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STUDY OF HETEROSIS AND COMBINING ABILITY IN EXOTIC AND INDIGENOUS CROSSES OF BARLEY *(HORDEUM VULGAR L.)* UNDER RAINFED ENVIRONMENT

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ABSTRACT

Ten selected exotic barley lines were crossed with each of four testers in a line × tester design to evaluate combining ability and heterosis, for yield and its component traits to identify promising hybrids of barley under drought condition.The mean squares forgeneral combining ability (GCA) and specific combining ability (SCA) effects were highly significant for all the traits studied. Among the parents, testers namely, BH 902 and RD 2508 and lines Priestige, Athoulpa, Marriya and Kheel were good general combiners for grain yield and its component traits. On the basis of SCA effects, Marriya X BH 902, Athoulpa X RD 2508, Himani X RD 2508, Yardu X Lakhan, Morac-9-75 X RD 2508 and Prestige X Lakhan for grain yield were observed as most promising crosses. While,Marriya X BH 902, V Morles X BH 902, Prestige X Lakhan and Yardu X Lakhanwere recorded highest magnitude of economic heterosis over standard check K- 603 for grain yield, which might be of practical use in barley improvement programme under rainfed environment.

INTRODUCTION

Barley belongs to genus *Hordeum* in the tribe Triticeae of the family,whichis a most paramount cereal crop and considered as the first cereal domesticated for use by man as food and feed (Potla *et al.* 2013). From its wild relative, *H. vulagre spp. spontaneum*, in the area of Middle East known as the Fertile Crescent (Badr *et al.*, 2000). Until the sixteenth century,barley flour was used instead of wheat to make bread (Bukantis and Goodman, 1980).At present, barley is the world's fourth most produced and marketed cereal. The malting industry absorbs most of the production, and the rest is commonly used as animal feed and for human consumption (Amabile *et al.*, 2007).It is an important winter cereal crop grown in the northern plains of India comprising the states of Rajasthan, Uttar Pradesh, Bihar, Haryana, Punjab, Madhya Pradesh, Himachal Pradesh and Uttarakhand that makes about 80% of total acreage of India.

Science barley is grown under marginal to sub marginal land in India and mostly under rainfed condition. Development of high-yielding cultivars requires a thorough knowledge of the existing genetic variation for yield and its components (Raikwar *et al.*, 2014). Thus, there is a need for the development of new barley cultivars that tolerate abiotic and biotic stresses for the improvement of crop productivity (Ellis *et al.*, 2000). The successful use of hybrid cultivars depends upon the existence of an economically significant level of heterosis, sufficient cross-pollination to make hybrid seed production cost competitive and an efficient and reliable system of producing the female parent of the hybrid. The possibilities of commercial exploitation of heterosis in barley have been discussed since the description of the first genetic male sterile by Suneson (1940). The first commercial hybrid barley was grown in the U.S. in Arizona in the winter of 1960-70 (Ramage, 1983). To formulate an efficient breeding program for development of superior genotypes, it is also essential to understand the mode of inheritance, the magnitude of gene effects and its interaction (Farshadfar *et al.*, 2001). Present investigation was studied with an objectives, compare the response to selection for grain yield using different drought parameters under moister stress (rainfed) and moister non-stress (irrigated) condition and find out the best general and specific combiners for drought tolerance.

MATERIALS AND METHODS

Genetic materials, for the present investigation comprised of four testers (RD 2508, K 603, BH 902 and Lakhan) and ten lines (Morac 9-75, Rihane, Pristage , Yardu, Himani, Athoulpa, V Morles, Kheel, BHSH 126 and Marriya). Line x Tester fashion was followed for making 41 F_{1s}, using testers as female and lines as male parents. These 40 F_{1s} were evaluated with parents in Randomized Block Design with 3 replications during 2012-13 and 2013-2014 at the Institute of Agricultural Sciences, Agricultural Research Farm of Banaras Hindu University, Varanasi, India (25Ú18 N lat., 83Ú03 E long. and 75 m amsl.) Single row 5.0 m in length at the distance between rows was

Table 1: Analysis of variance for line x tester analysis for yield and its component traits in barley

Source of s Variation	d. f.	Mean sum of square Days to heading	Days to maturity	Harvest index	Plant height	Grain per spike	Tillers per plant	Spike length	Awan length	1000 grain weight	Chlorophyll content	Proline content	Grain yield per plant
Replicates	2	0.38	0.018	0.04	0.46	0.47	0.02	0.005	0.004	0.002	0.23	0.51	0.14
Treatments	53	21.24	22.07	53.85	120.77	290.16	67.55	5.60	13.40	48.68	64.20	5.98	866.64
Parents	13	35.69	34.48	33.71	202.85	203.39	5.30	4.72	10.46	67.04	32.80	0.05	68.45
Parents vs Crosses	1	247.57	10.41	171.53	418.72	3268.04	960.14	63.18	154.52	78.45	73.71	0.66	23312
Line (male)	9	35.92	5.27	86.50	115.42	158.85	50.79	2.07	7.14	83.00	16.26	0.12	689.32
Tester (Female)	3	14.04	45.90	15.21	186.59	1005.85	95.10	23.34	45.05	44.18	339.6	0.10	926.49
L × T	27	23.18	19.48	52.59	64.67	185.89	66.99	3.09	8.16	27.80	64.36	0.08	472.08
Error	106	0.077	0.32	0.07	0.19	0.26	0.04	0.009	0.03	0.08		0.09	0.094

Table 2: Estimates of general combining ability effects for yield and its component traits in barley

Parents	Days to heading	Days to maturity	No. of tillers per plant	Plant height	Grain per spike	Spike length	Awn length	1000 grain weight	Chlorophyll content	Harvest index	Proline content	Grain yield per plant
MORAC-9-75	1.65***	0.43**	2.58***	0.05	-3.95***	0.18***	-0.69***	-3.86***	-0.22***	-0.28***	0.04	-8.33***
RIHANI	1.19***	0.77***	0.60***	0.54***	0.36*	0.08**	0.04	-2.11***	0.43***	-4.17***	-0.01	-4.76***
PRESTIGE	-1.24***	0.27	3.58***	-0.91***	-5.59***	-0.38***	0.58***	3.87***	1.64***	-4.53***	0.05	7.18***
YARDU	-0.71***	-0.73***	-0.59***	5.06***	6.04***	0.22***	0.32***	0.06*	1.53***	3.85***	0.15*	-1.93***
ATHOULPA	-0.91***	-0.82***	0.79***	2.75***	2.91***	0.53***	0.95***	-1.22***	-1.07***	2.71***	0.12	8.38***
HIMANI	-0.11	0.10	-1.40***	1.02***	-0.89***	-0.11***	1.03***	-1.20***	-0.75***	0.27***	-0.09*	-9.55***
MARRIYA	-1.31***	-0.82***	-0.13*	0.36**	4.07***	0.37***	-0.63***	2.05***	1.38***	2.06***	-0.02	11.10***
V MORULES	0.89***	0.18	-2.99***	-1.66***	-2.37***	-0.43***	0.23***	1.57***	0.47***	-0.05	-0.14*	-1.61***
KHEEL	-0.74***	-0.4*	0.07	-6.95***	-1.69***	-0.78***	-1.32***	-2.57***	-1.31***	0.12*	0.11*	6.16***
BHSH 126	1.17***	1.02***	-2.50***	-0.27*	1.09***	0.31***	-0.51***	3.41***	-1.16***	0.57***	0.08*	-6.45***
RD 2508	0.25***	1.05***	1.01***	2.92***	1.41	-0.05*	0.98***	1.34***	4.29***	-0.30***	-0.04	5.98***
K 603	-0.77***	-1.35***	1.78***	0.89***	-0.85***	0.70***	0.06*	0.68***	0.56***	0.01	0.01	-5.60***
BH 902	1.12***	1.05***	-1.95***	-2.91***	-7.27***	-1.23***	-1.75***	-0.81***	-1.12***	-0.69***	-0.04	3.38***
LAKHAN	-0.61***	-0.75***	-1.04***	-0.91***	6.71***	0.57***	0.70***	-1.21***	-3.74***	0.97	0.08*	-3.75***

Table 3: Estimates of specific combining ability effects for yield and its component traits in barley

Parents	Days to heading	Days to maturity	No. of tillers per plant	Plant height	Grain per spike	Spike length	Awn length	1000 grain weight	Chlorophyll content	Harvest index	Proline content	Grain yield per plant
MORAC-9-75 X RD 2508	-1.98***	-2.63***	-5.94***	-6.55***	1.21***	0.36***	-0.99***	-1.62	-6.79***	-2.34***	0.25	9.73***
MORAC-9-75 X K 603	2.98***	1.77***	8.92***	10.84***	-0.29	0.60***	0.22*	0.11	6.38***	6.46***	-0.12	4.21***
MORAC-9-75 X BH 902	1.13***	3.03***	0.74***	-0.92***	2.37***	-0.51***	0.48***	-2.15***	-1.81***	-5.76***	-0.22	-12.53***
MORAC-9-75 X LAKHAN	-2.13***	-2.17***	-3.87***	-3.37***	-3.28***	-0.46***	0.28**	3.88***	2.21***	1.65***	0.08	-1.42***
RIHANI XRD 2508	-0.57***	2.03***	-3.25***	-4.31***	-4.93***	0.24***	-2.16***	-4.16***	-4.87***	-0.91***	0.28	-.77***
RIHANI XK 603	0.468**	0.10	-.20***	5.08***	-4.79***	-0.86***	-0.58***	2.05***	-0.85***	-6.61***	-0.5	-1.75***
RIHANI XBH 902	2.67***	2.03***	-1.86***	0.01	-.12***	1.16***	2.36***	1.81***	-0.44	7.35***	0.09	-4.04***
RIHANI X LAKHAN	-2.53***	-4.17***	-4.10***	-0.78**	0.59	-0.54***	0.38***	0.30	6.16***	0.17	-0.33*	-3.98***
PRESTIGE XRD 2508	-2.92***	-1.80***	10.61***	-3.86***	-16.75***	-1.91***	-2.93***	1.78***	-1.37***	-0.42**	0.18	-0.74***
PRESTIGE XK 603	-0.06	-1.07***	-5.33***	6.06***	-2.48***	-0.75***	2.60***	-1.25***	-2.44***	-1.21***	0.13	2.78***
PRESTIGE XBH 902	-3.28***	-0.80*	-1.41***	0.83**	20.60***	2.08***	0.82***	3.06***	3.13***	-1.04***	-0.41*	-9.86***
PRESTIGE X LAKHAN	6.27***	3.66***	-3.87***	-3.04***	-1.37***	0.58***	-0.49***	-3.56***	0.68**	2.66***	0.09	7.82***
YARDU XRD 2508	2.29***	2.53***	-2.11***	-0.23	11.04***	0.18**	0.66***	-0.02	2.91***	-0.65***	-0.24	1.64***
YARDU XK 603	-2.54***	-3.06***	-5.56***	-3.28***	2.58***	0.71***	-0.62***	-0.13	-10.53***	-1.19***	-0.13	-7.97***
YARDU XBH 902	1.95***	0.20	4.62***	0.95***	-10.45***	-1.74***	-1.62***	-3.67***	4.81***	-6.31***	0.26	-5.77***
YARDU X LAKHAN	-1.70***	0.33	3.05***	2.57***	-3.14***	0.85***	1.58***	3.97***	-8.34***	8.16***	0.11	12.10***
ATHOULP XRD 2508	-0.39*	0.28	3.38***	4.86***	3.23***	0.12*	-0.21*	-0.50**	0.79***	2.76***	-0.06	20.50***
ATHOULP XK 603	-2.96***	-3.32***	-4.27***	-5.59***	-9.73***	-0.78***	1.44***	-2.13***	-2.65***	1.22***	0.08	-5.28***
ATHOULP XBH 902	3.31***	3.28***	0.76***	-3.09***	2.11***	1.57***	-1.34***	1.95***	-3.27***	-1.45***	-0.04	-7.17***
ATHOULP X LAKHAN	0.05	-0.25	0.14	3.83***	4.40***	-0.91***	0.12	-4.66***	5.12***	-2.53***	0.03	-8.04
HIMANI XRD 2508	-0.29	1.03**	3.36***	1.77***	2.73***	0.21***	0.48***	0.02	-1.54***	1.16***	-0.18	15.96***
HIMANI XK 603	0.79***	-0.23	-3.17***	2.18***	-0.79***	0.17**	-1.78	2.73***	4.44***	4.96***	-0.10	1.32***
HIMANI XBH 902	-0.19	-1.63***	-0.45***	0.74**	-5.40***	-0.67***	0.19	1.95***	-0.56***	-1.33***	0.26	-12.55***
HIMANI X LAKHAN	-0.30	0.83*	0.26*	-0.33	3.47***	0.29***	1.10***	-4.66***	-2.34***	-4.79***	0.03	-4.73***
MARRIYA XRD 2508	0.22	-0.38	-3.84***	-3.06***	1.35***	0.94***	1.14***	-1.56***	2.18***	3.75***	-0.4	-30.22***
MARRIYA XK 603	0.92***	0.35	-0.66***	-4.15***	5.83***	-0.58***	0.62***	-1.16***	0.88***	-4.16***	-0.01	1.30***
MARRIYA XBH 902	-2.93***	-2.38***	-0.49***	5.02***	-5.07***	-0.51***	-0.22*	2.02***	-0.99***	0.81***	-0.05	28.84***
MARRIYA X LAKHAN	1.79***	2.42***	5.01***	2.19***	-2.11	0.15*	-1.54***	0.69***	-2.07***	-0.39*	0.09	0.07
V MORULES XRD 2508	0.81***	0.28	-1.18***	0.82**	7.41***	0.46***	1.10***	3.47	5.74***	-4.19***	0.03	-16.96***
V MORULES X K 603	3.40***	2.02***	-1.87***	-0.41	-2.08***	-0.12*	-0.82***	-1.64***	-0.62***	-1.48***	0.12	2.89***
V MORULES XBH 902	-5.09***	-4.72***	0.98***	1.53***	-7.83***	-1.16***	-1.73***	0.01	-2.33***	4.32***	-0.08	13.90***
V MORULES X LAKHAN	0.88***	2.42***	2.06***	-1.93***	2.50***	0.82***	1.45***	-1.84***	-2.78***	1.36***	-0.06	0.16
KHEEL XRD 2508	1.44***	0.20	-0.34**	3.45***	-6.08***	-0.72***	2.38***	-0.42*	5.74***	-0.14	-0.28	0.21
KHEEL X K 603	-3.51***	0.60	3.99***	-4.87***	11.32***	1.15***	-1.60***	-1.13***	-0.62***	0.61***	0.20	-1.93***
KHEEL XBH 902	1.92***	-0.47	-3.18***	-2.93***	-5.04***	-0.45***	-0.62***	-2.73***	-2.33***	1.38***	0.22	6.22***
KHEEL X LAKHAN	0.12	-0.33	-0.47***	4.35	-0.18	0.01	-0.16	4.28***	-2.78***	-1.84	-0.14	-4.51***
BHSH 126 XRD 2508	1.41***	-1.55***	-0.84***	7.12***	0.81**	0.10	0.54***	3.20***	2.88***	1.01***	0.06	-9.91***
BHSH 126 X K 603	0.50**	2.85***	-1.26***	-1.48***	0.45	0.46***	0.52***	2.81***	1.24***	1.39***	-0.13	4.42***
BHSH 126 XBH 902	0.53**	1.45***	0.29*	-2.14***	-0.39	0.22***	1.66***	-0.48**	-2.69***	2.04***	-0.03	2.96***
BHSH 126 X LAKHAN	-2.44	-2.75	1.80***	-3.49***	-0.87**	-0.79***	-2.72***	-5.53***	-1.43***	-4.44	0.09	2.53***

Table 4:Estimates of standard heterosis for yield and its component traits in barley

Parents	Days to heading	Days to maturity	No. of tillers per plant	Plant height	Grain per spike	Spike length	Awn length	1000 grain weight	Chlorophyll content	Harvest index	Proline content	Grain yield per plant
MORAC-9-75 X RD 2508	10.69**	4.00**	27.74**	-11.43**	6.93**	17.48**	5.70**	-13.99**	-9.79**	0.02	24.24**	102.28**
MORAC-9-75 X K 603	9.35**	0.88*	182.62**	0.05	1.61**	21.13**	7.98**	-12.33**	8.88**	21.50**	-1.58*	39.42**
MORAC-9-75 X BH 902	12.45**	8.56**	45.20**	-11.62**	-3.65**	-5.33**	-3.55**	-20.48**	-10.75**	-12.43**	-7.09**	10.90**
MORAC-9-75 X LAKHAN	3.10**	-3.19**	24.40**	-14.06**	8.03**	7.09**	8.20**	-15.06**	-7.59**	9.84**	22.70**	25.47**
RIHANI XRD 2508	5.59**	3.52**	33.55**	11.32**	4.38**	8.42**	2.45*	-15.51**	-6.34**	-5.75**	18.47**	115.53**
RIHANI XK 603	5.61**	-0.29	208.88**	-4.70**	8.10**	4.68**	26.88**	-2.68**	-5.67**	-4.88**	-0.68	119.53**
RIHANI XBH 902	10.72**	3.52**	3.66**	-12.69**	19.33**	5.62**	36.90**	-9.58**	-8.49**	8.45**	6.08**	121.71**
RIHANI X LAKHAN	2.01**	-4.64**	18.85**	-11.61**	23.1**	5.13**	14.11**	-18.33**	0.31	-2.49**	-14.41**	98.10**
PRESTIGE XRD 2508	2.51**	3.98**	172.59**	-9.82**	-20.60**	-14.11**	0.79	5.90**	6.70**	-9.06**	21.75**	120.83**
PRESTIGE XK 603	2.04**	-1.76**	33.07**	-5.12**	2.64**	0.98	59.62**	-1.20*	-6.51**	-10.10**	16.44**	173.12**
PRESTIGE XBH 902	3.16**	4.89**	34.83**	-2.15**	55.57**	55.92**	35.68**	4.23**	22.24**	-11.34**	-7.42**	153.86**
PRESTIGE X LAKHAN	10.16**	1.74**	20.70**	-14.62**	12.19**	11.94**	11.74**	-14.53**	7.48**	0.81	34.44**	209.24**
YARDU XRD 2508	6.75**	1.45**	32.87**	-3.21**	34.73**	7.71**	20.10**	-10.59**	16.14**	11.12**	-24.94**	96.04**
YARDU XK 603	-0.56	-5.51**	20.78**	-8.17**	23.87**	20.83**	4.48**	-11.80**	-24.14**	10.61**	-15.09**	81.11**
YARDU XBH 902	7.42**	-0.58**	51.33**	-7.42**	-4.40**	-24.44**	-15.48**	-20.86**	24.84**	-4.31**	-.38**	127.47**
YARDU X LAKHAN	0.66*	-2.03**	124.22**	-4.15**	26.54**	20.93**	24.70**	-7.84**	12.74**	34.30**	7.78**	204.27**
ATHOULP XRD 2508	-0.03	-2.00**	88.06**	1.65**	19.40**	18.59**	19.24**	-6.68**	1.15	10.88**	4.05**	203.27**
ATHOULP XK 603	-4.40**	-7.14**	21.50**	-12.32**	4.51**	10.30**	24.59**	-9.20**	1.88	8.22**	17.57**	80.19**
ATHOULP XBH 902	5.54**	0.57	29.14**	-2.43**	24.44**	44.99**	-8.39**	-11.00**	-1.77	0.80	5.18**	108.53**
ATHOULP X LAKHAN	-0.53	-4.00**	36.48**	-5.10**	32.94**	5.99**	18.75**	-12.87**	-35.14**	2.08**	18.47**	76.56**
HIMANI XRD 2508	-1.14**	-0.85*	80.09**	-2.82**	13.35**	12.40**	29.63**	-5.70**	6.18**	0.72	-26.11**	120.69**
HIMANI XK 603	-1.06**	-3.99**	39.43**	-10.83	12.18**	13.52**	25.10**	0.48	-12.27**	9.75**	-18.22**	109.06**
HIMANI XBH 902	0.02	-3.13**	-1.72**	-0.28	5.43**	7.13**	31.32**	-7.58**	-1.04	-5.59**	0.61	51.88**
HIMANI X LAKHAN	-2.16	-2.56**	70.72**	-10.43**	26.06**	11.81**	26.34**	-25.61**	12.84**	-9.50**	-5.87**	66.85**
MARRIYA XRD 2508	-4.48**	-4.21**	20.01**	-7.90	18.40**	25.95**	22.09**	-2.39**	5.74**	12.29**	0.71	26.85**
MARRIYA XK 603	-4.86**	-5.62**	71.22**	-13.18**	29.55**	10.62**	31.54**	-2.76**	8.16**	-4.44**	1.80*	117.94**
MARRIYA XBH 902	-7.13**	-5.90**	9.32**	1.80**	13.66**	6.92**	14.77**	-1.24**	9.86**	4.96**	8.46**	264.11**
MARRIYA X LAKHAN	-3.65**	-3.37**	101.38**	-8.74**	25.16**	15.28**	-4.27**	-10.15**	-1.60	5.98**	28.57**	120.39**
V MORULES XRD 2508	2.29**	2.67**	18.02**	-6.19**	4.85**	-0.92	7.30**	6.44**	9.96**	-3.78**	-6.98**	28.86**
V MORULES X K 603	4.17**	0.88*	34.97**	-11.64**	-9.86**	0.72	-10.35**	-2.39**	-3.82**	5.65**	2.48**	139.18**
V MORULES XBH 902	-3.77**	-1.78**	-3.21**	-2.21**	-25.16**	-28.57**	-27.31**	-6.00**	-4.00**	10.90**	-14.41**	232.44**
V MORULES X LAKHAN	1.34**	0.58	47.99**	-14.30**	5.31**	8.77**	7.76**	-15.58**	-12.91**	9.71**	-5.41**	134.31**
KHEEL XRD 2508	-0.86**	0.00	57.51**	-8.64**	-11.08**	-5.29**	26.18**	-9.14**	16.14**	5.34**	-6.38**	120.56**
KHEEL X K 603	-7.90**	-1.74**	124.20**	-20.42**	7.83**	16.77**	5.39**	-9.88**	0.11	7.83**	25.68**	182.29**
KHEEL XBH 902	0.77**	-0.58	-13.25**	-12.12**	20.64**	3.16**	-1.83	-19.12**	-5.00**	4.65**	50.27**	232.91**
KHEEL X LAKHAN	-3.43**	-2.32**	44.71**	-13.40**	2.91**	2.00*	0.59	-11.99**	-12.73**	2.74**	20.92**	156.64**
BHSH 126 XRD 2508	6.09**	0.29	26.46**	-1.69**	6.38**	1.29	3.17**	8.46**	9.99**	-4.45**	15.60**	36.27**
BHSH 126 X K 603	3.70**	2.05**	36.94**	-11.35**	2.91**	12.07**	-2.93**	6.44**	-4.57**	-3.00**	0.68	52.95**
BHSH 126 XBH 902	6.06**	2.92**	-4.99**	-15.31**	-6.65**	-9.03**	-7.21**	-3.42**	-10.08**	-3.15**	16.37**	81.81**
BHSH 126 X LAKHAN	0.27	-3.19**	39.58**	-14.74**	11.12**	-1.39**	-19.76**	-18.89**	-13.33**	-12.99**	34.51**	52.77**

0.25 cm was followed for sowing of F_{1s} and parents. All the recommended cultural practices were applied to raise a good crop. Ten random plants were selected and tagged for recording the data on twelve yield and its contributing traits viz.,days to heading, days to maturity, no. of tillers per plant, plant height, grains per spike, spike length, awn length, 1000 grain weight, chlorophyll content, harvest index, proline content and grain yield per plant. The mean data of each plot was used for statistical analysis. Analysis of variance for Line x Tester was completed following Kempthorne (1957).The analysis of variance for combing ability was based on the following mathematical model.

$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$

Where,

μ = Population mean

g_i = gca effect of ith male parent

g_j = gca effect of jth female parent

s_{ij} = sca effect of ijth combinations

e_{ijk} = error associated with the observation X_{ijk}

i = number of male parents

j = numbrer of female parents

k = number of replications

The magnitude to heterosis as the difference in F_1s performance over better parent in percentage was calculated and presented as per Singh *et al.* (1996).

RESULTS AND DISCUSSION

Mean squares due to selected genotypeswere highly significant for all traits (Table 1), provided evidence for presence of largeamount of genetic variability, which is considered adequate for furtherbiometrical assessment.Variations due to crosses were partitioned in to male (lines), female (testers) and male x female (lines × females). General and specific combining ability variances and their effects were estimated with a view to decipher the geneticarchitecture of the characters under study. Combining ability describes the breeding value of parental lines to produce hybrids (Romanus *et al.* 2008). The parents Yardu, Athoulpa and Himani were superior general combiner for grains per spike. Prestige, Marriya and BHSH 126 showed high GCA rffrcts for 1000 grain weight, while Yardu and Athoulpa for plant height. Pristage , Yardu and RD 2508 showed more GCA for number of tillers per plant, harvest index and chlorophyll content respectively. For grain yield per plant parent's viz. Marriya, Athoulpa, Kheel, RD 2508, Pristige and BH 902 were found superior during the study (Table 2).

The crosses MORAC-9-75 X K 603, PRESTIGE X K 603 and MARRIYA X BH 902 showed significant and positive estimates of SCA effects for plant height. While the crosses, MARRIYA X BH 902, ATHOULPA X RD 2508, HIMANE X RD 2508, YARDU X LAKHAN, V MORLES X BH 902, KHEEL X BH 902, MORAC-9-75 X RD 2508 and PRESTIGE X LAKHAN showed significant positive SCA effects for grain yield (Table 3). YARDU X LAKHAN, RIHANE X BH 902, MORAC-9-75 X K 603 and HIMANI X K 603 revealed significant and positive SCA effects for Harvest index. Crosses MORAC-9-75 X K 603, RIHANE X LAKHAN, V MORLES X RD 2508 and ATHOULPA X LAKHAN showed positive and significant GCA effect for chlorophyll content.The crosses PRESTIGE X BH 902, KHEEL X K 603, YARDU X RD 2508, V MORLES X RD 2508 and MARRIYA X K 603 showed high significant SCA effect for number of grains per spike.PRESTIGE X LAKHAN, MORAC-9-75 X K 603, PRESTIGE X RD 2508, MARRIYA X LAKHAN, MORAC-9-75 X LAKHAN, KHEEL X LAKHAN, YARDU X LAKHAN and V MORLES X RD 2508 had snowed highly significant SCA effect for most of the yield contributing traits.

The extent of heterosis for different characters over standard check was apparent(Table 4).A number of crosses was observed good heterotic for number of tillers and grain yield per plant, where as MORAC-9-75 X RD 2508 for days to heading, KHEEL X K 603 for plant height, PRESTIGE X BH 902 for grain per spike and spike length, RESTIGE X K 603 for awn length, MORAC-9-75 X BH 902 for 1000 grain weight, ATHOULPA X LAKHAN for chlorophyll content, ATHOULPA X RD 2508 for harvest index, KHEEL X BH 902 for proline content were observed as good heterotic crosses. These results are in consonance with that of Potla *et al.* (2013), Dharam Pal and Sanjay Kumar (2009), Zengand Chen (2001) and Yap and Harvey (1971).

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