Frequency of Natural Out-Crossing in Partially Cleistogamous Pigeonpea Lines in Diverse Environments

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ABSTRACT

Natural out-crossing is the major cause of loss of varietal purity in pigeonpea [*Cajanus cajan* (L.) Millsp.]. The frequency of natural out-crossing of partially cleistogamous mutant lines, characterized by a modified keel and filamentous anthers, was studied at two locations in Sri Lanka and three locations in India. Indeterminate growth habit and normal floral morphology were used as dominant markers and the frequency of natural out-crossing was estimated as percentage of the observed hybrid plants. Natural out-crossing in the mutant lines in Sri Lanka ranged from 0.14 to 1.33%, in comparison to 6.34 to 19.64% in the controls. In the Indian environments, natural out-crossing ranged from 0.16 to 2.67%. The mutant was highly stable over diverse environments, and may be of considerable economic importance in pigeonpea improvement and seed-production programs.

PIGEONPEA, an important pulse crop of the semi-arid tropics, is a major source of dietary protein in Asia, Eastern Africa, and the Caribbean islands. Pigeonpea is a predominantly self-pollinated crop, with considerable insect-mediated cross-pollination (Saxena et al., 1990) the extent of which at any particular location depends primarily on the insect population (Bhatia et al., 1981; Onim, 1981). A partially cleistogamous trait was identified by Saxena et al. (1992) in pigeonpea that minimizes out-crossing and offers promise in helping safeguarding genetic purity as a consequence of more efficient selfing. This note reports the frequency of natural out-crossing in partially cleistogamous pigeonpea lines at two locations in Sri Lanka and three locations in India.

MATERIALS AND METHODS

A set of diverse environments was identified for experimentation. These were Maha Illuppallama (Dry Zone) and Palekelle (Intermediate Zone) in Sri Lanka and Hisar (Haryana), Modipuram (Uttar Pradesh), and Patancheru (Andhra Pradesh) in India. The partially cleistogamous lines used in the study were derived from a cross involving the mutant and cultivar Pragati. In Sri Lanka, two partially cleistogamous short-duration determinate lines, ICPL 87047 and ICPL 87154, were compared for natural out-crossing with two normal-flowered determinate cultivars, Pragati and Prabhat, having comparable flowering periods. A mixture (50:50) of two normal-flowering indeterminate cultivars, UPAS 120 and T.21, which differ for flower initiation by 2 to 3 wk was used as pollinator. The experiments at Maha Illuppallama and Palekelle were planted on 5 and 25 Nov. 1990, respectively. Each line was planted in plots of six 4-m long rows with inter- and intra-row spacing of 60 and 10 cm, respectively, in a randomized complete block design with three replications. To ensure abundant pollen would be available over a long period, the pollinator mixture was planted on both sides of each plot. At maturity, eight to 15 randomly selected plants were harvested individually from each row of the experimental plots and their progenies studied in the subsequent short rainy season (April to August) in 1991.

Due to lack of experimental facilities at Hisar, Modipuram, and Patancheru, 50 single-row plots of each of the two partially cleistogamous lines ICPL 87026 and ICPL 87018 were sown in 1989 rainy season in fields planted with materials possessing dominant genetic markers (normal flower and indeterminate growth) and matching flowering time. These plots, measuring 4 m in length, were scattered at different places in the field and each plot was bordered by at least 10 pollinator rows on each side. From each plot, two to 10 individual plants were randomly harvested. Progenies of the selections were sown in the subsequent post-rainy season at Patancheru.

Since indeterminate growth habit and normal floral morphology are dominant over determinate growth habit and partial cleistogamy respectively (Saxena et al., 1992), counts were made in each plant-progeny row, planted in Sri Lanka and India, for the self (partially cleistogamous flowers and determinate growth habit) and hybrid (normal flowers and indeterminate growth habit) plants. The frequency of natural out-crossing for an individual plot was estimated from the pooled data of its plant-progeny rows as percentage of the observed hybrid plants (Bhatia et al., 1981).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) of Sri Lankan data showed highly significant differences for natural out-crossing between the locations and among the lines. The interaction of location × lines was also significant. The frequency of natural out-crossing averaged over entries including controls (Table 2) was higher at Palekelle (8.92%) than at Maha Illuppallama (5.09%) suggesting more insect activity at the former which was perhaps encouraged by various established fruit trees in the vicinity. In comparison to the normal types the natural out-crossing in the partially cleistogamous lines was low but not totally prevented. At Maha Illuppallama, natural out-crossing in the partially cleistogamous lines was 0.14% (ICPL 87047) and 0.51% (ICPL 87154) and in the normal flower lines 13.35% (Prabhat) and 6.34% (Pragati). A similar trend was observed at Palekelle. The partially cleistogamous lines also differed among themselves for the extent of natural out-crossing. Saxena

Table 1. Analysis of variance for natural out-crossing of two normal and two cleistogamous lines of pigeonpea.

Source	df	Mean square
Replications	2	3.22
Locations	1	86.75**
Residual	2	1.57
Lines	3	357.88**
Loc × Lines	3	19.75*
Residual	12	6.73

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

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Table 2. Natural out-crossing in partially cleistogamous and normal lines of pigeonpea at Maha Illuppallama and Palekelle, Sri Lanka, during the 1990-1991 season.

Line	Maha Illuppallama			Palekelle			
	No. of plants			No. of plants			
	Total	Hybrids	Out-crossing	Total	Hybrids	Out-crossing	Mean out-crossing
			%			%	
ICPL 87047	2917	4	0.14†	7085	94	1.33	0.74
ICPL 87154	1753	9	0.51	8631	76	0.88	0.70
Prabhat (Control)	2780	371	13.35	8926	1753	19.64	16.50
Pragati (Control)	2650	168	6.34	7142	988	13.83	10.09
Mean			5.09			8.92	

† S.E. for comparing line means within a location (1.06), S.E. for comparing location means (0.36), and S.E. for comparing line means over locations (1.35).

et al. (1993) attributed such variation to the differences in insect activity on individual plants. More vigorous and prolific flowering types attract more pollinating insects and this results in a high level of out-crossing.

Crop growth at Patancheru was good while at Hisar and Modipuram a major proportion of the materials was damaged by blight disease (*Phytophthora drechsleri* Tucker f. sp. *cajani*). At Patancheru, natural out-crossing in ICPL 87026 and ICPL 87018 was 0.16 and 2.67%, respectively (Table 3). These lines exhibited less than 0.30% natural out-crossing at Modipuram and Hisar. The experimental design at the Indian locations did not permit direct comparison between normal and partially cleistogamous lines. However, the frequency of natural out-crossing recorded in the partially cleistogamous lines was extremely low in comparison to the 40% reported earlier by Gupta and Rao (1991) in the normal-flowered cultivar, Prabhat, at Patancheru and Hisar. Results of the present investigation suggest that the modification of pigeonpea flowers with respect to anther filament arrangement and keel has been able to restrict natural out-crossing to a great extent under diverse environmental conditions.

The inability to control pollination in breeding and seed production plots results in genetic contamination of selections and pure lines of pigeonpea. In spite of the fact that natural out-crossing is a common occurrence in pigeonpea, breeders have treated it as a self-pollinated crop as far as breeding methodology and selection procedures are concerned. The efficiency of selection may be reduced by unnoticed natural out-crossing of selected individual plants or the selection of vigorous hybrid plants (Saxena et al., 1989) arising because of out-crossing in the previous generation.

Pigeonpea breeders have been searching for genotypes with low natural out-crossing to develop lines which could maintain their purity under natural growing conditions. Prasad et al. (1972) and Gupta and Rao (1991) reported genotypic variation for natural out-crossing among pigeonpea cultivars. Also, cases of inherent cross-ability barriers (Singh et al., 1980; Saxena et al., 1987a) have been reported in pigeonpea where use of foreign pollen fails to produce hybrids. Such traits, though useful in maintaining genetic purity of lines, are difficult to select in segregating populations and therefore of no practical value in breeding programs. In Australia, Byth et al. (1982) reported a wrapped floral mutant which restricted natural out-crossing to less than 2%. This trait, however, was found to be unstable and could not inhibit natural out-crossing in dry environments (Saxena et al., 1987b).

The present studies conducted in India and Sri Lanka show that the partially cleistogamous trait that is easily identifiable and simply inherited (Saxena et al., 1992)

Table 3. Natural out-crossing in two partially cleistogamous lines of pigeonpea grown at three locations in India during the 1989-1990 season.

Location	Line	No. of plants			Frequency of out-crossing
		Progenies grown	Total	Hybrids	
					%
Patancheru	ICPL 87026	505	13 483	21	0.16 ± 0.06†
	ICPL 87018	143	2 432	65	2.67 ± 0.73
	Total/Mean	643	15 915	86	0.54
Hisar	ICPL 87026	210	3 493	7	0.20 ± 0.09
	ICPL 87018	81	1 978	6	0.30 ± 0.09
	Total/Mean	291	5 471	13	0.24
Modipuram	ICPL 87026	107	2 404	5	0.21 ± 0.07
	ICPL 87018	13	211	0	0.00 ± 0.00
	Total/Mean	120	2 615	5	0.19
Overall	Total/Mean	1054	24 001	104	0.43

† Frequency of out-crossing ± the standard error.

is stable over diverse environments and limits natural out-crossing to low levels. This trait, therefore, appears to be very useful for pigeonpea breeders in developing pure line cultivars which will maintain their elite genetic traits under natural growing conditions. It may also help seed producers maintain cultivar purity more efficiently and economically.

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