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RESEARCH ARTICLE

Hybrid vigour assessment for drought related traits in maize [*Zea mays* (L.)]

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SUMMARY

Experiments were carried out to identify best heterotic combination for three drought tolerant traits *viz.*, SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA) and proline content and grain yield. 36 hybrids derived from crossing twelve lines and three testers have been raised along with their parents in Zonal Agricultural Research Station, V.C. Farm, Mandya under Randomized Complete Block Design with two replications. Significant heterosis over two standard checks *viz.*, NAH-2049 and NAH-1137 had been observed in cross 2422 x HKI-164-4-1-3 for SCMR and proline content, cross 1201 x HKI-164-4-1-3 for proline content and significant mid parent heterosis has observed in cross MAI-105 x CML411 for SCMR, proline content and yield.

Key Words : Heterosis, SCMR, SLA, Proline content, *Per se* performance

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Exploitation of heterosis by single cross hybrid development in maize is achieving highest growth rate in productivity (73 kg/ha/year) as compared to other cereal crops (DMR, 2013) and is meeting increasing demand from poultry and livestock sectors in the country. About 95 per cent of maize area in tropics of India is rainfed and wheredrought is a major abiotic factor affecting maize yield significantly. Recently in 2009-10 maize has experienced severe drought caused yield reduction from 19.7 mt to 16.7 mt and again in 2012 the crop experienced moderate to severe drought during the early season especially in Karnataka, Rajasthan and Gujarat. Hence, development of drought tolerant and high yielding maize hybrids will be the most appropriate solution to mitigate this problem.In this study we have focussed on three important drought tolerance attributing traits *viz.*, free proline content, leaf chlorophyll content (SPAD) and specific leaf area (SLA) along with the grain yield.In this study attempt was made to assess the level of heterosis in a set of cross combination and to identify best single cross hybrids with highheterosis level for drought tolerant traits and yield.

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MATERIAL AND METHODS

Twelve lines and three testers were crossed in Zonal Agricultural Research Station, V.C. Farm, Mandya during Summer 2012. During *Kharif* 2012, 36 F_1s and along with their fifteen parents and two checks (NAH-2049 and NAH-1137) were raisedby following Randomized Complete Block Design in two replications with a spacing of 75 cm (between rows) × 30 cm (between hills). Observations were recorded on grain yield (t/ha.) and drought related traits *viz.*, free proline content, leaf chlorophyll content (SPAD) and specific leaf area (SLA). Mean of five randomly selected plants on each character for each entry was used to compute heterosis (relative heterosis, heterobeltiosis and standard heterosis) by Hayes *et al*. (1955).

Proline content in leaf tissue of maize genotypes was estimated when crop was of 45 days old which had experienced 20 days of moisture stress as per the method of Bates *et al.* (1973).Moisture stress was induced by withholding irrigation. Leaf chlorophyll content (SPAD chlorophyll meter reading) was measured in third leaf from the apex of plant under normal sunlight hour between 9 am to 4 pm by using a device developed by Minolta Company, New Jersey USA (SPAD-502). For estimation of specific leaf area (cm^2/g) fully expanded leaf of the middle region was selected, dried in oven at 70^0 C for 3 days and dry weight of leaf was measured.

RESULTS AND DISCUSSION

The highest *per se* mean performance was observed in lines *viz.*, SKV-50 for SCMR, NAI-137-2 for proline content and yield per plot and 1410-1 for SLA. Among the testers highest *per se* mean performance was observed in HKI-164-4-1-3 for SCMR and SLA; HKI-193-2 for proline content and yield per plot (Table 1a). Highest mean performance was observed in cross combinations *viz.*, 2422x HKI-164-4-1-3for SCMR, MAI-105x CML411 for proline content, 1201x HKI-164-4-1-3 for SLA and NAI-137-2x HKI-193-2 for yield per plot (Table 1b).

For SCMR, seven crosses showed significant desirable mid parent heterosis,five crosses showed standard heterosis over standard check (NAH-2049) and two crosses over another standard check (NAH-1137). Earlier workers including

Table 1a : *Per se* performance of lines and testers for drought tolerance attributing traits and yield in maize

Lines	SCMR values	Proline content (µg /g dry weight)	Specific leaf area (cm^2/g)	Yield per plot (kg)
1232	29.75	46.0	138.46	3.75
1005	27.30	19.10	158.57	0.80
1201	23.65	37.90	168.07	2.30
1396	23.95	41.45	158.79	3.0
772-2	30.85	50.90	128.75	4.25
1410-1	29.90	46.35	185.90	3.95
2422	25.50	50.55	112.74	4.10
262-55	30.60	44.20	110.42	3.90
634-2	30.05	39.45	146.01	3.15
NAI-137-2	25.50	55.54	142.89	5.15
MAI-105	25.50	46.45	125.31	3.45
SKV-50	36.35	49.0	144.39	4.10
Mean	28.24	43.91	143.36	3.49
S.E.±	0.72	0.67	9.04	0.14
CD (P=0.05)	1.41	1.31	17.72	0.27
CD (P=0.01)	1.85	1.73	23.29	0.36
Testers				
HKI-164-4-1-3	30.70	40.15	165.92	3.20
HKI-193-2	22.80	42.65	161.33	3.60
CML-411	23.45	38.90	137.30	2.40
Mean	25.65	40.57	154.85	3.07
S.E.±	0.36	0.33	4.52	0.07
CD (P=0.05)	0.71	0.65	8.86	0.14
CD (P=0.01)	0.93	0.85	11.64	0.18

Table 1b: Mean performance of hybrids for drought tolerant attributing traits and yield in maize

Hybrids	SCMR	Proline content	SLA	Yield per plot (kg)	Hybrids	SCMR	Proline content	SLA	Yield per plot (kg)
1232 x HKI-164-4-1-3	16.20	28.80	140.71	2.10	2422x CML411	25.25	43.10	119.56	3.85
1232 xHKI-193-2	11.80	26.40	143.38	1.75	262-55x HKI-164-4-1-3	29.40	46.60	144.49	3.55
1232xCML411	19.15	24.35	140.85	2.10	262-55x HKI-193-2	23.45	51.40	148.64	4.05
1005x HKI-164-4-1-3	18.80	34.70	144.26	2.45	262-55x CML411	23.35	43.40	124.51	3.30
1005x HKI-193-2	16.30	25.05	117.81	1.80	634-2x HKI-164-4-1-3	25.90	53.20	111.17	4.25
1005x CML411	14.90	22.0	139.43	1.30	634-2x HKI-193-2	24.95	36.70	151.42	2.25
1201x HKI-164-4-1-3	16.65	23.15	170.40	1.80	634-2x CML411	27.25	46.05	141.76	3.80
1201x HKI-193-2	18.40	12.95	129.59	0.75	NAI-137-2x HKI-164-4-1-3	33.25	52.35	110.35	4.30
1201x CML411	13.30	15.60	150.65	1.50	NAI-137-2x HKI-193-2	26.50	52.05	115.63	4.35
1396x HKI-164-4-1-3	14.90	12.40	131.01	0.85	NAI-137-2x CML411	25.35	51.25	104.92	4.20
1396x HKI-193-2	16.05	15.55	131.91	0.95	MAI-105x HKI-164-4-1-3	23.55	37.45	140.32	2.70
1396x CML411	11.45	16.45	165.35	1.10	MAI-105x HKI-193-2	32.25	22.70	128.81	1.65
772-2x HKI-164-4-1-3	11.25	13.30	156.93	1.0	MAI-105x CML411	29.25	53.65	122.59	4.30
772-2x HKI-193-2	18.05	20.95	130.87	1.35	SKV-50x HKI-164-4-1-3	33.90	50.95	120.11	3.95
772-2x CML411	15.65	38.40	121.30	3.05	SKV-50x HKI-193-2	25.50	41.35	148.0	3.05
1410-1x HKI-164-4-1-3	32.10	45.05	120.90	3.65	SKV-50x CML411	28.85	43.15	126.20	3.35
1410-1x HKI-193-2	32.15	49.15	126.69	3.80	Mean	23.06	34.73	134.93	2.66
1410-1x CML411	31.40	20.80	137.55	1.50	S.E.±	1.24	1.16	15.67	0.25
2422x HKI-164-4-1-3	34.45	37.10	166.12	2.25	C.D. (P=0.05)	2.43	2.27	30.71	0.49
2422x HKI-193-2	29.40	42.65	133.58	3.70	C.D. (P=0.01)	3.19	2.99	40.37	0.64

Table 2 : Per cent heterosis over mid parent (MP) and standard checks (SH) for drought tolerant attributing traits and yield in maize

Single cross hybrids	SCMR values			Specific leaf area(SLA)			Free proline			Yield per plot (kg)		
	MP	SH1	SH2	MP	SH1	SH2	MP	SH1	SH2	MP	SH1	SH2
1232xHKI-164-4-1-3	-46.40**	-45.91	-47.83	-7.54	-44.67	-48.43	-33.14**	7.62*	14.21	-39.57**	-53.33	-62.50
1232xHKI-193-2	-55.09**	-60.60	-62.00	-4.34	-49.28	-52.73	-40.44**	9.66*	16.38	-52.38**	-61.11	-68.75
1232xCML411	-28.01**	-36.06	-38.33	2.15	-53.22	-56.40	-42.64**	7.72*	14.33	-31.71**	-53.33	-62.50
1005x HKI-164-4-1-3	-35.17**	-37.23	-39.45	-11.09	-33.33	-37.87	17.13**	10.33**	17.09	22.50	-45.56	-56.25
1005x HKI-193-2	-34.93**	-45.58	-47.50	-26.34**	-51.87	-55.15	-18.87**	-9.90	-4.38	-18.18	-60.00	-67.86
1005x CML411	-41.28**	-50.25	-52.01	-5.75	-57.73	-60.61	-24.14**	6.64*	13.17	-18.75	-71.11	-76.79
1201x HKI-164-4-1-3	-38.73**	-44.41	-46.38	2.04	-55.52	-58.55	-40.68**	30.33**	38.31**	-34.55**	-60.00	-67.86
1201x HKI-193-2	-20.78**	-38.56	-40.74	-21.32**	-75.12	-76.81	-67.85**	-0.89	5.19	-74.58**	-83.33	-86.61
1201x CML411	-43.52**	-55.59	-57.17	-1.33	-70.03	-72.07	-59.38**	15.22**	22.28**	-36.17	-66.67	-73.21
1396x HKI-164-4-1-3	-45.47**	-50.25	-52.01	-19.31*	-76.18	-77.80	-69.61**	0.20	6.34	-72.58**	-81.11	-84.82
1396x HKI-193-2	-31.34**	-46.41	-48.31	-17.59*	-70.12	-72.16	-63.02**	0.89	7.07	-71.21**	-78.89	-83.04
1396x CML411	-51.69**	-61.77	-63.12	11.68	-68.40	-70.55	-59.05**	26.46**	34.21**	-59.26**	-75.56	-80.36
772-2x HKI-164-4-1-3	-63.44**	-62.44	-63.77	6.52	-74.45	-76.19	-70.79**	20.02**	27.38**	-73.15**	-77.78	-82.14
772-2x HKI-193-2	-32.71**	-39.73	-41.87	-9.77	-59.75	-62.49	-55.21**	0.09	6.23	-65.61**	-70.00	-75.89
772-2x CML411	-42.36**	-47.75	-49.60	-8.81	-26.22	-31.24	-14.48**	-7.23	-1.54	-8.27	-32.22	-45.54
1410-1x HKI-164-4-1-3	5.94	7.18	3.38	-31.27**	-13.45	-19.34	4.16	-7.53	-1.87	2.10	-18.89	-34.82
1410-1x HKI-193-2	22.01**	7.35	3.54	-27.03**	-5.57	-12.00	10.45**	-3.11	2.83	0.66	-15.56	-32.14
1410-1x CML411	17.71**	4.84	1.13	-14.88	-60.04	-62.76	-51.20**	5.20*	11.65	-52.76**	-66.67	-73.21
2422x HKI-164-4-1-3	22.60**	15.03**	10.95**	19.23*	-28.72	-33.57	-18.19**	27.05**	34.84**	-38.36**	-50.00	-59.82
2422x HKI-193-2	21.74**	-1.84	-5.31	-2.52	-18.06	-23.63	-8.48**	2.16	8.43	-3.90	-17.78	-33.93
2422x CML411	3.17	-15.69	-18.68	-4.37	-17.20	-22.83	-3.63	-8.56	-2.95	18.46*	-14.44	-31.25
262-55x HKI-164-4-1-3	-4.08	-1.84	-5.31	4.57	-10.47	-16.56	10.49**	10.51**	17.28	0.0	-21.11	-36.61
262-55x HKI-193-2	-12.17**	-21.70	-24.48	9.39	-1.25	-7.97	18.36**	13.68**	20.65	8.0	-10.00	-27.68
262-55x CML411	-13.60**	-22.04	-24.80	0.52	-16.62	-22.29	4.45	-4.77	1.06	4.76	-26.67	-41.07
634-2x HKI-164-4-1-3	-14.73**	-13.52	-16.59	-28.72**	2.21	-4.74	33.67**	-14.98	-9.76	33.86**	-5.56	-24.11
634-2x HKI-193-2	-5.58	-16.69	-19.65	-1.46	-29.49	-34.29	-10.60**	15.81**	22.91**	-33.33**	-50.00	-59.82
634-2x CML411	1.87	-9.02	-12.24	0.08	-11.53	-17.55	17.55**	8.42**	15.06	36.94**	-15.56	-32.14
NAI-137-2x HKI-164-4-1-3	18.33**	11.02**	7.09	-28.53**	0.58	-6.27	9.58**	-15.60	-10.43	2.99	-4.44	-23.21
NAI-137-2x HKI-193-2	9.73*	-11.52	-14.65	-23.98**	0.00	-6.80	6.17**	-11.56	-6.14	-0.57	-3.33	-22.32
NAI-137-2x CML411	3.58	-15.36	-18.36	-25.11**	-1.54	-8.24	8.70**	-19.76	-14.84	11.26	-6.67	-25.00
MAI-105x HKI-164-4-1-3	-16.19**	-21.37	-24.15	-3.63	-28.05	-32.95	-13.51**	7.32**	13.90	-18.80**	-40.00	-51.79
MAI-105x HKI-193-2	33.54**	7.68*	3.86	-10.12	-56.39	-59.36	-49.05**	-1.48	4.55	-53.19**	-63.33	-70.54
MAI-105x CML411	19.51**	-2.34	-5.80	-6.64	3.07	-3.94	25.72**	-6.24	-0.50	47.01**	-4.44	-23.21
SKV-50x HKI-164-4-1-3	1.12	13.19**	9.18**	-22.59**	-2.11	-8.77	14.30**	-8.14	-2.51	8.22	-12.22	-29.46
SKV-50x HKI-193-2	-1378**	-14.86	-17.87	-3.17	-20.56	-25.96	-9.77**	13.19**	20.13	-20.78**	-32.22	-45.54
SKV-50x CML411	-3.51	-3.67	-7.09	-10.39	-17.10	-22.74	-1.82	-3.48	2.44	3.08	-25.56	-40.18

* and ** indicate significance of values at P=0.05 and 0.01, respectively; SH1=NAH-2049, SH2=NAH-1137

Table 3 : Best drought tolerant single cross hybrids

Characters	Crosses	Grain yield (kg/plot)	% standard heterosis over 2040	% standard heterosis over1137	Type of cross
SPAD chlorophyll	772-2 x HKI-164-4-1-3	1.0	-62.44	-63.77	L x H
meter reading	1396 x CML 411	1.10	-61.77	-63.12	H x H
	1232 x HKI-193-2	2.10	-60.60	-62.0	H x L
	1201 x CML 411	1.50	-55.59	-57.17	L x H
Specific leaf area	1396 x HKI-164-4-1-3	0.85	-76.18	-77.80	H x H
(cm^2/g)	1201 x HKI-193-2	0.75	-75.12	-76.81	L x L
	772-2 x HKI-164-4-1-3	1.0	-74.45	-76.19	L x H
	1396 x HKI-193-2	0.95	-70.12	-72.16	H x L
Free proline	1201 x HKI-164-4-1-3	1.80	30.33	38.31	L x H
	2422 x HKI-164-4-1-3	2.25	27.05	34.84	L x H
	1396 x CML 411	1.10	26.46	34.21	H x H
	772-2 x HKI-164-4-1-3	1.0	20.02	27.38	L x H

H=high GCA value, L= Low GCA value

Schepers *et al*. (1992) and Zebrath *et al*. (2002) also reported highly significant heterotic effects for SCMR.The crosses, which exhibited significant heterosis, were obtained from parents with good GCA for drought tolerance. Hence, it is suggested that these hybrids will serve as useful genetic material for development of high water use efficient (WUE) parents by selection in advanced generations.Among thirty six crosses no single cross exhibited significant negative heterosis over standard check 1 (NAH-2049) and standard check 2 (NAH-1137) for specific leaf area (cm^2/g) (Table 2). But the importance of expression of negative heterosis for this trait was reported by Milla and Reich (2007).For free proline (µg /g dry weight) among thirty six crosses, seventeen and six crosses exhibited significant positive heterosis over commercial check 1 (NAH-2049) and commercial check 2 (NAH-1137), respectively.For grain yield per plot (kg) four crosses showed significant positive relative heterosis over mid parent. However, none of the crosses showed positive standard heterosis over NAH-2049 and NAH-1137 (Table 2).

In the present experimental result it was observed that, in most of the cases, crossing between two good general combiners may not necessarily result into a good specific combination. However,majority of the crosses having either of the parent with high GCA effect (high x high or high x low or low x high) yielded good specific combination. Only in few cases low x low crosses yielded better combination (Table 3). This indicates more the chance of getting good specific combiners if inbreds have better GCA. The two cross combinations *viz.*, MAI-105 x CML411 and SKV-50 x HKI-164-4-1-3 were shown significant and positive SCA effects for yield and two drought tolerance traits *viz.*, SCMR and proline content. Cross combinations 2422 x HKI-164-4-1-3 has revealed high level of heterosis over standard checks,NAH-2049 and NAH-1137 for proline content and SCMR and cross 1201 x HKI-164-4-1-3 for proline content over both checks. Cross MAI-105 x CML411 has shown significant mid parent heterosis for SCMR, proline content and yield.

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