

## **Combining Ability and Gene Action Studies for Yield and its Related Traits in Maize (*Zea mays* L.)**

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### **Abstract**

Present study was aimed to assess gene action, general combining ability effects of parents and specific combining ability effects of hybrids for yield and its related traits and explore their use in hybrid development. The material comprised of ten genetically diverse inbred lines at  $S_4$  stage and three well adapted testers. The parent along with their crosses were evaluated in randomized block design. There was greater contribution of lines towards  $\sigma^2_{sca}$  for all the traits. Prevalence of greater magnitude of non-additive genetic variance ( $\sigma^2_D$ ) relative to additive genetic variance ( $\sigma^2_A$ ) in present study favored production of hybrid cultivars. Inbred line viz. PMI-114 was good general combiner for all the traits except rows per ear and kernels per row. Among the selected hybrids, PMI-86  $\times$  PMI-401, PMI-105 $\times$ PS-66 and PMI-14 $\times$ C-15 exhibited highest magnitude of significant sca effect for grain yield per plant and most yield related traits. Heritability and genetic advance estimates were maximum for grain yield per plant and lowest for kernel row per ear. Hybrids showing high sca effect in favorable direction for grain yield per plant involved either High  $\times$  High, High  $\times$  Low, or Low  $\times$  Low general combiners as parent.

**Key words :** *Zea mays* L., GCA, SCA, Gene action.

Maize is grown in all countries under a wide range of climatic conditions. The aim of plant breeder is to identify parents that will combine well and produce productive progenies. The success depends on the choice of the parents, the nature and magnitude of gene action for components of productivity and efficiency of selection during segregating generations. The grain yield is the primary trait targeted for improvement of maize productivity especially to both favorable and unfavorable environment from its present level. In unfavorable environments early maturity genotypes may play an important role for improvement in grain yield. So improvement of local maize varieties and availability of HYV's suitable for cultivation for high altitudes (i.e. unfavorable environment) which comprises the largest production environment in northern zone, would go a long way in improving production and productivity of maize in the region. Combining ability studies provide information on the genetic mechanism controlling quantitative traits. Estimates of additive and dominance genetic variance help to choose the most effective breeding procedure to be followed for crop species. So the present investigation was undertaken to iden-

tify best general combiner inbred lines for desirable traits. Such lines could be crossed to constitute base population for derivation of lines excelling in maximum desirable characters and produce superior population and also the best crosses with respect to sca effect for use in hybrid combinations for commercial purpose.

### **Methods**

Ten diverse, vigorous inbred lines viz, PMI-13, PMI-14, PMI-56, PMI-73, PMI-86, PMI-88, PMI-94, PMI-96, PMI-105 and PMI-114 and three well adopted testers viz. C-15, PS-66 and PMI-401 were crossed in line  $\times$  tester design to generate 30  $F_1$  hybrids. These 30  $F_1$  hybrids along with 13 parents (10 lines and 3 testers) were planted in randomized block design with two replications in a single row plot of 5 m length having 60  $\times$  25 cm inter and intra row spacing and were evaluated at high altitude maize research sub-station Pahalgam (2,220 m asl). Recommended agronomic practices were followed to raise the crop. The data were recorded on maturity related traits and yield contributing traits on randomly selected competitive

**Table 1.** Combining ability analysis, heritability and genetic advance for ten characters in maize. \*, \*\* Significant at 5% and 1% respectively.

Source of variation	Df	Days to 50% anthesis	Days to 50% silk-ing	Days to 75% husk brow-ning	Ear len-gth (cm)	Ker-nal rows/ear	Ker-nals row	Ear dia-meter (cm)	Grain depth (cm)	100 grain wei-ght (g)	Grain yield/plant (g)
Replica-tions	1	1.06	5.40*	40.01**	1.09*	0.29	71.72**	4.66	77.06*	0.54	4.03
Crosses	29	14.21**	13.12**	24.74**	2.91**	2.30**	14.41**	1874.77**	239.53**	12.87**	986.10**
Lines	9	26.44*	24.74**	27.53**	3.03**	2.44**	13.46**	2144.63**	399.69	12.29**	1110.04**
Testers	2	0.61	0.71	82.61**	2.52	0.10	26.68**	3751.66**	103.64**	0.91	1784.32**
Lines × Testers	18	9.61**	8.69**	16.91**	2.90**	2.48**	18.35**	1531.29**	174.55**	14.48**	845.44**
$\sigma^2$ Error	29	2.61	3.08	2.46	0.19	0.75	4.66	83.04	37.10*	0.88	1.00
$\sigma^2$ Lines		3.97*	3.60*	4.17*	0.47*	0.28	1.46	343.59*	60.43*	1.90*	184.83*
$\sigma^2$ Testers		-0.10	-0.11	4.00	0.11	-0.03	1.10	183.43	3.32	0.00	89.16
$\sigma^2$ gca		0.83*	0.74*	4.04*	0.19*	0.04	1.18	220.39*	16.50*	0.44	111.24*
$\sigma^2$ sca		3.49*	2.80*	7.22**	1.35**	0.86**	6.84**	724.12**	68.72*	6.79**	417.21**
Heritabi-lity (ns)		25.87	25.43	28.90	21.47	6.09	20.53	36.53	27.44	10.83	34.75
Genetic advance		1.35	1.26	4.09	0.60	0.14	1.43	2.61	6.20	0.63	18.11

plants. Combining ability analysis was done according to procedure of Kempthorne (1).

### Results and Discussion

The analysis of variance revealed that the mean squares due to crosses were highly significant for all traits, reflecting presence of adequate diversity in material (Table 1). Variance for combining ability revealed that mean square due to lines, testers and lines × testers were highly significant for all characters due to testers for 100 grain weight, kernel rows per ear, ear length and days to 50% silking. This indicated that both additive and non-additive genetic variances were important in the genetic expression of most of the traits. These results are in general agreement with those of Joshi et al. (2). Mean square due to gca was significant for most traits except for kernel rows per ear, kernels per row and 100-grain weight (Table 1). However mean square due to sca was highly significant for all the traits. The estimates of mean square due to sca were higher than those due to gca for all traits. Based on estimates higher magnitude of  $\sigma^2$  sca in relation to  $\sigma^2$  gca implied the greater importance of non-additive gene effects in inheritance

of maturity related traits, grain yield per plant and its component traits. The results were similar with earlier findings of Joshi et al. (3). Contrarily, importance of additive gene effects was reported by Alamine et al. (4). Prevalence of greater magnitude of non-additive genetic variance in present study favors production of hybrid cultivars. The estimates of heritability (ns) ranged from 6.09 (kernel rows per ear) to 34.75 (grain yield per plant) and estimated values of genetic advance, expressed as percent of mean varied between 0.14 for kernel row per ear to 18.11 for grain yield per plant.

An important consideration in determining the utility of inbred lines developed is their combining ability. Starting from a general description the concept of combining ability was subsequently defined into general and specific combining ability by Sprague and Tatum (5). General combining ability (gca) as the comparative ability of a group of inbreds to combine with tester or a group of testers and specific combining ability (sca) as the deviation in performance of specific single cross from the performance expected on the basis of gca. General and specific combining ability have had a significant impact on inbred line

**Table 2.** Estimates of gca effects for different traits in inbred lines of maize. \*, \*\* Significant at 5% and 1% respectively.

Pedigree	Code name	Days to 50% anthesis	Days to 50% silk-ing	Days to 75% husk brow-ning	Ear len-gth (cm)	Ker-nal rows/ ear	Ker-nals/ row	Ear dia-meter (cm)	Grain depth (cm)	100-grain wei-ght (g)	Grain yield/ plant
<b>Lines</b>											
PMI-13	L <sub>1</sub>	0.16	0.40	0.35	0.38*	-0.24	-0.99	13.83**	-8.20**	-1.73**	-15.02**
PMI-14	L <sub>2</sub>	1.33*	1.06	0.18	0.33*	-0.76*	-1.64*	21.16**	5.63*	0.71	6.49**
PMI-56	L <sub>3</sub>	-4.00**	-3.60	-3.81**	-1.51**	1.00**	-0.30	-22.16**	-9.53**	1.84**	18.61**
PMI-73	L <sub>4</sub>	-0.33	-0.60	0.48	0.91**	-0.36	2.44**	-12.16**	-7.20*	-1.55**	-12.83**
PMI-86	L <sub>5</sub>	1.00	0.90	3.18**	-0.44**	0.11	-1.07	14.50**	0.53	0.49	6.41**
PMI-88	L <sub>6</sub>	-0.50	-0.06	0.35	0.28*	-0.92*	1.11	-30.50**	-9.36**	-0.93*	-0.91*
PMI-94	L <sub>7</sub>	0.83	0.06	-0.81	-0.26*	0.34	-1.59*	22.83**	10.30**	-0.22	10.32**
PMI-96	L <sub>8</sub>	0.33	-0.10	-1.15*	0.03*	0.94*	1.66*	-2.16	0.96	-1.72**	-25.64**
PMI-105	L <sub>9</sub>	3.66**	4.06**	3.51**	0.75**	-0.02	-0.97	14.50**	7.96*	1.76**	6.91**
PMI-114	L <sub>10</sub>	-2.50**	-2.26**	-1.31*	-0.48**	0.14	1.36	7.83*	9.96**	1.36**	5.64**
<b>Testers</b>											
C-15	T <sub>1</sub>	-0.01	-0.08	-1.48**	-0.13	-0.04	-0.51	14.83**	-2.05	-0.24	-5.60**
PS-66	T <sub>2</sub>	-0.16	-0.13	-0.83**	0.40**	0.08	-0.80	-2.66	-0.40	0.13	-5.29**
PMI-401	T <sub>3</sub>	0.18	0.21	2.31**	-0.26*	-0.03	1.32*	-12.16**	2.45*	0.10	10.90**

evaluation and population improvement in maize breeding (6).

The studies on general combining ability effect showed PMI-114 as good general combine for all traits except for kernel rows per ear and kernels per row (Table 2). PMI-56 showed highest desirable significant gca effects for maturity related traits and grain yield per plant and 100-grain weight. Similarly PMI-94, PMI-105, PMI-14 and PMI-86 showed desirable significant gca effect for grain yield per plant. These lines could be crossed *inter se* to constitute base population and sufficient recombination cycles would allow to dissipate non-allelic interactions and linkage groups. These populations could serve as source of new desirable inbred lines. Subsequent recurrent selection efforts in the source population would facilitate derivation of lines excelling in maximum desirable traits and these could be utilized for development of synthetic varieties.

A critical evaluation of the results with respect to specific combining ability effects showed none of the cross combination exhibited desirable significant sca effects for all the traits, however crosses PMI-86

× PMI-401, PMI-105 × PS-66 and PMI-14 × C-15 exhibited desirable sca effects for grain yield per plant and most of yield contributing traits. Studies on specific combining ability effects with 13 crosses showing desirable significant sca effects for grain yield per plant and among them PMI-88 × C-15 showed highest desirable sca effect for grain yield per plant followed by PMI-13 × PS-66, PMI-105 × PS-66, PMI-114 × PMI-401, and PMI-73 × PS-66 along with high *per se* performance (Table 3). Surya et al. (7) also reported high positive specific combining ability along with high *per se* performance for grain yield. PMI-96 × PS-66 showed significant positive effect for ear length, kernel rows per ear kernels per row, ear diameter and grain depth. PMI-13 × PS-66 was noted to be most suitable cross combination among nine desirable crosses for 100-grain weight. Crosses showing desirable sca effects for maturity related traits are PMI-14 × PS-66, PMI-13 × C-15, PMI-56 × PMI-401, PMI-86 × PS-66 and PMI-88 × PMI-401. Crosses showing desirable sca effect for grain yield per plant involved either High × High, High × Low or Low × Low. The results therefore revealed that high gca value of parent is no guarantee of high sca effects of these crosses and confirming ear-

**Table 3.** Estimates sca effects for different traits in Line × Tester crosses of maize.

Crosses	Days to 50% anthesis	Days to 50% silking	Days to 75% husk bowning	Ear length (cm)	Kernal rows per ear
PMI-13×C-15	-1.317	-0.750	-3.350**	-0.330	0.248
PMI-13×PS-66	1.333	1.300	1.000	1.530**	-0.582
PMI-13×PMI-401	-0.017	-0.550	2.350*	-1.200**	0.333
PMI-14×C-15	-1.483	-2.417*	1.317	-0.680*	-0.285
PMI-14×PS-66	-0.333	-0.367	-4.333**	-0.870*	1.485
PMI-14×PMI-401	1.817	2.783*	3.017*	1.550**	-1.200*
PMI-56×C-15	-1.150	0.250	0.817	-0.580	0.148
PMI-56×PS-66	1.500	0.300	2.667*	0.330	-1.082
PMI-56×PMI-401	-0.350	-0.550	-3.483	0.250	0.933
PMI-73×C-15	3.683**	3.750**	1.983	-0.513	0.215
PMI-73×PS-66	-1.667	-1.200	-1.667	0.697*	-0.615
PMI-73×PMI-401	-2.017	-2.550*	-0.317	-0.183	0.400
PMI-86×C-15	-0.150	0.250	-0.683	-1.197**	-0.485
PMI-86×PS-66	-3.000*	-3.200	-1.333	-0.487	-0.865
PMI-86×PMI-401	3.150*	2.950*	-2.017	1.683**	1.350*
PMI-88×C-15	1.850	0.083	-2.850*	1.470**	0.232
PMI-88×PS-66	2.000	1.133	4.000**	-1.270**	0.902
PMI-88×PMI-401	-3.850**	-1.217	-1.150	-0.200	-1.133*
PMI-94×C-15	-1.483	-0.417	1.817	-0.780*	0.815
PMI-94×PS-66	1.667	1.133	2.667*	0.780*	-1.615*
PMI-94×PMI-401	-0.183	-0.717	-4.483**	-0.000	0.800
PMI-96×C-15	0.517	1.250	-0.850	0.470	-0.985
PMI-96×PS-66	-1.833	-2.200	-0.500	0.880*	1.935**
PMI-96×PMI-401	1.317	0.950	1.350	-1.350**	-0.950
PMI-105×C-15	-0.317	-0.417	2.483*	1.703**	0.132
PMI-105×PS-66	0.833	1.133	-1.667	-0.987**	-0.248
PMI-105×PMI-401	-0.517	-0.717	-0.817	-0.717*	0.117
PMI-114×C-15	-0.150	-1.583	-0.683	0.437	-0.035
PMI-114×PS-66	-0.500	1.967	-0.833	-0.603*	0.685
PMI-114×PMI-401	0.650	-0.383	1.517	0.167	-0.650

**Table 3.** Continued.

Crosses	Kernels per row	Ear diameter (cm)	Grain depth (cm)	100 grain weight	Grain yield per plant
PMI-13×C-15	2.150	26.833**	1.550	-2.037**	-10.425**
PMI-13×PS-66	-1.560	-5.667	1.900	3.578**	29.279**
PMI-13×PMI-401	-0.590	-21.167**	-3.450	-1.542*	-18.854**
PMI-14×C-15	-2.050	41.833**	13.217**	-2.987**	3.480**
PMI-14×PS-66	2.090	-25.667**	-9.433*	2.328**	0.379
PMI-14×PMI-401	-0.040	-16.167*	-3.783	0.658	-3.858**
PMI-56×C-15	-2.883	-4.833	3.883	-2.370**	6.545**
PMI-56×PS-66	-0.943	-2.333	-0.267	-0.455	-6.846**
PMI-56×PMI-401	3.827*	7.167	-3.617	2.825**	0.302
PMI-73×C-15	-3.283	-14.833*	-1.950	1.180*	-12.860**
PMI-73×PS-66	1.457	27.667**	7.400	-0.805	18.549**
PMI-73×PMI-401	1.827	12.833**	-5.450	-0.375	-5.688**
PMI-86×C-15	-0.167	-1.500	1.383	0.330	7.626**
PMI-86×PS-66	-2.927	-34.00**	-9.767*	-1.805*	-22.534**
PMI-86×PMI-401	3.093*	35.00**	8.383*	1.475*	14.908**

Table 3. Continued.

Crosses	Kernels per row	Ear diameter (cm)	Grain depth (cm)	100 grain weight	Grain yield per plant
PMI-88×C-15	0.000	-11.500	-3.283	0.863	34.186**
PMI-88×PS-66	-1.110	6.00	-5.933	-2.422**	-30.949**
PMI-88×PMI-401	1.110	5.500	9.217*	1.558*	-3.237**
PMI-94×C-15	-1.250	-34.833**	-13.950**	0.747	-3.019**
PMI-94×PS-66	1.240	12.667**	6.900	-1.038*	7.291**
PMI-94×PMI-401	0.010	22.167**	7.050	0.292	-4.272**
PMI-96×C-15	1.500	10.167	-3.117	2.347**	-8.257**
PMI-96×PS-66	3.740*	22.667**	12.233*	-2.438	-0.018
PMI-96×PMI-401	-5.240**	32.833**	-9.117*	0.092	8.275**
PMI-105×C-15	2.633	-26.500**	-6.617	0.363	-18.282**
PMI-105×PS-66	1.023	20.000**	8.233*	4.678**	28.922**
PMI-105×PMI-401	-3.657*	0.100	-1.617	-5.042**	-10.640**
PMI-114×C-15	3.350*	15.167*	8.883*	1.563*	1.008
PMI-114×PS-66	-3.010*	-21.330	-11.267*	-1.622*	-24.073**
PMI-114×PMI-401	-0.340	12.167**	2.383	0.058	23.065**

lier reports of Dubey et al. (8). Crosses with desirable specific combining ability can be selected to recover transgressive segregants. The promising crosses showing desirable sca effects for yield and component traits can be tested extensively over environments in future and good performers can be utilized profitably by maize breeders for use in hybrid combinations for commercial purpose in high altitudes.

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