4 cm), short (style length between 1 and 3 cm) and rudimentary (< 1 cm). The observations were repeated during 1994 for the same set of plants.

To assess the function of different styled flowers, they were separately pollinated artificially. Pollen derived from them was analysed for their size and percent fertility using acetocarmine stain test². The number of ovules per ovary was counted under a stereo-binocular dissection microscope.

Means were compared between groups by Student's *t* test, the frequency distribution by Kolmogorov Smirnov Test¹⁰.

Caesalpinia pulcherrima produces four morphologically distinguishable flowers varying in stylar length within an inflorescence (Table 1). Although the style length varies from 0.4 to 6.5 cm, flowers could be categorized into four groups viz. long styled (mean \pm SE = 5.67 ± 0.046 & 5.74 ± 0.048 for yellow and red morph respectively), medium (3.79 ± 0.110 ; 3.44 ± 0.143), short (2.06 ± 0.058 ; 2.09 ± 0.042) and rudimentary (0.65 ± 0.022 ; 0.67 ± 0.020) (Table 1). The frequency distribution of stylar length was multi-moded and departed statistically from the normal distribution (Table 1 and Figure 1; KS tests were significant with $P < 0.001$ between frequency distributions). The mean stylar length of each of these categories did not differ between red and yellow morphs but differed significantly within a morph (Table 1).

Table 1. Stylar length variation (in cm) in *Caesalpinia*

Flower type	Yellow		Red	
	<i>n</i>	Mean \pm SE	<i>n</i>	Mean \pm SE
Long styled	67	$5.67^a \pm 0.046$	56	$5.74^a \pm 0.048$
Medium styled	25	$3.79^b \pm 0.110$	20	$3.44^b \pm 0.143$
Short styled	44	$2.06^c \pm 0.058$	63	$2.09^c \pm 0.042$
Rudimentary styled	40	$0.65^d \pm 0.022$	67	$0.67^d \pm 0.020$

Mean values with same superscript (within a flower morph) do not differ statistically ('*t*' test significant $P < 0.001$).

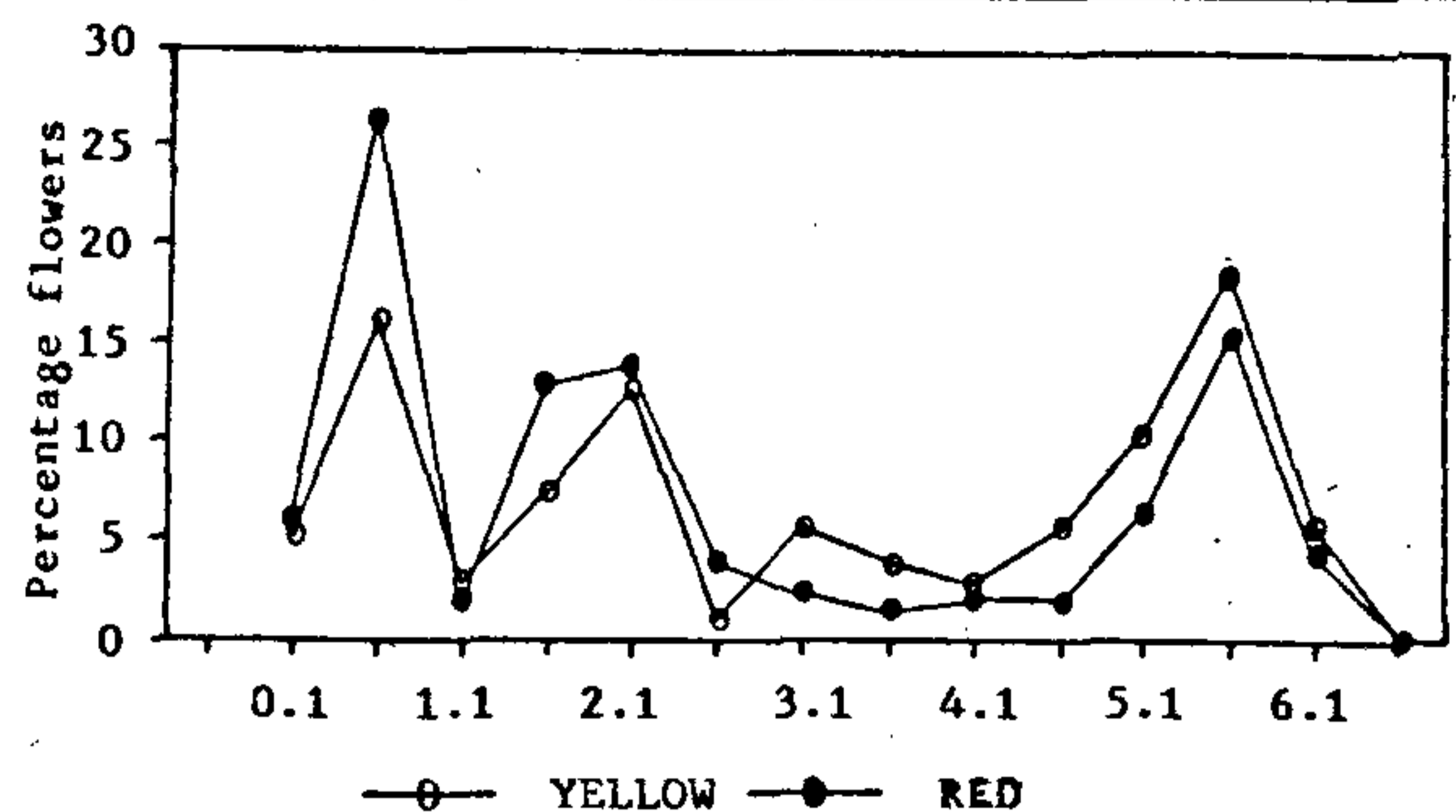


Figure 1. Distribution of stylar lengths of *Caesalpinia* (Yellow morph - open circle; red morph - closed circle).

Table 2. Result of artificial crossing/selfing between the flower groups in *Caesalpinia*

Category	Fruit set
Long (self)	Yes
Long \times long	Yes
Long \times medium	Yes
Long \times short	Yes
Long \times rudimentary	Yes
Medium (self)	No
Medium \times long	No
Medium \times medium	No
Medium \times short	No
Medium \times rudimentary	No
Short/Rudimentary \times Long or medium or self	No

There was a clear spatial segregation of different styled flowers within an inflorescence (Figure 2). The flowers towards basal region were more often long styled, while rudimentary styled flowers were borne towards the upper portion of the inflorescence. The medium and short styled flowers were distributed in the middle region (Figure 2). Generally, the style length of the flowers reduced from bottom to the top of the inflorescence. Owing to acropetal blooming pattern, in any inflorescence long-styled flowers bloomed first followed by medium, short and rudimentary. The long-styled flowers constitute about 44% ($44.52 \pm 8.63\%$) of the total flowers in an inflorescence, medium $5.64 \pm 3.11\%$, short $19.54 \pm 4.80\%$ and rudimentary-styled flowers $30.63 \pm 7.98\%$.

The long-styled flowers produced mature fruits when pollinated with pollen derived from flower of any other stylar class as well as self pollen (Table 2). This indicates that the long-styled flowers are bisexual and pollen from all categories is fertile (Table 3). However, medium, short and rudimentary-styled flowers did not set fruits when they were pollinated from any other group or selfed hence function as males (Table 2). No differences

Table 3. Pollen size (value $\times 50$ microns), fertility (per cent) and ovule number (per flower) in different categories of flowers in *Caesalpinia*

Flower type	Yellow morph		<i>n</i>	Red morph	
	Sample size	Mean \pm SE		Mean \pm SE	
<i>Pollen size</i>					
1. Long	31	17.516 \pm 0.10	40	20.525 \pm 0.09	
2. Medium	36	18.306 \pm 0.17	22	20.318 \pm 0.23	
3. Short	42	18.571 \pm 0.17	38	17.237 \pm 0.13	
4. Rudimentary	40	18.425 \pm 0.11	43	20.302 \pm 0.10	
<i>Pollen fertility</i>					
1. Long	31	100 \pm 0.00	40	100 \pm 0.00	
2. Medium	36	100 \pm 0.00	22	100 \pm 0.00	
3. Short	42	100 \pm 0.00	38	100 \pm 0.00	
4. Rudimentary	40	100 \pm 0.00	43	100 \pm 0.00	
<i>Ovule number per flower</i>					
1. Long	44	7.886 \pm 0.07	35	7.914 \pm 0.15	
2. Medium	19	7.842 \pm 0.16	15	7.867 \pm 0.17	
3. Short	33	8.121 \pm 0.10	32	7.938 \pm 0.12	
4. Rudimentary	25	7.600 \pm 0.14	29	7.724 \pm 0.14	

'*t*' test non-significant.

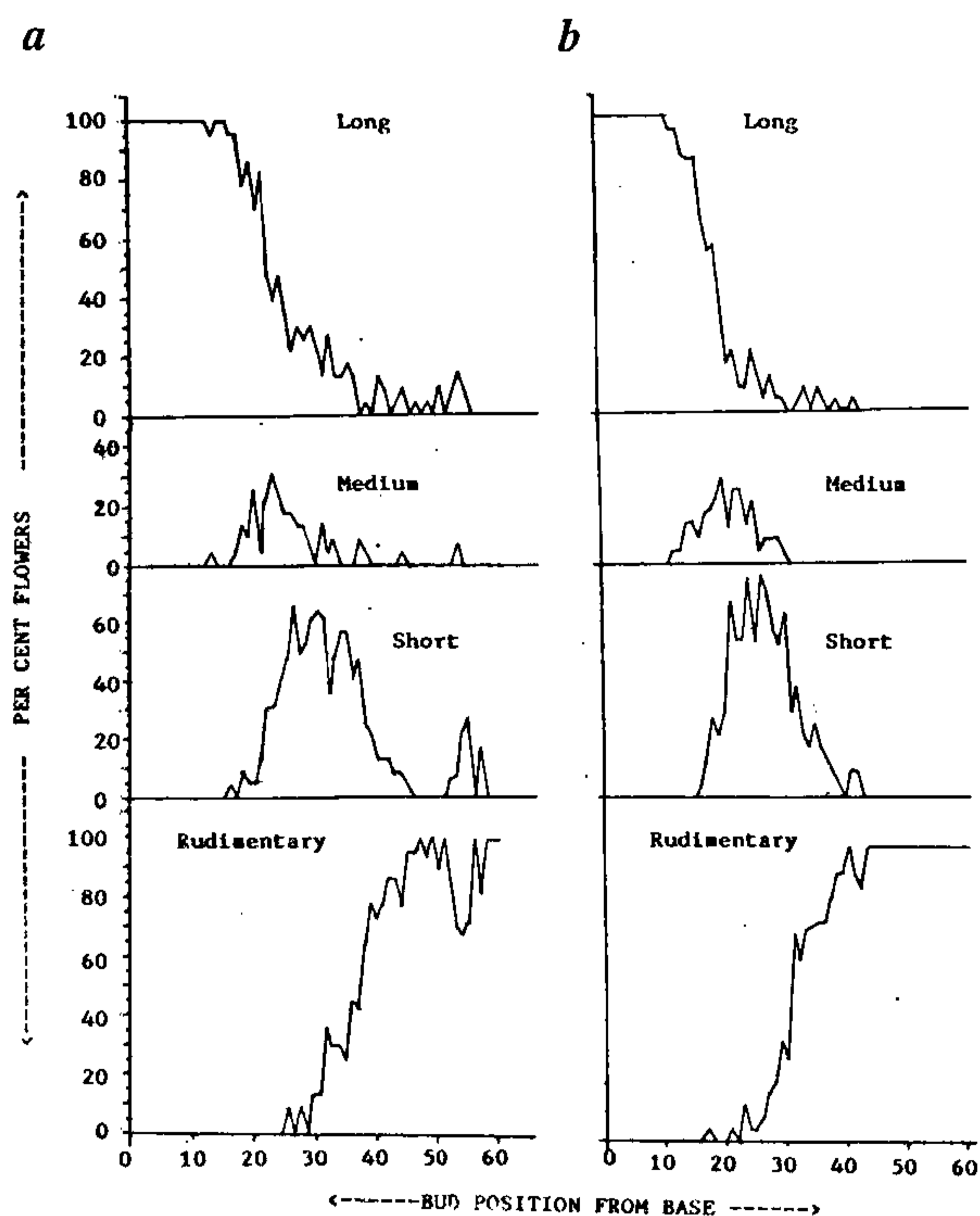


Figure 2a, b. Spatial segregation of flowers with different stylar lengths within an inflorescence. *a*, Yellow morph and *b*, Red morph.

were observed in pollen size and fertility and ovule number in respect of different categories of flowers (Table 3).

Table 4. Dry weight (per flower basis including the stalk; in mg) of different categories of flowers in *Caesalpinia*

Flower type	Yellow		Red	
	<i>n</i>	Mean \pm SE	<i>n</i>	Mean \pm SE
Long styled	21	73.29 ^a \pm 5.136	27	84.67 ^a \pm 3.808
Medium styled	9	71.22 ^a \pm 6.144	28	70.57 ^b \pm 2.812
Short styled	20	56.55 ^b \pm 4.867	37	69.35 ^b \pm 2.642
Rudimentary styled	21	48.86 ^c \pm 3.152	29	51.93 ^c \pm 3.452

Mean values with same superscript (within a morph) do not differ statistically but with different superscripts differ statistically ('*t*' test significant $P < 0.001$).

These results show that in *Caesalpinia pulcherrima*, four morphologically distinguishable flowers based on stylar length are produced within primary inflorescences (Figure 1). Further, *Caesalpinia* plants produce nearly 45% flowers within an inflorescence which normally set into fruits while 55% flowers are functionally pollen donors (Table 3). Hermaphroditic flowers require higher levels of energy for their construct and maintenance and also require higher energy during pod-filling stage when compared to functional male flowers (Table 4).

Interestingly, it was observed that if the basal long-styled floral buds were either removed intentionally or predated, the subsequent medium and short styled floral buds reverted to long-styled flowers and set into fruits (personal observation). This suggests that failure of fruit set in categories like medium, short and rudimentary may largely be determined by post-fertilizational events. Infact, competition for limited resources among developing pods has been shown to be severe in *Caesal-*

*pinia*¹¹. Flowers with rudimentary styles never set fruit, because they are devoid of a normal style and stigma, however, the function of the ovules in this category is not known.

Caesalpinia produces energetically expensive flowers during early stages of inflorescence growth while less energetic and less expensive medium and short styled flowers at later stages might act as a reserve for the possible risk of floral predation^{12,13}. This developmental plasticity of floral function mediated by energy constraints may also be adaptive in increasing pollination efficiency. Because flowers are retained on the inflorescence for more than two days after blooming, the display size of an inflorescence would increase substantially when terminal flowers in an inflorescence are in bloom. This would also increase pollinator visitation, hence the plant may gain more through pollen export in the later stages of inflorescence growth^{14,15}.

1. Barrett, S. C. H., *Trends Ecol. Evol.*, 1990, 5, 144–148.
2. Kearns, C. A. and Inouye, D. W., *Techniques for Pollination Biologists*, University Press of Colorado, Colorado, 1993, pp. 240–241.
3. Anderson, G. J. and Symon, D. E., *Evolution*, 1989, 43, 204–219.
4. Schlessman, M. A., Lowry, P. P. II, and Lloyd, B. G., *Biotropica*, 1990, 22, 133–139.

5. Mayer, S. S. and Charlesworth, D., *Trends Ecol. Evol.*, 1991, 6, 320–325.
6. Lord, E. M. and Eckard, K. J., *Science*, 1984, 223, 695–696.
7. Cruden, R. W. and Hermann-Parker, S. M., *J. Ecol.*, 1979, 67, 155–168.
8. Prarthana Kathuria, Ganeshaiyah, K. N., Uma Shaanker, R. and Vasudeva, R., *Curr. Sci.*, 1995, 68, 1047–1049.
9. Oliver, D., *Flora of Tropical Africa*, Reeve and Co., London, 1871, vol. II, p. 262.
10. Siegel, S. and Castellan Jr. N. J., *Non Parametric Statistics for the Behavioural Sciences*, McGraw-Hill, New York, 1988.
11. Uma Shaanker, R. and Ganeshaiyah, K. N., *Evolutionary Trends in Plants*, 1988, vol. 2, pp. 91–98.
12. Charnov, E. L., *The Theory of Sexual Selection*. Princeton University Press, Princeton, New Jersey, USA, 1982.
13. Vasudeva, R., Ganeshaiyah, K. N. and Uma Shaanker, R., in *Pollination in Tropics* (eds Veeresh, G. K., Uma Shaanker, R. and Ganeshaiyah, K. N.), IUSI, Indian Chapter, Bangalore, 1993, pp. 6–8.
14. Bell, G., *Proc. R. Soc. London*, 1985, 224, 223–265.
15. Stanton, M. I. and Preston, R. E., *Am. J. Bot.*, 1988, 75, 540–544.

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Trondhjemite of the Alwar basin, Rajasthan: Implications of late Proterozoic rifting in the North Delhi Fold Belt

M. K. Pandit, Maher Khaled Khatatneh and Rakesh Saxena

Department of Geology, University of Rajasthan, Jaipur 302 004, India

Ajitgarh pluton, a minor granite–trondhjemite body, intrudes the Delhi metasediments of Alwar basin in the North Delhi Fold Belt (NDFB). The granite and trondhjemite, representing different pulses of anorogenic felsic magmatism, are distinct from the syntectonic granites of NDFB. The present work is also the first report of trondhjemite from Proterozoic environs of northwestern Indian peninsular region. Ajitgarh trondhjemite (AT) demonstrates trondhjemite mineralogy and chemical characters consistent with parameters prescribed for trondhjemite nomenclature. It is enriched in silica and depleted in CaO, MgO and FeO, as compared to the Archean TTG, and appears to be genetically related to the anorogenic magmatism of sodic affinity.

THE Trondhjemite–Tonalite–Granodiorite (TTG) association, a characteristic feature of the Archean granite–

greenstone terranes, is hitherto unreported from the Proterozoic Delhi Super-group rocks from northern fringe of Indian peninsular shield. We report here the trondhjemite occurrence from a trondhjemite–granite suite from Ajitgarh pluton (27°26'N: 75°50'E), a minor intrusive body in the North Delhi Fold Belt.

Ajitgarh pluton, a composite granite–trondhjemite body, intrudes the sericite quartzite of Delhi Super-group. The geological set-up of the area is shown in the lithostratigraphic map (Figure 1). The contact between country rocks and the intrusive granitoids is obliterated by alluvial sand cover. Intrusive nature of the pluton is manifested by its emplacement discordant to the regional structural grain. Post-orogeny emplacement of granitoids is evident from absence of planar fabric, other textural characters and discordant nature of the pluton.

The generalized geological set-up of the area is summarized below:

Quartz–pegmatite veins
Granite
Trondhjemite
–Intrusive contact–
Sericite quartzite

The trondhjemite (AT), occupying the southeastern part of the pluton is in sharp contact with granite and