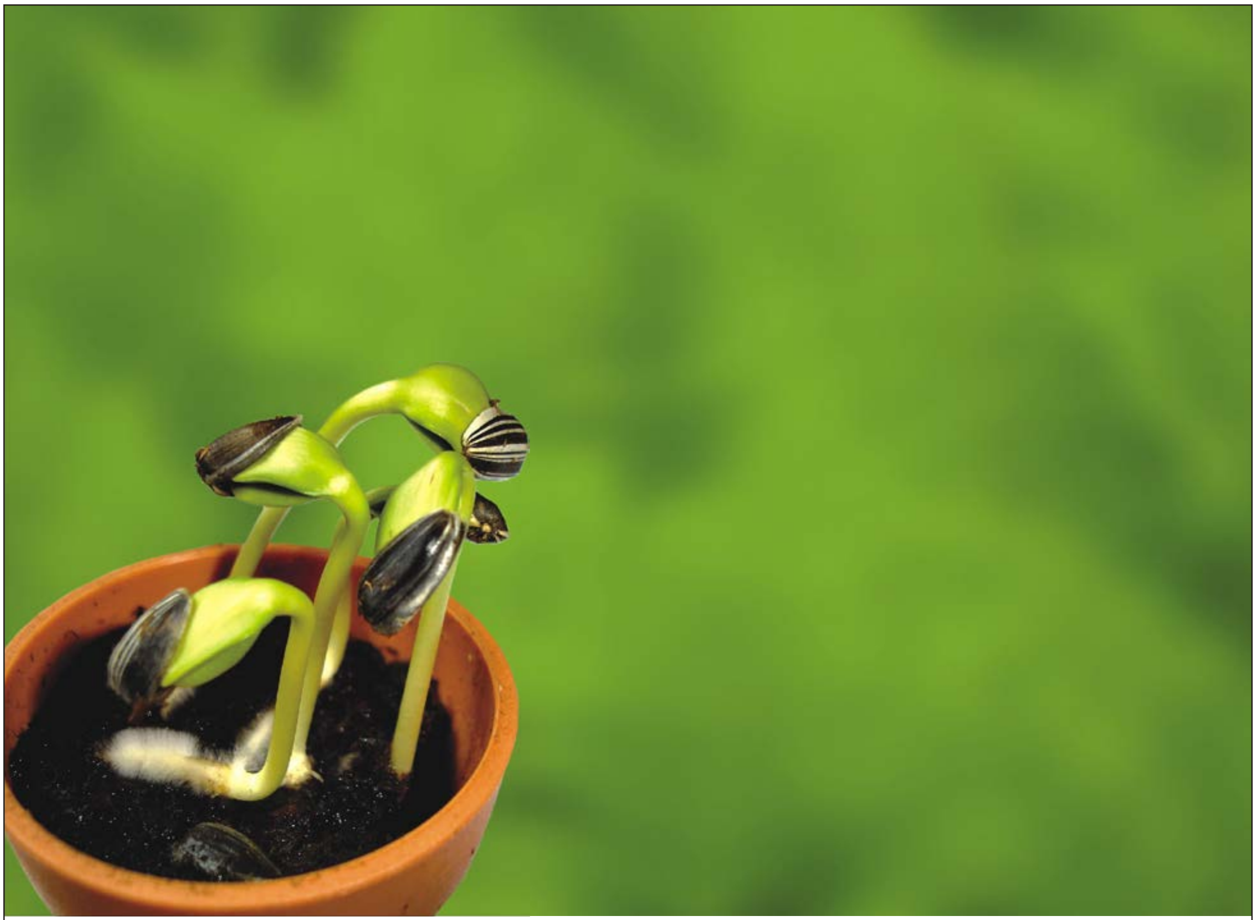

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Combining Abilities for Yield and Yield Components in Diallel Crosses of Six New Yellow Maize Inbred Lines

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ABSTRACT
Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE), kernel number per row (KR) and 100 Kernel Weight (KW) are the most important yield components (YCTs) of grain yield in maize (*Zea mays* L.). Many investigations have been conducted on grain yield combining ability and the results have been widely used in maize breeding programs. Limited research has been done on combining ability of maize YCTs, however, no reports on the relationship between grain yield combining ability and YCTs combining abilities exist. The objectives of this study were to estimate combining abilities of grain yield and of EL, ED, RE, KR and KW and examine the relationship between grain yield combining abilities and the combining abilities of the YCTs. Both general (GCA) specific (SCA) combining ability and reciprocal mean squares were highly significant for all studied traits excepted Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE) and 100 kernel weight for (GCA) and Ear Diameter (ED) and number of rows per ear (RE) for (r_{ij}). The ratio of GCA/SCA was less than unity for all studied traits. These results indicating that the non-additive genetic effects were more important and played the major role in all studied traits indicating the non-additive gene was more important than additive gene action. The ratio of GCA/SCA for grain yield and for the YCTs were between 0.006 and 0.65, indicating non-additive genetic effects were more important for these traits. The results showed the general combining ability GCA effects for six parental line indicating that the parental inbred line P_4 was good combiner for Ear Length (EL) and number of rows per ear (RE). The parental inbred line P_5 was good combiner for kernel number per row (KR) and the parental inbred lines P_1 was good combiner for grain yield (ard/fed). This study also showed that the GCA effects of grain yield were related to YCTs' GCA effects in an inbred line and the SCA effects of grain yield were also related to the YCTs' SCA effects in the same crosses. Significantly positive grain yield SCA effects usually were highly correlated with the number of the YCTs that had significantly positive SCA effect, i.e., all the F_1 crosses out yielded significantly better than the check SC162, except four crosses. Single crosses ($P_4 \times P_1$) was significantly better than the best check SC155 for grain yield, however, there were seven single crosses, i.e., ($P_5 \times P_4$), ($P_4 \times P_2$), ($P_1 \times P_4$), ($P_1 \times P_5$), ($P_2 \times P_3$), ($P_6 \times P_1$) and ($P_2 \times P_6$) which statistically equal the check cross 155. For (SCA) effects of the 15 F_1 crosses had positive and highly significant effects. However for maternal effect or reciprocal (SCA) effects were found that single crosses i.e, ($P_5 \times P_4$), ($P_3 \times P_6$), ($P_4 \times P_2$), ($P_5 \times P_3$), ($P_1 \times P_3$) and ($P_6 \times P_1$) yielded highly significant for grain yield. Thus, selecting inbred lines with positive GCA effects in either all or most of YCTs will have greater chance to obtain crosses with higher grain yield. The information of GCA and SCA effects

for YCTs is very useful for maize breeders to determine which maize line should be selected to improve local lines and which parent lines should be used for making hybrids with greater grain yields.

Key words: Corn, diallel, combining ability

INTRODUCTION

Genetic diversity is the basis for maize improvement (Hallauer and Miranda, 1988). Introduction of exotic germplasm was shown to be effective to increase genetic diversity and to improve local maize varieties (Hallauer and Miranda, 1988; Vasal *et al*., 1992; Fan *et al*., 2002). Combining ability analyses are widely used in maize breeding programs to determine GCA and SCA information from maize populations for genetic diversity evaluation, inbred line selection, heterotic pattern classification, heterosis estimation and hybrid development (Kauffman *et al*., 1982; Sughroue and Hallauer, 1997; Fan *et al*., 2002; Melani and Carena, 2005; Barata and Carena, 2006). Diallel mating models developed by Griffing (1956) and Gardner and Eberhart (1966), are the major models used in combining ability analyses. Researchers from different countries have studied combining ability via crosses between CIMMYT germplasms and local germplasms. Maize grain yield is the expression of a unique combination of yield components (Agrama, 1996). Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE), number of kernels per row (KR) and 100 Kernel Weight (KW) are the most important grain yield components; these yield component traits (YCTs) are significantly correlated with maize grain yield (Austin and Lee, 1998). Maize grain yield combining ability has been studied intensively and the results have been widely used in maize breeding programs (Kauffman *et al*., 1982; Fan *et al*., 2002; Menkir *et al*., 2004; Melani and Carena, 2005; Barata and Carena, 2006). Limited research, however, has been reported on maize YCT combining abilities and the relationship between grain yield combining ability and YCT combining abilities. The objectives of this research were to estimate the combining ability of grain yield and five YCTs, viz., EL, ED, RE, KR and KW and study the relationship between grain yield combining ability and combining abilities of the five YCTs.

MATERIALS AND METHODS

The following six new yellow parental inbred lines were studied: 10RF, 11RF, 39RF, 45RF, 48RF and 50RF. These lines were differed considerably in expression of various agronomy traits. Six inbred lines were crossed at Gemmeiza in a full diallel to give 30 crosses including reciprocal crosses in the summer of 2010 at Agricultural Research Center in Egypt (ARC). The parents and their 30 F_1 hybrids and two check hybrids (single cross 155 and single cross 162) were evaluated at Gemmeiza location on Randomized Complete Block Design (RCBD) with four replications in two different planting dates in 15 April and 15 May 2011. Kernels were hand-sown at 3-4 grains were placed per hill then thinned at two plants per hell after emergence. Each replication contained 38 plotted and each plot consisted of one ridge with 6 m a long and spacing of 35 cm between plants within ridge and 80 cm between ridges. In experiments for each data were recorded on the following characters on plot basis Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE), kernel number per row (KR) and 100 Kernel Weight (KW) and grain yield (YG), which was adjusted to 15.5% moisture content (estimated in and ard/fed).

Statistical analysis procedure: Analysis of variance for mean of performance according to the method outlined by Snedecor and Cochran (1977) was used for each experiment and then combined over the two planting dates. The L.S.D. test at 5 and 1% according to Steel and Torrie (1980) was used for comparison the mean performance of the different genotypes.

General Combining Ability (GCA) and Specific Combining Ability (SCA) effects were estimated according to Griffing (1956) Method 1 Model 1. In addition, the mathematical model for a single inbred cross was tested for normality by statistical software. Then, data was analyzed using AGR 21 statically software (Agrobase, 2001). The evaluating main genotype effects obtain GCA, SCA, reciprocal, maternal and non-maternal effects and their interaction with environment.

The GCA and SCA combining ability estimates according to Griffing(1956) diallel cross analysis designated as method 1 model 1 for each date. The combined analysis over two dates was carried out whenever homogeneity of variance was detected (Steel and Torri, 1980). Means of genotypes were compared using LSD at 5 and 1% probability level.

RESULTS AND DISCUSSION

Analysis of variance: The analysis of variance for ordinary analysis and combining ability based on combined data over two planting dates Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE), kernel number per row (KR), 100 Kernel Weight (KW) and grain yield (ardab/fed) is presented in Table 1. Mean squares were significant for all the studied traits. Hybrids mean squares were highly significant for the studied six traits excepted Ear Diameter (ED), number of rows per ear (RE) and 100 Kernel Weight (KW) indicating that the hybrids performance differed from planting date to another. These results agree with those obtained by Nawar and El-Hosary (1985), Nass *et al.* (2000), Vacaro *et al.* (2002) and Barakat and Abd EI-Aal (2006).

Results in Table 1 showed that both general (GCA) specific (SCA) combining ability and reciprocal mean squares were highly significant for all studied traits excepted Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE) and 100 kernel weight for (GCA)and Ear Diameter (ED) and number of rows per ear (RE) for (r_{ij}). These results indicated that both additive and non additive types of gene effects were involved in the inheritance of these traits. The ratio of GCA/SCA was less than unity for all studied traits. These results indicating that the non-additive genetic effects were more important and played the major role in all studied traits indicating that

Table 1: Analysis of variance for ordinary analysis and combining ability based combined data over two planting dates for studied traits

S.O.V.	D.F.		Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/row	Weight of 100-kernel	Grain yield (ard/fed)
Date	-	1	21.34	8.96	8.26	117.30	39.60	1.79
Rep	-	3	8.33**	1.36	3.37	24.65	23.52	2.29
Rep×Date	-	6	6.16**	0.10	2.55	9.21	20.84	2.37*
Genotype	35	35	53.06**	0.51	3.43	121.65**	61.54	530.13**
Genotype×Loc	-	35	14.87**	0.27	2.47	26.97**	33.62	10.37**
Error	105	210	4.50	0.22	2.04	12.71	16.20	3.55
GCA	5	5	0.91	0.04	0.24	8.80**	1.59	0.99**
SCA	15	15	14.05**	0.07*	0.59**	27.42**	13.09**	151.50**
Reciprocal	15	15	1.12*	0.05	0.32	5.12**	4.32**	2.714**
GCA×Date	-	5	12.11**	0.10**	0.47*	21.31**	4.45**	2.62*
SCA×Date	-	15	16.44**	0.16**	1.18**	34.41**	23.60**	154.80**
Reciprocal×date	-	15	3.66**	0.11**	1.10**	9.69**	12.47**	4.939**
Error (me)	105	210	0.564	0.03	0.25	1.59	2.02	0.44
GCA/SCA			0.06	0.56	0.40	0.32	0.12	0.006

*, **Significant at 0.05 and 0.01 level of probability, respectively

the non-additive gene was more important than additive gene action. These results agree with the finding of Hallauer and Filho (1981), El-Hosary (1989) and Soliman *et al.* (2005).

The interaction between GCA, SCA and reciprocal with planting dates (Table 1) were significant for all studied traits, the magnitude of the interaction was lowest for GCA×planting dates than the SCA×planting dates and reciprocal×planting dates for dates Ear Length (EL), Ear Diameter (ED), number of rows per ear (RE), kernel number per row (KR), 100 Kernel Weight (KW) and grain yield (ardab/fed). This indicates that non-additive genetic variance was influenced by environment. The non-additive component interacted more with the environment than the additive. This conclusion supports the findings by El-Hosary (1989), Mostafa *et al.* (1996), Sughroue and Hallauer (1997), Soliman *et al.* (2005) and Motawei and Mosa (2009).

The closer of GCA/SCA genetic ratio (Baker, 1978) to unity shows the predictability based on GCA alone. Also the GCA/SCA ratio reveals that different traits show an additive or non-additive genetic effect. The GCA/SCA ratio with a value greater than one indicates additive genetic effect, whereas, GCA/SCA ratio with a value lower than one indicates dominant genetic effect. In accordance to our results, other researchers indicated dominance of non-additive genetic effects for all traits studies (Vacaro *et al.*, 2002).

Mean performance of traits: Considering of ear length for genotypes are presented in Table 2. Ear length for parents were ranged from 13.8-17.5 cm over the two dates. The highest parental inbred line was P_6 over the two dates. The differences between ear length for crosses were non-significant. Ear length were ranged from 20.15-24.88 in over two dates. Ear diameter for genotypes regarding the differences between ear diameter for parental inbred line were ranged from 3.75-4.5 cm in over two dates in combined data. The highest value was recorded by P_4 in combined data. Meanwhile, the lowest values were recorded by P_1 in combined data. The differences between ear diameter for all crosses studied were non-significant for all traits studied in both planting dates and combined over them. Ear diameter ranged from 3.58-4.68 cm over the two dates in combined data, Singh (2005), Machado *et al.* (2009) and Sultan *et al.* (2011). The differences between rows number for genotypes were ranged from 13.43-16.05 over the two dates. The highest values were recorded by P_4 in combined data. Meanwhile, the lowest values were recorded by P_1 in two planting dates and combined data. The highest values were recorded by (P_4×P_3) in combined data, meanwhile, the lowest value was recorded by cross (P_2×P_5) in combined data. Concerning of kernels number per row for genotype are tabulated in Table 2. The differences between number of kernels per row for parents were ranged from 23.80-33.45 in over the two dates in combined data. The highest value was recorded by P_4 in combined data. Meanwhile, the lowest value was recorded by P_2 in combined data. Number of kernels per row for all studied crosses were non-significant comber with S.C.162. The differences between 100 kernel weight for parents were ranged from 24.06-30.11 g in combined data. All crosses for 100 kernel weight were non-significant. The highest grain yield was obtained from crosses (P_4×P_1) 32.82 ard/fed and (P_5×P_4) 32.72 ard/fed in combined, these crosses were significantly out yielded the two checks SC 155 and SC 162 at 5%. More over crosses (P_1×P_4) 32.05 ard/fad, (P_1×P_5) 31.85 ard/fed (P_6×P_1) 31.28 ard/fed, (P_4×P_2) 32.52 ard/fed, (P_2×P_3) 31.33 ard/fed and (P_3×P_6) 31.83 ard/fed these crosses were insignificantly better than the checks. Hence, it could be concluded that these crosses may be useful for improving maize grain yield program.

Table 2: Mean performance of maize genotypes at Gemmeiza their combined for the traits studied in growing season 2011

Genotypes	Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/row	Weight of 100 kernel	Grain yield (ard/fad)
P_1 (10RF)	13.80	3.75	13.43	24.60	24.69	9.464
P_2 (11RF)	15.02	4.25	15.70	23.80	24.06	8.339
P_3 (39RF)	16.70	4.15	14.30	27.17	30.11	9.064
P_4 (45RF)	15.88	4.50	16.05	33.45	26.31	8.088
P_5 (48RF)	16.60	4.10	14.60	32.33	28.76	9.970
P_6 (50RF)	17.50	4.32	15.05	27.95	29.31	9.905
$P_1 \times P_2$	23.02	4.18	14.05	36.40	32.96	30.65
$P_2 \times P_1$	20.70	4.15	14.40	38.15	30.91	30.27
$P_1 \times P_3$	21.60	4.43	15.70	37.00	29.06	30.42
$P_3 \times P_1$	21.95	4.32	15.25	35.67	30.96	27.75
$P_1 \times P_4$	24.88	3.58	14.02	31.63	25.64	32.05
$P_4 \times P_1$	22.60	4.42	14.75	36.33	33.60	32.82
$P_1 \times P_5$	22.23	4.32	14.90	39.08	33.44	31.85
$P_5 \times P_1$	22.02	4.22	15.20	37.15	32.09	30.34
$P_1 \times P_6$	21.77	4.25	15.15	34.92	30.55	28.81
$P_6 \times P_1$	21.08	4.25	14.60	37.25	31.69	31.28
$P_2 \times P_3$	20.95	3.97	15.15	34.80	28.81	31.33
$P_3 \times P_2$	22.17	4.30	14.68	36.97	30.65	30.63
$P_2 \times P_4$	23.25	4.18	14.30	36.75	28.71	29.54
$P_4 \times P_2$	24.02	3.92	13.97	29.13	29.56	32.52
$P_2 \times P_5$	21.52	3.65	13.70	34.20	32.66	29.38
$P_5 \times P_2$	22.35	4.40	14.40	38.42	30.44	30.93
$P_2 \times P_6$	22.83	4.53	14.15	37.10	34.09	31.04
$P_6 \times P_2$	21.63	4.60	14.40	37.78	32.52	29.72
$P_3 \times P_4$	20.70	4.35	14.45	36.25	33.09	30.43
$P_4 \times P_3$	22.00	4.68	16.20	33.20	33.61	30.72
$P_3 \times P_5$	20.60	4.20	13.90	34.90	31.55	28.21
$P_5 \times P_3$	21.52	4.40	14.65	37.88	33.71	30.93
$P_3 \times P_6$	22.13	4.05	14.95	32.45	29.83	31.83
$P_6 \times P_3$	21.15	3.97	14.10	32.47	25.73	28.82
$P_4 \times P_5$	22.92	4.53	14.63	35.83	26.74	28.37
$P_5 \times P_4$	21.30	4.47	15.30	38.40	27.63	32.72
$P_4 \times P_6$	20.15	4.05	14.65	35.65	33.05	28.91
$P_6 \times P_4$	23.45	4.38	14.48	38.70	29.65	28.02
$P_5 \times P_6$	22.33	4.30	15.45	37.67	26.71	29.01
$P_6 \times P_5$	23.38	4.22	13.80	36.10	29.86	28.28
Checks 155	25.34	4.40	14.85	35.63	32.99	30.94
162	34.65	4.53	14.73	40.10	36.49	26.65
C.V.	10.08	11.16	9.73	10.29	13.38	7.037
L.S.D. 0.05	2.07	0.46	1.39	3.49	3.94	1.8468
0.01	2.72	0.60	1.83	4.58	5.17	2.4209

Combining ability effects: Estimates of general combining ability effects (gi) of parental inbred lines were presented in Table 3. Results showed that for Ear Length (EL) and number of rows per ear (RE), the parental inbred lines (P_4) possessed positive and GCA effects (desirable) in combined data over the two planting dates. Whereas, (P_5) exhibited highest significant positive GCA effects (desirable) for kernel number per row (KR) in combined data over the two dates at 1%. Whereas, the parental inbred lines (P_1) had significant positive GCA effects in combined data over the two planting dates for grain yield (ard/fed).

Table 3: Estimates of G.C.A. effects of six parents maize genotypes at Gemmeiza their combined for the traits studied in growing season 2011

	Parents					
Trait	Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/row	Weight of 100 kernel	Grain yield (ard/fad)
P_1	-0.25	-0.09*	-0.11	-0.25	-0.05	0.39*
P_2	-0.01	-0.04	-0.12	-0.71*	-0.12	0.19
P_3	-0.36*	0.01	0.12	-0.82**	0.52	-0.26
P_4	0.37*	0.06	0.23*	0.24	-0.58	0.07
P_5	0.07	0.01	-0.08	1.53**	0.12	-0.01
P_6	0.19	0.03	-0.03	0.01	0.11	-0.37
LSD 5% (gi)	0.35	0.07	0.23	0.58	0.75	0.30
LSD 1% (gi)	0.45	0.10	0.30	0.75	0.98	0.40
LSD 5% (gi-gj)	0.60	0.13	0.41	1.01	1.14	1.53
LSD 1% (gi-gj)	0.78	0.17	0.52	1.31	1.48	0.69

*, **Significant at 0.05 and 0.01 level of probability, respectively

General combining ability for six parental line indicated that the parental inbred line P_4 was good combiner for Ear Length (EL) and number of rows per ear (RE). The parental inbred line P_5 was good combiner for kernel number per row (KR) and the parental inbred lines P_1 was good combiner for grain yield (ard/fed). In plant breeding, decreasing yield component traits (YCTs) character is suitable for grain yield improvement program. Therefore, these crosses seem to be suitable conformed that result by Alam *et al*. (2008).

Estimates of SCA effects of 15 yellow single maize crosses: The estimates of specific (sij) combining ability effects in the 15 F_1 crosses for the studied traits are given in Table 4. For Ear Length (EL) showed positive (Sij) effects were detected for crosses ($P_1 \times P_2$), ($P_1 \times P_3$), ($P_1 \times P_4$), ($P_1 \times P_5$), ($P_2 \times P_4$), ($P_2 \times P_3$), ($P_2 \times P_5$), ($P_2 \times P_6$) and ($P_5 \times P_6$) in combined data. For Ear Diameter (ED) results showed significant positive (SCA) effect for crosses ($P_1 \times P_3$), ($P_2 \times P_6$), ($P_3 \times P_4$) and ($P_4 \times P_5$) in combined data over two planting dates. Therefore, these crosses seem to be suitable for plant height improvement. Similar results were obtained by Muraya *et al*. (2006) and Alam *et al*. (2008). For number of rows per ear (RE) showed positive SCA effect for crosses ($P_1 \times P_3$) and ($P_1 \times P_5$), for kernel number per row (KR) crosses ($P_1 \times P_2$), ($P_1 \times P_3$), ($P_1 \times P_5$), ($P_1 \times P_6$), ($P_2 \times P_3$), ($P_2 \times P_6$) and ($P_4 \times P_6$) were positively significant (sij) based on combined data. For 100 Kernel Weight (KW) results showed positive significant SCA effect for crosses ($P_1 \times P_2$), ($P_1 \times P_5$), ($P_2 \times P_6$), ($P_3 \times P_4$), ($P_3 \times P_5$) and ($P_4 \times P_6$) in combined data. For grain yield, the best SCA effects were significantly positive. These crosses also had the highest combined analysis values. It could be concluded that the parental inbred line for that crosses could made themselves recombinations. Similar results were obtained by Muraya *et al*. (2006), Amaregouda and Kajidoni (2007), Akbar *et al*. (2008) and Fan *et al*. (2009).

Estimates of reciprocal effects of 15 yellow single crosses maize: Maternal effects and sex-linkage give rise to differences between reciprocal crosses. In diallel cross analyses, the presence of these effects will cause biases in the estimates of genetical components of the variation.

The estimates of specific (r_{ij}) combining ability effects of the 15 F_1 crosses for the studied traits are given in Table 5. For Ear Length (EL) showed positive and significant (r_{ij}) effects for crosses ($P_2 \times P_1$) and ($P_4 \times P_1$). For kernel number per row (KR) cross ($P_4 \times P_2$) showed positively significant (r_{ij}) based on combined data. For 100 Kernel Weight (KW) results showed positive and significant

Table 4: Estimates of S.C.A. effects of 15 yellow single crosses maize genotypes at Gemmeiza their combined for the traits studied in growing season 2011

Crosses	Traits: Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/row	Weight of 100-kernel	Grain yield (ard/fad)
$P_1 \times P_2$	1.08**	0.06	-0.21	3.58**	2.03**	3.77**
$P_1 \times P_3$	1.35**	0.22*	0.77*	2.76**	-0.53	2.03**
$P_1 \times P_4$	2.57**	-0.20*	-0.41	-0.66	0.18	5.09**
$P_1 \times P_5$	1.27**	0.12	0.56*	2.17**	2.62**	3.13**
$P_1 \times P_6$	0.44	0.07	0.33	1.67*	0.98	4.08**
$P_2 \times P_3$	0.88*	-0.73**	0.23	2.77**	-0.74	3.28**
$P_2 \times P_4$	2.22**	-0.21**	-0.63*	-1.24	-0.23	4.46**
$P_2 \times P_5$	0.82*	-0.19	-0.41	0.83	1.47	3.87**
$P_2 \times P_6$	0.99*	0.32**	-0.25	3.48**	3.23**	3.43**
$P_3 \times P_4$	0.29	0.19*	0.29	0.65	3.33**	3.63**
$P_3 \times P_5$	0.31	0.03	-0.44	1.02	1.91*	3.84**
$P_3 \times P_6$	0.76	-0.27	-0.25	-1.38	-2.94	4.39**
$P_4 \times P_5$	0.62	0.22*	0.14	0.68	-2.43	3.69**
$P_4 \times P_6$	0.18	-0.12	-0.31	2.26**	1.74*	1.97**
$P_5 \times P_6$	1.54**	-0.02	0.05	0.68	-2.02	2.24**
LSD 5% (Sij)	0.81	0.18	0.54	1.36	1.53	0.70
LSD1% (Sij)	1.06	0.23	0.07	1.78	2.02	0.94
LSD 5% (Sij-Sik)	1.34	0.29	0.90	2.25	2.54	1.19
LSD1% (Sij-Sik)	1.76	0.39	1.18	2.95	3.33	1.56

*,**Significant at 0.05 and 0.01 level of probability, respectively

Table 5: Estimates of reciprocal effects of 15 yellow single crosses maize genotypes at Gemmeiza their combined for the traits studied in growing season 2011

Crosses	Traits: Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/row	Weight of 100 kernel	Grain yield (ard/fad)
$P_2 \times P_1$	1.16*	0.01	-0.17	-0.87	1.02	-0.901
$P_3 \times P_1$	-0.17	0.05	0.22	0.66	-0.95	-1.254**
$P_4 \times P_1$	1.13*	-0.42	-0.36	-2.35**	-3.98**	0.609
$P_5 \times P_1$	0.10	0.05	-0.15	0.96	0.67	0.656
$P_6 \times P_1$	0.35	0.00	0.27	-1.16	-0.56	-1.450**
$P_3 \times P_2$	-0.61	-0.16	0.23	-1.08	-0.91	2.014**
$P_4 \times P_2$	-0.38	0.12	0.16	3.81**	-0.42	0.932*
$P_5 \times P_2$	-0.41	-0.37	-0.35	-2.11*	1.11	-0.371
$P_6 \times P_2$	0.60	-0.03	-0.12	-0.33	0.78	-1.030*
$P_4 \times P_3$	-0.65	-0.16	-0.87	1.52	-0.26	-1.370**
$P_5 \times P_3$	-0.46	-0.10	-0.37*	-1.48	-1.08	-0.576
$P_6 \times P_3$	0.48	0.04	0.42	-0.01	2.05*	1.294**
$P_5 \times P_4$	0.81	-0.03	-0.33	-1.28	-0.44	-2.176**
$P_6 \times P_4$	-1.65	-0.16	0.08	-1.52	1.70	0.445
$P_6 \times P_5$	-0.52	0.04	0.82*	0.78	-1.57	0.363
LSD 5% (rij)	1.05	0.23	0.70	1.75	1.98	0.928
LSD 1% (rij)	1.36	0.30	0.92	2.28	2.75	1.210
LSD 5% (rij-rik)	1.47	0.32	0.99	1.77	2.80	1.312
LSD 1% (rij-rik)	1.92	0.42	1.29	2.31	3.65	1.71162

*,**Significant at 0.05 and 0.01 level of probability, respectively

(r_{ij}) for crosses ($P_6 \times P_3$). For grain yield, the best (r_{ij}) effects were positive and highly significant for crosses ($P_3 \times P_2$) and ($P_6 \times P_3$) from combined data over the two planting dates, ($P_4 \times P_2$) was positive and significant. Crosses ($P_3 \times P_1$), ($P_6 \times P_1$), ($P_4 \times P_3$) and ($P_5 \times P_4$) had negatively and highly significant for (r_{ij}) effect of grain yield and ($P_6 \times P_2$) had negatively and significant for (r_{ij}) effect of grain yield.

In these crosses showing high (r_{ij}) only good combiner. Such combinations, providing that the additive genetic system present in the good combiner as well as the complementary and epistatic effects present in cross. Therefore, the previous crosses might be important in breeding program for traditional breeding procedures.

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