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Influence of Mating Systems on Trait Associations in Segregating Populations of Maize (*Zea mays* L.) Double Cross

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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

In the present challenging scenario of climate change, it is essential to breed maize cultivars that withstand stress especially abiotic stresses in a broader sense. Diversification of existing germplasm is invariable to harness the actual potential of maize hybrids which are bred for specific agroecosystems. Double crosses interact less with environment compared to single crosses and

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their broad parentage enables better performance under varied situations of cultivation. In the present study, impact of mating systems ie., self pollination, sib mating and open pollination was studied in a high yielding double cross of maize so as to identify robust and diverse recombinants. The double cross, (BML-32 x BML-6) x (BML-10 x BML-7) was imposed with the three types of mating systems for three consecutive seasons and the resultant S3 (F4) populations were evaluated for trait interrelationssips. It was observed that sib mating established stronger and highest number of positive correlations with seven and twelve additional positive correlations than self and open pollinations respectively among the yield and its attributing traits in its progenies. Therefore deploying sib mating cycles during line development may result in more effective selection processes. Results of path analysis, however, did not significantly vary with the mating type though sib mating showed lowest residual effect.

Keywords: Correlation; maize; mating system; open pollination; path analysis; self pollination; sib mating.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the major cereal food crops besides rice and wheat providing nutrition to a vast portion of population. Maize and wheat are the primary providers of dietary energy, indispensable proteins, micronutrients, and a wide range of non-nutritional bioactive compounds in our diets [1]. Global crop production faces mounting pressure driven by three primary factors: the expanding global population, elevated meat and dairy consumption due to rising affluence, and the growing demand for biofuels [2]. To fulfill the escalating demands, it might be necessary to raise global agricultural production by 60 to 110% by the year 2050 [3]. The global average rate of yield increase is 1.6 % against a required rate of 2.4% per year which is insufficient to meet the goal of doubling crop production by 2050 for ensuring food security [4].

Maize yields are affected by an array of biotic and environmental stresses especially in rainfed ecosystem thereby limiting the accrued on-farm yield levels. Inspite of commendable improvement in maize productivity over the past two decades, the increasing vulnerability of cultivars to various stresses keeps alive the challenge of reaping sustainable benefits amidst changing climatic patterns [5]. It is therefore crucial to develop climate smart maize cultivars that are tolerant to drought, heat, water logging in addition to resistance for biotic constraints so as to stabilize the yields over a broad regime of environmental conditions. The concept of double cross hybrids emerged commercially when there was difficulty to meet the seed demands from single cross hybrids because of weak and inferior inbreds. Although, modern inbreds are much superior comparatively in terms of yield potential and stress tolerance, performance of single cross hybrids is mostly restricted to a specific environment and subject to best management conditions. Double crosses exhibit a lower degree of interaction with environments compared to single crosses, and they surpass single crosses in terms of maintaining stable performance across varying conditions [6]. Double crosses are made from four inbreds, hence retain more heterozygosity and variability, unlike single crosses. It is a well-established fact that heterozygous and heterogeneous populations interact less with environments and have broader adaptability to diverse environments resulting in high rate of stability and increased resilience against stresses through population buffering [7]. As per Sprague and Federer [6], double crosses excel in maintaining performance stability, making them particularly effective in adverse conditions when compared to single crosses. Double crosses possess more variability in plant and ear traits resulting in lesser yields than single crosses but more consistent performance under challenging climatic conditions [8]. Three way and double crosses where the female parent is a high yielding single cross are more fetching in terms of resistance to pests and diseases [9].

In cross-pollinated crops like maize which do not have self-incompatibility concerns, inbred lines used as parents for producing hybrids are developed through self pollination. Extensive studies on inbreeding depression in maize have indicated that selfing is important in inbred development because it leads to rapid gene homozygosity and desirable favorable genes can be accumulated while the undesirable ones are eliminated [10]. However, the performance of inbred lines or lines produced from selfing decrease drastically, resulting in yield reduction, increase in the number of stunted plants, reduced plant resistance to pests and diseases and reduced growth rate [11,12]. Sib mating becomes a viable option while considering less severe inbreeding systems. Less restrictive forms of inbreeding which would permit less rapid fixation of deleterious genes as compared to selfing have been suggested for producing more vigorous inbred lines [9]. The third approach is random mating of the segregating populations. The expected gains from this method would be breakup of linkage blocks that are maintained intact due to lack of recombination. Comparison of the three methods for their ability to generate superior recombinants is an interesting study that can assist during inbred line development programmes.

Correlation studies in plant breeding programs play a crucial role in understanding the relationships between different traits and identifying potential markers for desired characteristics. By analyzing the correlation between traits, plant breeders can make more informed decisions on which traits to focus on during the breeding process. Additionally, correlation studies can uncover unexpected relationships between traits, providing valuable insights that may not be immediately apparent. This can lead to innovative approaches in plant breeding, ultimately contributing to the development of improved and resilient crop varieties. Likewise understanding the direction of effect of each trait on grain yield helps the breeder in making selections. The present study was taken up in the S_3 generation populations of two maize double crosses generated *via* three systems of mating viz., selfing, sib mating and random mating to make a comparative assessment of the trait relationships among the individuals as influenced by different mating systems.

2. MATERIALS AND METHODS

The experiment was initiated during *kharif* 2016 at Regional Agricultural Research Station, Palem, Telangana State, India with F_1 crop of the double cross *i.e*., (BML-32 x BML-6) x (BML-10 x BML-7). The crop was divided into three equal sections to impose three matings *ie*., selfing, sib mating and open pollination. The resultant seed was harvested individually mating-wise to raise the S_1 crop in the ensuing season. Likewise, the progenies were imposed with the same mating system for three continuous seasons while advancing the generations till S_3. The three S_3 (F_4) populations thus generated were sown in three replications in randomized block design during *rabi* 2017-18 to study and compare the effects of mating type on trait relationships. Data was collected for twelve agronomical traits *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 seed weight (g), shelling percentage (%) and grain yield plant^{-1} (g). Statistical analysis for calculating Pearson's correlation coefficients was conducted using R software (version 4.0.2) while OPSTAT was used for the path analysis.

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis of Agronomic Traits

After three selfing generations, the progenies of the double cross (BML-32 x BML-6) x (BML-10 x BML-7) were evaluated for trait interrelationships. All the yield attributing characters such as ear length (0.637**), ear circumference (0.864**), number of kernel rows (0.425*), number of kernels row^{-1} (0.814**), 100 seed weight (0.805**) and shelling percentage (0.719**) were strongly and positively correlated with grain yield plant^{-1} including plant height (0.054) and ear height (0.392*) indicating an effective selection system with these traits for line development programmes. Similar findings were reported by Munawar et al. [13], Aman et al. [14], Yahaya et al. [15], Reddy et al. [16] and Verma et al. [17]. The traits days to 50% tasseling (-0.250), days to 50% silking (-0.277) and days to maturity (-0.235) showed negative associations with grain yield indicating the opportunities for selection of early maturing and high yielding lines [18,19] (Table 1, Fig. 1).

Sib mated progenies of the cross exhibited similar results with ear length (0.761**), ear circumference (0.778**), number of kernel rows (0.844*), number of kernels row^{-1} (0.615**), 100 seed weight (0.776**) and shelling percentage (0.018) showing positive associations with grain yield plant^{-1} [20,14]. However, the traits plant height (-0.279) and ear height (-0.184) exhibited negative correlations with grain yield plant^{-1} in addition to days to 50% tasseling (-0.470**), 50% silking (-0.145) and maturity (-0.161). High plant height and ear height require higher investment of resources towards vegetative growth and therefore can negatively affect the yields. Hence selection for short genotypes should be made for earliness and better yield performance. The characters ear length, ear circumference, number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 seed weight and shelling percentage showed highly significant positive associations with each other though shelling percentage exhibited non-significant positive associations with the aforementioned traits in addition to displaying a negative correlation with ear length (-0.270) (Table 1, Fig. 2).

Open pollinated populations revealed a mixture of positive and negative correlations between yield and its attributing traits many of them being weak associations. Only two traits *ie*., days to 50% silking (0.520**) and days to maturity (0.585**) exhibited significant positive correlation with grain yield plant^{-1} whereas plant height (0.328), ear height (0.179), ear circumference (0.270), number of kernel rows ear^{-1} (0.155), 100 seed weight (0.136), shelling percentage (0.096) and days to 50% tasseling (0.020) showed non-significant positive associations. In contrary, negative association with grain yield plant^{-1} was observed for ear length (-0.089) and number of kernels row^{-1}(-0.329) (Table 1, Fig. 3).

Comparison of the three mating systems indicates that sib mating manifested seven and twelve additional positive associations with grain yield over self and open pollination systems respectively. 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. Thomas [21] opined that genetic correlation between traits may be due to linkage or/and pleiotropic effect of the genes. While pleiotropic effect cannot be manipulated, association due to linkage can be affected by deploying appropriate breeding programmes. He further reported that biparental mating produced additional desirable correlations in sunflower compared to selfing and open pollination methods. Singh and Murty [22] reported additional twelve favorable associations in biparental mated progenies than selfs in a study made in pearl millet. 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. Humphrey et al. [23] observed a decrease in yield in *Nicotiana* with increased generations of random mating due to disruption of internally balanced chromosomal effects.

3.2 Path Coefficient Analysis

Path coefficient analysis was conducted to assess the contribution of various factors by breaking down the correlation coefficients into direct and indirect effects in order to propose a more robust selection criterion. In the selfed progeny, 100 seed weight (0.697) exhibited highest direct positive effect on grain yield plant^{-1} followed by ear circumference (0.606), ear length (0.347), number of kernel rows (0.155), plant height (0.102), number of kernels row^{-1} (0.053) and days to 50% tasseling (0.052). These results are in accordance with Vishnu et al. [24] and Verma et al. [17]. In contrast direct negative effects on grain yield plant^{-1} were shown by shelling percentage (-0.491), ear height (-0.388), days to 50% silking (-0.117) and days to maturity (-0.247) [20,25]. Shelling percentage showed direct negative effect inspite of significant positive correlation with grain yield which may be an implication of high weight of de-shelled cob in contrary to the findings of Devasree et al. [26]. However, shelling percentage continued to influence the grain yield through other yield attributing traits like ear length, ear circumference, number of kernel rows, number of kernels row^{-1} and 100 seed weight in addition to days to 50% silking, days to 50% tasseling and days to maturity (Table 2, Fig. 1).

Dissection of trait contributions towards grain yield among the sib mated progenies suggested that 100 seed weight had highest direct positive effect on grain yield (0.391) followed by number of kernels row^{-1} (0.359) and days to maturity (0.302) which was also reflected as significant correlations of these traits with grain yield. In addition, the traits ear length (0.289), shelling percentage (0.142) and ear circumference (0.107) have also shown direct positive effects on grain yield [13,27]. In contrary, direct negative effects on grain yield were exhibited by plant height (-0.317), ear height (-0.075), number of kernel rows (-0.096), days to50% tasseling (-0.069) and days to 50% silking (-0.335). Matin et al. [20] reported indirect negative effects of days to 50% tasseling, days to 50% silking, ear height and days to maturity on yield implying the effectiveness of indirect selection. However, these traits influenced grain yield through other factors. For instance, number of kernel rows manifested high positive indirect effects on grain yield through 100 seed weight (0.305), number of kernels row^{-1} (0.359) and ear length (0.202) besides ear circumference (0.072) and shelling percentage (0.028). This was also indicated by the strong positive correlation exhibited by this trait with grain yield (*rg*=0.844**) (Table 2, Fig. 2).

Table 1. Genotypic correlation coefficients for yield and yield related traits of maize double cross after selfing, sib mating and open pollination for three seasons

Trait		PH	EH	EL	EC	KR	KPR	SW	GY	SP	DT	DS	DM
PH	**Self**		0.526**	0.013	0.256	-0.02	-0.140	-0.024	0.054	-0.291	-0.186	-0.058	0.093
	Sib		0.128	-0.102	-0.232	-0.315	0.072	-0.027	-0.279	0.006	0.123	-0.484**	-0.634**
	Open		0.165	0.231	-0.225	-0.082	-0.167	0.005	0.328	-0.359	-0.178	0.268	0.194
EH	**Self**			0.483**	0.557**	0.130	0.393*	0.205	0.392*	0.158	-0.370	-0.156	-0.139
	Sib			-0.051	-0.05	-0.095	0.041	-0.079	-0.184	0.147	0.336	0.029	-0.207
	Open			-0.533**	-0.065	0.311	0.120	0.400*	0.179	-0.007	0.165	-0.035	0.275
EL	**Self**				0.498**	0.356	0.531**	0.504**	0.637**	0.631**	-0.217	-0.097	-0.229
	Sib				0.608**	0.672**	0.482**	0.556**	0.761**	-0.270	-0.538**	-0.173	-0.291
	Open				-0.109	0.065	-0.125	-0.180	-0.089	0.235	0.029	0.173	0.117
EC	**Self**					0.271	0.683**	0.655**	0.864**	0.472**	-0.323	-0.183	-0.081
	Sib					0.636**	0.510**	0.584**	0.778**	0.026	-0.093	-0.008	-0.232
	Open					-0.038	0.146	0.169	0.270	0.068	-0.096	0.374*	0.243
KR	**Self**						0.396*	0.330	0.425*	0.376*	-0.115	-0.123	-0.449*
	Sib						0.475**	0.589**	0.844**	0.072	-0.501**	-0.257	-0.288
	Open						0.112	0.343	0.155	0.104	0.181	0.295	0.323
KPR	**Self**							0.724**	0.814**	0.697**	-0.194	-0.135	-0.225
	Sib							0.458*	0.615**	0.038	-0.134	-0.136	-0.247
	Open							0.363*	-0.329	0.015	0.455*	-0.043	-0.088
SW	**Self**								0.805**	0.745**	-0.034	-0.179	-0.104
	Sib								0.776**	0.231	-0.274	-0.214	-0.319
	Open								0.136	0.064	0.261	0.168	0.597**
GY	**Self**									0.719**	-0.250	-0.277	-0.235
	Sib									0.018	-0.470**	-0.145	-0.161
	Open									0.096	0.020	0.520**	0.585**
SP	**Self**										-0.07	-0.118	-0.272
	Sib										0.330	0.140	-0.081
	Open										0.091	0.147	0.341
DT	**Self**											0.116	0.190
	Sib											0.535**	0.160
	Open											-0.01	0.055
DS	**Self**												0.260
	Sib												0.543**
	Open												0.468**

*** 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)

Table 2. Direct (diagonal) and indirect effects of yield related traits on grain yield plant $^{-1}$ in maize double cross after selfing, sib mating and open pollination for three seasons

Trait	Mating System	PH	EH	EL	EC	KR	KPR	SW	SP	DT	DS	DM	GY
PH	**Self**	**0.102**	-0.229	0.020	0.167	-0.011	0.002	-0.045	0.158	-0.018	0.016	-0.034	0.054
	Sib	**-0.317**	-0.013	-0.036	-0.027	0.035	0.012	-0.001	0.020	-0.009	0.213	-0.183	-0.279
	OP	**-1.940**	-0.162	-0.286	-0.062	-0.028	1.266	-0.330	-0.020	-0.123	3.171	-1.184	0.328
EH	**Self**	0.060	**-0.388**	0.197	0.374	0.029	0.043	0.187	-0.082	-0.027	0.032	0.040	0.392
	Sib	-0.055	**-0.075**	-0.020	-0.003	0.012	0.039	-0.054	0.038	-0.032	-0.024	-0.033	-0.184
	OP	0.572	**0.548**	1.257	-0.057	-0.206	-1.197	0.407	0.002	0.179	-0.353	-0.895	0.179
EL	**Self**	0.006	-0.221	**0.347**	0.361	0.061	0.031	0.535	-0.369	-0.023	0.026	0.078	0.637**
	Sib	0.039	0.005	**0.289**	0.069	-0.067	0.267	0.269	-0.047	0.057	0.058	-0.052	0.761**
	OP	-0.310	-0.385	**-1.792**	0.046	-0.317	1.694	-0.145	0.020	0.072	1.352	-0.466	-0.089
EC	**Self**	0.028	-0.239	0.207	**0.606**	0.060	0.054	0.641	-0.258	-0.031	0.038	0.030	0.864**
	Sib	0.079	0.002	0.187	**0.107**	-0.065	0.212	0.313	0.010	0.003	0.027	-0.029	0.778**
	OP	0.426	-0.112	-0.296	**0.281**	0.042	-1.339	0.300	0.014	-0.035	2.452	-1.401	0.270
KR	**Self**	-0.007	-0.072	0.137	0.236	**0.155**	0.025	0.251	-0.211	-0.012	0.018	0.136	0.425
	Sib	0.115	0.009	0.202	0.072	**-0.096**	0.255	0.305	0.028	0.052	0.097	-0.053	0.844**
	OP	-0.100	0.211	-1.058	-0.022	**-0.536**	0.003	0.543	0.010	0.103	2.301	-0.997	0.155
KPR	**Self**	0.004	-0.319	0.203	0.623	0.072	**0.053**	0.847	-0.413	-0.024	0.001	-0.013	0.814**
	Sib	-0.011	-0.008	0.215	0.063	-0.068	**0.359**	0.337	0.006	0.012	0.058	-0.073	0.615**
	OP	-0.997	-0.266	-1.232	-0.153	-0.001	**2.463**	-0.194	-0.002	-0.242	0.548	0.219	-0.329
SW	**Self**	-0.007	-0.104	0.266	0.556	0.056	0.064	**0.697**	-0.469	0.008	0.045	0.013	0.805**
	Sib	0.001	0.010	0.199	0.085	-0.075	0.309	**0.391**	0.039	0.047	0.077	-0.097	0.776**
	OP	0.613	0.213	0.249	0.081	-0.279	-0.457	**1.045**	0.004	0.342	0.669	-2.309	0.136
SP	**Self**	-0.033	-0.065	0.261	0.318	0.067	0.044	0.667	**-0.491**	-0.003	0.021	0.084	0.719**
	Sib	-0.046	-0.020	-0.096	0.008	-0.019	0.016	0.109	**0.142**	-0.050	-0.100	-0.072	0.018
	OP	1.535	0.044	-1.417	0.159	-0.209	-0.203	0.173	**0.026**	0.321	1.438	-1.518	0.096
DT	**Self**	-0.035	0.202	-0.153	-0.357	-0.035	-0.024	0.102	0.024	**0.052**	-0.014	-0.047	-0.250
	Sib	-0.042	-0.035	-0.237	-0.005	0.072	-0.061	-0.268	0.103	**-0.069**	-0.377	0.152	-0.470**
	OP	-0.042	-0.035	-0.237	-0.005	0.072	-0.061	-0.268	0.103	**-0.069**	-0.377	0.152	0.020
DS	**Self**	-0.014	0.106	-0.077	-0.196	-0.024	-0.000	-0.269	0.088	0.006	**-0.117**	-0.093	-0.277
	Sib	0.202	-0.005	-0.050	-0.009	0.028	-0.062	-0.090	0.043	-0.078	**-0.335**	0.181	-0.145
	OP	-1.381	-0.043	-0.544	0.155	-0.277	0.303	0.157	0.008	-0.066	**4.456**	-1.564	0.520**
DM	**Self**	0.014	0.062	-0.110	-0.075	-0.085	0.003	-0.036	0.167	0.010	-0.044	**-0.247**	-0.235
	Sib	0.192	0.008	-0.050	-0.010	0.017	-0.087	-0.126	-0.034	-0.035	-0.200	**0.302**	-0.161
	OP	-1.362	0.291	-0.495	0.233	-0.317	-0.320	1.430	0.023	-0.055	4.131	**-1.687**	0.585**

r = 0.460 (self); 0.158(sib); 1.455 (op)

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)

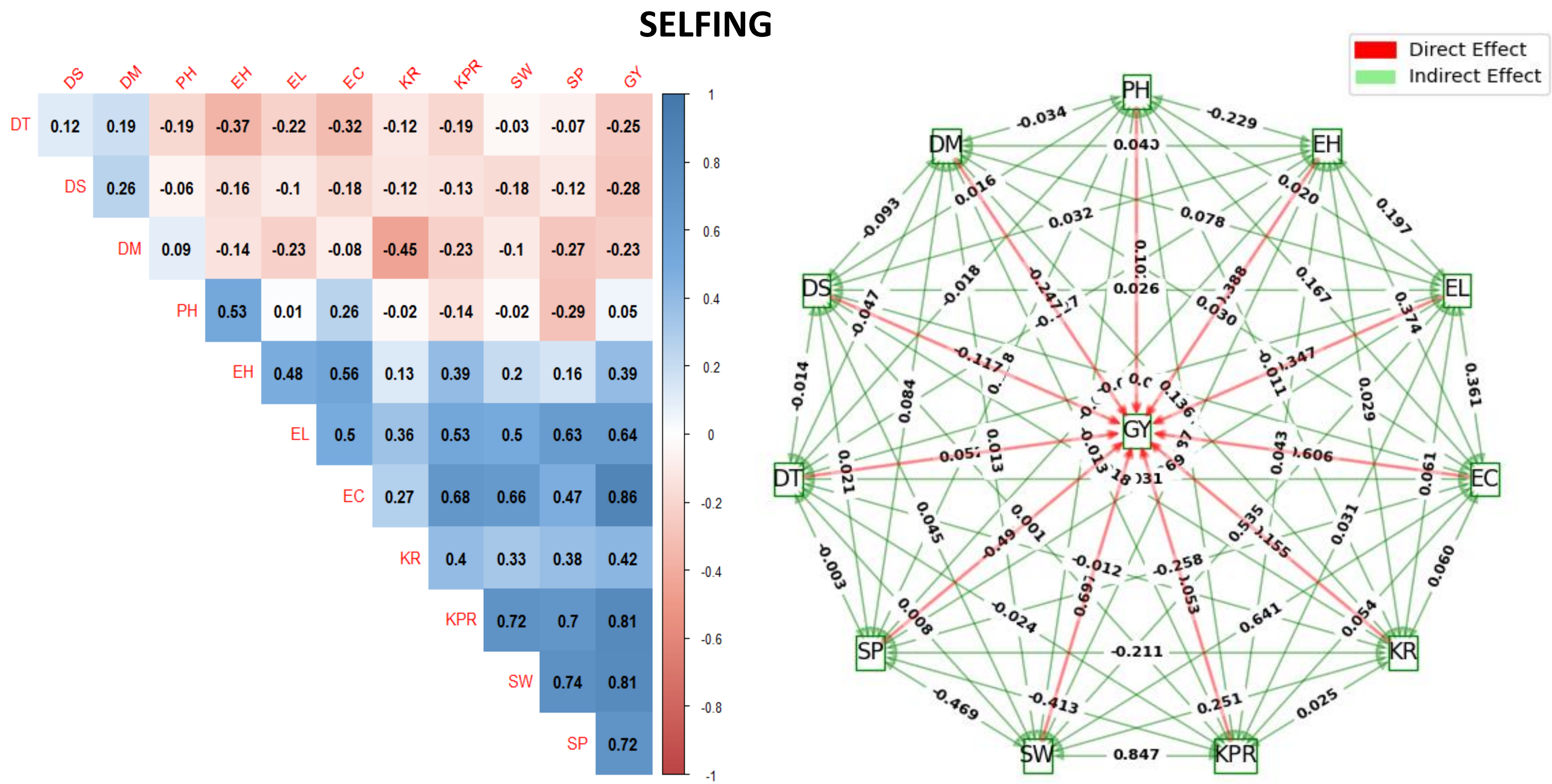

Fig. 1. Graphs showing correlations, direct and indirect effects of yield related traits in maize double cross progenies after selfing

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)

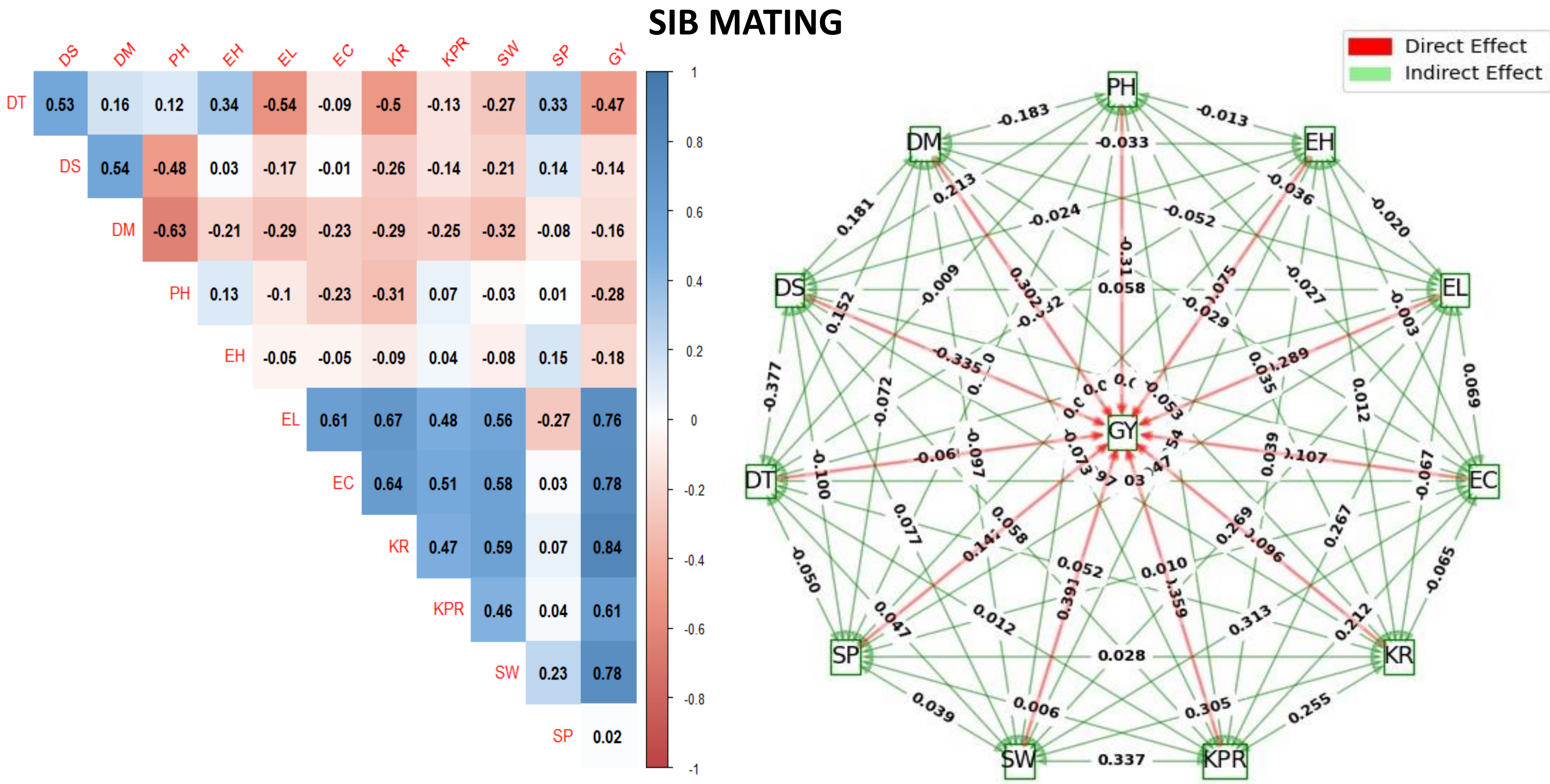

Fig. 2. Graphs showing correlations, direct and indirect effects of yield related traits in maize double cross progenies after sib mating

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)

OPEN POLLINATION

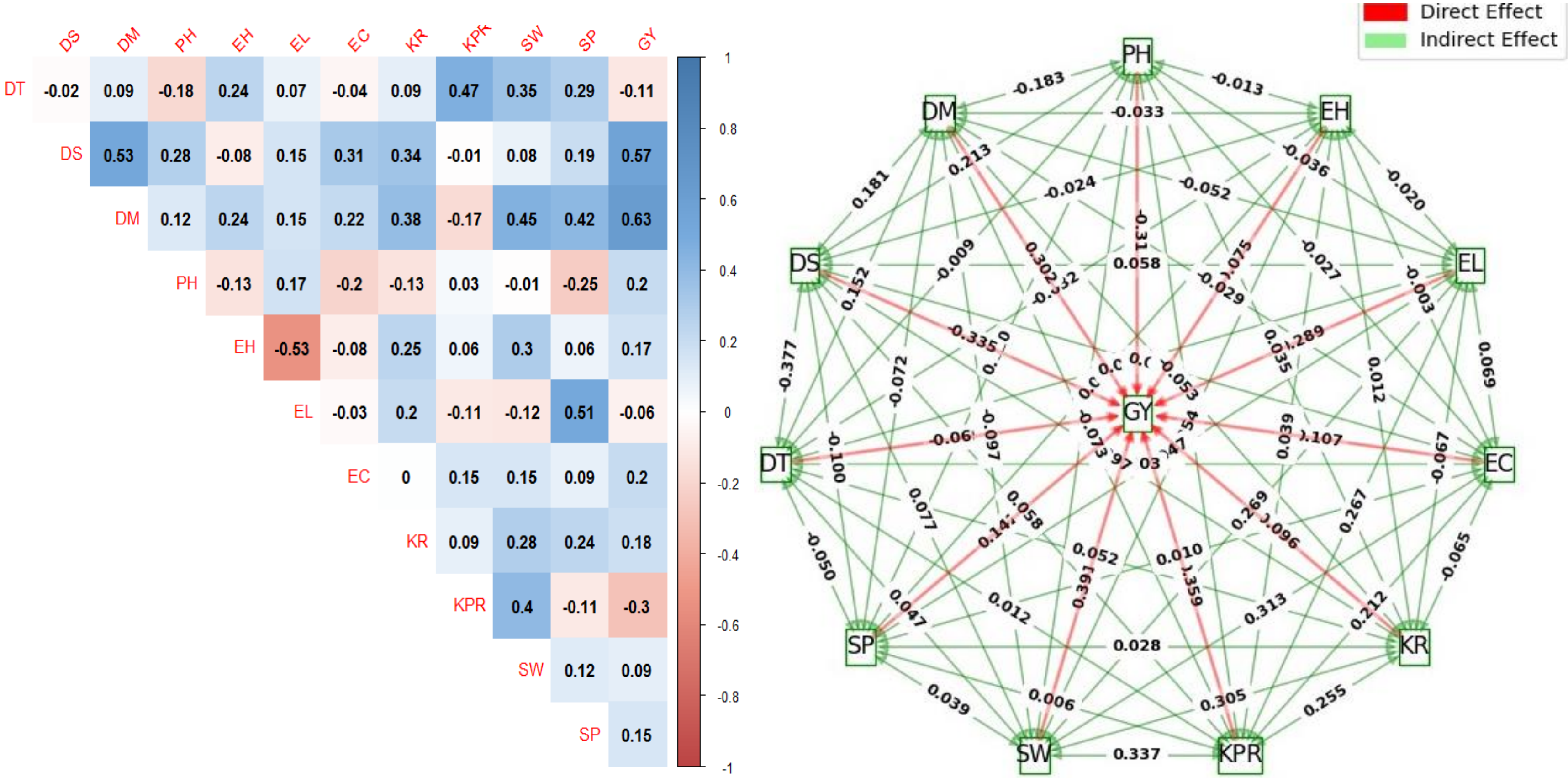

Fig. 3. Graphs showing correlations, direct and indirect effects of yield related traits in maize double cross progenies after open pollination

DT - Days to 50 per cent tasseling; DS - Days to 50 per cent 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)

In open mated progeny, highest direct positive effect on grain yield was exhibited by days to 50% silking (4.456) followed by number of kernels row^{-1} (2.463), 100 seed weight (1.045), days to 50% tasseling (0.426), ear circumference (0.281) and shelling percentage (0.026) while plant height (-1.94), ear length (-1.792), number of kernel rows (-0.536) and days to maturity (-1.687) showed direct negative effects in contrary to the findings of Yahaya et al. [15] who observed highest direct effect of plant height on maize grain yield. This suggests that higher grain yield was due to high cob girth, greater number of kernels, high 100 seed weight [28] and high shelling percentage inspite of having smaller cob size and fewer kernel rows (Table 2, Fig. 3).

It is therefore implied that 100 seed weight, number of kernels row^{-1} and ear circumference have profound direct and positive influence on the grain yield in all the three mating systems. However, the residual effect which denotes the unexplained variance is lowest in sib mating (0.158) suggesting its comparative advantage over other systems.

4. CONCLUSION

The results on influence of three mating systems on S_3 (F_4) population of the maize double cross on trait correlations have shown that higher number of positive correlations with grain yield was manifested through sib mating. The traits ear length, ear circumference, number of kernel rows, number of kernels row^{-1}, 100 seed weight and shelling percentage played a key role in influencing the grain yield and hence should be focused while making selections. Path analysis indicated that 100 seed weight, number of kernels row^{-1} and ear circumference have strong direct and positive effects on grain yield. While the mating systems did not much influence the direction of influence of these traits on grain yield, most of the variance was contributed by the traits studied in sib mating while the magnitude of unexplained variance was higher in self and open pollination systems. Therefore, it can be suggested that sib mating may be adopted in the line development programmes of maize for obtaining diverse, robust and better 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.

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