Journal of Experimental Agriculture International

Volume 46, Issue 8, Page 1090-1102, 2024; Article no.JEAI.121563
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Effects of Mating Systems on Segregating Populations of Three Way Cross of Maize (*Zea mays* L.)

P. Bindu Priya [a*], T. Pradeep [b++], K. Sumalini [a] and D. Vishnuvardhan Reddy [b#]

[a] *Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, 500030, India.*
[b] *Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana, 500030, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i82796

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121563

Original Research Article

Received: 17/06/2024
Accepted: 19/08/2024
Published: 23/08/2024

ABSTRACT

Maize is one among those crops privileged with rich genetic diversity; however the currently cultivated hybrids barely represent this scale of variability as they are developed from more or less genetically similar lines. Tad changes in environmental factors can fail today's hybrids which otherwise perform exceedingly well. This stresses the need for development of diverse genotypes which can adapt to the changing climatic conditions. A study was conducted to estimate and

[++] *Director (Seeds) (Rtd.);*
[#] *Dean of Student Affairs (Rtd.);*
**Corresponding author: E-mail: bindupriya.gpb1@gmail.com;*

Cite as: *Priya, P. Bindu, T. Pradeep, K. Sumalini, and D. Vishnuvardhan Reddy. 2024. "Effects of Mating Systems on Segregating Populations of Three Way Cross of Maize (Zea Mays L.)". Journal of Experimental Agriculture International 46 (8):1090-1102. https://doi.org/10.9734/jeai/2024/v46i82796.*

compare the efficiency of three mating systems *viz*., self pollination, sib mating and open pollination in development of superior inbred lines with wider adaptability and sturdy genetic makeup in maize. Fourth filial segregating populations of three way cross obtained from three mating systems were used for studying genetic variability and character associations. Results indicated that sib mated progeny exhibited highest genotypic coefficient of variability, heritability and genetic advance for most of the yield traits while desirable mean values, highest number of recombinants and highest phenotypic coefficients of variability were observed in open pollinated population. Sib mated progenies exhibited highest number of significant positive correlations specifically among yield related characters while open pollination resulted in weak associations. From this study, it can be concluded that sib mating or a blend of sib mating and selfing can be adopted for development of diverse and superior inbred lines in maize.

Keywords: Maize; inbred development; mating systems; genetic variability; correlations.

1. INTRODUCTION

Maize (*Zea mays* L. 2n=20) or Indian corn, is the world's most widely cultivated cereal crop and an essential food source for millions of world's poor. It is a versatile crop grown in a variety of altitudinal, geographical and fertility conditions. Maize, together with rice and wheat, provides about 30 per cent of the food calories to more than 4.5 billion people in 94 developing countries (https://archive.maize.org/why-maize/). It has dual importance as both feed and fodder besides being an important industrial product. Though significant portion of corn produced is used as animal feed, it is also consumed as human food in many parts of the world especially in Latin America, Africa, Southern Europe and some Asian countries. Industrially, maize beholds a number of roles such as manufacture of industrial alcohol, vegetable oil, corn starch, *etc.* while maize stalks are used in making rayon, bio degradable plastics, biofuel and wall boards. Maize crop is less water demanding than other similar cereals, offers higher productivity in short period and can be cultivated during all the seasons. The fact that a whopping 15 million Indian farmers are engaged in maize cultivation underscores its importance in India. It is noteworthy to mention that in spite of vast improvement in maize production, India is way behind in productivity than other leading nations of the world and there lays an immense scope for its improvement in the country. Hence, the strategy to meet future corn demands should be *via* increase in productivity rather than increase in cultivated area and such yield enhancement is possible only through deliberate and meticulous planning. The most viable options are pre-breeding, enhancement and diversification of germplasm, biotechnological interventions and more pertinently development of diverse and productive inbreds.

Even though maize has a long history of cultivation as a cross pollinated heterozygous crop, modern maize hybrids are genetically highly uniform. Apparently, many of the maize hybrids sold under different names continue to depend on a few closely related inbred lines. Breeding and genetic improvement of any crop relies mainly on the presence of substantial magnitude of variability in the population and the extent to which the desired trait is heritable. Experts warn of massive slash in global maize production in coming years owing to surging temperatures as a result of climate change thereby emphasizing the need for germplasm diversification and enhancement of its tenacity. Improving the genetic potential of Indian maize would continue to be a major challenge. Even though hybrids with yield potential of up to 14 t ha^{-1} are available in the country, it is difficult to achieve even half of this potential because of various biotic and abiotic constraints. Development of inbred lines with greater yielding abilities as well as cushioning for biotic and abiotic hassles is a major step towards producing potential hybrids [1,2,3,4].

Selfing is the commonly adopted conventional method for development of inbred lines, but such inbreds are weak and inferior *per se*. Sib mating is a less severe form of inbreeding which would permit less rapid fixation of deleterious genes as compared to selfing and can be suggested for producing more vigorous inbred lines [5]. Random mating or open pollination can aid in breakup of linkage blocks that were maintained intact due to lack of recombination. Occurrence of some rare recombinants often becomes crucial for the success of breeding programmes.

However, studies on influence of different mating systems on the segregating individuals for developing superior inbreds are limited. Hence, an attempt was made to deviate from the conventional approach and investigate the effects and efficiency of three mating systems *i.e.,* self pollination, sib mating and open mating systems on segregating populations of maize derived from three way cross in developing potential inbred lines that can produce durable and superior hybrids suitable for wider spectrum of circumstances.

2. MATERIALS AND METHODS

2.1 Experimental Site Location

The present investigation was carried out at Regional Agricultural Research Station, Palem, Nagarkurnool district in Telangana State, India for four seasons *i.e., kharif* 2016, *rabi* 2016-17, *kharif* 2017 and *rab*i 2017-18. The present study was conducted on the crop raised during *rab*i 2017-18. The research station is located in the Southern Telangana agro climatic zone of Telangana State. Geographically, it lies at 16^o 35' N latitude, 78^o 1' E longitude with an altitude of 662 meters above Mean Seal Level and average rainfall of 546 mm. The soils are sandy loams with a p^H of 7.2.

2.2 Experimental Material

The experimental material comprised of three populations belonging to fourth filial generation of maize three way cross [(BML-14 x BML-6) x BML-51. The parental lines BML-6, BML-14 and BML-51 were developed at Maize Research Centre, Rajendranagar, Hyderabad while the three way cross hybrid was developed at Agricultural Research Station, Karimnagar.

2.3 Experimental Techniques

During *kharif* 2016, F_1 crop of the three way cross [(BML-14 x BML-6) x BML-51was raised and subjected to three mating systems during flowering stage *i.e.,* selfing, sib-mating and open pollination. The second season crop comprising three populations obtained from three matings was taken up during *rabi* 2016-17 in randomized block design with three replications each. Each replication consisted of twenty rows from which ten rows were utilized for imposing the mating system while the remaining rows were used for recording observations. Third and fourth season crops were raised during *kharif* 2017 and *rabi* 2017-18 respectively following the same methodology as in the second season. The crop was raised under irrigated conditions during post rainy season and supplemental irrigation was given as and when necessary, during rainy seasons. Fertilizer application, weeding, irrigation, plant protection and all other recommended cultural practices were followed to raise a healthy crop.

2.4 Mating Systems

Three mating systems *viz.,* self pollination, sib mating and open pollination (random mating) were imposed on the experimental material. Selfing and sib mating systems involved additional steps of silk cutting and bagging before pollination. Silks were cut back on shoot three to four days before pollination to achieve uniform silk emergence. Bagging was done a day prior to pollination by firmly placing a heavy craft paper bag with water proof glue over the tassel and fastening with a paper clip. Pollen grains were collected 24 hours after bagging the tassel taking due care to prevent contamination and avoid pollen spilling.

Cobs were selfed by dusting the pollen collected in the tassel bag on to silk of the same plant after carefully removing the silk bag without touching or exposing the silks. Bottom of the tassel bag is flipped upwards, causing the pollen to fall upon the silk. The tassel bag is pulled down over the shoot and fastened with stapler or paperclip. For sib mating, pollen grains collected from all the tassel bags of a single plot were thoroughly mixed in a fresh tassel bag and this pollen bulk was applied carefully to the silk of each plant of the same plot. Utmost care was taken to not to expose the silks for longer time and are immediately covered with a fresh tassel bag after pollination. Open pollination was effected by allowing all the plants in the plot to freely out cross.

2.5 Observations

Observations were recorded on thirty randomly selected plants for the characters days to 50% tasseling, days to 50% silking, days to maturity, plant height (cm), ear height (cm), ear length (cm), ear circumference (cm), number of kernel rows, number of kernels row^{-1}, 100 seed weight (g), shelling percentage (%) and grain yield plant^{-1} (g).

2.6 Statistical Analysis

Data was subjected to one-way variance analysis with p value at 0.05. Mean, range, phenotypic and genotypic coefficients of variability, heritability (broad sense), genetic advance as per cent of mean and correlations were calculated using Windowstat 9.0. The graphs used in the manuscript were developed using R studio.

3. RESULTS AND DISCUSSION

3.1 Comparison of the Three Mating Systems for Genetic Variability Parameters

Analysis of variance of the progenies obtained from self pollination, sib mating and open pollination systems indicated the presence of significant genetic variation among the genotypes for the various characters studied implying abundant scope for improvement of these traits through selection (Table 1) [6,7].

3.1.1 Mean

Estimates of mean for different characters in the three way cross are presented in Table 1. After three mating seasons, open pollinated population was found to exhibit highest mean values for yield and yield related characters like ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight, shelling percentage and grain yield plant^{-1} and lowest for days to 50% tasseling, days to 50% silking, days to maturity indicating earliness. It was observed that the mean values of self and sib mated progenies were inferior to open pollinated progeny for various characters studied and this superiority of open pollination increased with progressing mating cycles. Inbreeding depression has resulted in lower mean values of self and sib mated progenies and hence comparing the mating systems based on mean values may not be appropriate. Sib mated populations took highest number of days for flowering in contrary to the findings of Okoye et al. [8] who reported that progenies obtained from self pollination took significantly longer days to 50% tasseling and silking than sib mated progeny. Sib progeny showed lowest means for ear height and this trait can be useful for developing machine harvest-friendly genotypes besides possessing lodging tolerance. Ahmmed and Mehra [9] opined that changes observed between F_3 progenies and intermated population of cotton may be attributed to epistasis and differences in population size resulting in genetic drift, besides correlated response due to selection (Table 2).

3.1.2 Magnitude of diversity

Similarly, open pollination showed highest diversity for most of the characters studied (Table 2). Selfed progenies showed large range for grain yield plant^{-1} while sib mating exhibited for days to 50% silking and 100 seed weight. Remaining characters exhibited maximum diversity in open pollinated population. Open pollination also produced best recombinants for all characters studied except days to 50% silking and days to maturity whose best segregants were observed in sib mated and selfed progenies respectively. Increasing homozygosity and eventual surge in inbreeding depression in self and sib mated progenies are perhaps the reasons for their under-performance compared to open pollinated population in producing diverse and robust recombinants. Nonetheless, comparison of selfing and sib mating indicated that the best recombinants for yield and its attributing traits were found in sib mated plants while flowering traits were best expressed in selfed progenies [10].

3.1.3 Coefficients of variability

The PCV values were higher than GCV suggesting the profound influence of environment on trait expression (Table 3, Fig. 1) [11]. Open pollination excelled the other two mating systems as it recorded highest PCV for most of the characters like days to 50% tasseling, days to 50% silking, days to maturity, ear circumference, number of kernel rows ear^{-1}, 100 seed weight, shelling percentage and grain yield plant^{-1}. Selfing manifested highest PCV for plant height and ear height while sib mating for ear length and number of kernels row^{-1} [6]. In general, high PCV (>20%) was exhibited by ear height and number of kernel rows ear^{-1} in selfing, number of kernels row^{-1} and 100 seed weight in sib mating and days to 50% tasseling, ear circumference, number of kernels row^{-1} and number of kernels row^{-1} in open pollination. Low PCV (< 10%) was observed for days to 50% silking and shelling percentage (selfing), days to 50% tasseling, days to 50% silking, days to maturity and shelling percentage (sib mating) and shelling percentage (open pollination) while the remaining traits displayed moderate PCV (10-20%) [12,13,14,15].

Table 1. Mean sum of squares comparision for traits studied in F_4 populations of maize three way cross

Traits	Replicates (df=2)			Treatments (df=19)			Error (df=38)		
	Selfing	Sib mating	Open Pollination	Selfing	Sib mating	Open Pollination	Selfing	Sib mating	Open Pollination
Days to 50% tasseling	36.617	44.15	24.467	136.887 **	80.811 *	95.979 *	42.95	42.834	40.695
Days to 50% silking	26.717	8.267	10.217	188.613 ***	73.196	107.294 **	54.05	40.512	43.094
Days to maturity	79.217	204.867	19.017	634.365 ***	265.911 *	91.35	124.778	130.814	61.087
Plant height	18640.020 ***	4012.867 **	1924.017	6932.325 ***	2097.841 **	2067.856 *	1430.789	680.428	1047.648
Ear height	2615.417 **	4200.617 ***	2062.217 **	856.185 **	625.663 *	715.490 *	347.311	280.371	343.322
Ear length	54.353 **	6.155	187.156 ***	17.515 *	33.728 ***	39.823 *	8.486	10.198	16.669
Ear circumference	55.446 ***	91.467 ***	164.867 ***	10.892	11.846 *	8.912	6.167	5.625	5.481
Number of kernel rows ear^{-1}	5	28.867	49.400 *	12.547 *	23.214 *	28.435 *	6.474	10.551	13.961
Number of kernels row^{-1}	94.317	118.117	8.867	114.718 *	208.192 ***	125.123 ***	54.913	52.766	31.112
100 Seed weight	1.278	34.121	358.054 ***	71.208 *	79.762 **	65.788 *	37.263	27.62	31.544
Shelling percentage	76.413	208.114 **	121.958	63.737 *	63.483 *	81.479 *	27.128	27.766	39.868
Grain yield $plant^{-1}$	422.226	4495.585 **	116.229	1318.070 *	1299.374	929.21	683.685	775.144	635.674

**Significance at P < 0.05; **Significance at P < 0.01; ***Significance at P < 0.001*

Table 2. Means and range values for the traits studied in S_3 (F_4) generation of maize three way cross

S.No.	Character	Mean			Range		
		Selfing	Sib mating	Open pollination	Selfing	Sib mating	Open pollination
1	Days to 50 per cent tasseling	60.32	66.72	56.40	53.67-70.33	60.67-74.33	45.33-72.33
2	Days to 50 per cent silking	63.10	70.38	57.78	55.33-71.67	65.33-77.67	44.33-79.00
3	Days to maturity	106.02	108.93	93.33	95.67-120.33	99.00-115.67	85.33-124.33
4	Plant height (cm)	165.35	163.78	152.18	132.53-185.64	153.33-208.67	126.73-179.56
5	Ear height (cm)	81.77	78.88	94.48	66.32-98.57	64.76-90.43	67.85-112.36
6	Ear length (cm)	12.78	13.05	17.96	10.57-15.32	10.28-18.43	12.45-23.53
7	Ear circumference (cm)	9.22	11.68	11.93	7.28-11.52	9.75-14.96	9.35-15.66
8	Number of kernel rows ear^{-1}	11.00	13.20	14.20	9.67-14.33	9.00-17.67	10.00-18.67
9	Number of kernels row^{-1}	16.97	22.25	34.58	12.67-20.67	17.67-30.00	21.33-39.67
10	100-kernel weight (g)	26.00	28.40	33.90	21.07-31.17	23.37-34.00	25.87-41.73
11	Shelling percentage (%)	71.72	75.43	80.44	69.97-73.93	72.94-80.72	74.26-85.92
12	Grain yield $plant^{-1}$ (g)	48.79	112.71	123.07	39.97-57.97	96.00-129.13	87.90-146.93

Table 3. Estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability broad sense (h^2) and genetic advance as per cent of mean (GAM) in S_3 (F_4) generation of three way cross

S.No.	Character	PCV (%)			GCV (%)			h^2 (%)			GAM (%)		
		Self	Sib	Open	Self	Sib	Open	Self	Sib	Open	Self	Sib	Open
1	DT	12.55	9.30	20.78	11.22	7.33	14.61	79.9	62.2	49.5	20.66	11.92	17.72
2	DS	9.62	8.07	10.78	6.63	4.16	5.21	47.5	26.5	23.4	9.42	4.41	4.24
3	DM	11.01	5.79	13.76	7.83	3.42	6.22	50.6	35.0	20.4	11.47	4.18	5.05
4	PH	19.03	16.42	17.24	16.37	9.74	10.93	74.0	35.2	40.2	29.92	10.71	11.31
5	EH	30.07	19.34	18.45	26.09	10.47	10.33	75.3	29.3	31.3	46.63	11.68	12.87
6	EL	14.52	18.01	15.57	8.71	13.70	8.42	36.0	57.9	29.3	10.76	18.61	11.27
7	EC	14.69	16.03	20.69	7.33	12.69	11.17	24.9	62.7	29.1	7.53	20.69	12.42
8	KR	21.85	18.45	26.49	15.56	13.36	16.61	50.7	52.5	39.3	19.95	22.03	21.45
9	KPR	17.43	23.57	18.56	10.58	15.72	8.32	36.8	44.5	20.1	13.22	15.88	9.99
10	SW	18.84	21.09	22.14	9.09	12.06	10.14	23.3	32.7	21.0	9.05	14.20	9.56
11	SP	7.35	8.83	9.25	5.96	7.95	6.10	65.7	80.9	43.5	8.74	13.47	8.29
12	GY	18.36	14.41	25.35	11.26	10.49	6.14	37.6	53.0	5.9	14.22	15.74	3.06

DT - Days to 50% tasseling; DS - Days to 50% silking; DM - Days to maturity; PH - Plant height (cm); EH - Ear height (cm); EL - Ear length (cm); EC - Ear circumference (cm); KR - Number of kernel rows^{-1}; KPR - Number of kernels row^{-1}; SW - 100 seed weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

Table 4. Correlation coefficients between different characters due to three mating systems in S_3 (F_4) generation of maize three way cross

Trait		PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
PH	**Self**		0.757**	-0.144	0.305	-0.143	-0.018	-0.223	-0.150	-0.250	0.033	0.120	-0.205
	Sib		-0.187	0.313	-0.096	0.063	-0.027	-0.055	0.128	0.111	0.219	0.436*	0.261
	Open		-0.062	0.003	0.085	0.204	0.071	0.102	0.309	0.317	-0.149	-0.035	0.281
EH	**Self**			-0.219	0.254	-0.302	0.042	-0.214	-0.162	-0.239	-0.064	0.204	-0.183
	Sib			0.270	0.237	0.304	0.268	-0.257	0.137	0.124	-0.259	-0.126	-0.030
	Open			-0.388*	0.187	-0.115	-0.024	-0.039	-0.111	-0.104	0.323	0.488**	-0.357
EL	**Self**				0.471**	0.346	0.223	0.108	0.236	0.135	0.394*	0.267	0.380*
	Sib				0.358	0.782**	0.692**	0.268	0.715**	0.114	0.352	0.360	0.486**
	Open				-0.341	0.087	-0.392*	-0.131	-0.214	-0.216	-0.157	-0.359	0.029
EC	**Self**					0.361*	0.179	0.239	0.437*	0.464**	-0.027	0.137	0.205
	Sib					0.481**	0.610**	-0.116	0.675**	0.397*	-0.092	-0.113	0.006
	Open					-0.120	0.557*	-0.312	0.400	-0.294	-0.258	-0.040	-0.241
KR	**Self**						0.298	0.823**	0.905**	0.496**	0.001	-0.099	0.202
	Sib						0.756**	0.457**	0.796**	0.228	0.342	0.183	0.415*
	Open						-0.005	0.266	-0.117	0.070	0.014	-0.188	0.084

Trait		PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
KPR	**Self**							0.175	0.293	0.300	-0.230	0.04	0.246
	Sib							0.298	0.803**	0.169	0.135	-0.055	0.295
	Open							-0.069	0.126	-0.002	-0.014	-0.266	0.089
SW	**Self**								0.889**	0.563**	-0.078	-0.013	0.270
	Sib								0.184	0.089	0.314	-0.079	0.194
	Open								-0.139	0.118	0.405	-0.110	0.275
GY	**Self**									0.529**	-0.044	-0.130	0.123
	Sib									0.270	0.255	0.059	0.252
	Open									0.206	-0.073	-0.142	-0.253
SP	**Self**										-0.314	0.196	0.314
	Sib										-0.324	-0.226	-0.335
	Open										0.245	-0.130	0.511**
DT	**Self**											0.503**	0.104
	Sib											0.647**	0.753**
	Open											-0.262	-0.194
DS	**Self**												0.636**
	Sib												0.630**
	Open												-0.194

*** Significant at 1 per cent   * Significant at 5 per cent*

DT - Days to 50% tasseling; DS - Days to 50% silking; DM - Days to maturity; PH - Plant height (cm); EH - Ear height (cm); EL - Ear length (cm); EC - Ear circumference (cm); KR - Number of kernel rows^{-1}; KPR - Number of kernels row^{-1}; SW - 100 seed weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

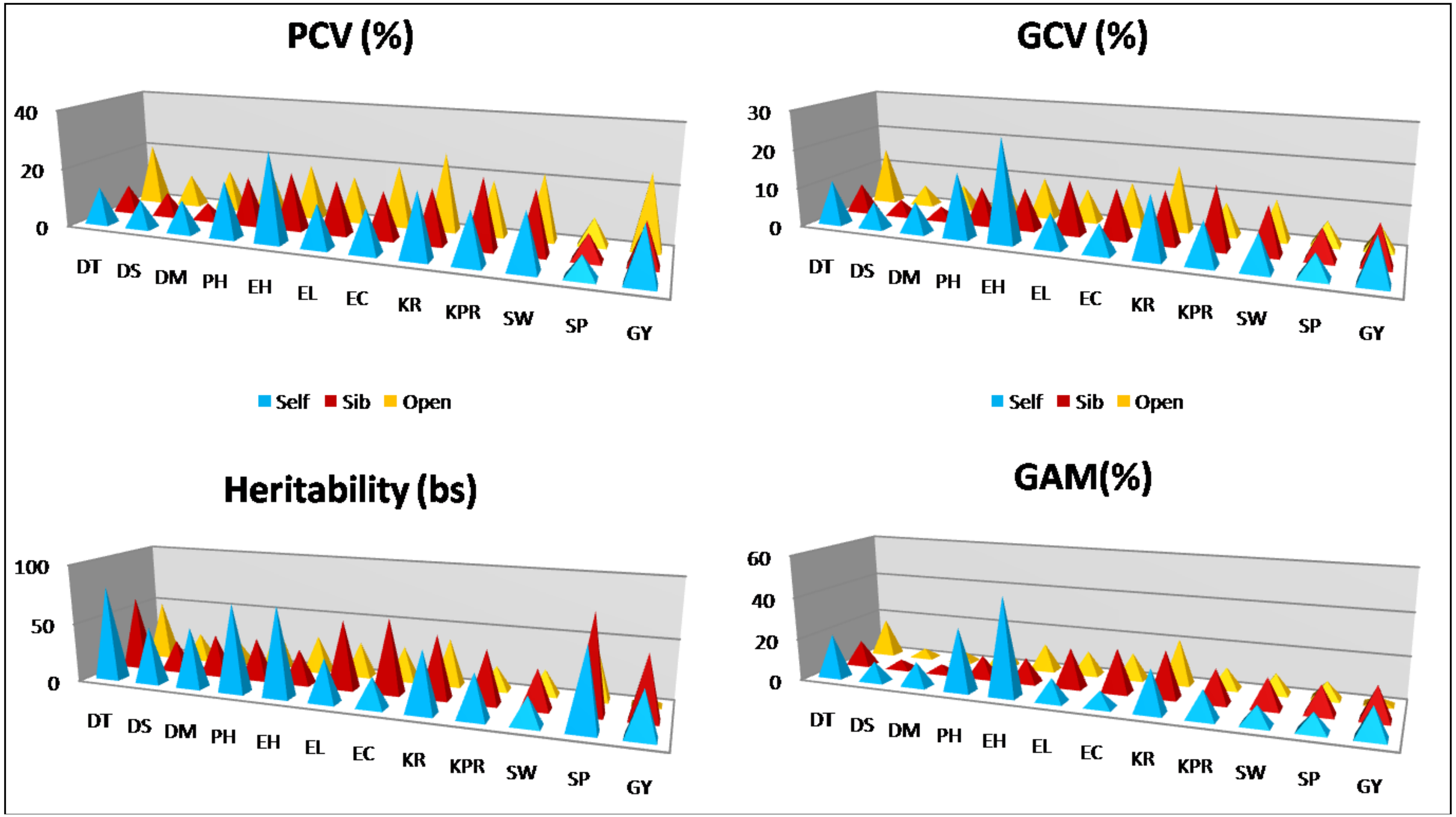

Fig. 1. Estimates of Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), Heritability (bs) and Genetic Advance as percent of Mean (GAM) in S_3 (F_4) generation of three way cross

DT - Days to 50% tasseling; DS - Days to 50% silking; DM - Days to maturity; PH - Plant height (cm); EH - Ear height (cm); EL - Ear length (cm); EC - Ear circumference (cm); KR - Number of kernel rows^{-1}; KPR - Number of kernels row^{-1}; SW - 100 seed weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

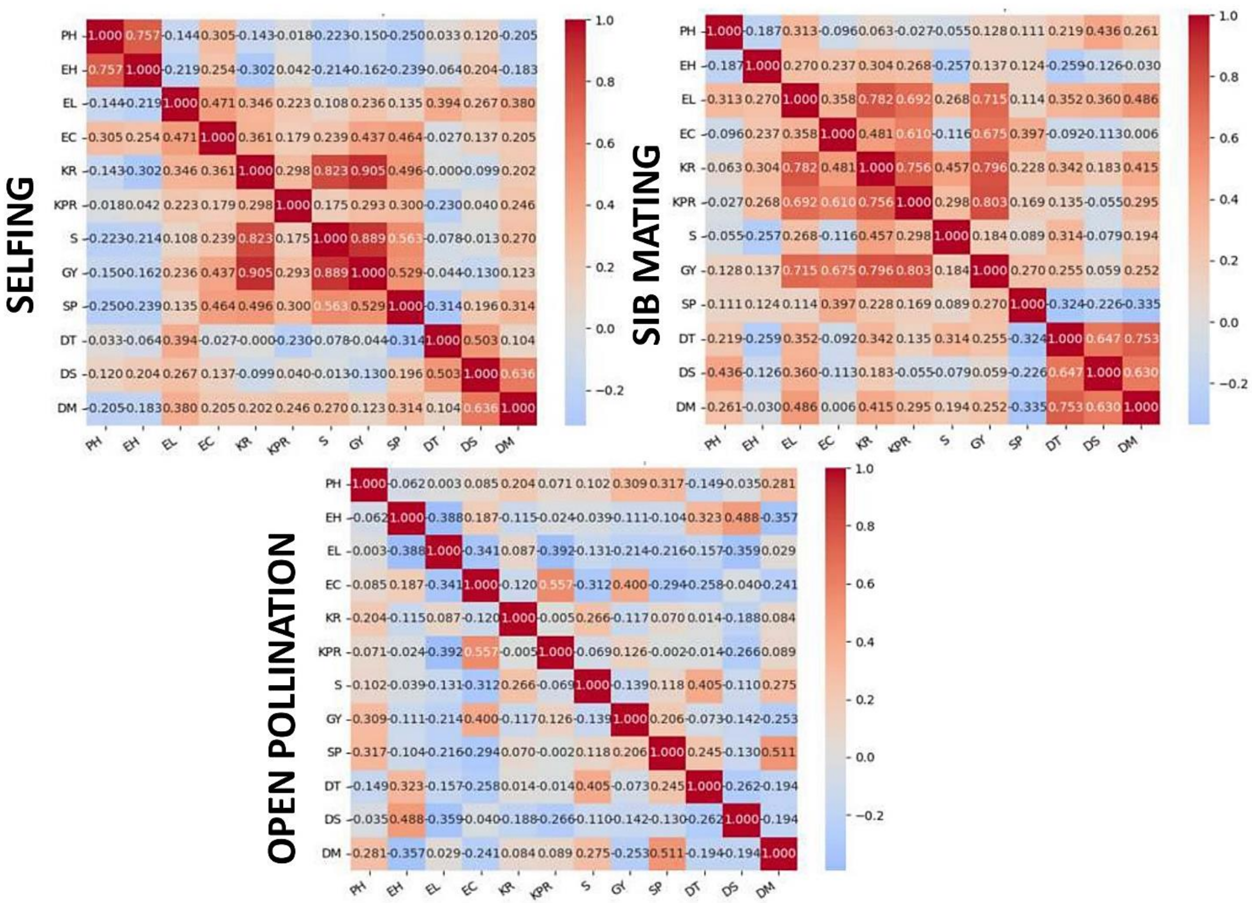

Fig. 2. Estimates of correlation coefficients in S_3 (F_4) generation of three way cross

DT - Days to 50% tasseling; DS - Days to 50% silking; DM - Days to maturity; PH - Plant height (cm); EH - Ear height (cm); EL - Ear length (cm); EC - Ear circumference (cm); KR - Number of kernel rows^{-1}; KPR - Number of kernels row^{-1}; S - 100 seed weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

On the other hand, open pollination was surpassed by the other two mating systems for GCV, as highest GCV in its populations were restricted to days to 50 per cent tasseling and number of kernel rows ear^{-1}. Selfed progeny revealed highest GCV for days to 50 per cent silking, days to maturity, plant height, ear height and grain yield plant^{-1} while sib mating exhibited highest GCV for ear length, ear circumference, number of kernels row^{-1}, 100 seed weight and shelling percentage. High GCV (> 20%) was observed for ear height in selfed progenies while low GCV (< 10%) was seen for days to 50% silking, days to 50% tasseling, ear length, ear circumference, 100 seed weight and shelling percentage (selfing), days to 50% tasseling, days to 50% silking, days to maturity, plant height and shelling percentage (sib mating), days to 50% silking, days to maturity, ear length, number of kernels row^{-1}, shelling percentage and grain yield plant^{-1} (open pollination). The values of GCV are more pivotal in breeding programmes than PCV and many yield related traits showed highest GCV in sib mating while selfed progenies showed for flowering traits besides plant height, ear height and grain yield (Table 3) (Fig. 1). The better performance of selfed and sib mated progenies over open mated populations may be due to accumulation of desirable genes and/or breakage of undesirable linkages. Linkage disequilibrium could be a serious factor causing reduced genetic variability in some traits of the populations advanced through open mating as compared to selfing and sib mating. Higher GCV implies the active role of additive genes thus making the selection for such traits highly effective [16].

3.1.4 Heritability (broad sense) and genetic advance as per cent of mean (GAM)

Our study showed high (> 60%), moderate (30-60%) and low (< 30%) heritability for various characters studied as given by [17] (Table 3, Fig. 1). Selfed progenies showed high heritability for days to 50% tasseling, plant height and ear height [6] while sib mated progenies exhibited similar response for days to 50% tasseling, ear circumference and shelling percentage. None of the traits showed high heritability in open pollinated populations. Among the three mating systems, flowering and maturity traits, plant height and ear height showed highest heritability in self pollination while yield and its contributing traits like ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight and shelling percentage were found to exhibit highest heritability in sib mating.

The estimates of genetic advance as percent of mean (GAM) also revealed similar results with days to 50% tasseling, days to 50% silking, days to maturity, plant height and ear height showing highest GAM in selfed plants while sib mated plants exhibited highest GAM for ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight, shelling percentage and grain yield plant^{-1}. Selfing revealed high GAM (>20%) for days to 50% tasseling, plant height, ear height, low (<10%) for days to 50% silking, ear circumference, 100 seed weight and shelling percentage while remaining traits exhibited moderate GAM (10-20%) [17]. Among sibbed plants, high GAM was seen for ear circumference and number of kernel rows ear^{-1}, low for days to 50% silking and days to maturity and moderate for remaining traits. High GAM in open mated plants was observed for number of kernel rows ear^{-1}, low for days to 50% silking, days to maturity, number of kernels row^{-1}, 100 seed weight, shelling percentage and grain yield plant^{-1} and moderate GAM for remaining traits. High heritability and GAM directly affect the success of selection and traits showing low estimates of these parameters cannot be improved through direct selection. High heritability and high GAM indicates additive gene action controlling the trait while non-additive gene effects may result in high heritability but low GAM. High heritability does not necessarily represent high genetic gains but indicates the efficacy of selection process. High estimates of GAM result from selection of genotypes possessing superior traits with high heritability [18]. In our study, selfing manifested high heritability and high GAM for days to 50% tasseling, PH and ear height while similar response was observed for ear circumference in sib mating.

3.2 Changes in Character Associations Due to Different Mating Systems

In the selfed progenies, the traits ear length (0.236), ear circumference (0.437), number of kernel rows ear^{-1} (0.905), number of kernels row^{-1} (0.293), 100 seed weight (0.889), shelling percentage (0.529) and days to maturity showed positive correlations with GY while days to 50 per cent tasseling (-0.044), days to 50 per cent silking (-0.130), plant height (-0.150) and ear height (-0.162) exhibited negative associations [19]. Further, it was observed that number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight and shelling percentage showed positive correlations among themselves and also with grain yield plant^{-1} making selection for yield easier. Sib mating expressed positive correlations between grain yield plant^{-1} and all the other traits studied which is highly desirable for making simultaneous selection of many traits [20]. The significant positive associations among these characters indicated higher possibilities for simultaneous improvement of these traits through selection. However positive association between flowering traits and grain yield plant^{-1} may be dealt with carefully while selecting for early genotypes unlike in selfed progenies where early genotypes possessed better yielding traits. The characters ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight and shelling percentage revealed positive associations among themselves many of which were significant, and also with grain yield plant^{-1} except where negative correlation was observed between ear circumference and 100 seed weight (-0.116). Among open mated populations, grain yield plant^{-1} exhibited non-significant positive correlations with plant height (0.309), ear circumference (0.400), number of kernels row^{-1} (0.126) and shelling percentage (0.206) while negative associations with grain yield plant^{-1} was expressed by ear height, ear length, number of kernel rows ear^{-1}, 100 seed weight, days to 50% tasseling, days to 50% silking and days to maturity [21,22,23]. It was also observed that a negative association existed between ear length and ear circumference in contrary to the findings of [20] and [24] (Table 3, Fig. 2).

Comparison of the three mating systems showed that sib mating produced additional thirteen positive correlations than self pollination and thirty new correlations over open pollination among various characters. Although sib mating also produced twelve negative correlations which were positive in self or open pollination methods, it is noteworthy that these were mostly related to plant height or ear height or flowering characters which need not be considered as shortcomings as long as desired yield levels are attainable. Nonetheless, all traits showing positive association with grain yield plant^{-1}, with yield attributing traits like ear length, ear circumference, number of kernel rows ear^{-1}and number of kernels row^{-1} exhibiting significant association implies that sib mating manifested better trait associations than selfing and open pollination. The new positive correlations exhibited by sib mating may have been a result of new recombinations reinforced by the mating system resulting in conversion of repulsion type of linkages into coupling type for these character combinations [25,26,27].

4. CONCLUSION

Sib mating produced higher number of transgressive segregants compared to self pollination suggesting higher chances of developing potential inbreds. Open pollination for four or more cycles maybe adopted for breaking tight linkages between traits. Sib mating manifested high GCV, heritability and GAM for yield traits while selfing for flowering traits. Therefore, sib mating or a concoction of few early cycles of sib mating followed by selfing may be adopted for development of vigorous inbred lines in maize for development of diverse and superior inbreds.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khan MU, Shah SMA, Rahman H, Iqbal A, Aslam E. Evaluation of maize hybrids for yield and maturity traits. Sarhad Journal of Agriculture. 2019;35:7-12.
2. Kresović B, Tapanarova A, Tomić Z, Životić L, Vujović D, Sredojević Z, Gajić B. Grain yield and water use efficiency of maize as influenced by different irrigation regimes through sprinkler irrigation under temperate climate. Agric. Water Manag. 2016;169:34-43. Avilable:https://doi.org/10.1016/j.agwat.2016.01.023
3. Makore F, Magorokosho C, Dari S, Gasura E, Mazarura U, Kamutando CN. Genetic potential of new maize inbred lines in single-cross hybrid combinations under low-nitrogen stress and optimal conditions. Agronomy. 2022;12(9):2205. Avilable:https://doi.org/10.3390/agronomy12092205
4. Prasanna BM. Developing and deploying abiotic stress-tolerant maize varieties in

the tropics: challenges and opportunities. In: Molecular Breeding for Sustainable Crop Improvement. Sustainable Development and Biodiversity. 2016;11. Springer Cham.
Avilable:https://doi.org/10.1007/978-3-319-27090-6_3

5. Stringfield GH. Developing heterozygous parent stocks for maize hybrids. DeKalb Ag Research Inc.: 1974; DeKalb IL USA.
6. Bartaula SU, Panthi K, Timilsena SS, Acharya, Shrestha J. Variability, heritability and genetic advance of maize (*Zea mays* L.) genotypes. Res. Agric. Livest. Fish. 2019;6(2):163-169.
7. Kandel BP, BK Sharma, S Sharma and J Shrestha. Genetic variability, heritability, and genetic advance estimates in early maize (*Zea mays* L.) genotypes in Nepal. Agricultura, 2018;107(3-4):29-35.
8. Okoye NF, Oluwaranti A, Fakorede MAB, Akinwale RO. Seed production growth and grain yield of self half-sib and bulk-sib progenies developed from an early-maturing maize (*Zea mays* L.) population. Asian Research Journal of Agriculture. 2018;9(4):1-12.
9. Ahmmed MA, Mehra RB. Impact of mating systems on genetic variability in a cross of *Gossypium barbadense*. Indian Journal of Genetics. 2000; 60(3): 359-371.
10. Pradeep T, Sumalini K. Transgressive segregation for yield and yield components in some inter and intra specific crosses of desi cotton. Madras Agricultural Journal, 2003;90(1-3):152-154.
11. Khan S, Mahmud F. Genetic Variability and character association of yield components in maize (*Zea mays* L.). American Journal of Plant Sciences. 2021;12:1691-1704.
12. Choudhary AK, Chaudhary LB. Genetic studies in some crosses of maize (*Zea mays* L.). Journal of Research Birsa Agricultural University. 2002;5(1/2):10-16.
13. Dogar, MW, Hussain Z, Ashraf MI, Naveed M. Evaluation of genetic variability in maize (*Zea mays* L.) based on yield and its attributed traits. Asian Journal of Biotechnology and Genetic Engineering. 2023;6(2):200-210.
14. Singh P, Das S, KumarY, Dutt Y, Sangwan O. Variability studies for grain yield and its component traits in maize (*Zea mays* L.). Annals of Agri-Bio Research. 2003;8:2-31.24.
15. Sivasubramanian S, Menon M. Heterosis and inbreeding depression in rice. Madras Agric. J. 1973;60:1139.
16. Jilo T, Tulu L, Birhan T, Beksisa L. Genetic variability, heritability and genetic advance of maize (*Zea mays* L.) inbred lines for yield and yield related traits in South Western Ethiopia. J. Plant Breed. Crop Sci. 2018;10(10):281-289.
DOI:10.5897/JPBCS2018.0742
17. Johnson HW, Robinson HF, Cornstock RE. Estimates of genetic and environmental variability in soybeans. Agr. J. 1955;47:314–318.
18. Magar BT, Acharya S, Gyawali B, Timilsena K, Upadhayaya J, Shrestha J. Genetic variability and trait association in maize (*Zea mays* L.) varieties for growth and yield traits. Heliyon. 2021;7 e07939.
19. Barros LB, Moreira RMP, Ferreira JM. Phenotypic additive genetic and environment correlations of maize landraces populations in family farm systems. Sci. Agric. (Piracicaba Braz.). 2010;67(6):685-691.
20. Chetan HT, Potdar MP, Nadagouda BT, Patil PL, Patil CR. Correlations among Grain yield and Yield attributes in Maize Hybrids as Influenced by Site Specific Nutrient Management (SSNM). Int. J. Curr. Microbiol. Appl. Sci. 2017;6(8):2292-2296.
Avilable:https://doi.org/10.20546/ijcmas.2017.608.269
21. Altman DW, Busch RU. Random intermating before selection in spring wheat. Crop Sci. 1984;24:1085-1089.
22. Hanson WD. The breakup of initial linkage blocks under selected mating systems. Genetics. 1959;44:857-868.
Avilable:https://doi.org/10.4236/ajps.2021.1211118
23. Miller PA, Rawlings JO. Breakup of initial linkage blocks through intermating in a cotton breeding population. Crop Sci. 1967;7:199-204.
24. Kumar V, Singh SK, Bhati PK, Sharma A, Sharma SK, Mahajan V. Correlation, path and genetic diversity analysis in maize (*Zea mays* L.). Environ. Ecol. 2015;33(2A):971-975.
25. Bains SS. Genetics of yield and fibre quality in an intervarietal cross in *G. hirsutum* L. Ph. D. Thesis IARI, New Delhi India; 1971.
26. Singh BB, Murty BR. A comparative analysis of biparental mating and selfing in

pearl millet (*P. lyphoides* S and H). Theor. Appl. Genet. 1973;43:18-22.
27. Thomas G. Studies on effect of mating systems on genetic variability association and path coefficient analysis in Sunflower (*Helianthus annus* L.). Ph.D Thesis. CCS Haryana Agricultural University Hisar India; 1998.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121563