J. Oilseeds Res. 10(1) 1993 : 99-104
ISSN 0970-2776

NATURAL OUTCROSSING IN GROUNDNUT AND ITS IMPLICATIONS IN GROUNDNUT BREEDING

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ABSTRACT

Estimates of outcrossing in four groundnut (*Arachis hypogaea* L.) varieties belonging to different botanical types were made from a rectangular crossing design where the normal plants were surrounded in all directions by a 'Krinkle' dominant leaf marker. In a three year study conducted during the 1983-84 postrainy season and 1984 and 1985 rainy seasons at ICRISAT Centre, the percentage of outcrossing on individual plants ranged from 0.0 to 5.35 across seasons and genotypes. A marked increase in outcrossing was noticed during the postrainy season compared to the rainy season. The spanish and valencia types showed slightly greater outcrossing than the virginia types. The levels of outcrossing at various locations in groundnut are reviewed and possible ways of utilising outcrossing in groundnut improvement are discussed.

Key words : Peanut; *Arachis hypogaea* ; Natural hybrids.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a self-pollinating species. However, as in most other self-pollinating species, some outcrossing occurs in groundnut also. The recovery of natural hybrids in groundnut nurseries where there was concentrated bee activity suggested the involvement of bees as natural outcrossing agents. Heide (1923) was the first to identify the bees as the primary cross pollinating agents in groundnut. Additional evidence that bees are the pollinating vectors in groundnut was provided by Hammons (1963), who showed that the bee-collected groundnut pollen was fully viable. Girardeu *et al.*, (1975) showed that the honeybee, *Apis mallifera*, can hybridize groundnut plants by conducting a controlled experiment in cages. Other workers (Stokes and Hull, 1930; Kushman and Beattie, 1946; Pelerenis, 1957) indicated that thrips could be the crossing agents without substantiating their claims. Wind pollination in groundnut is virtually ruled out since the stigma lies buried among the dehisced anthers in the tightly closed keel of mature flowers.

Several wild bee species have been reported as agents of natural cross-pollination in groundnut. At ICRISAT Centre, Patancheru (18° N, 78° E) India, in fields where pesticides are not used, about 20 different bee species have been found to forage on groundnut (ICRISAT, 1980). In the USA, Middtchell, (1960;1962) reported that, of the several bee pollinators in groundnut *Pyrobombes impatiens* (Cresson), *Megachile mendica* Cresson, *Apis mellifera* L. and *Lasioglossum versatum* (Robertson) were more abundant and widely distributed. In Indonesia, bee species *Xylocopa aestuans* L., *Apis indica Fab.* and *Ceratina bieroglyphica* sm. have been reported as pollinators in groundnut (Heide, 1923). The commonest bee species foraging on groundnut was *Nomia microsoma* in Malawi and *Anthopora concinnia* in Harare, Zimbabwe (Gibbons and Tattersfield, 1969).

Received for publication on 28th October 1992

In a self-pollinated crop such as groundnut, even a small amount of outcrossing poses problems in maintaining the genetic purity of cultivars. The maintenance of varietal purity in breeding nurseries was considered impossible due to outcrossing in Indonesia (Bolhuis, 1951). On the other hand, natural outcrossing generates additional variability upon which breeders can capitalize (Nigam *et al.*, 1983).

Several factors influence the extent of natural outcrossing that occurs at a given location. They include the abundance of insect pollinators in relation to the available flowers, cropping intensity, flowering habit of varieties, location of the field in relation to the habitat of the pollinators, frequency of pesticide usage, and various environmental factors such as temperature, humidity, wind velocity and direction (Bhatia *et al.*, 1981). Estimates of outcrossing in groundnut have been reported from the USA (Coffelt, 1989; Knauft *et al.*, 1987; Culp *et al.*, 1968; Kushman and Beattie, 1946), Puerto Rico (Stone *et al.*, 1973), Malawi, Zimbabwe, and Zambia (Gibbons and Tattersfield, 1969)), Congo (Pelerenis, 1957), Indonesia (Bolhuis, 1951) and India (Srinivasulu and Chandrasekharan, 1958). There has been only one report in literature from India (location, Madras). The present study was undertaken to estimate the outcrossing on four groundnut varieties belonging to different botanical types at ICRISAT Center, Patancheru, India.

MATERIALS AND METHODS

Four groundnut genotypes, M-13, Kadiri 3, J-11, and NC Ac 17090, belonging to different botanical types and growth habits (Table 1) were used as female parents. These parents were planted along with a dominant leaf marker, Krinkle (ICG 8456), with krinkled leaves (Hammons, 1964a) in a rectangular design where each plant in the female parent rows was surrounded by the krinkle leaf marker plant in all the directions (Fig. 1). The row-to-row distance was maintained at 60 cm and plant-to-plant within the row at 10 cm. The study was conducted for three seasons, the 1983-84 postrainy season, and the 1984 and 1985 rainy seasons. During the 1983-84 postrainy season, the plot size comprised one row of 4m length which was replicated twice for each variety. During the 1984 and 1985 rainy seasons, the plot size was one row of 9m length

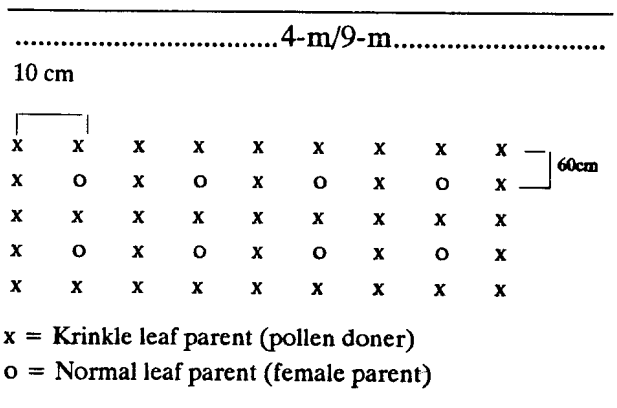

Fig. 1. Field layout used to determine the extent of outcrossing on individual plants in groundnut

which was replicated thrice for each variety. The seeds from each female plant were collected separately and grown in progeny rows the next season.

RESULTS AND DISCUSSION

Observations on the number of female parental families showing krinkle-leaved plants and the total number of krinkle-leaved plants in these families were made. The percentage of families showing outcrossing ranged from 0 to 66.67% across varieties and seasons (Table 1). The differences in the percentage of outcrossed families among the different varieties indicate the preference of bees for one variety over the other. On the basis of mean percentage of outcrossed families across the three seasons, the *fastigiata* types had a higher number of outcrossed families compared to *hypogaea* types. Also, during the 1983-84 postrainy season, the

Table 1. Number of outcrossed families in different botanical types of groundnut at ICRISAT Center, 1983-85

Genotype	Botanical type	Growth habit	1983/84 Postrainy[1]		1984 Rainy		1985 Rainy		Mean percentage of families showing outcrossing
			Total families	No. of families showing outcrossing	Total families	No. of families showing outcrossing	Total families	No. of families showing outcrossing	
M 13	Ssp. *Hypogaea* Var. *Hypogaea* (Virginia)	Spreading	38	3 (7.89)[2]	150	8 (5.33)	132	8 (6.06)	5.94
Kadiri	Ssp.*Hypogaea* Var. *Hypogaea* (Virginia)	Semi-spreading	35	6 (17.14)	146	9 (6.16)	110	5 (4.55)	6.87
J 11	Ssp. *Fastigiata* Var. *Vulgaris* (Spanish)	Bunch	36	24 (66.67)	66	4 (6.06)	120	0 (0.00)	12.61
NC Ac 17090	Ssp. *Fastigiata* Var. *Fastigiata* (Valencia)	Bunch	35	17 (48.57)	108	1 (0.92)	88	8 (9.09)	11.26
			144	50 (34.72)	470	22 (4.62)	450	21 (4.67)	8.74

1. The years and seasons refer to the period of initiation of the experiment and the respective families were raised in the subsequent years/seasons
2. Figures in the parentheses indicate the percentage of families showing outcrossing

Table 2. Estimates of outcrossing in various botanical types of groundnut

Variety	Year[1] / season	Total no. of plants studied[3]	No. of plants with krinkle leaf	percentage of outcrossing
M 13	1983/84 PR[2]	636	3	0.47
	1984 Rainy	1689	11	0.65
	1985 Rainy	1759	13	0.74
		4084	27	0.66
Robut 33-1	1983/84 PR	670	6	0.90
	1984 Rainy	2375	7	0.29
	1984 Rainy	1965	5	0.25
		5010	18	0.36
J 11	1983/84 PR	841	45	5.35
	1984 Rainy	872	6	0.69
	1984 Rainy	1895	0	0.00
		3608	18	1.41
NC Ac 17090	1983/84 PR	774	25	3.23
	1984 Rainy	1731	1	0.06
	1984 Rainy	1080	9	0.83
		3585	35	0.98

1.Year/season refers to the period of initiation of the experiment.
2.Postrainy.
3.Studied during the succeeding year/season

percentage of outcrossed families was higher in all the varieties . This increase in the outcrossed families might be due to concentrated activity of bees as smaller plots were used and no other groundnut crop was in the vicinity of the experimental field, during the 1983-84 postrainy season.

The percentage of outcrossing on individual plant basis ranged from 0 to 5.35 (Table 2). It was higher in the postrainy season than in both the rainy seasons in all varieties except M13 which is late flowering variety. The increased levels of outcrossing during the postrainy season could be due to more concentrated and increased foraging activity of the bees on the crop, because of the lower number of both crop and weed species available for insect foraging.

On a three-season average, spanish and valencia types showed slightly greater percentages of outcrossing compared to the virginia bunch and runner types. This observation is in agreement with that of Gillier and Silvestre (1969), who reported that cross-pollination is always greater in spanish and valencia (subspecies, *fastigiata*) varieties than in virginia (subspecies, *hypogaea*) varieties. The valencia variety, NC Ac 17090, showed a higher percentage of outcrossing compared to the virginia varieties in two out of three seasons. Similar observations were made by Culp *et al.*, (1968) who reported that in the USA, 'Tennessee Red', a valencia variety had greater outcrossing than 'Virginia Bunch 67', a virginia variety. The reason for the increased outcrossing in valencia and spanish types may be their fewer number of branches resulting in more exposure of flowers to bee activity. Also, these types flower early compared to virginia types.

Reports on outcrossing levels in groundnut from various locations are

presented in Table 3. The outcrossing levels observed in the present study are within the range reported in other countries such as the USA and Indonesia. No marked differences were noticed by Culp et al., (1968) in the USA, in the outcrossing estimates made by using two different markers, Krinkle (a dominant leaf marker) and a purple petiole (an incomplete dominant marker).

Table 3. Natural outcrossing levels reported in groundnut

Location/Country	Outcrossing percentage	Reference
Lilongwe, Malawi	0.0 - 0.72	Gibbons and Tattersfield (1969)
Harare, Zimbabwe	0.25 - 1.67	Gibbons and Tattersfield (1969)
Chipata, Zambia	0.0 - 0.35	Gibbons and Tattersfield (1969)
Congo	0.6 - 2.0	Pelerenis (1957)
Java, Indonesia	2.0 - 6.6	Bolhuis (1951)
Florida, USA	0.0 - 2.56	Norden (1980)
Georgia, USA	0.48 - 0.54	Leuck and Hammons, (1965)
Georgia, USA	0.73 - 2.56	Hammons (1964)
Georgia, USA	10.0	USDA (1963)
Virginia, USA	0.09 - 0.27	Culp et al., (1968)
Virginia, USA	0.0 - 2.81	Coffelt (1989)
Puerto Rico	0.27 - 0.99	Stone et al., (1973)
Madras, India	0.99	Sreenivasulu and Chandrasekharan (1958)
ICRISAT Center Patancheru, A.P., India	0.0 - 5.35	Present study

Although several modifications have been suggested for artificial hybridization of groundnut ever since Stok (1910) first developed the procedure, it still remains a tedious operation and the number of hybrid seeds obtained per pollination are limited compared to other crops.

While natural outcrossing poses problems in the purity of germplasm, systematic utilization of natural hybrids has been found to be a useful method of groundnut improvement (Nigam *et al.*, 1983). At ICRISAT Center, by utilizing natural hybrids, these researchers developed four groundnut varieties, ICGS 11, ICGS 44, ICGS 37 and ICGS 1, which have been released for cultivation in India. Similarly in Zimbabwe, a groundnut cultivar 'Egret' was developed from selections arising due to natural outcrossing in 'Makulu Red' cultivar (Hildebrand, 1975).

Hammons (1964b), proposed a new technique termed as 'pedigreed natural crossing, as a means to utilize natural outcrossing in groundnut improvement. In this method, both male and female parents are known and can be chosen and sufficient hybrid seeds can be produced if land is not a limitation. The limitations of this method according to Coffelt (1989) are the need for the presence of simple genetic markers along with some desirable characteristics in the male parent and large amount of land and/or labour required for the identification of the hybrids. However, it is not necessary to use unadapted parents with distinct genetic markers to identify genuine F_1 hybrids. Instead, several commonly present simply inherited traits such as testa colour, growth habit and pod reticulation could be employed. Also, hybrid indices involving some quantitative characters can be used.

Land and labour costs can be drastically reduced if outcrossing rates can be enhanced. This may be achieved by growing bee- attractant crops such as sunn hemp and sunflower in the groundnut crossing block as suggested by Gibbons and Tattersfied (1969). Recently , Dutta *et al.*, (1987) reported that low doses of radiations can be utilized to increase the levels of outcrossing in groundnut. They observed that pollen sterility induced through gamma irradiation (5 kR) could produce as high as 33% outcrossing in a groundnut cultivar, M 13. So, if proper male gametocides are identified, the enhanced outcrossing rates can be utilized

in groundnut improvement programmes where manual hybridizations cannot be undertaken.

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