Int.J.Curr.Microbiol.App.Sci (2018) Special Issue-7: 1166-1177

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-7 pp. 1166-1177
Journal homepage: http://www.ijcmas.com

Original Research Article

Characterization of Maize Hybrids for Green Fodder and Grain Yield along with their nutritional aspects over environments

Tajwar Izhar[1]*, Manigopa Chakraborty[1], Nutan Verma[1] and Naiyar Ali[2]

[1]Department of Plant Breeding and Genetics, Birsa Agricultural University, Ranchi -06 (Jharkhand), India
[2]Department of Agronomy, Birsa Agricultural University, Ranchi -06 (Jharkhand), India
**Corresponding author*

A B S T R A C T

Twelve inbred lines were crossed with each of five testers in a line×tester design to evaluate combining ability and heterosis to identify promising hybrids of normal maize and green cob for various characters like, 50% tasseling, 50% silking, 75% dry husk, grain yield, no. and weight of green ears, green fodder yield, dry weight, pericarp thickness and various quality parameters. The resulting F_1s along with three checks and seventeen parents were evaluated in two environments during *kharif* 2010 and *rabi* 2010-11. Crosses excelled their perspective parents in performance for most of the traits studied. BQPM-2 among the parental lines and BAUIM-2 among the testers were identified as the best general combiners for grain yield and green ear yield. Whereas among the hybrids, BAUIM-4×HKI-163 and BQPM-2×HKI-163 were identified as potential cross combinations for grain yield and green ear yield. However for quality parameters, BQPM-2×BAUIM-2 exhibited the highest magnitude of economic heterosis for calcium, crude fibre, dry ash and reducing sugar contents while for iron and phosphorus contents, BAUIM-4×HKI 163 exhibited the most desirable value of heterosis. So the crosses (BAUIM-4×HKI 163) and (BQPM-2×BAUIM-2) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigor.

Keywords

Characterization, Combining ability analysis, Environments, Green ear, Green fodder, Heterosis, Line×Tester, Maize, Nutritional aspects, Pericarp, *Zea mays* L

Introduction

Maize *(Zea mays* L.) is the world's most widely grown cereal and is the primary staple food in many developing countries (Morris *et al*. (1999). It is a versatile crop with wider genetic variability and able to grow successfully throughout the world covering tropical, subtropical and temperate agro-climatic conditions. Maize acreage and production have an increasing tendency with the introduction of hybrids due to its high yield potential.

In addition to staple food for human being and quality feed for animals as fresh green fodder, it serves as a source of basic raw materials for the production of starch, oil, protein, alcoholic beverages, food sweeteners, cosmetic and more recently biofuel. Due to the change in food pattern and shift in cropping system, maize is gaining its importance for dual purpose use as baby corn, green ear, dry grain, popcorn for human consumption along with green and dry fodder for ruminant animal consumption. Hence, diversified uses of maize have led to its ever increasing demand.

Cultivation of maize for green ear and grain production are the common practices in India. At present, the country faces a net deficit green fodder, dry crop residues and feeds. So, there is an increasing demand for increasing the productivity of green fodder yield. Immature ears harvested in 25 to 28 days after pollination with moisture content of 70 to 80% is called green ear corn. In India, green ear maize finds its importance as food point of view as well a rich source of animal feed. Cultivation of maize harvested as green ear has several distinct advantages (Paliwal, 2001). Maize harvested as green ear do not face the problem of ear rot and grain insect damage in field. It is a shorter duration crop and occupies field for fewer days thus permitting more intensive cropping pattern. Green plant left over after harvesting of green ear provides better fodder for livestock than dry stover. Farmers can get more return from green ear harvest than grain yield.

Efforts are, therefore, required to develop hybrids with high yield potential in order to increase production of maize along with high tonnage of biomass. On account of more emphasis on food production at the national level the actual potential of quality fodder production for animal feed has not yet been fully tapped in the country which needs to be accomplished. Most efficient use of such materials would be possible only when adequate information on the amount and type of genetic variation and combining ability effects existing in the genetic materials. Heterosis and combining ability is prerequisite for developing a good economically viable hybrid maize variety. Combining ability analysis is useful to assess the potential inbred lines and also helps in identifying the nature of gene action involved in various quantitative characters. This information is helpful to plant breeders for formulating hybrid breeding programmes. Information on the heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development by (Beck *et al.* (1990). In maize, appreciable percentage of heterosis for yield and combining ability were earlier reported by Roy *et al*. (1998), Paul *et al.* (1999) and Rokadia *et al*. (2005). A wide array of biometrical tools is available to breeders for characterizing genetic control of economically important traits as a guide to decide upon an appropriate breeding methodology to involve in hybrid breeding. Line×tester mating design developed by Kempthorne (1957), which provides reliable information on the general and specific combining ability effects of parents and their hybrid combinations was used to generate the information. The design has been widely used in maize by Sharma *et al*. (2004) and others and continues to be applied in quantitative genetic studies. Considering the diversified uses of maize, interest has been demonstrated for the evaluation of maize hybrids with regard to their green ear and grain yield production ability.

Materials and Methods

The basic material for the present study comprised 17 parents i.e., twelve diverse, vigorous and productive maize (*Zea mays* L.) inbred lines and five well adapted testers of varying genetic base. These were crossed in line×tester mating design and evaluated during *kharif* 2010 and *rabi* 2010-11 at B.A.U research farm, Ranchi. These 60 hybrids and seventeen parental lines with three standard checks viz., HQPM-1, Vivek Hybrid-9 and Suwan were grown in a randomized block design in three replications. Each entry was sown in two rows having 70 cm×25 cm crop geometry in two environments for yield and green ear traits while in single environment for quality parameters. All the characters were studied following the standard methods while the pericarp thickness of kernel was studied following the methods of Helm and Zuber (1972) as modified by Ito and Brewbaker (1991). Combining ability analysis was carried as per procedure given by Kempthorne (1957) and modified by Elitriby (1981) for multiple environments.

Results and Discussion

Pooled analysis of variance to test the significance of difference among the genotypes revealed highly significant differences for most of the traits reflecting thereby presence of adequate diversity in the genetic material chosen for the study.

The analysis of combining ability effects revealed that none of the parents possessed desirable *gca* effects for all the traits studied (Table 1). However, BQPM-2 was found to have the highest positive and highly significant *gca* effect for grain yield followed by 1025, V 341, BQPM-4, CML161 and HKI 163.These parents also showed significant positive gca effect and simultaneously possessed high mean value indicating that the *per se* performance of the parents could prove as an useful index for combining ability. Roy *et al*. (1998), Hussain *et al.* (2003) and Izhar and Chakraborty (2013) also observed similar phenomenon. Regarding maturity related traits, CM 151 revealed the most desirable negative and significant value for tasseling and silking while BQPM-2 revealed the most desirable negative and significant value for dry husk. For green ear, 1025 and BQPM-2 exhibited the highest positive and highly significant *gca* effect for no. of green ears and weight of green ears per plant, respectively. However, for green fodder yield and dry weight of green ears, BAUIM-1, followed by BAUIM-3, CM 111 and BQPM-2 revealed highly significant positive gca effect (Table 2). For pericarp thickness, lines, CM 111, BAUIM-3, V 341 and 1025 exhibited the most desirable value of gca effect. For various quality attributes, the inbreds viz., BAUIM-4, BQPM-2 and BQPM-4 exhibited the best quality parameters, like calcium, iron, phosphorus, reducing sugars, crude fibre and dry ash contents (Table 3). The lines with desirable *gca* should be extensively used in the crossing programme to exploit maximum genetic variability.

A critical evaluation of the results with respect to specific combining ability effects showed that none of the cross combinations exhibited desirable significant sca effects for all the characters. The estimates of specific combining ability based on pooled analysis demonstrated various cross combinations having significant positive *sca* effects (Table 4). The highest magnitude of desirable *sca* effects for grain yield in q/ha was detected in (BAUIM-4×HKI 163) followed by (CM 152×BAUIM-2) and (BAUIM-1×BAUIM-2). Beck *et al.* (1990), Singh and Mishra (1996), Chaudhary *et al*. (2000) and Surya and Ganguli (2004) also reported high positive specific combining ability effects along with high *per se* performance for grain yield. However for maturity related traits, (BQPM-2×K1105) showed the most desirable value for tasseling and silking while (CM 151×CM 150) revealed the most desirable value for dry husk. For number of green ears per plant, V 341×BAUIM-2 and V 341×K-1105 revealed the highest positive sca effect while for weight of green ears per plant, BAUIM-4×HKI-163 and BQPM-2×HKI-163 revealed the highest magnitude of desirable *sca* effects.

Table.1 GCA effects of parents for Tasseling, Silking, Dry Husk and Grain yield (q/ha) of normal maize

Parents	Days to 50%Tasseling			Days to 50% Silking			Days to 75% Dry Husk			Grain (q/ha) yield		
	Env1	Env2	Pooled	Env1	Env2	Pooled	Env1	Env2	Pooled	Env1	Env2	Pooled
BAUIM-3	1.35 **	4.19 **	2.77 **	1.42 **	4.27 **	2.85 **	0.74 **	1.61 **	1.17 **	4.29 **	-9.26 **	-2.48 **
CM111	0.75 **	-2.94 **	-1.10 **	0.89 **	-2.73 **	-0.92 **	-0.13	1.21 *	0.54	-5.27 **	-11.63 **	-8.45 **
CM151	-1.58 **	-6.28 **	-3.9 **	-1.31 **	-6.06 **	-3.69	-0.46	-2.06 **	-1.26 **	-0.24	-5.84 **	-3.04 **
CM152	-0.32 *	-1.21 **	-0.76 **	-0.18	-1.19 **	-0.69 **	0.21	-0.92	-0.36	-2.09 **	-0.32	-1.20
BAU1M-1	-0.25	-1.21 **	-0.73**	-0.38	-1.26 **	-0.82 **	0.21	-0.92	-0.36	-2.09 **	-0.32	-1.20
BAU1M-4	0.15	2.72 **	1.44 **	-0.11	2.74 **	1.31 **	-0.06	2.68 **	1.31 **	-7.86 **	-11.82 **	-9.84 **
V341	0.15	0.59 *	0.37**	-0.04	0.74 *	0.35*	-0.26	3.28 **	1.51 **	-3.45 **	14.21 **	5.38 **
1025	0.68 **	0.26	0.47**	0.89 **	0.34	0.61 **	0.14	0.61	0.38	7.60 **	4.56 **	6.08 **
BQPM-2	-1.92 **	0.06	-0.93 **	-1.84 **	-0.79 *	-1.32 **	-1.39 **	-1.46 **	-1.42 **	8.04 **	7.94 **	7.99 **
BQPM-4	-2.45 **	0.86 **	-0.80**	-2.11 **	1.07 **	-0.52 **	-1.99 **	0.01	-0.99 **	4.08 **	3.52 **	3.80 **
CML161	2.68 **	4.12 **	3.40 **	2.42 **	4.07 **	3.25 **	2.41 **	-1.59 **	0.41	-1.51 *	4.48 **	1.49*
V351	0.75 **	-1.14 **	-0.20	0.36	-1.19 **	-0.42*	0.61 *	-2.46 **	-0.93**	-1.51 *	4.48 **	1.49*
CM-150 (T1)	-2.17 **	-2.36 **	-2.27 **	-2.33 **	-2.34 **	-2.34 **	-1.82 **	0.75 *	-0.54	-0.63	1.15	0.26
BAU1M-2(T2)	-1.06 **	0.94 **	-0.06	-1.08 **	1.22 **	0.07	-0.63 **	-0.64 *	-0.63	2.83 **	1.37	2.10 **
K1105 (T3)	-0.14	0.25	0.05	-0.08	-0.34	-0.21	-0.24	-2.14 **	-1.19	0.44	-2.71 **	-1.14**
HKI 193-1 (T4)	1.24 **	-0.86 **	0.19	1.08 **	-0.84 **	0.12	1.09 **	0.69 *	0.89	-1.72 **	0.92	-0.40
HKI-163 (T5)	2.13 **	2.03 **	2.08 **	2.42 **	2.30 **	2.36 **	1.59 **	1.33 **	1.46	-0.91 *	-0.73	-0.82
SE(gi-gj) ±(Line)	0.21	0.42	0.23	0.30	0.53	0.25	0.34	0.69	0.40	0.87	1.60	0.66
CD at 5%	0.41	0.83	0.46	0.59	1.04	0.48	0.66	1.36	0.79	1.72	3.16	1.31
CD at 1%	0.54	1.09	0.61	0.78	1.38	0.64	0.88	1.80	1.04	2.28	4.18	1.73
SE(gi-gj) ±(Tester)	0.13	0.27	0.15	0.19	0.34	0.16	0.22	0.44	0.26	0.56	1.03	0.43
CD at 5%	0.26	0.53	0.29	0.38	0.67	0.31	0.43	0.88	0.51	1.11	2.04	0.85
CD at 1%	0.35	0.71	0.39	0.50	0.89	0.41	0.57	1.16	0.67	1.47	2.70	1.12

*, ** = Significant at P = 0.05 and P = 0.01 respectively., Maximum and minimum values in Bold figure

Table.2 GCA effects of parents for No.of Green Ears/ Plant, Weight of Green Ears/ Plant and Green fodder yield of green ear

Parents	**No. of Green Ears/ Plant**			**Weight of Green Ears/ Plant**				**Green fodder yield (kg/plot)**		
	Env1	**Env2**	**Pooled**	**Env1**	**Env2**	**Pooled**		**Env1**	**Env2**	**Pooled**
BAUIM-3	**-0.22** **	**-0.20** **	**-0.21** **	-4.93	-16.34 **	-10.63 **	-0.34	-0.34 **	0.68 **	0.61 **
CM111	-0.12 **	-0.17 **	-0.15 **	-32.80 **	-31.99 **	-32.39 **	-0.33	-0.33 **	0.22 **	0.18 **
CM151	0.06 *	0.05	0.05**	**-73.17** **	**-65.51** **	**-69.34** **	-0.32	-0.32 **	-0.28 **	-0.25 **
CM152	-0.18 **	-0.12 **	-0.15 **	32.45 **	32.70 **	32.58 **	**-0.22**	**-0.22**	0.06	0.07
BAU1M-1	0.09 **	0.08 **	0.09 **	-1.13	3.92	1.40	-0.14	-0.14 **	**0.77** **	**0.73** **
BAU1M-4	0.07 **	0.07 *	0.07 **	31.33 **	31.15 **	31.24 **	-0.12	-0.12 **	**-0.53** **	**-0.44** **
V341	0.12 **	0.05	0.09 **	-3.03	-5.72	-4.38	-0.05	-0.05 **	-0.33 **	-0.33 **
1025	**0.22** **	**0.21** **	**0.21** **	-4.50	-5.22	-4.86	0.06	0.06 **	-0.40 **	-0.36 **
BQPM-2	0.06 *	0.04	0.05*	**45.62** **	**48.27** **	**46.95** **	0.08	0.08	0.13 **	0.10**
BQPM-4	0.01	0.00	**0.01**	31.03 **	44.80 **	37.91 **	0.15	0.15 *	-0.04	-0.08*
CML161	0.02	0.05	0.04	11.92 *	-7.54 *	2.19	**0.55**	**0.55**	-0.06	-0.06
V351	-0.12 **	-0.06 *	0.09*	-32.80 **	-28.51 **	-30.66 **	0.70	0.70 *	-0.20 **	-0.17 **
CM-150 (T1)	**0.11** **	**0.12** **	**0.12** **	-13.88 **	-13.82 **	-13.85 **	**-0.20**	**-0.20** **	**-0.23** **	**-0.22**
BAU1M-2(T2)	0.02	0.01	0.02	**19.26** **	**21.70** **	**20.48** **	-0.09	-0.09 *	0.00	-0.04
K1105 (T3)	-0.01	-0.02	-0.01	-4.32	-5.65 **	-4.99*	-0.01	-0.01	-0.03	-0.02
HKI 193-1 (T4)	-0.06 **	-0.04 *	-0.05 **	**-14.15** **	**-14.67** **	**-14.41** **	0.08	0.08 *	0.07 *	0.08**
HKI-163 (T5)	**-0.07** **	**-0.07** **	**-0.07** **	13.10 **	12.45 **	12.77 **	**0.22**	**0.22** **	**0.19** **	**0.20** **
SE(gi-gj)±Line	0,03	0.04	0.03	8.32	4.52	4.23	0.08	0.08	0.07	0.05
CD at 5%	0.06	0.08	0.06	16.47	8.96	8.42	0.16	0.16	0.13	0.10
CD at 1%	0.09	0.11	0.08	21.78	11.84	11.10	0.21	0.21	0.18	0.14
SE(gi-gj)±tester	0.02	0.03	0.02	4.52	2.92	2.76	0.05	0.05	0.04	0.03
CD at 5%	0.04	0.05	0.04	8.96	5.78	5.44	0.10	0.10	0.09	0.07
CD at 1%	0.06	0.07	0.05	11.84	7.64	7.16	0.13	0.13	0.11	0.09

*, ** = Significant at P = 0.05 and P = 0.01 respectively.,Maximum and minimum values in Bold figure

Table.2 Continued GCA effects of parents for Dry weight of above ground part and Pericarp thickness of green ear

Parents	Dry weight of above ground part (g/plot)			Pericarp thickness (µm)		
	Env1	**Env2**	**Pooled**	**Env1**	**Env2**	**Pooled**
BAUIM-3	47.56 **	111.68 **	79.62 **	-5.21 **	-5.54 **	-5.38 **
CM111	4.22	33.94 **	19.08 **	-7.05 **	-7.52 **	7.29 **
CM151	27.56 **	-44.92 **	-8.68	2.77 **	2.35 **	2.56 **
CM152	42.89 **	6.34	24.62 **	0.50 *	0.12	0.31*
BAU1M-1	**95.56** **	**126.14** **	**110.85 ** **	**6.54** **	**6.63** **	**6.58 ** **
BAU1M-4	-39.78 **	**-77.26** **	-58.52 **	1.26 **	1.48 **	1.37 **
V341	-51.11 **	-42.86 **	-46.98 **	**-11.43** **	**-11.21** **	**-11.32 ** **
1025	**-63.78** **	-67.32 **	**-65.55 ** **	-5.06 **	-4.84 **	-4.95 **
BQPM-2	35.56 **	9.48	22.52 **	5.14 **	5.36 **	5.25 **
BQPM-4	-15.78 *	-8.32	-12.05*	3.08 **	3.30 **	3.19 **
CML161	-43.11 **	-11.72	-27.42 **	3.10 **	3.32 **	3.21 **
V351	-39.78 **	-35.19 **	-37.48 **	6.36 **	6.58 **	6.47 **
CM-150 (T1)	**-17.17** **	**-36.15** **	**-26.66 ** **	0.18	0.11	0.15 **
BAU1M-2(T2)	0.33	1.68	1.01	**0.87** **	**0.82** **	**0.85 ** **
K1105 (T3)	-14.67 **	-1.96	-8.31*	-0.02	0.07	0.03
HKI 193-1 (T4)	10.61 *	6.66	8.63*	0.07	0.08	0.07
HKI-163 (T5)	**20.89** **	**29.77** **	**25.33 ** **	**-1.11** **	**-1.09** **	**-1.10 ** **
SE(gi-gj)±Lines	9.77	12.15	0.05	0.27	0.28	0.19
CD at 5%	19.35	24.06	0.10	0.54	0.55	0.39
CD at 1%	25.58	31.81	0.14	0.71	0.73	0.51
SE(gi-gj)±Testers	6.31	7.84	0.04	0.17	0.18	0.13
CD at 5%	12.49	15.53	0.07	0.35	0.36	0.25
CD at 1%	16.51	20.54	0.09	0.46	0.47	0.33

*, ** = Significant at P = 0.05 and P = 0.01 respectively.,Maximum and minimum values in Bold figure.

Table 3: General Combining Ability (GCA) effects of parents for Quality Parameters of Green ear

Parents	Moisture (%)	Calcium (mg/100g)	Iron (mg/100g)	Phosphorus (mg/100g)	Reducing sugar (%)	Crude fibre (%)	Dry ash (%)
BAUIM-3	-0.19 **	-0.13 **	**-0.23** **	**-11.72** **	**-0.23** **	-0.03	**-0.05** **
CM111	-0.04	0.16 **	0.01	4.94 **	-0.02	0.03*	0.03 **
CM151	-0.05 *	0.01	-0.15 **	-0.72	0.03*	-0.04**	-0.01
CM152	-0.22 **	-0.26 **	-0.08 **	-11.06 **	-0.03**	-0.04**	0.00
BAU1M-1	0.02	-0.31 **	-0.06 **	-1.32	0.02	-0.01	-0.02 **
BAU1M-4	**0.32** **	**0.96** **	0.09 **	**15.34** **	0.10 **	0.01	0.03 **
V341	0.07 **	0.08 **	0.07 **	0.34	**0.11** **	0.00	0.00
1025	-0.17 **	-0.20 **	0.09 **	-2.19*	0.02	**-0.05** **	**0.04** **
BQPM-2	0.29 **	0.14 **	**0.17** **	6.28 **	0.03*	0.05 **	0.00
BQPM-4	0.21 **	0.27 **	0.07 **	6.88 **	0.05 **	**0.07** **	0.00
CML161	**-0.24** **	**-0.45** **	0.03*	-8.66 **	-0.04 **	0.00	-0.01
V351	0.00	-0.27 **	-0.02	1.88	-0.04**	0.00	0.00
CM-150 (T1)	**-0.08** **	**-0.29** **	**-0.11** **	-0.87	-0.02**	-0.02*	**-0.03** **
BAU1M-2(T2)	0.03*	0.14 **	0.02	1.58*	-0.01	-0.01	0.01*
K1105 (T3)	**0.09** **	0.11 **	0.02*	-0.42	-0.02	**0.01**	0.01*
HKI 193-1 (T4)	-0.07 **	-0.18 **	0.00	**-2.12** **	**0.00**	**0.00**	0.00
HKI-163 (T5)	0.03*	**0.22** **	**0.07** **	**1.83****	**0.05** **	0.01	**0.02** **
SE(gi-gj)±(Line)	0.03	0.03	0.02	1.36	0.02	0.02	0.01
CD at 5%	0.06	0.06	0.04	2.69	0.03	0.04	0.02
CD at 1%	0.09	0.08	0.05	3.56	0.05	0.05	0.02
SE(gi-gj)±(Tester)	0.02	0.02	0.01	0.88	0.01	0.01	0.01
CD at 5%	0.04	0.04	0.03	1.74	0.02	0.02	0.01
CD at 1%	0.05	0.05	0.03	2.30	0.03	0.03	0.01

*, ** = Significant at P = 0.05 and P = 0.01 respectively.,Maximum and minimum values in Bold figure.

Table.4 SCA effects of crosses for Tasseling, Silking, Dry Husk and Grain yield (q/ha) of normal maize hybrids

Crosses	Days to 50% Tasseling			Days to 50% silking			Days to 75% Dry Husk			Grain yield (q/ha)		
	Env1	**Env2**	**Pooled**	**Env1**	**Env2**	**Pooled**	**Env1**	**Env2**	**Pooled**	**Env1**	**Env2**	**Pooled**
BAU1M-3× HKI 193-1	-0.04	-3.61 **	-1.83 **	-0.95**	-4.16**	-2.56**	-0.29	1.64**	0.67	7.25**	13.06**	10.16**
CM111× HK1-163	1.67 **	-0.03	0.82*	1.92*	0.37	1.14**	1.07**	1.73**	1.40*	2.61**	6.85**	4.73**
CM151× CM150	0.31**	-2.64**	-1.17 **	0.53**	-2.66**	-1.06	-0.18	**-5.75****	**-2.96****	1.77**	7.82**	4.79**
CM152× BAU1M-2	-0.07	-1.34	-0.71	0.15*	-1.08**	-0.47	-0.04	-1.49**	-0.77	9.29**	6.50**	7.89
BAU1M-1× BAU1M-2	-0.14	-1.34**	-0.74*	0.35**	-1.35**	-0.50	-0.04	-1.49**	-0.77	9.29**	6.50**	7.89**
BAU1M-4× HKI163	0.27 **	2.97**	1.62**	0.25*	2.57**	1.41**	0.01	-0.07**	-0.03	**14.83****	11.69**	**13.26****
BQPM-2× K1105	-1.39 **	**-4.25****	**-2.82** **	-1.18**	**-9.26****	**-5.22****	-0.83**	0.21	-0.31	5.06**	-0.66	2.20
BQPM-2× HKI163	1.00 **	5.64**	**3.32****	1.65**	**7.43****	**4.54****	1.34**	3.40**	2.37**	13.83**	0.46	7.15
BQPM-4× CM150	0.17	0.23	0.20	0.33*	0.21	0.27	0.36*	-0.82*	-0.23	13.58**	2.02**	7.80**
V351× HKI 193-1	0.56 **	4.39**	2.47	0.78**	4.64**	2.71**	0.84**	-2.63**	-0.89	-3.08**	-0.72	-1.90
SE-Sij-Skl ±	0.46	0.93	0.52	0.67	1.18	0.55	0.75	1.54	0.89	1.95	3.57	2.11
CD at 5%	0.91	1.85	1.03	1.32	2.33	1.09	1.48	3.04	1.77	3.85	7.08	4.16
CD at 1%	1.20	2.45	1.36	1.75	3.08	1.44	1.96	4.02	2.33	5.09	9.36	5.48
SE-Sij-Sik ±	0.74	1.51	0.85	1.08	1.90	0.89	1.21	2.48	1.45	3.14	5.76	3.40
CD at 5%	1.46	2.98	1.67	2.13	3.76	1.76	2.39	4.91	2.85	6.21	11.41	6.71
CD at 1%	1.94	3.94	2.19	2.81	4.97	2.31	3.16	6.49	3.76	8.21	15.09	8.81

*, ** = Significant at P = 0.05 and P = 0.01 respectively., Maximum and minimum values in Bold figure

Table.5 SCA effects of crosses for No. of Ears/ Plant, Weight of Green Ears/ Plant, green fodder yield, dry weight and pericarp thickness of green ear maize

Crosses	No. of Green Ears/ Plant			Weight of Green Ears/ Plant			Green fodder yield (kg/plot)			Dry weight of above ground part (g/plot)			Pericarp thickness (µm)		
	Env1	Env2	Pooled	Env1	Env2	Pooled	Env1	Env2	Pooled	Env1	Env2	Pooled	Env1	Env2	Pooled
CM111× K1105	-0.11**	0.04*	-0.03	17.11**	40.49**	28.80**	0.46**	0.52**	0.49**	78.00**	89.89**	83.94**	1.62**	1.63**	1.63**
BAU1M-4× HKI163	-0.22**	-0.09**	-0.16**	**134.83****	**132.65****	**133.74****	-0.07	-0.14**	-0.10**	86.44**	19.03**	52.74**	-7.33**	-7.36**	-7.35**
V341× BAU1M-2	**0.45****	0.21**	0.33**	9.85*	-19.85**	-5.00	0.00	-0.14**	-0.07	-31.67**	12.72**	-9.48	5.01**	5.06**	5.03**
V341× K1105	**0.45****	0.21**	**0.33****	9.85**	-19.85**	-5.00	0.00	-0.14**	-0.07	33.33**	-16.64**	8.34	-3.67**	-3.76**	-3.71**
BQPM-2× HKI 193-1	0.01**	0.09**	0.05	88.98**	81.18**	85.08**	0.59**	**0.83****	**0.71****	**104.72****	100.08**	**102.40****	9.65**	9.64**	9.65**
BQPM-2× HKI163	-0.06**	-0.12**	-0.09*	-29.99**	-31.72**	-30.86**	**-0.69****	**-0.68****	**-0.68****	-72.22**	-100.70**	-86.46**	-9.10**	-9.13**	-9.12**
BQPM-4× HKI 193-1	-0.01	0.04*	0.02	-48.74**	-80.35**	-64.55**	-0.37**	-0.32**	-0.35**	-60.61**	-48.79**	-54.70**	**-18.22****	**-18.23****	**-18.23****
SE-Sij-Skl ±	0.07	0.09	0.06	18.60	10.11	9.56	0.18	0.15	0.12	21.85	27.17	17.83	0.60	0.63	0.44
CD at 5%	0.15	0.18	0.13	36.84	20.03	18.83	0.35	0.30	0.24	43.26	53.81	35.12	1.20	1.24	0.86
CD at 1%	0.19	0.24	0.17	48.70	26.48	24.82	0.46	0.39	0.32	57.20	71.14	46.29	1.58	1.64	1.14
SE-Sij-Sik ±	0.07	0.15	0.11	29.99	16.31	15.42	0.28	0.24	0.19	35.23	43.81	28.75	0.97	1.01	0.71
CD at 5%	0.15	0.30	0.21	59.40	32.29	30.37	0.56	0.48	0.38	69.76	86.76	56.64	1.93	2.00	1.39
CD at 1%	0.19	0.39	0.27	78.53	42.69	40.03	0.75	0.63	0.51	92.23	114.71	74.65	2.55	2.64	1.84

*, ** = Significant at P = 0.05 and P = 0.01 respectively.,Maximum and minimum values in Bold figure.

Table.6 SCA effects of crosses for Quality parameters of Green Ear

Crosses	Moisture (%)	Calcium (mg/100g)	Iron (mg/100g)	Phosphorus (mg/100g)	Reducing sugar (%)	Crude fibre (%)	Dry ash (%)
BAU1M-4× K1105	**-0.30****	0.17**	-0.03	-11.84**	-0.11**	-0.08**	-0.01**
BQPM-2× BAU1M-2	**0.93****	**1.25****	**0.20****	20.22**	**0.21****	**0.15**	**0.13****
BQPM-4× BAU1M-2	-0.25**	0.00**	0.01	-3.04**	0.13	-0.05**	-0.02**
SE-Sij-Skl ±	0.07	0.07	0.05	3.04	0.04	0.04**	0.02
CD at 5%	0.14	0.14	0.09	6.02	0.08	0.08	0.04
CD at 1%	0.19	0.18	0.12	7.96	0.10	0.11	0.05
SE-Sij-Sik ±	0.12	0.11	0.07	4.91	0.06	0.07	0.03
CD at 5%	0.23	0.22	0.15	9.71	0.12	0.13	0.06
CD at 1%	0.31	0.29	0.19	12.84	0.16	0.18	0.08

*, ** = Significant at P = 0.05 and P = 0.01 respectively.,Maximum and minimum values in Bold figure.

Table.7 Identified hybrid combinations showing consistent performance over environments based on superiority over check Vivek hybrid-9 for normal maize hybrids

Crosses	Days to 50% Tasseling			Days to 50% Tasseling				Days to 75% dry husk		Grain yield (q/ha)		
	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled
CM151× CM150	**-14.16****	-11.03**	**-13.28****	-8.84**	**-13.65****	**-12.25****	-3.57**	**-4.19**	**-3.95**	37.33**	57.72**	
CM152× HK1-163	-5.20**	-2.21*	-4.36**	0.00	-5.29**	-3.75**	-1.07	0.00**	-0.41**	16.80*	45.24**	35.63**
BAU1M-1× BAU1M-2	-5.78**	-6.62**	-6.02**	-4.76**	-5.57**	-5.34**	-1.43	-1.54**	-1.50*	69.01**	65.57**	66.73**
1025× BAU1M-2	-0.29**	-2.21*	-0.83	-2.04	-0.56	-0.99	-1.07	-0.22**	-0.54**	85.65**	78.94**	81.21**
BQPM-2× BAU1M-2	-5.49**	-13.24**	-7.68**	**-12.24****	-4.74**	-6.92**	-4.64**	-1.32**	-2.59	96.95**	78.29**	**84.60****
BQPM-2× HKI163	2.31**	-0.74	1.45	2.04	3.06**	2.77**	0.71	2.64*	1.91*	**107.00****	65.77**	79.71**
BQPM-4× CM150	-5.49**	-13.24**	-7.68**	-10.88**	-5.29**	-6.92**	-4.64**	0.44**	-1.50*	93.35**	64.04**	73.95**
BQPM-4× BAU1M-2	-1.45**	-11.03**	-4.15*	-10.20**	-1.67	-4.15**	-3.57**	0.66**	-0.95**	61.03**	49.70**	53.53**

*, ** = Significant at P = 0.05 and P = 0.01 respectively., Maximum and minimum figures in Bold figure

Table.8 Identified hybrid combinations showing consistent performance across seasons based on superiority over check Vivek hybrid-9 for green ear maize

Crosses	No. of Green Ears/ Plant			No. of Green Ears/ Plant			Fresh wt.			Dry weight			Pericarp thickness		
	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled	Env_1	Env_2	Pooled
BAU1M-1× BAU1M-2	-9.09*	0.00**	-4.76	-10.86*	-7.36**	-9.04**	**15.22**	**27.66****	**21.51****	**9.68***	**27.65****	**18.71****	12.50**	12.54**	12.52**
1025× CM150	18.18**	**30.00**	**23.81****	6.76**	4.94*	5.81**	-29.35**	-21.28**	-25.27**	-32.26**	-21.26**	-26.73**	-16.14**	-16.14**	-16.14**
QPM-2× HKI 193-1	-13.64**	0.00**	-7.14	27.85	23.32**	25.49**	6.52	23.40**	15.05**	9.68*	12.77*	11.23**	**12.62****	**12.62****	**12.62****
BQPM-4× BAU1M-2	-4.55	0.00**	-2.38	26.62	**29.93****	**28.34****	-20.65**	-10.64*	-15.59**	-16.13**	-10.66*	-13.38**	12.20**	12.20**	12.20**

*, ** = Significant at P = 0.05 and P = 0.01 respectively; (Maximum and minimum values in bold figures)

Table.9 Identified hybrid combinations showing consistent performance based on superiority over the best check for quality parameters of green ear maize

Crosses	Calcium	Iron	Phosphorus	Reducing sugar	Crude fibre	Dy ash	
BAU1M-4× HKI163	17.55**	**12.04** **	21.97**	4.89**	2.80	10.02	**
BQPM-2× BAU1M-2	**18.72****	10.83 **	23.92**	**6.09****	**9.50****	**12.89**	**
BQPM-4× BAU1M-2	8.07**	2.57	13.75**	4.43**	1.25	1.91	
BQPM-4× K1105	17.04**	7.58 **	19.43**	-2.49*	7.94**	8.11	**

*, ** = Significant at P = 0.05 and P = 0.01 respectively., Maximum and minimum figures in Bold figure

For green fodder yield and dry weight, BQPM-2×HKI 193-1 showed the maximum positive and highly significant sca effect followed by CM 111×K-1105. For pericarp thickness, BQPM-4×HKI 193-1 revealed the most desirable sca effect followed by BQPM-2 ×HKI-163 (Table 5). The maximum positive and highly significant sca effect was exhibited by BQPM-4×K-1105 for calcium and crude fibre contents, while for iron and phosphorus contents, BQPM-2×BAUIM-2 exhibited the most desirable value and for reducing sugar content, BQPM-4×BAUIM-2 exhibited the most desirable value of sca effect (Table 6). The superiority of crosses as parents could be explained on the basis of interaction between positive alleles from good combiners and negative alleles for the poor combiners as parents. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding.

All the crosses exhibited highly significant positive heterosis over mid parent and better parent for grain yield in pooled analysis (Table 7). The cross combination (BQPM-2×BAUIM-2) followed by (1025×BAUIM-2) and (BQPM-2×HKI163) revealed highest magnitude of economic heterosis (84.60%) over the best check Vivek hybrid-9 for grain yield in q/ha. Appreciable percentage of heterosis for grain yield in maize was also reported by Lonnquist and Gardner (1961), Akhtar and Singh (1981) and Gerrish (1981). In another study, Debnath (1987) and Roy *et al.*(1998), respectively, observed 13.95 to 245.10 per cent and -16.42 to 71.82 per cent heterobeltiosis. The cross combination (CM 151×CM 150) showed the most desirable value for heterosis for maturity traits. For green ear traits, 1025×CM 150 and BQPM-4×BAUIM-2 showed the most desirable value of heterosis for number and weight of green ears respectively (Table 8). For green fodder yield and dry weight, BAUIM-1×BAUIM-2 revealed the highest magnitude of heterosis. For pericarp thickness, BQPM-2×HKI 193-1 revealed the most desirable value of heterosis. However for quality parameters, BQPM-2×BAUIM-2 exhibited the highest magnitude of economic heterosis for calcium, crude fibre, dry ash and reducing sugar contents while for iron and phosphorus contents, BAUIM-4×HKI 163 exhibited the most desirable value of heterosis (Table 9).

Therefore these promising crosses were identified as overall high general combiners and these could be utilized for development of either the synthetic varieties or an elite breeding population by allowing thorough mixing among them to achieve new genetic recombination and then subjecting the resultant population to recurrent selection.

Acknowledgements

The work has been carried out in Ph.D. programme under the financial support of Department of Science and Technology, Govt. of India for professional fellowship through INSPIRE programme.

References

Akhtar SA and Singh TP (1981) Heterosis in varietal crosses of maize. Madras Agric. J 68:47-51.

Beck DL, Vasal S.K and Crossa J (1990) Heterosis and combining ability of CYMMYT's tropical early and intermediate maturity maize (Zea mays L.) germplasm. Mydica 35: 279-285.

Chaudhary AK, Chaudhary LB, Sharma KC (2000) Combining ability estimates of early generation inbred lines derived from two maize populations. Indian J. Genet 60: 55-61

Das UR and Islam MH (1994) Combining ability and genetic studies for grain yield and its components in maize (Zea mays L.). Bangladesh J Pl Breed Genet 7(2):41-47.

Debnath SC (1987) Heterosis in maize (Zea mays L.). Bangladesh J Agric 12(3):161-168.

Elitriby HA, Selim AR and Shehata AH (1981) Genotype x environment interaction from combining estimates in maize (Zea mays L.). Egyptian J Genet Cytol 10: 175-186.

Gerrish EE (1981) Indications from a diallel study for interracial maize hybridization in Corn Belt. Crop Sci 23:1082-1084.

Helm JL and Zuber MS (1972). Inheritance of pericarp thickness of Corn Belt maize. Crop Sci 12: 425-430.

Hussain SA, Amiruzzaman M and Hossain Z (2003) Combining ability estimates in maize. Bangladesh J Agril Res 28(3):435-440.

Ito G.M and Brewbaker JL (1991) Genetc advance through mass selection for tenderness in sweet corn. J Amer Soc. Hort Sci 106 : 96-499.

Izhar T and Chakraborty M (2013) Combining ability and heterosis for grain yield and its components in maize inbreds over environments (Zea mays L.). African J Agril Res 8(25): 3276-3280.

Kempthrone O (1957) An introduction to genetic statistics. John Willy and Sons, New York.

Lonnquist JH and Gardner CO (1961) Heterosis in inter varietal crosses of maize and its implications in breeding procedure. Crop Sci 1: 179-183.

Morris MLRisopoulos J and Beck D. (1999) Genetic change in farmer- recycled maize seed; a review of the evidence. Cimmyt economic Working Paper No. 99-07. Mexico, D.F. Cimmyt, pp:1.

Paliwal RL (2001) Tropical maize improvement and production. FAO, Rome, Italy.

Paul K.K and Debnath SC (1999) Heterosis and combining ability for grain yield and its components in maize (Zea mays L.). Bangladesh J Agri 24: 61-68.

Rokadia Pand Kaushik SK (2005). Exploitation of combining ability for heterosis in maize (Zea mays L.). In: Pixley, K. and S.H. Zhang (ed). Proc. 9th Asian Reg.Maize Workshop. Beijing, China, pp: 89-91.

Roy NC, Ahmed SU, Hussain AS and Hoque MM (1998) Heterosis and combining ability analysis in maize (Zea mays L.). Bangladesh J Pl Breed Genet 11(172):35-41.

Sharma S, Narwal R, Kumar M. S and Dass S. (2004) Line x tester analysis in maize (Zea mays L.). Forage Res 30: 28-30

Singh S.D., Mishra, S.N. (1996) Combining ability of maize over the environments. Crop Improv., 23: 229-32.

Surya P and Ganguli DK (2004) Combining ability for various yield component and characters in maize. Jr of Research (BAU) 16: 55-60.