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BC Chandana
Assistant Professor, Department of Genetics & Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

SK Deshpande
Professor, Department of Genetics & Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Jayanth Subraya Bhat
Senior Scientist, Department of Genetics & Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Correspondence
BC Chandana
Assistant Professor, Department of Genetics & Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Heterosis studies on earliness, growth and quality parameters in single cross hybrids of maize (*Zea mays* L.)

BC Chandana, SK Deshpande and Jayanth Subraya Bhat

Abstract
The study was undertaken to estimate the extent of heterosis for earliness, growth parameters and protein content of grain in seventy two Maize single crosses developed by crossing 12 lines and 6 testers using line × tester design. Seventy two hybrids, parents along with three checks were evaluated during during *kharif* 2012. The investigation on heterosis for earliness, growth parameters and protein content resulted in the identification of single crosses that exhibited significant heterosis. BM24×RNBL4611 and BM423×BM59 were considered as early for tasseling which showed significant highest negative heterosis. The hybrids BM423×RNBL4711 and BM136×RNBL4611 recorded significant highest negative heterosis for days to 50% silking. BM254×BM59 showed significant highest positive heterosis for plant height. Combinations BM136×BM1 and BM254×RNBL4711 witnessed highest heterosis for plant girth. BM24×BM59 evidenced highest fodder yield among the cross combinations. With respect to protein content the cross BM60×RNBL4711 recorded highest per cent of protein among hybrids.

Keywords: Heterosis, maize, heterobeltiosis, standard heterosis, mid parental heterosis, protein content

Introduction
Maize is a versatile crop with wider genetic variability plays a significant role in human and livestock nutrition worldwide. It plays a vital source of daily human food and as a feed for livestock either as fresh, silage or grains. The normal maize grain under Indian conditions on an average, contains 14.9 % moisture, 11.1 % protein, 3.6 % fat, 2.7 % fibre, 66.2 % other carbohydrates and 1.5% minerals. So it can be a supplementary food along with rice and wheat. The crop is gaining popularity as food and feed with the increasing poultry, dairy and fisheries sector. Good results have been achieved in increasing maize yield through successful exploitation of heterosis for yield characters. However as plant breeding efforts result in emergence of newer varieties with increased productivity and better adaptation to diverse ecosystems as well as increased resistance/tolerance to biotic and abiotic stress factors and changing farming practices, so also is the possibility of changes in growth parameters which may be morphological, physiological or a combination of both. In other words, the gains in grain yield attributable to maize breeding (Kamara *et al*., 2004) [11], may also have been accompanied by changes including early growth characteristics and other morpho-physiological characteristics. Therefore, a great attention should be paid to raise maize productivity by maximizing yield per unit area in order to reduce the gap between its production and consumption.
Heterosis is the phenomenon wherein the performance of an F1 derived by crossing two genetically different individuals is superior to that of the parents or the better parent. Heterosis is important in maize breeding and is dependent on level of dominance and diversity. The manifestation of heterosis depends on genetic divergence of two parental varieties (Hallauer and Miranda, 1988) [9]. Information of heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al*. 1990) [6]. In the present investigation an attempt was done to study the extent of heterosis for earliness, growth and protein content in the single cross hybrids.

Material and Methods
The experimental material used in the present investigation comprised of twelve lines and six testers which were previously evaluated in three consecutive years (2009-2011) for resistance

Against Turcicum leaf blight. These selected lines were used as parents and were crossed in line X tester design at Main Agricultural Research station, College of agriculture, Dharwad during rabi-summer 2012. The 72 F1 hybrids thus generated were evaluated in RCBD with two replications along with the parental lines and three checks *viz*., Arjun (Local check), Bioseed-9681 (National check) and Super900M (Private check) at botanical garden, Department of genetics and plant breeding, MARS, Dharwad during kharif 2012. The recommended package of practices were followed to raise good crop. The observation on earliness, growth and protein content were recorded from five competitive plants which were selected randomly from each treatment. The mean values of these five plants were used for analysis as per the method suggested by Kempthrone (1957) [12]. Protein content was estimated by NIRS (Near Infrared Reflectance Spectrometer) installed at the Main Agricultural Research Station, Dharwad, by using a random sample of cleaned and dried seeds of each entry.

The mean values of hybrids and their respective parents were used to estimate the heterosis per cent. The magnitude of heterosis in hybrids were expressed in percentage of increase or decrease of character over mid parent, better parent and standard check and was computed using the formula of Fonseca and Patterson (1968) [8]. The following heterotic effects were also computed,

1. Mid-parent Heterosis (%) = ((F1 - MP) / MP) × 100
2. Best-parent Hetrosis (%) = ((F1 - BP) / BP) × 100
3. Standard heterosis (%) = ((F1 - CC) / CC) × 100

Where, F1 = Mean of F1 hybrid for a specific trait, MP = Mean of the two parents in a cross for a specific trait, BP = Mean of the best parent in a cross for a specific trait, CC = Mean value of commercial check.

Results and Discussion

The pertinent data on magnitude of heterosis over mid parent, better parent and checks for different characters are detailed in Tables 1, 2, 3, 4, 5 and 6.

Table 1: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for days to 50% tasseling

Crosses	Days to 50% tasseling					Crosses	Days to 50% tasseling				
	Heterosis over (%)						Heterosis over (%)				
	MP	BP	Arjun	Bioseed-9681	Super 900M		MP	BP	Arjun	Bioseed-9681	Super 900M
BM259 × BM59	-7.87**	-8.59**	1.74	0	-2.50*	BM60 × BM59	-8.59**	-8.59**	1.74	0	-2.50*
BM259 × BM258	-6.67**	-7.75**	3.48**	1.71	-0.83	BM60 × BM258	-7.39**	-7.75**	3.48**	1.71	-0.83
BM259 × BM32	-5.65**	-7.14**	1.74	0	-2.50*	BM60 × BM32	-5.60**	-7.81**	2.61*	0.85	-1.67
BM259 × RNBL 4611	-6.72**	-7.09**	2.61*	0.85	-1.67	BM60 × RNBL 4611	-8.24**	-8.59**	1.74	0	-2.50*
BM259 × RNBL 4711	-8.66**	-9.38**	0.87	-0.85	-3.33**	BM60 × RNBL 4711	-8.59**	-8.59**	1.74	0	-2.50*
BM259 × BM1	-5.88**	-6.98**	4.35**	2.56*	0	BM60 × BM1	-8.95**	-9.30**	1.74	0	-2.50*
BM127 × BM59	-6.67**	-7.03**	3.48**	1.71	-0.83	BM51 × BM59	-10.08**	-10.77**	0.87	-0.85	-3.33**
BM127 × BM258	-8.59**	-9.30**	1.74	0	-2.50*	BM51 × BM258	-8.11**	-8.46**	3.48**	1.71	-0.83
BM127 × BM32	-6.02**	-7.87**	1.74	0	-2.50*	BM51 × BM32	-8.73**	-11.54**	0	-1.71	-4.17**
BM127 × RNBL 4611	-7.87**	-7.87**	1.74	0	-2.50*	BM51 × RNBL 4611	-10.51**	-11.54**	0	-1.71	-4.17**
BM127 × RNBL 4711	-7.45**	-7.81**	2.61*	0.85	-1.67	BM51 × RNBL 4711	-9.30**	-10.00**	1.74	0	-2.50*
BM127 × BM1	-7.81**	-8.53**	2.61*	0.85	-1.67	BM51 × BM1	-10.42**	-10.77**	0.87	-0.85	-3.33**
BM136 × BM59	-8.17**	-8.53**	2.61*	0.85	-1.67	BM52 × BM59	-6.67**	-7.03**	3.48**	1.71	-0.83
BM136 × BM258	-9.30**	-9.30**	1.74	0	-2.50*	BM52 × BM258	-9.38**	-10.08**	0.87	-0.85	-3.33**
BM136 × BM32	-5.98**	-8.53**	2.61*	0.85	-1.67	BM52 × BM32	-6.83**	-8.66**	0.87	-0.85	-3.33**
BM136 × RNBL 4611	-10.16**	-10.85**	0	-1.71	-4.17**	BM52 × RNBL 4611	-7.87**	-7.87**	1.74	0	-2.50*
BM136 × RNBL 4711	-8.95**	-9.30**	1.74	0	-2.50*	BM52 × RNBL 4711	-9.02**	-9.38**	0.87	-0.85	-3.33**
BM136 × BM1	-10.85**	-10.85**	0	-1.71	-4.17**	BM52 × BM1	-8.59**	-9.30**	1.74	0	-2.50*
BM24 × BM59	-9.80**	-10.16**	0	-1.71	-4.17**	BM254 × BM59	-7.81**	-7.81**	2.61*	0.85	-1.67
BM24 × BM258	-8.59**	-9.30**	1.74	0	-2.50*	BM254 × BM258	-10.51**	-10.85**	0	-1.71	-4.17**
BM24 × BM32	-4.42**	-6.30**	3.48**	1.71	-0.83	BM254 × BM32	-4.80**	-7.03**	3.48**	1.71	-0.83
BM24 × RNBL 4611	-10.24**	-10.24**	-0.87	-2.56*	-5.00**	BM254 × RNBL 4611	-8.24**	-8.59**	1.74	0	-2.50*
BM24 × RNBL 4711	-9.02**	-9.38**	0.87	-0.85	-3.33**	BM254 × RNBL 4711	-8.59**	-8.59**	1.74	0	-2.50*
BM24 × BM1	-8.59**	-9.30**	1.74	0	-2.50*	BM254 × BM1	-8.17**	-8.53**	2.61*	0.85	-1.67
BM423 × BM59	-11.63**	-12.31**	-0.87	-2.56*	-5.00**	BM36 × BM59	-9.02**	-9.38**	0.87	-0.85	-3.33**
BM423 × BM258	-10.42**	-10.77**	0.87	-0.85	-3.33**	BM36 × BM258	-8.59**	-9.30**	1.74	0	-2.50*
BM423 × BM32	-7.14**	-10.00**	1.74	0	-2.50*	BM36 × BM32	-6.83**	-8.66**	0.87	-0.85	-3.33**
BM423 × RNBL 4611	-10.51**	-11.54**	0	-1.71	-4.17**	BM36 × RNBL 4611	-7.87**	-7.87**	1.74	0	-2.50*
BM423 × RNBL 4711	-11.63**	-12.31**	-0.87	-2.56*	-5.00**	BM36 × RNBL 4711	-8.24**	-8.59**	1.74	0	-2.50*
BM423 × BM1	-10.42**	-10.77**	0.87	-0.85	-3.33**	BM36 × BM1	-8.59**	-9.30**	1.74	0	-2.50*
BM8 × BM59	-8.95**	-9.30**	1.74	0	-2.50*	BM83 × BM59	-7.87**	-8.59**	1.74	0	-2.50*
BM8 × BM258	-8.53**	-8.53**	2.61*	0.85	-1.67	BM83 × BM258	-9.02**	-10.08**	0.87	-0.85	-3.33**
BM8 × BM32	-8.37**	-10.85**	0	-1.71	-4.17**	BM83 × BM32	-4.84**	-6.35**	2.61*	0.85	-1.67
BM8 × RNBL 4611	-7.81**	-8.53**	2.61*	0.85	-1.67	BM83 × RNBL 4611	-5.93**	-6.30**	3.48**	1.71	-0.83
BM8 × RNBL 4711	-8.17**	-8.53**	2.61*	0.85	-1.67	BM83 × RNBL 4711	-7.09**	-7.81**	2.61*	0.85	-1.67
BM8 × BM1	-8.53**	-8.53**	2.61*	0.85	-1.67	BM83 × BM1	-9.80**	-10.85**	0	-1.71	-4.17**

Table 2: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for days to 50% silking

Crosses	Days to 50% silking					Crosses	Days to 50% silking				
	Heterosis over (%)						Heterosis over (%)				
	MP	BP	Arjun	Bioseed-9681	Super 900M		MP	BP	Arjun	Bioseed-9681	Super 900M
BM259 × BM59	-3.76**	-4.48**	3.23**	3.23**	0	BM60 × BM59	-7.35**	-8.70**	1.61	1.61	-1.56
BM259 × BM258	-4.83**	-6.57**	3.23**	3.23**	0	BM60 × BM258	-6.91**	-7.25**	3.23**	3.23**	0
BM259 × BM32	-3.08**	-4.55**	1.61	1.61	-1.56	BM60 × BM32	-4.51**	-7.97**	2.42*	2.42*	-0.78
BM259 × RNBL 4611	-4.87**	-5.93**	2.42*	2.42*	-0.78	BM60 × RNBL 4611	-7.69**	-8.70**	1.61	1.61	-1.56
BM259 × RNBL 4711	-7.46**	-8.82**	0	0	-3.13**	BM60 × RNBL 4711	-10.22**	-10.87**	-0.81	-0.81	-3.91**
BM259 × BM1	-4.83**	-6.57**	3.23**	3.23**	0	BM60 × BM1	-8.36**	-8.70**	1.61	1.61	-1.56
BM127 × BM59	-3.73**	-3.73**	4.03**	4.03**	0.78	BM51 × BM59	-5.88**	-7.25**	3.23**	3.23**	0
BM127 × BM258	-7.01**	-8.03**	1.61	1.61	-1.56	BM51 × BM258	-7.64**	-7.97**	2.42*	2.42*	-0.78
BM127 × BM32	-4.58**	-6.72**	0.81	0.81	-2.34*	BM51 × BM32	-6.77**	-10.14**	0	0	-3.13**
BM127 × RNBL 4611	-7.06**	-7.41**	0.81	0.81	-2.34*	BM51 × RNBL 4611	-9.89**	-10.87**	-0.81	-0.81	-3.91**
BM127 × RNBL 4711	-5.19**	-5.88**	3.23**	3.23**	0	BM51 × RNBL 4711	-9.49**	-10.14**	0	0	-3.13**
BM127 × BM1	-7.75**	-8.76**	0.81	0.81	-2.34*	BM51 × BM1	-9.82**	-10.14**	0	0	-3.13**
BM136 × BM59	-4.44**	-5.15**	4.03**	4.03**	0.78	BM52 × BM59	-5.54**	-6.57**	3.23**	3.23**	0
BM136 × BM258	-4.76**	-5.11**	4.84**	4.84**	1.56	BM52 × BM258	-9.49**	-9.49**	0	0	-3.13**
BM136 × BM32	-4.55**	-7.35**	1.61	1.61	-1.56	BM52 × BM32	-5.66**	-8.76**	0.81	0.81	-2.34*
BM136 × RNBL 4611	-9.23**	-9.56**	-0.81	-0.81	-3.91**	BM52 × RNBL 4611	-8.82**	-9.49**	0	0	-3.13**
BM136 × RNBL 4711	-8.09**	-8.09**	0.81	0.81	-2.34*	BM52 × RNBL 4711	-9.89**	-10.22**	-0.81	-0.81	-3.91**
BM136 × BM1	-9.89**	-10.22**	-0.81	-0.81	-3.91**	BM52 × BM1	-8.76**	-8.76**	0.81	0.81	-2.34*
BM24 × BM59	-7.81**	-8.15**	0	0	-3.13**	BM254 × BM59	-7.41**	-8.09**	0.81	0.81	-2.34*
BM24 × BM258	-7.35**	-8.03**	1.61	1.61	-1.56	BM254 × BM258	-9.16**	-9.49**	0	0	-3.13**
BM24 × BM32	-2.66**	-5.19**	3.23**	3.23**	0	BM254 × BM32	-3.79**	-6.62**	2.42*	2.42*	-0.78
BM24 × RNBL 4611	-7.41**	-7.41**	0.81	0.81	-2.34*	BM254 × RNBL 4611	-5.54**	-5.88**	3.23**	3.23**	0
BM24 × RNBL 4711	-8.49**	-8.82**	0	0	-3.13**	BM254 × RNBL 4711	-7.35**	-7.35**	1.61	1.61	-1.56
BM24 × BM1	-8.82**	-9.49**	0	0	-3.13**	BM254 × BM1	-6.23**	-6.57**	3.23**	3.23**	0
BM423 × BM59	-6.62**	-7.97**	2.42*	2.42*	-0.78	BM36 × BM59	-5.97**	-5.97**	1.61	1.61	-1.56
BM423 × BM258	-10.55**	-10.87**	-0.81	-0.81	-3.91**	BM36 × BM258	-7.01**	-8.03**	1.61	1.61	-1.56
BM423 × BM32	-6.02**	-9.42**	0.81	0.81	-2.34*	BM36 × BM32	-5.34**	-7.46**	0	0	-3.13**
BM423 × RNBL 4611	-9.89**	-10.87**	-0.81	-0.81	-3.91**	BM36 × RNBL 4611	-7.06**	-7.41**	0.81	0.81	-2.34*
BM423 × RNBL 4711	-10.95**	-11.59**	-1.61	-1.61	-4.69**	BM36 × RNBL 4711	-6.67**	-7.35**	1.61	1.61	-1.56
BM423 × BM1	-9.09**	-9.42**	0.81	0.81	-2.34*	BM36 × BM1	-7.75**	-8.76**	0.81	0.81	-2.34*
BM8 × BM59	-6.67**	-7.35**	1.61	1.61	-1.56	BM83 × BM59	-5.22**	-5.22**	2.42*	2.42*	-0.78
BM8 × BM258	-7.69**	-8.03**	1.61	1.61	-1.56	BM83 × BM258	-7.75**	-8.76**	0.81	0.81	-2.34*
BM8 × BM32	-5.30**	-8.09**	0.81	0.81	-2.34*	BM83 × BM32	-3.82**	-5.97**	1.61	1.61	-1.56
BM8 × RNBL 4611	-6.27**	-6.62**	2.42*	2.42*	-0.78	BM83 × RNBL 4611	-6.32**	-6.67**	1.61	1.61	-1.56
BM8 × RNBL 4711	-8.09**	-8.09**	0.81	0.81	-2.34*	BM83 × RNBL 4711	-5.19**	-5.88**	3.23**	3.23**	0
BM8 × BM1	-6.23**	-6.57**	3.23**	3.23**	0	BM83 × BM1	-8.49**	-9.49**	0	0	-3.13**

Table 3: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for plant height (cm)

Crosses	Plant height (cm)					Crosses	Plant height (cm)				
	Heterosis over (%)						Heterosis over (%)				
	MP	BP	Arjun	Bioseed-9681	Super 900M		MP	BP	Arjun	Bioseed-9681	Super 900M
BM259 × BM59	12.83**	-7.25*	-11.16**	-10.97**	-10.78**	BM60 × BM59	-5.43*	-6.45*	-8.42**	-8.23**	-8.03**
BM259 × BM258	19.42**	-2.59	-4.84	-4.64	-4.44	BM60 × BM258	-0.75	-0.86	-2.95	-2.74	-2.54
BM259 × BM32	-0.64	-20.85**	-17.68**	-17.51**	-17.34**	BM60 × BM32	-2.19	-5.06	-1.26	-1.05	-0.85
BM259 × RNBL 4611	16.64**	-3.36	-9.26**	-9.07**	-8.88**	BM60 × RNBL 4611	-4.5	-6.45*	-8.42**	-8.23**	-8.03**
BM259 × RNBL 4711	15.88**	-3.83	-10.11**	-9.92**	-9.73**	BM60 × RNBL 4711	1.65	-0.65	-2.74	-2.53	-2.33
BM259 × BM1	9.64**	-11.37**	-11.37**	-11.18**	-10.99**	BM60 × BM1	4.04	2.95	2.95	3.16	3.38
BM127 × BM59	-5.42*	-6.64*	-8.21**	-8.02**	-7.82**	BM51 × BM59	20.00**	4.18	-0.21	0	0.21
BM127 × BM258	-10.85**	-11.13**	-12.63**	-12.45**	-12.26**	BM51 × BM258	9.39**	-5.82*	-8.00**	-7.81**	-7.61**
BM127 × BM32	-9.26**	-11.74**	-8.21**	-8.02**	-7.82**	BM51 × BM32	-6.63*	-21.66**	-18.53**	-18.35**	-18.18**
BM127 × RNBL 4611	0.11	-2.14	-3.79	-3.59	-3.38	BM51 × RNBL 4611	6.53*	-6.73*	-12.42**	-12.24**	-12.05**
BM127 × RNBL 4711	-2.96	-5.35	-6.95*	-6.75*	-6.55*	BM51 × RNBL 4711	14.51**	0.45	-6.11*	-5.91*	-5.71*
BM127 × BM1	-5.52*	-6.32*	-6.32*	-6.12*	-5.92*	BM51 × BM1	14.81**	-2.11	-2.11	-1.9	-1.69
BM136 × BM59	-8.43**	-11.00**	-9.68**	-9.49**	-9.30**	BM52 × BM59	18.25**	1.1	-3.16	-2.95	-2.75
BM136 × BM258	-14.16**	-15.77**	-14.53**	-14.35**	-14.16**	BM52 × BM258	14.61**	-2.8	-5.05	-4.85	-4.65
BM136 × BM32	-27.54**	-28.42**	-25.56**	-25.40**	-25.24**	BM52 × BM32	-9.18**	-24.90**	-21.89**	-21.73**	-21.56**
BM136 × RNBL 4611	-19.18**	-22.20**	-21.05**	-20.89**	-20.72**	BM52 × RNBL 4611	8.71**	-6.28*	-12.00**	-11.81**	-11.63**
BM136 × RNBL 4711	1.3	-2.7	-1.26	-1.05	-0.85	BM52 × RNBL 4711	10.04**	-4.95	-11.16**	-10.97**	-10.78**
BM136 × BM1	-3.45	-4.15	-2.74	-2.53	-2.33	BM52 × BM1	11.03**	-6.74*	-6.74*	-6.54*	-6.34*
BM24 × BM59	4.03	0.62	3.16	3.38	3.59	BM254 × BM59	11.46**	10.11**	5.47*	5.70*	5.92*
BM24 × BM258	4.52	2.05	4.63	4.85	5.07	BM254 × BM258	2.42	0.22	-2.11	-1.9	-1.69
BM24 × BM32	-0.51	-1.21	2.74	2.95	3.17	BM254 × BM32	-1.07	-6.07*	-2.32	-2.11	-1.9
BM24 × RNBL 4611	-2.25	-6.37*	-4	-3.8	-3.59	BM254 × RNBL 4611	2.47	2.24	-4	-3.8	-3.59
BM24 × RNBL 4711	-1.83	-6.16*	-3.79	-3.59	-3.38	BM254 × RNBL 4711	9.23**	9.23**	2.11	2.32	2.54

BM24 × BM1	-9.56**	-10.68**	-8.42**	-8.23**	-8.03**	BM254 × BM1	7.29**	3.79	3.79	4.01	4.23
BM423 × BM59	5.41*	4.84	0.42	0.63	0.85	BM36 × BM59	12.86**	2.2	-2.11	-1.9	-1.69
BM423 × BM258	2.58	1.03	-1.31	-1.1	-0.89	BM36 × BM258	2.52	-7.97**	-10.11**	-9.92**	-9.73**
BM423 × BM32	-2.33	-6.68*	-2.95	-2.74	-2.54	BM36 × BM32	3.36	-9.72**	-6.11*	-5.91*	-5.71*
BM423 × RNBL 4611	-0.67	-1.11	-6.32*	-6.12*	-5.92*	BM36 × RNBL 4611	9.94**	0.45	-5.68*	-5.49*	-5.29
BM423 × RNBL 4711	3.58	2.89	-2.53	-2.32	-2.11	BM36 × RNBL 4711	11.69**	2.25	-4.42	-4.22	-4.02
BM423 × BM1	4.22	1.47	1.47	1.69	1.9	BM36 × BM1	11.85**	-0.63	-0.63	-0.42	-0.21
BM8 × BM59	-1.68	-5.66*	-1.68	-1.48	-1.27	BM83 × BM59	3.31	-0.44	-4.63	-4.43	-4.23
BM8 × BM258	1.15	-2.02	2.11	2.32	2.54	BM83 × BM258	4.97	0.22	-2.11	-1.9	-1.69
BM8 × BM32	-8.39**	-8.48**	-4.63	-4.43	-4.23	BM83 × BM32	3.71	-3.85	0	0.21	0.42
BM8 × RNBL 4611	3.72	-1.41	2.74	2.95	3.17	BM83 × RNBL 4611	12.90**	9.87**	3.16	3.38	3.59
BM8 × RNBL 4711	-4.58	-9.49**	-5.68*	-5.49*	-5.29	BM83 × RNBL 4711	-0.23	-2.7	-9.05**	-8.86**	-8.67**
BM8 × BM1	-4.74*	-6.67*	-2.74	-2.53	-2.33	BM83 × BM1	-4.35	-9.68**	-9.68**	-9.49**	-9.30**

Table 4: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for plant girth (cm)

Crosses	Plant girth (cm)					Crosses	Plant girth (cm)				
	Heterosis over (%)						Heterosis over (%)				
	MP	BP	Arjun	Bioseed-9681	Super 900M		MP	BP	Arjun	Bioseed-9681	Super 900M
BM259 × BM59	2.99	0.58	-14.43**	-13.13**	-13.57**	BM60 × BM59	1.66	-3.66	-8.46**	-7.07*	-7.54*
BM259 × BM258	5.78	0	-8.96**	-7.58*	-8.04**	BM60 × BM258	-6.95*	-8.90**	-13.43**	-12.12**	-12.56**
BM259 × BM32	6.40*	1.1	-8.96**	-7.58*	-8.04**	BM60 × BM32	-11.29**	-13.61**	-17.91**	-16.67**	-17.09**
BM259 × RNBL 4611	6.52*	-1.05	-6.47*	-5.05	-5.53	BM60 × RNBL 4611	-14.44**	-14.66**	-18.91**	-17.68**	-18.09**
BM259 × RNBL 4711	17.16**	13.14**	-1.49	0	-0.5	BM60 × RNBL 4711	-4.37	-8.38**	-12.94**	-11.62**	-12.06**
BM259 × BM1	-0.84	-8.76**	-11.94**	-10.61**	-11.06**	BM60 × BM1	-7.01*	-7.73*	-10.95**	-9.60**	-10.05**
BM127 × BM59	13.57**	7.89*	1.99	3.54	3.02	BM51 × BM59	1.49	-0.58	-15.42**	-14.14**	-14.57**
BM127 × BM258	-1.34	-3.16	-8.46**	-7.07*	-7.54*	BM51 × BM258	9.51**	3.83	-5.47	-4.04	-4.52
BM127 × BM32	-7.82**	-10.00**	-14.93**	-13.64**	-14.07**	BM51 × BM32	7.83*	2.76	-7.46*	-6.06*	-6.53*
BM127 × RNBL 4611	-11.58**	-11.58**	-16.42**	-15.15**	-15.58**	BM51 × RNBL 4611	10.73**	3.16	-2.49	-1.01	-1.51
BM127 × RNBL 4711	-2.47	-6.32*	-11.44**	-10.10**	-10.55**	BM51 × RNBL 4711	4.42	1.14	-11.94**	-10.61**	-11.06**
BM127 × BM1	-4.69	-5.67	-8.96**	-7.58*	-8.04**	BM51 × BM1	-15.08**	-21.65**	-24.38**	-23.23**	-23.62**
BM136 × BM59	9.24**	2.03	0	1.52	1.01	BM52 × BM59	14.97**	12.28**	-4.48	-3.03	-3.52
BM136 × BM258	-12.63**	-15.74**	-17.41**	-16.16**	-16.58**	BM52 × BM258	19.65**	13.11**	2.99	4.55	4.02
BM136 × BM32	-6.88*	-10.66**	-12.44**	-11.11**	-11.56**	BM52 × BM32	-7.56*	-12.15**	-20.90**	-19.70**	-20.10**
BM136 × RNBL 4611	-5.43*	-7.11*	-8.96**	-7.58*	-8.04**	BM52 × RNBL 4611	7.65*	0	-5.47	-4.04	-4.52
BM136 × RNBL 4711	-8.60**	-13.71**	-15.42**	-14.14**	-14.57**	BM52 × RNBL 4711	-3.55	-6.86*	-18.91**	-17.68**	-18.09**
BM136 × BM1	8.95**	8.12**	5.97*	7.58*	7.04*	BM52 × BM1	7.56*	-1.03	-4.48	-3.03	-3.52
BM24 × BM59	12.32**	10.11**	-2.49	-1.01	-1.51	BM254 × BM59	9.20**	7.34*	-5.47	-4.04	-4.52
BM24 × BM258	-3.05	-4.37	-12.94**	-11.62**	-12.06**	BM254 × BM258	6.67*	4.92	-4.48	-3.03	-3.52
BM24 × BM32	-4.74	-5.52	-14.93**	-13.64**	-14.07**	BM254 × BM32	1.12	0	-9.95**	-8.59**	-9.05**
BM24 × RNBL 4611	5.98*	2.63	-2.99	-1.52	-2.01	BM254 × RNBL 4611	-8.45**	-11.58**	-16.42**	-15.15**	-15.58**
BM24 × RNBL 4711	-7.65*	-8.43*	-18.91**	-17.68**	-18.09**	BM254 × RNBL 4711	19.89**	19.21**	4.98	6.57*	6.03*
BM24 × BM1	-6.45*	-10.31**	-13.43**	-12.12**	-12.56**	BM254 × BM1	4.04	-0.52	-3.98	-2.53	-3.02
BM423 × BM59	3.12	0	-9.45**	-8.08**	-8.54**	BM36 × BM59	-8.59**	-13.16**	-17.91**	-16.67**	-17.09**
BM423 × BM258	0.82	0.55	-8.46**	-7.07*	-7.54*	BM36 × BM258	-7.24*	-8.95**	-13.93**	-12.63**	-13.07**
BM423 × BM32	-3.58	-3.85	-12.94**	-11.62**	-12.06**	BM36 × BM32	-5.12	-7.37*	-12.44**	-11.11**	-11.56**
BM423 × RNBL 4611	0.54	-1.58	-6.97*	-5.56	-6.03*	BM36 × RNBL 4611	-4.21	-4.21	-9.45**	-8.08**	-8.54**
BM423 × RNBL 4711	7.56*	5.49	-4.48	-3.03	-3.52	BM36 × RNBL 4711	-5.75*	-9.47**	-14.43**	-13.13**	-13.57**
BM423 × BM1	-23.40**	-25.77**	-28.36**	-27.27**	-27.64**	BM36 × BM1	-7.81**	-8.76**	-11.94**	-10.61**	-11.06**
BM8 × BM59	10.40**	9.14**	-4.98	-3.54	-4.02	BM83 × BM59	5.6	4.68	-10.95**	-9.60**	-10.05**
BM8 × BM258	-9.50**	-11.48**	-19.40**	-18.18**	-18.59**	BM83 × BM258	-1.42	-5.46	-13.93**	-12.63**	-13.07**
BM8 × BM32	-8.43**	-9.94**	-18.91**	-17.68**	-18.09**	BM83 × BM32	14.04**	9.94**	-1	0.51	0
BM8 × RNBL 4611	-9.59**	-13.16**	-17.91**	-16.67**	-17.09**	BM83 × RNBL 4611	3.35	-2.63	-7.96**	-6.57*	-7.04*
BM8 × RNBL 4711	0	0	-12.94**	-11.62**	-12.06**	BM83 × RNBL 4711	-6.71*	-8.57*	-20.40**	-19.19**	-19.60**
BM8 × BM1	2.44	-2.58	-5.97*	-4.55	-5.03	BM83 × BM1	0.55	-6.19*	-9.45**	-8.08**	-8.54**

Table 5: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for fodder yield (gm)

Crosses	Fodder yield per plant (g)					Crosses	Fodder yield per plant (g)				
	Heterosis over (%)						Heterosis over (%)				
	MP	BP	Arjun	Bioseed-9681	Super 900M		MP	BP	Arjun	Bioseed-9681	Super 900M
BM259 α BM59	-15.19	-19.46	-13.36	-46.19**	-46.55**	BM60 × BM59	2.11	-10.74	-3.97	-40.36**	-40.76**
BM259 × BM258	27.97	24.63	20.58	-25.11*	-25.61*	BM60 × BM258	24.95	17.32	7.58	-33.18**	-33.63**
BM259 × BM32	-5.26	-15.29	3.97	-35.43**	-35.86**	BM60 × BM32	12.97	-6.47	14.8	-28.70*	-29.18*
BM259 × RNBL 4611	-10.97	-21.27	-23.83	-52.69**	-53.01**	BM60 × RNBL 4611	15.62	11.21	-10.47	-44.39**	-44.77**
BM259 × RNBL 4711	23.22	20.79	21.66	-24.44	-24.94*	BM60 × RNBL 4711	47.01*	32.26	33.21	-17.26	-17.82
BM259 × BM1	24.92	11.4	37.55	-14.57	-15.14	BM60 × BM1	15.4	-4.68	17.69	-26.91*	-27.39*
BM127 × BM59	4.98	3.95	14.08	-29.15*	-29.62*	BM51 × BM59	32.04	25.17	34.66	-16.37	-16.93
BM127 × BM258	0	-8.22	0.72	-37.44**	-37.86**	BM51 × BM258	52.02**	48.31*	42.96*	-11.21	-11.8
BM127 × BM32	-11.49	-16.18	2.89	-36.10**	-36.53**	BM51 × BM32	-13.01	-22.35	-4.69	-40.81**	-41.20**

BM127 × RNBL 4611	12.94	-5.26	3.97	-35.43**	-35.86**	BM51 × RNBL 4611	0.21	-11.24	-14.44	-46.86**	-47.22**
BM127 × RNBL 4711	38.25*	32.57	45.49*	-9.64	-10.24	BM51 × RNBL 4711	19.41	16.85	17.69	-26.91*	-27.39*
BM127 × BM1	-18.27	-22.81	-4.69	-40.81**	-41.20**	BM51 × BM1	-19.21	-28.07	-11.19	-44.84**	-45.21**
BM136 × BM59	-1.63	-4.43	9.03	-32.29*	-32.74**	BM52 × BM59	0.88	-3.36	3.97	-35.43**	-35.86**
BM136 × BM258	4.56	-5.7	7.58	-33.18**	-33.63**	BM52 × BM258	6.26	2.56	1.08	-37.22**	-37.64**
BM136 × BM32	-28.66	-31.18	-15.52	-47.53**	-47.88**	BM52 × BM32	-13.54	-22.06	-4.33	-40.58**	-40.98**
BM136 × RNBL 4611	-13.41	-28.48	-18.41	-49.33**	-49.67**	BM52 × RNBL 4611	8.98	-4.4	-5.78	-41.48**	-41.87**
BM136 × RNBL 4711	0.17	-5.7	7.58	-33.18**	-33.63**	BM52 × RNBL 4711	-11.96	-12.9	-12.27	-45.52**	-45.88**
BM136 × BM1	-11.55	-14.91	5.05	-34.75**	-35.19**	BM52 × BM1	-10.89	-19.88	-1.08	-38.57**	-38.98**
BM24 × BM59	30.08*	11.19	68.59**	4.71	4.01	BM254 × BM59	12.36	10.36	23.1	-23.54	-24.05
BM24 × BM258	11.87	-10.24	36.1	-15.47	-16.04	BM254 × BM258	22.56	11.65	24.55	-22.65	-23.16
BM24 × BM32	-5	-14.05	30.32	-19.06	-19.6	BM254 × BM32	-1.39	-5.88	15.52	-28.25*	-28.73*
BM24 × RNBL 4611	-16.29	-37.62**	-5.42	-41.26**	-41.65**	BM254 × RNBL 4611	20.78	0.65	12.27	-30.27*	-30.73*
BM24 × RNBL 4711	-33.33*	-44.52**	-15.88	-47.76**	-48.11**	BM254 × RNBL 4711	-4.42	-9.06	1.44	-37.00**	-37.42**
BM24 × BM1	-36.48**	-42.38**	-12.64	-45.74**	-46.10**	BM254 × BM1	-12.14	-16.37	3.25	-35.87**	-36.30**
BM423 × BM59	6.81	1.2	21.66	-24.44	-24.94*	BM36 × BM59	17.58	7.72	15.88	-28.03*	-28.51*
BM423 × BM258	-4.6	-15.92	1.08	-37.22**	-37.64**	BM36 × BM258	26.69	25.2	14.8	-28.70*	-29.18*
BM423 × BM32	6.69	5.59	29.6	-19.51	-20.04	BM36 × BM32	-1.7	-15	4.33	-35.20**	-35.63**
BM423 × RNBL 4611	21.71	-1.5	18.41	-26.46*	-26.95*	BM36 × RNBL 4611	2.2	-6.45	-16.25	-47.98**	-48.33**
BM423 × RNBL 4711	-5.56	-13.21	4.33	-35.20**	-35.63**	BM36 × RNBL 4711	43.07*	35.13	36.1	-15.47	-16.04
BM423 × BM1	5.19	3.8	28.16	-20.4	-20.94	BM36 × BM1	-3.73	-16.96	2.53	-36.32**	-36.75**
BM8 × BM59	1.71	-0.34	7.22	-33.41**	-33.85**	BM83 × BM59	8.03	-0.67	6.86	-33.63**	-34.08**
BM8 × BM258	1.85	-3.85	-0.72	-38.34**	-38.75**	BM83 × BM258	-0.79	-1.57	-9.75	-43.95**	-44.32**
BM8 × BM32	-19.49	-25.88	-9.03	-43.50**	-43.88**	BM83 × BM32	13.56	-1.47	20.94	-24.89*	-25.39*
BM8 × RNBL 4611	-21.14	-32.17	-29.96	-56.50**	-56.79**	BM83 × RNBL 4611	13.6	3.6	-6.5	-41.93**	-42.32**
BM8 × RNBL 4711	10.44	9.09	12.64	-30.04*	-30.51*	BM83 × RNBL 4711	10.78	5.02	5.78	-34.30**	-34.74**
BM8 × BM1	-9.87	-17.25	2.17	-36.55**	-36.97**	BM83 × BM1	16.22	0.58	24.19	-22.87	-23.39

Table 6: Magnitude of heterosis over mid parent, better parent and standard checks (Arjun, Bioseed-9681 and Super 900M) for protein content (%)

Crosses	Protein content (%)					Crosses	Protein content (%)				
	Heterosis over (%)						**Heterosis** over (%)				
	MP	**BP**	**Arjun**	**Bioseed-9681**	**Super 900M**		**MP**	**BP**	**Arjun**	**Bioseed-9681**	**Super 900M**
BM259 × BM59	-34.82**	-38.14**	-26.63**	-19.78	-31.13**	BM60 × BM59	-5.69	-12.29	4.02	13.74	-2.36
BM259 × BM258	9.28	0	6.53	16.48	0	BM60 × BM258	0.26	-6.4	-4.52	4.4	-10.38
BM259 × BM32	-14.29	-19.34*	-14.07	-6.04	-19.34*	BM60 × BM32	2.05	-1.97	0	9.34	-6.13
BM259 × RNBL 4611	-25.43**	-28.77**	-24.12*	-17.03	-28.77**	BM60 × RNBL 4611	-8.59	-10.84	-9.05	-0.55	-14.62
BM259 × RNBL 4711	4.55	-2.36	4.02	13.74	-2.36	BM60 × RNBL 4711	19.90*	14.29	16.58	27.47**	9.43
BM259 × BM1	-6.19	-7.08	-1.01	8.24	-7.08	BM60 × BM1	-12.9	-13.94	-10.05	-1.65	-15.57
BM127 × BM59	-21.72**	-22.88**	-8.54	0	-14.15	BM51 × BM59	-11.35	-13.98	2.01	11.54	-4.25
BM127 × BM258	-15.56	-25.33**	-14.07	-6.04	-19.34*	BM51 × BM258	-5.53	-15.32	-5.53	3.3	-11.32
BM127 × BM32	-10.58	-18.78*	-6.53	2.2	-12.26	BM51 × BM32	-14.91	-21.62*	-12.56	-4.4	-17.92*
BM127 × RNBL 4611	-9.48	-16.59*	-4.02	4.95	-9.91	BM51 × RNBL 4611	-9.88	-15.77	-6.03	2.75	-11.79
BM127 × RNBL 4711	9.93	-0.87	14.07	24.73*	7.08	BM51 × RNBL 4711	-15.27	-22.52**	-13.57	-5.49	-18.87*
BM127 × BM1	-12.13	-16.16	-3.52	5.49	-9.43	BM51 × BM1	-23.26**	-25.68**	-17.09	-9.34	-22.17*
BM136 × BM59	-10.48	-13.14	3.02	12.64	-3.3	BM52 × BM59	-19.63**	-25.42**	-11.56	-3.3	-16.98
BM136 × BM258	2.51	-8.11	2.51	12.09	-3.77	BM52 × BM258	4.23	-2.48	-1.01	8.24	-7.08
BM136 × BM32	12.96	4.05	16.08	26.92*	8.96	BM52 × BM32	3.34	-0.5	1.01	10.44	-5.19
BM136 × RNBL 4611	-14.7	-20.27*	-11.06	-2.75	-16.51	BM52 × RNBL 4611	12.91	10.4	12.06	22.53*	5.19
BM136 × RNBL 4711	6.9	-2.25	9.05	19.23	2.36	BM52 × RNBL 4711	1.04	-3.47	-2.01	7.14	-8.02
BM136 × BM1	-9.3	-12.16	-2.01	7.14	-8.02	BM52 × BM1	6.83	5.29	10.05	20.33	3.3
BM24 × BM59	0.23	-6.78	10.55	20.88*	3.77	BM254 × BM59	-19.06*	-27.12**	-13.57	-5.49	-18.87*
BM24 × BM258	16.09	8.37	10.55	20.88*	3.77	BM254 × BM258	5.75	2.12	-3.02	6.04	-8.96
BM24 × BM32	11.79	7.39	9.55	19.78	2.83	BM254 × BM32	-11.17	-11.64	-16.08	-8.24	-21.23*
BM24 × RNBL 4611	14.14	11.33	13.57	24.18*	6.6	BM254 × RNBL 4611	-6.28	-7.25	-10.05	-1.65	-15.57
BM24 × RNBL 4711	3.36	-1.48	0.5	9.89	-5.66	BM254 × RNBL 4711	12.6	11.11	5.53	15.38	-0.94
BM24 × BM1	-8.03	-9.13	-5.03	3.85	-10.85	BM254 × BM1	-20.91*	-24.52**	-21.11*	-13.74	-25.94**
BM423 × BM59	1.59	-5.51	12.06	22.53*	5.19	BM36 × BM59	-3.93	-11.86	4.52	14.29	-1.89
BM423 × BM258	-2.37	-8.87	-7.04	1.65	-12.74	BM36 × BM258	-10.99	-15.74	-16.58	-8.79	-21.70*
BM423 × BM32	16.41	11.82	14.07	24.73*	7.08	BM36 × BM32	16.67	13.71	12.56	23.08*	5.66
BM423 × RNBL 4611	-7.07	-9.36	-7.54	1.1	-13.21	BM36 × RNBL 4611	-0.51	-1.52	-2.51	6.59	-8.49
BM423 × RNBL 4711	1.29	-3.45	-1.51	7.69	-7.55	BM36 × RNBL 4711	18.11*	14.21	13.07	23.63*	6.13
BM423 × BM1	0.24	-0.96	3.52	13.19	-2.83	BM36 × BM1	-0.74	-3.37	1.01	10.44	-5.19
BM8 × BM59	-3.53	-13.14	3.02	12.64	-3.3	BM83 × BM59	-14.47*	-17.37*	-2.01	7.14	-8.02
BM8 × BM258	20.55*	16.4	10.55	20.88*	3.77	BM83 × BM258	16.16	4.55	15.58	26.37*	8.49
BM8 × BM32	11.17	10.58	5.03	14.84	-1.42	BM83 × BM32	-4.18	-11.36	-2.01	7.14	-8.02
BM8 × RNBL 4611	1.57	0.52	-2.51	6.59	-8.49	BM83 × RNBL 4611	-1.69	-7.73	2.01	11.54	-4.25
BM8 × RNBL 4711	-6.7	-7.94	-12.56	-4.4	-17.92*	BM83 × RNBL 4711	-31.19**	-36.82**	-30.15**	-23.63*	-34.43**
BM8 × BM1	-0.25	-4.81	-0.5	8.79	-6.6	BM83 × BM1	-5.61	-8.18	1.51	10.99	-4.72

Days to 50 per cent tasseling

The negative heterosis recorded for this trait serves as useful information in breeding for earliness Yusuf *et al.* (2009) [21]. Mid parental heterosis among hybrids ranged from -11.63 (BM423×BM59, BM423×RNBL4711) to -4.42 (BM24×BM32) per cent. Heterobeltiosis values ranged from -12.31 (BM423×BM59, BM423×RNBL4711) to -6.30 (BM24×BM32, BM83×RNBL4611) per cent. Economic heterosis obtained the range values from -0.87 (BM24×RNBL4611) to 4.35 (BM259×BM1) per cent over Arjun, -2.56 (BM24×RNBL4611, BM423×BM59, BM423×RNBL4711) to 2.56 (BM259×BM1) over Bio seed and -5.0 (BM423×RNBL4711) to 0 (BM259×BM1) over Super900M. All the 72 crosses exhibited significant mid parental heterosis and better parental heterosis in desirable direction. 3 crosses displayed significant heterosis over Bioseed-9681 and 48 crosses displayed significant heterosis over Super900M.

BM24×RNBL4611, BM423×BM59, BM423×RNBL4711, BM254×BM258 and BM8×BM32 were the top five crosses which recorded earliness significant mid parental and better parental heterosis in negative direction. BM423×BM59 and BM423×RNBL4711, involved at least one good combiner especially female parent, the superiority of these crosses could be explained on the basis of interaction between positive alleles from good combiner and negative allele from other parent. This result is supported by Amiruzzaman *et al.* (2013) [4] who suggested that including one good combiner especially female parent during crossing to obtain higher heterosis.

Days to 50 per cent silking

Days to 50 per cent silking is another important maturity character often used and more reliable to predict maturity (Shaw and Thom, 1951) [18]. With respect to heterosis over mid-parent and better parent all the 72 hybrids were superior and significant. Over Super900M, fifty seven crosses showed heterosis, among them thirty five showed significant heterosis in desirable direction with negative values. None of the hybrids showed significant heterosis over Arjun and Bioseed-9681. Mid parental heterosis among hybrids ranged from -10.95 (BM423×RNBL4711) to -2.66 (BM24×BM32) per cent. The range values for heterosis over better were from -11.59 (BM423×RNBL4711) to -3.43 (BM127×BM59) per cent. Heterosis over Arjun and Bio seed ranged from -0.81 to 4.84 (BM136×BM258) per cent. Whereas over Super900M, magnitude of heterosis ranged from -4.69 (BM423×RNBL4711) to 1.56 (BM136×BM258) per cent.

The hybrids BM423×RNBL4711, BM136×RNBL4611, BM136×BM1, BM60×RNBL4711 and BM423×BM258 were top five crosses which recorded superiority for the trait. Among these hybrids one cross BM423×RNBL4711 involved high x high type of general combiners. High performance of hybrid involving high x high combiners was reported earlier in maize by Salgotra *et al.* (2009) [17]. BM60×RNBL4711 and BM423×BM258, involved at least one good combiner, where high performance was may be due to interaction between dominant alleles from a good general combiner and a recessive allele from other parent. This is corroborated with the results of Aguiar *et al.* (2003) [2] and Amiruzzaman *et al.* (2013) [4].

Plant height

Plant height is one of the major concerns to plant breeders since yield has positive correlation with plant height (Rupak *et al.* 1979) [16]. Hybrid performance with respect to mid-parent heterosis ranged from -27.54 to 20 per cent in the crosses BM136×BM32 and BM51×BM59, respectively. The cross BM136×BM32 received lowest value for heterobeltiosis (-28.42) and standard heterosis over Arjun (-25.56), Bio seed (-25.40) and Super900M (-25.24) per cent. While the cross, BM254×BM59 registered highest values for heterobeltiosis (10.11%), over Arjun (5.47%), Bio seed (5.7%) and Super900M (5.92%).

All the five top superior hybrids, BM254×BM59, BM24×BM258, BM254×BM1, BM24×BM59 and BM83×RNBL4611, possessed at least one good combiner for the trait, which lead to high performance of these hybrids. Among them, BM254×BM59, BM254×BM1 and BM24×BM59 had high x high type general combiners, where high performance was may be due to interaction between positive and positive alleles in crossing high x high combiners, suggesting that involvement of good combiners to be essential to get the better specific combination. This result was in general agreement with the findings of Dass *et al.* (1997) [7].

BM83×RNBL4611 accommodated parents with high x low gca effects. This may be due to interaction between positive alleles from good combiner and negative alleles from poor combiner. The findings are in consonance with earlier workers Singh and Gupta (1969) [19] who suggested that cross with high *sca* value usually include a parent with high *gca* and a parent with a low gca value.

Plant girth

Among 72 hybrids evaluated, twenty one hybrids exhibited significant mid-parental heterosis. Ten hybrids registered significant heterosis over better parent. With respect to checks, one hybrid possessed significant heterosis over Arjun, two hybrids over Bio seed and two hybrids over Super900M. Per cent heterosis values ranged from -23.40 (BM423×BM1) to 19.89 (BM254×RNBL4711) over mid-parent, -25.77 (BM423×BM1) to 19.21 (BM254×RNBL4711) over better parent and from -28.36 (BM423×BM1) to 5.97 (BM136×BM1) over Arjun, -27.27 (BM423×BM1) to7.58 (BM136× BM1) and -27.64 (BM423×BM1) to 7.04 (BM136×BM1) over Super900M.

BM136×BM1, BM254×RNBL4711, BM52×BM258, BM127×BM59 and BM136×BM59 were top five hybrids for the trait with high heterosis over mid parent and better parent. Most these hybrids involved at least one good combiner. BM136×BM1, BM254×RNBL4711 and BM52×BM258 involved high x average type of gca effects. Superiority of these hybrids may be due to interaction between dominant alleles from good combiner and recessive allele from other parent. The findings are consonance with earlier worker Roy *et al.* (1998) [15] who noticed the superior hybrids involved high x average general combiners. One hybrid BM136×BM59, possessed parents with high gca effects, *i.e.* high x high type. This indicated additive x additive type of gene action between favourable alleles contributed by two respective parents, which was considered to be fixable.

Fodder yield per plant

Five hybrids expressed significantly higher mid-parent heterosis values with range values from -36.48 (BM24×BM1) to 52.02 (BM51×BM258). Heterosis over better parent was found to be significant in only one cross BM51×BM258 (48.31 %). The expression varied from -44.52 (BM24×RNBL4711) to 48.31per cent (BM51×BM258).

Magnitude of heterosis over checks ranged from -29.96 (BM8×RNBL4611) to 68.59 (BM24×BM59) for Arjun, -56.50 (BM8×RNBL4611) to 4.71 (BM24×BM59) for Bioseed and -56.79 (BM8×RNBL4611) to 4.01 (BM24×BM59) for Super900M. Three crosses showed significant positive heterosis for Arjun, but none of the crosses exhibited significant positive heterosis for the trait over Bioseed and Super900M.

Interestingly, all the top hybrids, BM24 x BM59, BM127 x RNBL4711, BM51 x BM258, BM259 x BM1 and BM24 x BM258 involved parents which expressed non-significant gca effects. This confirmed prevalence of non-additive gene effects in such crosses. So, these crosses could be further exploited for hybrid breeding program. Bassey (2002) [5] reported highest mid-parent heterosis. Amaregouda (2007) [3], Pradeepa (2007) [14], Pavan (2009) [13], Wali *et al.* (2010) [20] have reported mid parent, better parent heterosis and standard heterosis for the fodder yield.

Protein content

With respect to mid-parent heterosis three crosses exhibited significant heterosis over mid-parent. The magnitude of mid-parent heterosis ranged from -34.82 (BM259 x BM59) to 20.55 (BM8 x BM258) per cent. None of the crosses exhibited significant heterosis over better parent in desirable direction. Heterobeltiosis ranged from -38.14 (BM259×BM59) to 16.4 (BM8×BM258) per cent. Magnitude of heterosis over checks ranged from -30.15 (BM83×RNBL4711) to 16.58 (BM60×RNBL4711) per cent for Arjun, -23.63 (BM83×RNBL4711) to 27.47 (BM60×RNBL4711) per cent for Bio seed and -34.43 (BM83×RNBL4711) to 9.43 (BM60×RNBL4711) per cent for Super900M. Thirteen crosses showed significant positive heterosis over Bio seed, but none of the crosses exhibited significant positive heterosis for the trait over Arjun and Super900M.

All the top best hybrids possessed parents which expressed non-significant Gca effects depicting the prevalence of non-additive gene effects in such crosses, which could be further exploited for hybrid breeding program. Yusuf *et al.* (2009) [21] and Ikramullah *et al.* (2011) [10] exhibited positive mid-parent heterosis among single cross hybrids. The values of crude protein in the studied crosses showed positive heterosis over the best parent in the investigation by Abou-Deif *et al.* (2012) [1].

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