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Evaluation of outcrossing rate in different species of grain amaranth

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Abstract
Grain amaranth (*Amaranthus* spp.) has been cultivated since ancient times in some countries in the world which is one of the ancient food crops. Studies of intra specific and inter specific outcrossing rates were carried out for grain amaranths using populations of *A. hypochondriacus*, *A. caudatus* and *A. cruentus*. Studies of outcrossing were carried out using different species at Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India, which resulted that the highest outcrossing rate was observed in Annapurna (*A. cruentus*) (25–35%) followed by IC–381135 (*A. caudatus*) (11–20%) and the lowest in GA-1 (*A. hypochondriacus*) (4–11%), while no outcrossing rate was observed in GA-2 (*A. hypochondriacus*). The outcrossing rate showed substantial variation between and among the species. Significant variations in the outcrossing rates might be due to variation in location and season.

Keywords: *Amaranthus hypochondriacus, A. cruentus, A. caudatus*, outcrossing

Introduction

The genus amaranth is dibasic with X=16 and X=17 chromosome, almost equally distributed in section amaranth. Grant (1959) [3] has reported the information regarding the chromosome number of 30 species of *Amaranthus*. Among the 30 species, *A. caudatus* L. (2n=32), *A. cruentus* L. (2n=34) and *A. hypocondriacus* L. (2n=32) are domesticated species and among these three species *A. caudatus* L. is drooping type and the rest two are erect type species (Pagi *et al*. 2017) [6]. These three main amaranth species are grown for grain purpose (Gelotar *et al*., 2019) [2]. *A. caudatus* is early maturing species having 60 to 70 days require for maturity. This species is mostly grown in Kenya. The maturity depends on altitude; amaranth grain matures faster at lower altitudes. Usually, *A. caudatus* matures within 60 to 70 days in Africa. Due to early maturity, this species is favorable for the areas that have a short rainy season. *A. cruentus* is a medium duration species having 60 to 120 maturity days. *A. hypochondriacus* is long duration species having 150 maturity days. It is high yielding and disease tolerant species.

Hauptli and Jain (1985) [4] studied that the genus *Amaranthus* provides fascinating material for geneticists to tackle. Amaranth is a predominantly self-pollinated crop, with varying amounts of out crossing. By growing amaranth in isolation, it is possible to control the amount of outcrossing for the development of true-to-type lines from segregating accessions within only a few generations of selection. Agong and Ayiecho (1991) observed that out crossing rate was estimated in several collections of grain amaranths in three sets of data. The first involved a red-green seedling color locus (R,r); progenies of recessive mothers (rr) grown at Davis gave a wide range of values (mean rate of out crossing 31 percent. SE = 25 percent). Families of plants collected at four sites in India gave estimates of 3.5 to14 percent outcrossing at locus R/r. Using two allozyme loci, progenies of individual plants collected from fields in India and South America gave estimates of a 3 to 25 percent outcrossing rate, with significant inter population variation. This level of variation in breeding systems of grain amaranths should be of special interest in further studies of its ecological and morphological components, and in relation to the effects of domestication on the breeding structure of different populations. Jain *et al*. (1982) [5] studied in grain amaranths varies from high rates of selfing (over 90%) to mixed mating with as much as 30% out crossing. Out crossing rates varied significantly with genotype and environmental factors between years. A bidirectional selection experiment based on male/female flower ratio per plant suggested that breeding system is under genetic control, and thus, it can be modified to suit breeding procedures for either inbreeding or out-breeding species. The present study was conducted to find out the outcrossing rate within and between the species of grain amaranth.

Materials and Methods

Three species and genotypes of grain amaranth were used for outcrossing study are listed in Table 1. The plants were selected on the basis of direction *viz*., N (North)→S (South), S→N, E (East)→W (West), W→E. Total 16 plants were selected within 1 m distance of the line and selection was carried out up to 8 m of the line. The selected plants were harvested separately and grown in the next season for the study of out crossing. The layout of the field study is shown in the Figure 1. The total number of plants of different species showing out crossing were counted in each line and calculated the percentage mean of out crossing in each species of grain amaranth.

Table 1: List of genotypes used in the out crossing study

Sr. No.	*Amaranthus* Species	Genotype
1	*A. hypocondriacus L.*	GA-1, GA-2
2	*A. cruentus* L.	Annapurna
3	*A. caudatus* L.	IC-381135

Fig 1: Layout of field for outcrossing study

Result and Discussion

The outcrossing was determined by the different directions with specific distance in different grain amaranth species. The study revealed that Annapurna, a species of *A. cruentus* had highest outcrossing percentage, IC-381135, species of *A. caudatus* had moderate outcrossing and lowest outcrossing was found in GA-1 which is species of *A. hypochodriacus*. While no outcrossing was observed in GA-2 which is a species of *A. hypochodriacus*. The data revealed that GA-2 (GA-1), GA-2 (IC-381135) and GA-2 (Annapurna) had no outcrossing. (Table 2). The highest out crossing rate observed in Annapurna having 22.09–35.39% outcrossing in the direction of E→W, followed by IC- 381135 with 11.93–16.45% outcrossing in the direction of E→W and 11.05–20.35% outcrossing in the direction of W→E showing moderate outcrossing and lowest outcrossing was observed in GA-1 with 4.87–11.04% outcrossing in the direction of W→E and 5.86–10.08% outcrossing in the direction of E→W. Highest outcrossing were found in Annapurna with the average of 31.59%. Interspecific outcrossing rate studies including *A. hypochondriacus* and *A. cruentus* presented low estimates with a mean of 6.5% and an average of 0–15.0% (Agong and Ayiecho, 1991) [1]. *Amaranthus* flowers found monoecious and found cross pollination, but outcrossing observed less due to pollen grain blowing very short. Therefore, some inflorescence transmits pollen, which fertilized same female flower.

Table 2: Outcrossing percentage in GA-2

Distance (m.)	Outcrossing rate (%)			
	E→W (%)	W→E (%)	N→S (%)	S→N (%)
1 m	0	0	0	0
2 m	0	0	0	0
3 m	0	0	0	0
4 m	0	0	0	0
5 m	0	0	0	0
6 m	0	0	0	0
7 m	0	0	0	0
8 m	0	0	0	0

Table 3: Outcrossing percentage in GA-1, Annapurna and IC-381135

Distance (m)	GA-1 (GA-2)		Annapurna (GA2)		IC- 381135 (GA-2)	
	W→E	E→W	W→E	E→W	W→E	E→W
1 m	06.96	05.86	28.46	25.12	14.54	13.94
2 m	05.28	05.93	31.17	28.49	18.97	14.52
3 m	09.16	06.28	22.09	28.69	20.35	11.93
4 m	06.04	05.96	33.89	31.34	19.34	16.45
5 m	04.87	07.79	33.96	26.33	13.35	14.64
6 m	08.14	10.08	35.39	30.65	11.75	15.73
7 m	08.75	08.13	33.88	35.03	18.05	15.76
8 m	11.04	09.33	33.83	34.06	11.05	14.77
Average	07.53	07.42	31.59	29.97	15.93	14.72
Range	04.87 - 11.04	05.86 - 10.08	22.09 - 35.39	25.12 - 35.03	11.05 - 20.35	11.93 - 16.45
Values indicate % outcrossing						

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