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Comparative Study on Impact of Mating Systems on Character Associations in Single Crosses of Maize (*Zea mays* L.)

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Authors' contributions

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

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ABSTRACT

Although global maize breeding programmes are in momentum with high number of superior hybrids releasing annually, the full potential of hybrids is seldom achieved in real time due to various biotic and abiotic stresses. It is pertinent to broaden the diversity of available germplasm to suit to the needs of present changing climatic conditions. In this study, six segregating populations

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of two maize single crosses developed by imposing three types of matings (self, sib and random mating) were evaluated to assess their potential in future breeding programmes. Trait association studies were conducted in these populations to estimate the success rate of selections, time required to develop superior inbreds and assist in parental choice for hybrid development programmes. Results indicated that sib mating was the most effective among the three mating systems, as its progeny showed highest number of significant positive correlations among the yield and its related traits. Selfed progenies exhibited lesser number or weak positive correlations while random mating largely resulted in negative and weak positive correlations.

Keywords: Single cross; mating systems; selfing; sib mating; random mating; 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. Together with rice and wheat, maize provides at least 30% of the food calories to more than 4.5 billion people in 94 developing countries [1]. It has dual importance as 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. Global population is predicted to reach 9.7 billion by 2050 implying an annual requirement of 37 M t of maize as food [2] thus demanding a three-fold increase of production in India [3].

Changing climatic scenario resulting in increased biotic and abiotic stresses, and stagnating yields are the current challenges for increasing maize production to meet the future demands. Although maize yields appear satisfactory on paper, they are seldom achieved to the full given their sensitivity to various external limiting factors. Hence research efforts should invariably be focussed on strengthening the genetic base for meeting the current challenges in order to develop stable hybrids. Enhancing the genetic diversity of germplasm to develop robust inbreds and thereby hybrids is a viable option [4]. Self pollination is commonly used in the inbred line development programmes though it is associated with high inbreeding depression. Use of other forms of matings can assist in generation of diverse recombinants that retain certain magnitude of heterozygosity till advance generations. Assessment of correlations among yield and yield related characters is a pre requisite for determining the suitability of these lines in hybrid development programmes. Correlation analysis is a valuable tool in plant breeding programs, helping breeders to make informed decisions about trait selection, parent choices, resource allocation, and also assisting in monitoring the progress. Hence, conducting trait association studies forms an important part of any inbred development programme. With this background, the present study was made to assess the character associations between different traits among the recombinants developed from two single crosses of maize as influenced by three mating systems *ie*., selfing, sib mating and random mating.

2. MATERIALS AND METHODS

The base experimental material comprised of two single crosses *ie.,* BML-14 x BML-6 (SC-1) and BML-51 x BML-32 (SC-2) which was grown during *kharif* 2016 at Regional Agricultural Research Station, Palem, Telangana State, India. Three mating systems *viz.* selfing, sib mating and random mating (open pollination) were imposed separately on the two crosses and resultant seed was harvested separately. Same procedure was followed for three seasons to obtain S_3 generation of selfed and sib mated progenies and third open pollinated (OP3) generation of random mating. The six S_3 populations thus generated from the two single crosses were raised during *rabi* 2017-18 in randomized block design with three replications each. Observations were recorded for twelve characters *viz*., 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 kernel weight (g), shelling percentage (%) and grain yield plant^{-1} (g) to evaluate the S_3 progenies for trait association studies.

For statistical analysis, the variance components of each character and the covariance components for each pair of characteristics were calculated using the methods described by [5] and the phenotypic and genotypic correlation coefficients were calculated.

Genotypic correlation coefficient = Covxy (genotypic) / √(var x) (var y) (genotypic)

Where,

Genotypic variance = Treatment MS – Error MS / Number of replications

Similarly,

Genotypic covariance = Treatment Cov – Error Cov / Number of replications

Phenotypic correlation coefficient = Covxy (phenotypic) / √(var x)(var y)(phenotypic)

The simple correlation coefficients were calculated to determine the degree of association of different characters with grain yield and among yield components in the population. Correlation coefficients were compared against Table "r" values [6] at (n-2) degrees of freedom at the probability levels of 0.05 and 0.01 to test their significance.

3. RESULTS AND DISCUSSION

3.1 Comparison of Effect of Mating Systems in Single Cross-1 (BML-14 x BML-6)

3.1.1 Selfing

Grain yield plant^{-1} exhibited significant positive association with ear length (0.790), ear circumference (0.821), number of kernel rows ear^{-1} (0.664), number of kernels row^{-1} (0.670), 100 kernel weight (0.793) and shelling percentage (0.748) and negative association with days to 50% tasseling (-0.093), days to 50% silking (-0.339) and days to maturity (-0.462).

The character days to 50% tasseling showed negative correlation with most of the other characters like plant height (-0.227), ear height (-0.195), ear length (-0.185), number of kernel rows ear^{-1} (-0.097), number of kernels row^{-1} (-0.547), shelling percentage (-0.110) and grain yield plant^{-1} (-0.093) while it showed positive correlation with ear circumference (0.059) and 100 kernel weight (0.006). Nonetheless, all the correlations (positive and negative) exhibited by this trait were non significant except for number of kernels row^{-1} where it showed significant negative correlation. Days to 50% silking and days to maturity exhibited positive correlation only with plant height (0.326) and ear height (0.373) and negative for the remaining characters. Days to 50% silking showed significant correlation with ear height (0.373) while days to maturity showed significant negative correlation with ear circumference (-0.617), 100 kernel weight (-0.435), grain yield plant^{-1} (-0.462) and shelling percentage (-0.531).

Plant height and ear height exhibited positive correlation with each other (0.943) and also with number of kernel rows ear^{-1} (0.184, 0.111), days to 50% silking (0.326, 0.373), and days to maturity (0.107, 0.164). Ear length showed significant positive correlation with ear circumference (0.692), number of kernel rows ear^{-1} (0.380), number of kernels row^{-1} (0.777), 100 kernel weight (0.739), grain yield plant^{-1} (0.790), shelling percentage (0.706) and days to maturity (0.547). Similarly, ear circumference showed significant positive correlation with number of kernel rows ear^{-1} (0.460), number of kernels row^{-1} (0.542), 100 kernel weight (0.840) and shelling percentage (0.729). Number of kernel rows ear^{-1} revealed positive association with number of kernels row^{-1} (0.320), 100 kernel weight (0.398), grain yield plant^{-1} (0.664) and shelling percentage (0.249) though association was significant only with 100 kernel weight and grain yield plant^{-1}. 100 kernel weight showed significant positive association with grain yield plant^{-1} (0.793) and shelling percentage (0.749) (Table 1).

3.1.2 Sib mating

Sib mating showed positive correlations among most of the characters while negative correlation was observed between plant height and shelling percentage (-0.248), ear height and days to maturity (-0.269), days to maturity and grain yield plant^{-1} (-0.019) and days to 50% silking and shelling percentage (-0.097). It was observed that grain yield plant^{-1} showed significant positive correlation with ear length (0.484), ear circumference (0.488), number of kernel rows ear^{-1} (0.745) and number of kernels row^{-1} (0.748). Days to 50% tasseling showed significant positive correlation with number of kernel rows ear^{-1} (0.369) and 100 kernel weight (0.415) whereas days to 50% silking showed significant positive correlation with plant height (0.480), number of kernel rows ear^{-1} (0.383), 100 kernel weight (0.385), grain yield plant^{-1} (0.380) and days to 50% tasseling (0.683) while days to maturity exhibited significant positive correlation with number of kernel rows ear^{-1} (0.374).

Ear height showed significant positive association with number of kernels row^{-1} (0.476) and 100 kernel weight (0.443) while ear length exhibited similar relation with ear circumference (0.898), number of kernel rows ear^{-1} (0.784), number of kernels row^{-1} (0.666), 100 kernel weight (0.555) and grain yield plant^{-1} (0.484). Number of kernel rows ear^{-1} (0.745), number of kernels row^{-1} (0.748) and 100 kernel weight (0.809) showed significant positive associations with grain yield plant^{-1} and also among themselves (Table 1).

3.1.3 Random mating

Grain yield plant^{-1} showed positive correlation with plant height (0.139), ear height (0.099), number of kernels row^{-1} (0.026) and days to 50% tasseling (0.394) while it exhibited negative correlation with ear length (-0.193), ear circumference (-0.006), number of kernel rows ear^{-1} (-0.255), 100 kernel weight (-0.143), shelling percentage (-0.036), days to 50% silking (-0.141) and days to maturity (-0.086). Days to 50% tasseling exhibited positive correlation with plant height (0.106) and ear length (0.077) while days to 50% silking displayed positive correlation with plant height (0.059), ear circumference (0.322), number of kernels row^{-1} (0.312) and 100 kernel weight (0.159) whereas days to maturity showed positive correlation with plant height (0.203), ear height (0.118) and number of kernel rows ear^{-1} (0.080).

Plant height showed positive correlation with ear height (0.170), number of kernel rows ear^{-1} (0.087), 100 kernel weight (0.075), grain yield plant^{-1} (0.139), days to 50% tasseling (0.106), days to 50% silking (0.059) and days to maturity (0.203) while it exhibited negative correlation with ear length (-0.442), ear circumference (-0.274), number of kernels row^{-1} (-0.151) and shelling percentage (-0.035). Ear height showed positive association with ear length (0.315), 100 kernel weight (0.491), grain yield plant^{-1} (0.099) and days to maturity (0.118) while ear length exhibited positive correlation with ear circumference (0.143), number of kernel rows ear^{-1} (0.166), 100 kernel weight (0.174), shelling percentage (0.299) and days to 50% tasseling (0.077). Ear circumference exhibited positive association with ear length (0.143), number of kernels row^{-1} (0.237) and days to 50% silking (0.322). Results also indicated that number of kernel rows ear^{-1} was positively correlated with plant height (0.087), ear length (0.166), 100 kernel weight (0.311), shelling percentage (0.142) and days to maturity (0.080) while number of kernels row^{-1} was positively associated with ear circumference (0.237), grain yield plant^{-1} (0.026), shelling percentage (0.095) and days to 50% silking (0.312). 100 kernel weight showed positive correlation with plant height (0.075), ear height (0.491), ear length (0.174), number of kernel rows ear^{-1} (0.311) and days to 50% silking (0.159) while shelling percentage displayed positive correlation with ear length (0.299), number of kernel rows ear^{-1} (0.142) and number of kernels row^{-1} (0.095) (Table 1).

It was observed that thirty two additional correlations were established in sib mating compared to selfing and random mating between different characters in the progeny of SC-1. However, correlation between ear height and days to maturity was found to be negative in sib mating while it was positive in the other two mating systems (Fig. 1).

3.2 Comparison of Effect of Mating Systems in Single Cross-2 (BML-51 x BML-32)

3.2.1 Selfing

Grain yield plant^{-1} showed strong positive correlation with ear circumference (0.415), number of kernel rows ear^{-1} (0.456), number of kernels row^{-1} (0.836) and 100 kernel weight (0.735), non-significant positive correlation with ear height (0.082) and negative correlation with days to 50% tasseling (-0.002), plant height (-0.325) and shelling percentage (-0.053).

The character days to 50% tasseling exhibited positive correlation with plant height (0.205), ear length (0.007), number of kernel rows ear^{-1} (0.005), 100 kernel weight (0.080) and shelling percentage (0.116) and negative correlation with ear height (-0.045), ear circumference (-0.114), number of kernels row^{-1} (-0.099) and grain yield plant^{-1} (-0.002). Days to 50% silking showed significant positive correlation with plant height (0.387) and days to 50% tasseling (0.806) and non-significant positive association with number of kernels row^{-1} (0.014) and grain yield plant^{-1} (0.024) and negative association with ear height (-0.115), ear length (-0.064), ear circumference (-0.022), number of kernel rows ear^{-1} (-0.042), 100 kernel weight (-0.013) and shelling percentage (-0.133). Days to maturity showed significant positive correlation with number of kernels row^{-1} (0.363), 100 kernel weight (0.520) and days to

50% tasseling (0.363) and non-significant positive association with ear circumference (0.164), number of kernel rows ear^{-1} (0.201), grain yield plant^{-1} (0.323), shelling percentage (0.018) and days to 50% silking (0.293).

Plant height exhibited positive correlation with ear height (0.085), ear circumference (0.007) while ear height exhibited positive association with characters ear circumference (0.093) and grain yield plant^{-1} (0.082). Ear length showed positive association with number of kernel rows ear^{-1} (0.021), number of kernels row^{-1} (0.224), 100 kernel weight (0.199) and grain yield plant^{-1} (0.251) and negative association with ear circumference (-0.203) and shelling percentage (-0.120) whereas ear circumference revealed significant positive correlation with number of kernel rows ear^{-1} (0.701), number of kernels row^{-1} (0.399), 100 kernel weight (0.532) and grain yield plant^{-1} (0.415) and non-significant positive correlation with shelling percentage (0.001). Number of kernel rows ear^{-1} and number of kernels row^{-1} showed significant positive correlations among themselves and also with 100 kernel weight and grain yield plant^{-1} (Table 2).

3.2.2 Sib mating

Grain yield plant^{-1} showed significant positive correlation with ear length (0.914), ear circumference (0.812), number of kernel rows ear^{-1} (0.818), number of kernels row^{-1} (0.865) and 100 kernel weight (0.930) and non-significant positive correlation with plant height (0.097), ear height (0.082) and days to 50% tasseling (0.125) while it showed negative correlation with days to 50% silking (-0.002) and days to maturity (-0.193).

Days to 50% tasseling showed positive correlation with all traits while days to 50% silking exhibited similar behaviour except with grain yield plant^{-1} (-0.002) which was a negative association. Days to maturity showed significant positive correlation with days to 50% tasseling (0.808) and days to 50% silking (0.902), non-significant positive association with plant height (0.209), ear height (0.034), ear length (0.010), ear circumference (0.010), number of kernel rows ear^{-1} (0.038) and shelling percentage (0.187) while it exhibited non-significant negative correlation with number of kernels row^{-1} (-0.011), 100 kernel weight (-0.111) and grain yield plant^{-1} (-0.193). Plant height showed significant positive correlation with ear height (0.613) and number of kernel rows ear^{-1} (0.431) while it showed non-significant positive association with ear length (0.144), ear circumference (0.238), number of kernels row^{-1} (0.304), 100 kernel weight (0.137), grain yield plant^{-1} (0.097) and shelling percentage (0.101). The character ear height exhibited non-significant positive correlation with ear circumference (0.259), number of kernel rows ear^{-1} (0.236), 100 kernel weight (0.055), grain yield plant^{-1} (0.082) and shelling percentage (0.117) while it was negatively correlated with ear length (-0.017) and number of kernels row^{-1} (-0.013). The traits ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1} and 100 kernel weight showed significant positive correlations among themselves and also with grain yield plant^{-1}. Shelling percentage had non-significant and negative association with ear length (-0.068), number of kernel rows ear^{-1} (-0.234), number of kernels row^{-1} (-0.063), 100 kernel weight (-0.007) and grain yield plant^{-1} (-0.099) while it displayed non-significant positive association with plant height (0.101) and ear height (0.117) (Table 2).

3.2.3 Random mating

Results indicated that grain yield plant^{-1} exhibited positive correlation with ear height (0.132), ear circumference (0.149), number of kernels row^{-1} (0.257), shelling percentage (0.017), days to 50% silking (0.081) and days to maturity (0.129) while it exhibited negative correlation with plant height (-0.196), ear length (-0.451), number of kernel rows ear^{-1} (-0.313), 100 kernel weight (-0.472) and days to 50% tasseling (-0.121).

Table 1. Correlation coefficients between different characters due to three mating systems in SC-1 of maize

Character	Mating system	PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
PH	Self		0.943**	-0.009	-0.289	0.184	-0.025	-0.116	-0.120	-0.240	-0.227	0.326	0.107
	Sib		0.319	0.261	0.288	0.309	0.235	0.145	0.171	-0.248	0.304	0.480**	0.171
	Random		0.170	-0.442	-0.274	0.087	-0.151	0.075	0.139	-0.035	0.106	0.059	0.203
EH	Self			-0.135	-0.419	0.111	-0.099	-0.220	-0.206	-0.318	-0.195	0.373*	0.164
	Sib			0.167	0.247	0.282	0.476**	0.443*	0.298	0.169	0.012	0.057	-0.269
	Random			0.315	-0.049	-0.238	-0.315	0.491**	0.099	-0.082	-0.016	-0.229	0.118
EL	Self				0.692**	0.380*	0.777**	0.739**	0.790**	0.706**	-0.185	-0.343	0.547**
	Sib				0.898**	0.784**	0.666**	0.555*	0.484**	0.096	0.001	0.152	0.225
	Random				0.143	0.166	-0.381*	0.174	-0.193	0.299	0.077	-0.383	-0.197
EC	Self					0.460*	0.542**	0.840**	0.821**	0.729**	0.059	-0.318	-0.617**
	Sib					0.761**	0.720**	0.570**	0.488**	0.126	0.117	0.265	0.160
	Random					-0.437	0.237	-0.155	-0.006	-0.020	-0.082	0.322	-0.196
KR	Self						0.320	0.398*	0.664**	0.249	-0.097	-0.204	-0.115
	Sib						0.909**	0.867**	0.745**	0.104	0.369*	0.383*	0.374*
	Random						-0.048	0.311	-0.255	0.142	-0.196	-0.009	0.080
KPR	Self							0.690**	0.670**	0.519**	-0.547**	-0.062	-0.247
	Sib							0.942**	0.748**	0.259	0.329	0.348	0.207
	Random							-0.034	0.026	0.095	-0.531**	0.312	-0.164
SW	Self								0.793**	0.749**	0.006	-0.205	-0.435*
	Sib								0.809**	0.180	0.415*	0.385*	0.215
	Random								-0.143	-0.193	-0.006	0.159	0.122
GY	Self									0.748**	-0.093	-0.339	-0.462*
	Sib									0.141	0.346	0.380*	-0.019
	Random									-0.036	0.394*	-0.141	-0.086
SP	Self										-0.110	-0.197	-0.531*
	Sib										0.166	-0.097	0.077
	Random										-0.159	-0.029	-0.301
DT	Self											-0.185	-0.213
	Sib											0.683**	0.296
	Random											0.014	-0.147
DS	Self												-0.138
	Sib												0.249

Character	Mating system	PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
	Random												-0.044

*** Significant at 1% ,* Significant at 5%*

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 ear^{-1}; KPR - Number of kernels row^{-1}; SW - 100 kernel weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

Table 2 .Correlation coefficients between different characters due to three mating systems in SC-2 of maize

Character		PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
PH	Self		0.085	-0.185	0.007	-0.141	-0.281	-0.395*	-0.325	-0.165	0.205	0.387*	-0.007
	Sib		0.613**	0.144	0.238	0.431*	0.304	0.137	0.097	0.101	0.006	0.140	0.209
	Random		-0.048	0.348	-0.315	0.207	0.180	0.270	-0.196	0.008	-0.186	0.302	-0.130
EH	Self			-0.041	0.093	-0.202	-0.006	-0.073	0.082	-0.205	-0.045	-0.115	-0.376*
	Sib			-0.017	0.259	0.236	-0.013	0.055	0.082	0.117	0.051	0.051	0.034
	Random			-0.260	0.084	-0.006	0.277	0.290	0.132	-0.282	0.007	0.122	-0.266
EL	Self				-0.203	0.021	0.224	0.199	0.251	-0.120	0.007	-0.064	-0.056
	Sib				0.792**	0.877**	0.900**	0.874**	0.914**	-0.068	0.233	0.176	0.010
	Random				-0.213	0.115	-0.025	0.110	-0.451*	0.176	0.072	0.151	-0.020
EC	Self					0.701**	0.399*	0.532*	0.415*	0.001	-0.114	-0.022	0.164
	Sib					0.697**	0.722**	0.793**	0.812**	0.109	0.245	0.180	0.010
	Random					-0.381*	-0.187	0.331	0.149	-0.096	-0.145	-0.204	0.381*
KR	Self						0.366*	0.611**	0.456*	0.163	0.005	-0.042	0.201
	Sib						0.877**	0.806**	0.818**	-0.234	0.135	0.154	0.038
	Random						-0.073	-0.144	-0.313	0.059	-0.361*	0.198	-0.173
KPR	Self							0.710**	0.836**	-0.143	-0.099	0.014	0.363*
	Sib							0.851**	0.865**	-0.063	0.101	0.132	-0.011
	Random							-0.191	0.257	0.152	0.226	0.385*	-0.246
SW	Self								0.735**	-0.083	0.080	-0.013	0.520*
	Sib								0.930**	-0.007	0.164	0.122	-0.111
	Random								-0.472**	-0.377*	-0.008	0.132	0.096
GY	Self									-0.053	-0.002	0.024	0.323
	Sib									-0.099	0.125	-0.002	-0.193

Character		PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
	Random									0.017	-0.121	0.081	0.129
SP	Self										0.116	-0.133	0.018
	Sib										0.249	0.147	0.187
	Random										-0.038	-0.274	0.008
DT	Self											0.806**	0.363*
	Sib											0.835**	0.808**
	Random											-0.109	-0.232
DS	Self												0.293
	Sib												0.902**
	Random												-0.212

*** Significant at 1%; * Significant at 5%*

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 ear^{-1}; KPR - Number of kernels row^{-1};SW - 100 kernel weight (g);SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

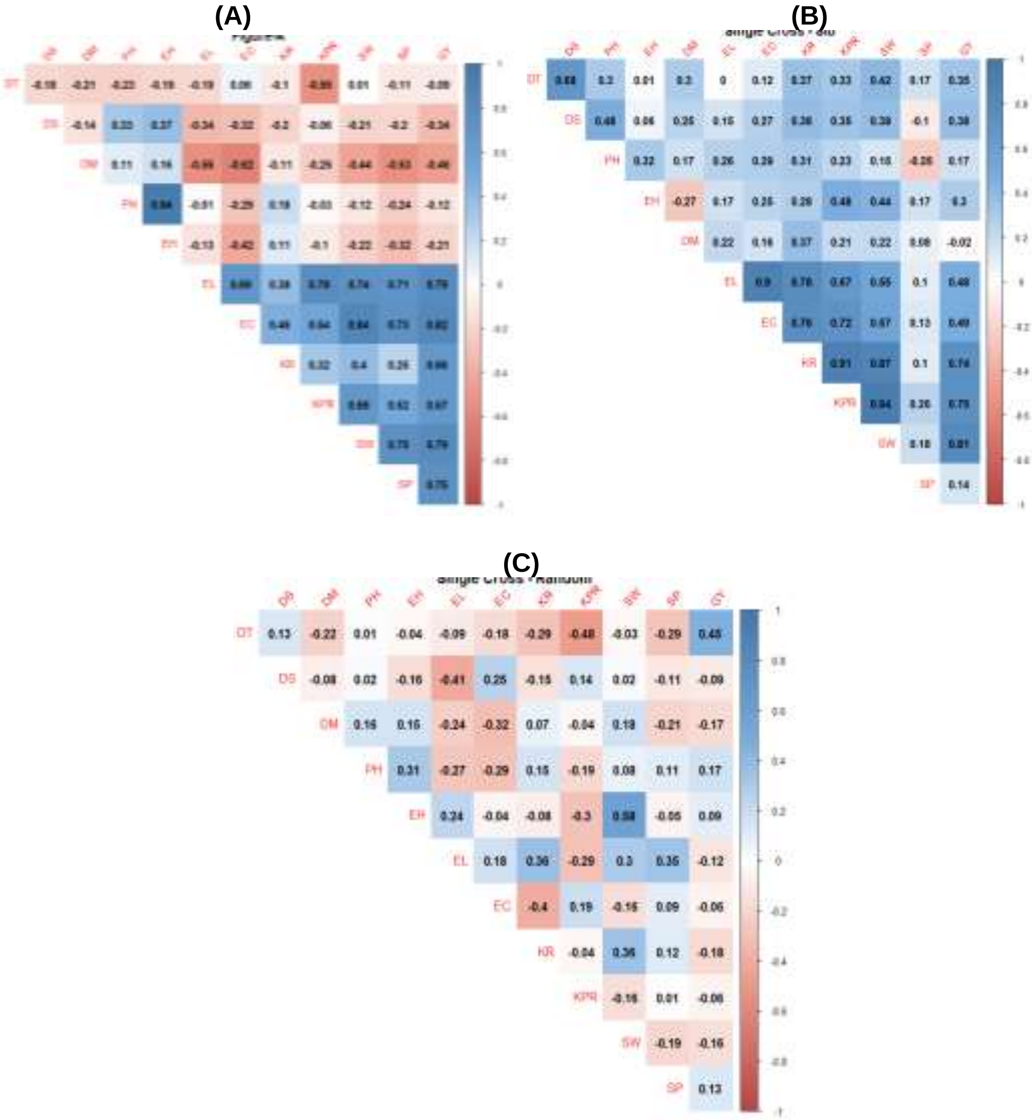

Fig. 1. Changes in correlations due to selfing (A), sibmating (B) and random mating (C) in Single Cross-1 of maize

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 ear^{-1}; KPR - Number of kernels row^{-1}; SW - 100 kernel weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

Days to 50% tasseling showed positive association with ear height (0.007), ear length (0.072) and number of kernels row^{-1} (0.226) while days to 50% silking exhibited positive association with ear height (0.122), ear length (0.151), number of kernel rows ear^{-1} (0.198), number of kernels row^{-1} (0.385), 100 kernel weight (0.132) and grain yield plant^{-1} (0.081). It was observed that days to maturity was positively correlated with ear circumference (0.381), 100 kernel weight (0.096), grain yield plant^{-1} (0.129) and shelling percentage (0.008). Positive association for plant height was observed only with ear length (0.348) while ear height exhibited positive association with ear circumference (0.084), number of kernels row^{-1} (0.277), 100 kernel weight (0.290) and grain yield plant^{-1} (0.132). Ear length showed positive correlation with number of kernel rows ear^{-1} (0.115), 100 kernel weight (0.110) and shelling percentage (0.176) while ear circumference exhibited desirable correlation with100 kernel weight (0.331) and grain yield plant^{-1} (0.149). Positive associations were also observed between number of kernel rows ear^{-1} and shelling percentage (0.059), number of kernels row^{-1} and grain yield plant^{-1} (0.257), number of kernels row^{-1} and shelling percentage (0.152) (Table 2).

Comparison of the three mating systems for correlation coefficients in SC-2 indicated that sib mating resulted in twenty one and thirty one additional correlations over selfing and random mating respectively for different traits. However, nine negative correlations were also found in sib mated progenies which were positive in either of the other two mating systems (Fig. 2).

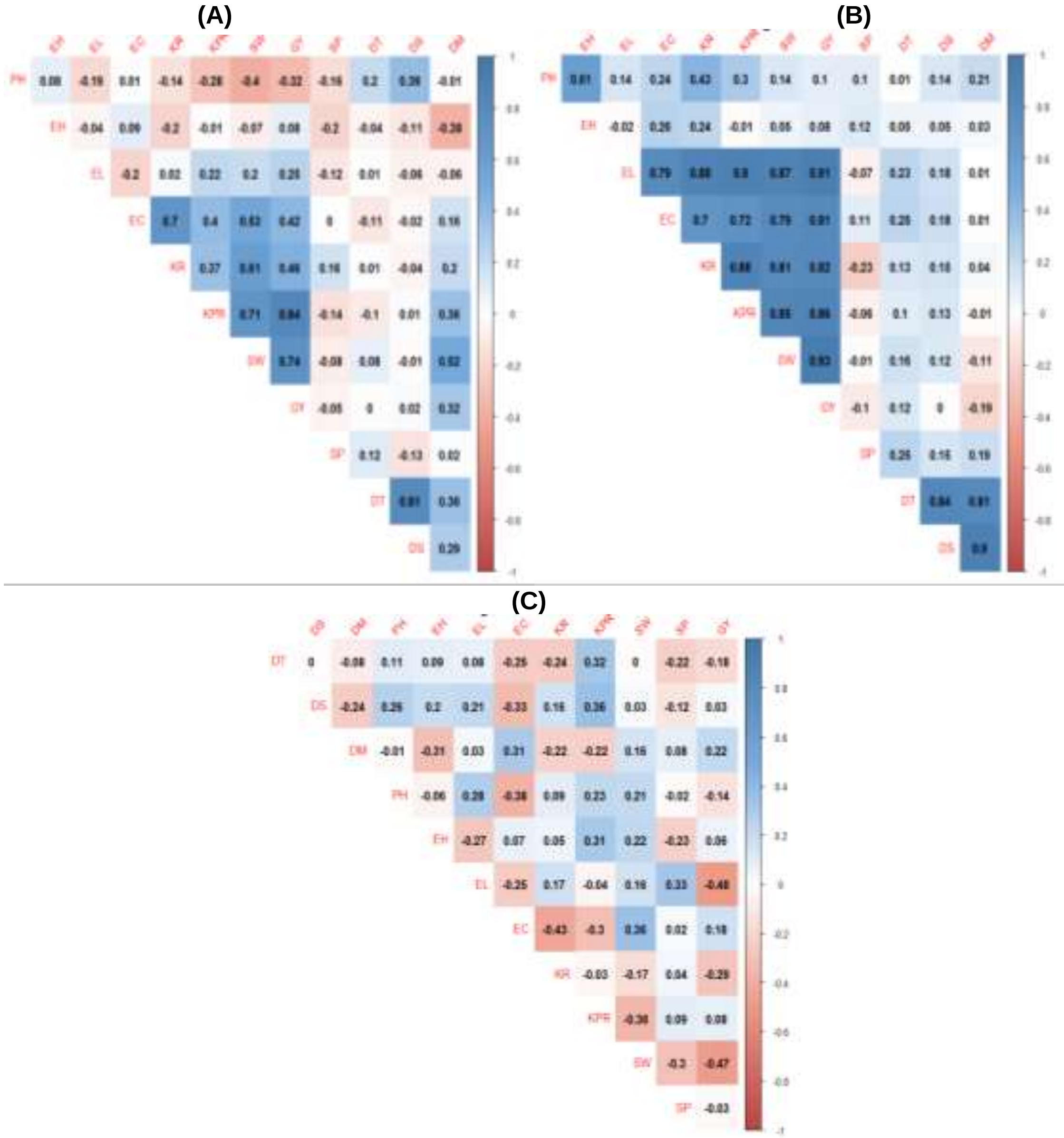

Fig. 2. Changes in correlations due to selfing (A), sibmating (B) random mating (C) in Single Cross-2 of maize

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 ear^{-1}; KPR - Number of kernels row^{-1}; SW - 100 kernel weight (g); SP - Shelling percentage (%); GY - Grain yield plant^{-1} (g)

Thus, it is evident that sib mating established significant and highest number of positive correlations between different characters among the three mating systems. The significant and positive associations for these groups of characters indicate the increased possibilities for simultaneous improvement of traits through selection. The additional positive correlations exhibited by sib mated progenies 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. Further, genetic correlation between traits may be due to linkage or/and pleiotropic effect of the genes [2]. While pleiotropic effect cannot be manipulated, association due to linkage can be affected by deploying appropriate breeding programmes. In a study, biparental mated progenies of pearl millet exhibited additional twelve favourable associations than selfs [7]. The negative or non-significant correlations observed in open pollination indicate that these populations are in linkage disequilibrium and any linkage observed may be due to prevalence of repulsion type linkage. Similarly, a decrease in yield was observed in *Nicotiana* with increased generations of random mating due to disruption of internally balanced chromosomal effects [8]. However, studies indicated that intermating in F_2 population preferably for four generations prior to selfing and selection could break linkage block of fibre strength and yield in cotton [1]. Likewise, atleast four cycles of intermating are required for breakage of initial linkage between yield and lint strength in cotton [9]. In contrary, some reports concluded that the linkage blocks in cotton were still of appreciable length after four or five generations of random mating [10] and random mating cannot be considered as a primary breeding procedure prior to selection as compared to intermating [11]. However, in the absence of linkage equilibrium, genetic correlations move towards the equilibrium value with random mating [1].

Most of the yield related traits showed significant and positive association with yield in selfed and sib mated progenies which is an encouraging aspect, however the magnitude of association was stronger in sib mating. All the selfed progeny showed negative correlation between grain yield and developmental characters (days to 50% tasseling, days to 50% silking and days to maturity) indicating that selection for early lines can result in increased grain yield. This type of relationship between grain yield and phenological characters is highly desirable for developing high yielding short duration genotypes which currently is the pressing priority. Negative and significant estimates of correlation coefficients between grain yield and days to flower in maize landraces suggested that the selection for earliness could result in greater yield [12]. Days to tassel, silk and maturity were observed to possess a negative correlation coefficient with grain yield in twenty four maize inbred lines evaluated by [13]. However, sib mated progeny of SC-1 and random mated populations of SC-2 exhibited positive relationship between the phenological characters and grain yield which implies that these progeny will give reduced yields if selected for early maturity. This association may be expected because the late maturing genotypes possess greater leaf area and more time resulting in greater accumulation of grain dry matter. In agreement to these results, [14] opined that a shift towards later maturity can be expected if selection is based upon grain yield alone in corn. The characters plant height and ear height showed positive correlation with each other in SC-1 in all matings, but showed negative correlation after random mating in SC-2. Positive and significant correlation between plant height and ear height was also reported [15]. Further selfed progeny of both crosses showed a negative correlation of plant height with grain yield and also between grain yield and plant height in high oil maize lines [16].

Sib mated progeny exhibited desirable positive correlation between ear length and ear circumference while selfed and random mated populations of SC-2 showed a negative correlation. [13] also reported significant positive correlation between ear length and ear circumference in 77 maize genotypes evaluated for correlation analysis. The selfed and sib mated progeny have displayed strong positive correlations between yield and yield related traits such as ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 kernel weight and shelling percentage. Such positive relationship of these characters with yield indicates that these traits can play an imperative role in inbred and hybrid development programmes. Selection for these traits can indirectly bring desirable yield levels in the breeding programmes. Positive correlation of grain yield with number of kernels row^{-1} [17] and close correlations between grain yield and 100 kernel weight [18] were also reported. [19] identified cob length as a suitable marker for selecting genotypes with high grain yield along with other yield attributes like cob girth, test weight and number of kernel rows cob^{-1} [20].

4. CONCLUSION

A comparison of correlation coefficients among various characters in S_3 populations of single crosses of maize generated *via* selfing, sib mating and random mating for three seasons showed that sib mating established highest number of additional desirable correlations among the characters studied. It also showed new negative correlations, however, these were mostly among the non-yield related characters like plant height, ear height, days to 50% tasseling, days to 50% silking and days to maturity unlike the new positive correlations that were established among yield and yield related traits like ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 kernel weight and shelling percentage. The associations among yield and yield contributing traits were stronger in sib mating compared to self pollination which also exhibited positive correlations among most of the yield related traits. The associations among different traits in random mating were either negative or weak positive in both the crosses with few exceptions. These differences in correlations may be either due to chance sampling or the impact of mating system itself which could give different genotypic composition of the progenies. Therefore, it is evident that sib mating positively affected the magnitude, number and direction of associations for the characters studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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