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Combining Ability Analysis for Seed and Seedling Traits in Indigenous Maize (*Zea mays* L) Germplasm of Himachal Pradesh

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Experiments were conducted to identify the best parents and hybrids for gca and sca effects in maize under mid hill conditions of Himachal Pradesh. Females and males were crossed in Line x tester analysis involving 24 females and 3 males from adverse origin. The study revealed that dominance component of variance (σ_{2D}) was greater than additive component (σ_{2A}) for all the characters during both years as well as when combined over years. Six lines *viz.,* 4, 8,11,13,17 and 23 performed consistently better for important seed and seedling traits, such as accelerated aging test, osmotic stress test, 100-seed weight, 100-seed volume, germination percentage and field emergence. Two cross combinations *viz.,* line-5 x Early Composite and line-17 x Early composite were observed to be promising as these revealed significant and positive SCA effects for two most important features of drought tolerance *viz.,* accelerated aging test and field emergence. Among testers, early composite showed desirable gca effects for 100 seed weight, 100 seed volume and field emergence.

Key words: Combining ability, gene action, seed quality traits

Maize (*Zea mays* L.) is one of the most important cereal crops in India and in the world. In India, about 95 per cent of the maize area in tropics is rainfed and the major maize growing season, *kharif* account for more than 80 per cent of total maize area in the country. In case of Himachal Pradesh, maize is extensively grown under rainfed condition but average yield per hectare is slightly higher than national average yield. Maize is a major kharif crop in Himachal Pradesh cultivated in an area of 3.0 lakh ha, which is over 70 per cent of the total cultivated area of 4.30 lakh ha. The average annual production in the state is over 6.0 lakh MT, which is more than 80 per cent of total kharif production of 7.78 lakh MT of food grains. India is the tenth largest producer with a production of 11.10 mMT from an area of 6.6 million ha. The average yield in India is 1.77 MT/ha which is very low as against 7 MT/ha in temperate areas of developed economies and 3.8 MT/ha of global average. Keeping in view its potential, still there is a considerable scope for yield improvement in this region. One of the most important factor affecting maize yield under rainfed condition is the drought during crop season for short or long periods. The extent of yield reduction depends upon the degree, duration and time of drought occurrence. The varieties presently under cultivation in the region do not express high seedling vigor and thus pose problems in field emergence under stress conditions.

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Thus, the investigation was designed to explore the possibility of identifying some lines or crosses of maize suitable to germinate and strive well under moisture stress conditions. The concept of combining is an important tool for selecting potential parental lines for hybridization and narrowing down on specific crosses for further exploitation.

Material and Methods

Twenty four inbred lines (S-5 stage), derived from local germplasm collected from different parts of Himachal Pradesh were crossed with three broad based testers, *viz.,* Early composite, Girija composite and KH-2001 in a line x tester fashion. The experimental material, comprising one hundred entries (72 crosses, 27 parents and one standard check, PMZ-4) were evaluated in completely randomized block design (CRBD) in the Seed Technology laboratory of CSK HPKV, Palampur and the data was recorded for seven seed and seedling traits *viz.,* accelerated aging test at 40 ±1 ^{0}C for 96 hours, osmotic stress test (-5 bar by using PEG 6000), germination percentage, 100-seed weight (g), 100-seed volume (ml), seed density (g/ml) and field emergence. Seed density showed non significant result in the anova and not discussed in results and discussion. Accelerated aging test was conducted as suggested by Byrd and Delouche (1971); osmotic stress test as per the method of Langerwerff *et al*., (1961); standard germination test was carried out using top of paper method in seed germinater at 25 ± 1 ^{0}C temperature and 90 ± 5 per

cent relative humidity, as per the guidelines of ISTA (1985). Final count was recorded on seventh day. The general combining ability (gca) and specific combining ability (sca) effects were estimated following Kempthorne (1957).

Results and Discussion

Significant variation among treatments implied possibility of the utilization of existing variability for further improvements of traits as well as identification of prospective combinations. Analysis of variance for combining ability for seed and seedling traits, lines differed in their general combining ability variances for all the traits studied except germination percentage (Table 1). Testers on the other hand differed consistently in general combining ability for osmotic stress test but showing variable behavior for other traits in individual years as well as when combined over years. L x T interaction, an indicative of SCA revealed significant difference for all the seed and seedling traits studied. The interaction of lines, testers as well as of line x

Table 1. Analysis of variance (combined over years) for seed and seedling traits in maize

Characters	Mean squares					
Source:	Year	Replications	Block	Genotypes	Genotype x Year	Error
df	1	1	18	99	99	181
Accelerated aging test	124.32	24.50	67.08*	68.54*	76.126*	8.17
Osmotic stress test	1.44	0.09	56.50*	71.02*	49.253*	7.91
100-seed weight	0.11	0.43	38.08*	36.50*	9.399*	2.08
100-seed volume	0.04	0.49	26.42*	25.05*	7.155*	1.57
Seed density	0.001	0.01	0.001	0.001	0.001	0.001
Germination (%)	5.06*	0.60	5.54*	6.31*	1.209*	2.00
Field emergence	292.41*	0.00	82.53*	58.54*	48.753*	10.18

*Significant at P<0.05

tester with years was significant for all the traits except germination percentage indicating that germination percentage was not much influenced over years compared to other traits (Table 2). Katna *et al.* (2002) observed high variability in seedling emergence from seeds having variable shape, size and sowing dates.

The GCA effects are direct utility to decide the next phase of the breeding programme, since it is a general view that better general combiner inbreds may be yield better crosses. Superior inbred lines can be used for development of synthetics as direct release for cultivation as short term approach. The estimate of general combining ability effects (table 2) for parental line i.e. line 4 showed desirable significant gca effects for all the six traits. However, in general it was observed that the parental line 4, line 8, line 11, line 13 and line 17 were found to be significantly superior general combiners for majority of seed and seedling traits. Line 1 for osmotic stress test, 100 seed weight, 100 seed volume and field emergence. Line-8 for osmotic stress test, 100-seed weight and germination percentage, line-4 and 10 for accelerated aging test, osmotic stress test, 100-seed weight and 100-seed volume, line11 for

Table 2. Desirable general combiners for seed and seedling traits as combined over years

Parents	Accelerated aging test	Osmotic stress test	100-seed weight	100-seed volume	Germination percentage	Field emergence
Lines / Females						
Line 1	-1.10*	1.00*	4.23*	19.44*	-1.32*	0.68*
Line 3	-0.94*	1.50*	-5.69*	5.10*	-0.82*	-0.35
Line 4	0.90*	1.08*	6.87*	16.16*	1.18*	0.76*
Line 8	-1.10*	0.66*	4.48*	-15.81*	0.93*	-0.32
Line 11	2.56*	0.50*	1.89	-0.60	0.93*	0.83*
Line 13	-0.35*	-0.67*	4.44*	19.03*	1.09*	0.29
Line 17	0.65*	0.16	-0.27	20.06*	1.68*	0.15
Line 19	1.40*	0.66*	-11.20*	-30.94*	-0.82*	-0.37
Line 23	1.15*	-0.09	9.94*	-3.24*	-0.24	-1.09*
Line 24	-0.60*	-0.34*	4.96*	1.66	-1.82*	-0.05
SE(gi)±	0.16	0.16	1.57	1.56	0.38	0.20
CD (P<0.05)	0.23	0.23	2.21	2.20	0.54	0.28
Testers / Males						
Early composite	-0.24*	-0.09	1.74*	3.89*	-0.34*	0.16*
Girija	0.32*	-0.14*	-0.98*	-3.70*	-0.09	-0.17*
KH-2001	-0.08	0.23*	-0.76	-0.18	0.44*	0.01
SE(gj)±	0.05	0.05	0.46	0.46	0.11	0.06
CD (P<0.05)	0.07	0.07	0.65	0.65	0.16	0.08

*Significant at P<0.05

accelerated aging test, 100-seed weight, germination percentage and field emergence, line-13 for 100-seed weight ,100 seed volume and germination percentage, line17 for accelerated aging test, 100-seed volume and germination percentage, line-23 and 24 for germination percentage, 100-seed weight and 100-seed volume.

High GCA estimates for osmotic stress test, accelerated aging test, 100 seed weight and 100 seed volume) and high positive GCA estimates for germination percentage and 100 seed weight were earlier reported by workers Katna *et a*l., (2002) and Kumar (1996) and Moterle (2011). Among testers, early composite showed desirable gca effects for 100-seed weight, 100-seed volume and field emergence, KH 2001 for osmotic stress test and germination percentage.

Specific combining ability effects (Table 3) revealed a very wide range of variation for all the characters. Cross combination line 5 x Early composite exhibited significant positive sca effects for all the traits except germination percentage. From

Table 3. Superior specific combiners for seed and seedling traits as combined over years

Hybrids	Accelerated aging test	Osmotic stress test	100-seed weight	100-seed volume	Germination percentage	Field emergence
	1	2	3	4	5	6
Line 5 x Early composite	0.49*	0.50*	8.60*	16.32*	0.09	0.99*
Line 7 x Early composite	0.57*	0.84*	6.53*	-1.30	0.01	-0.47
Line 8 x Early composite	-0.01	0.84*	7.27*	4.57*	1.18*	-0.06
Line 13 x Early composite	0.49*	0.42	9.16*	9.37*	0.26	-1.56*
Line 17 x Early composite	0.74*	-0.91*	-1.12	-7.05*	1.68*	0.98*
Line 21 x Early composite	0.32	-0.41	-0.95	9.02*	2.84*	1.74*
Line 24 x Early composite	0.24	0.34	6.89*	17.75*	0.18	2.13*
Line 2 x Girija	1.18*	0.47*	8.05*	17.19*	-0.18	-0.23
Line 9 x Girija	0.51*	-0.69*	4.83*	12.01*	1.34*	-0.23
Line 10 x Girija	0.68*	1.06*	7.90*	-10.35*	0.51	-0.83*
Line 11 x Girija	1.26*	1.06*	3.77	-2.98	1.18*	0.22
Line 15 x Girija	-0.91*	1.06*	5.61*	3.70	1.09*	-0.03
Line 16 x Girija	1.26*	1.31*	-3.27	20.62*	-0.07	-0.56*
Line 3 x KH-2001	0.17	0.94*	-7.14*	8.79*	1.90*	0.17
Line 6 x KH-2001	-1.08*	-0.06	10.31*	14.80*	1.65*	0.64*
Line 9 x KH-2001	0.42	0.94*	-1.18	9.25*	1.06	1.34*
Line 12 x KH-2001	0.42	1.44*	5.70*	-4.43*	-1.35*	1.15*
Line 18 x KH-2001	2.67*	0.94*	4.53*	-6.72*	-0.52	-0.66*
Line 21 x KH-2001	1.17*	0.77*	4.64*	5.75*	-4.44*	-1.26*
SE(sij) ±	0.22	0.23	2.22	2.21	0.54	0.28
CD (P<0.05)	0.31	0.32	3.13	3.12	0.76	0.39

*Significant at P<0.05

drought resistant point of view, cross combinations Line 5 x Early composite and Line 17 x Early composite exhibited significant desirable sca effects for two most important drought tolerant traits viz., accelerated aging test and field emergence; in addition to them these cross combinations also indicated desirable sca effects for seedling traits. These two cross combinations; the later in particular, can play an important role in the development of drought tolerant maize genotypes.

Seven cross combinations *viz.,* Line 5 x Early composite, line -17 x Early composite, Line 21 x Early composite, Line 24 x Early composite, line-6 x KH-2001, line-9 x KH-2001 and line-12 x KH-2001 were observed good SCA effect for high field emergence and seedling traits. These cross combinations, in general, involved parents with low and high GCA effects, mainly in low x low and low x high pattern. Further, the study revealed a close correspondence between the *per se* performance and SCA performance of different cross combinations. Alamnie *et al*., (2003) and Sofi and Rather (2006) have also reported similar significant sca effects for accelerated aging test and field emergence.

The other cross combinations line 8 x Early composite, line 21 x Early Composite, Line 21 x Girija, Line 15 x Girija, Line 3 x KH 2001, Line 6 x KH 2001 and Line 21 x KH 2001 were observed to be promising for 100 seed weight, 100 seed volume as well as field emergence. These cross combinations, in general, involved parents with low and high GCA effects, mainly in low x low and low x high pattern.

Further, the study revealed a close correspondence between the *per se* performance and SCA performance of different cross combinations. A comparison of the combining ability effects of the parents and their corresponding crosses indicated that the GCA effects of the parents were not reflected in the SCA effects of the crosses for most of the traits studied.

Thus, in most cases, crossing the two good general combiners may not necessarily result into a good specific combination and the same was true for certain poor combinations which involved one good combiner, while in very few cases, both good combiners could produce superior combinations. In some cases, when two poor combiners were crossed, best combinations were observed to be produced. This indicated wide diversity in nicking ability of the inbreds to produce hybrid vigor. In general, no generalized order of nicking among the parents to produce desirable combinations was observed. Any sort of combination among the parents could give hybrid vigor over the parents who might be due to favorable dominant genes, over-dominance or epistatic action of genes. Based on the present results, it could be concluded that the production of hybrids based on the parental performance was not practically true. Such types of results were also reported by Kumar (1996).

The cross combinations Line 7 x Early composite, Line 2 x Girija, Line12 x Girija, Line 11 x Girija, Line 16 x Girija, Line 18 x KH2001 and Line 21 x KH 2001 were observed as good specific combiners for most of the seed and seedling traits. The cross combinations Line 5 x Early composite and Line 17 x Early composite can be tested extensively over wide range of environments in future and good performers may be utilized under drought prone environments.

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