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GCA AND SCA EFFECTS ANALYSIS FOR GRAIN YIELD AND ITS QUANTITATIVE TRAITS IN SIX-ROWED BARLEY (*Hordeum vulgare* L.) IN AGRA REGION

RAJIV KUMAR SINGH RATHORE[1a] AND YASHASVITA CHAUHAN[b]

[a]Department of Botany,Ch. Suraj Singh (P.G.) College Jagir,Mainpuri ,U.P. India.

[b] Department of Biotechnology, Agra College, Agra, U.P.,India.

ABSTRACT

The present study was aimed for estimating genetic components of variance and GCA and SCA effects of 10 parents and 45 F_1 hybrids of six-rowed barley in Agra region. The experimental data recorded for two consecutive years showed that the Ritambhara, Gitanjali, Jagrati and Lakhan were good general combiners for grain yield per plant. In all 14 crosses out of 45 F_1 crosses Narmada X Haritima, Narmada X Jagrati, Gitanjali X Azad, Ritambhara X Lakhan, Jyoti X Ritambhara, Azad X Gitanjali, Gitanjali X Lakhan, Prajapati X Azad, Ritambhara X Prajapati, Azad X Jagrati and Haritima X Manjula have expressed positive and highly significant desirable SCA effect for seed yield per plant. And therefore, above study could be useful in developing desirable genotypes/hybrids/varieties with better yield or other associated traits under crop improvement.

KEYWORDS: Barley (*Hordeum vulgare* L.), GCA, hybrid, SCA

Barley (*Hordeum vulgare* L.) is widely known as world fourth most important cereal crop after wheat, maize and rice (Bengtsson; 1992 and Anonymous; 2010). The member of family Poaceae, Barely comprise of 32 species, all with basic chromosome no x=7. Barley was domesticated about 10,000 years ago from its wild relative *vulgare* ssp. spontaneum, in the area of the Middle East known as Fertile Crescent. The present day cultivated six-rows barley appeared about 8000 years ago (Komatsuda et al.; 2007). Cultivated barley, *Hordeum vulgare* L. ssp. vulgare and its wild progenitor *H. vulgare* L. ssp. spontaneum are tetraploid sp. with (2n=4x=28) or hexaploid (2n=6x=42) (Komatsuda et al.; 1999).Barley is cultivated as a rabi crop in India. The major producers of barley in the country are Uttar Pradesh (43.37%), Rajasthan (27.21%), Haryana (7.45%), Madhya Pradesh (6.13%) and Punjab (7.20%).In addition to direct human consumption barley is utilized by the beer industry, food processing industry and feed manufacturing industry in India. Annual demand for beer and feed industry is estimated to be around 60,000 tons and 25000 tons respectively.

In view for its rising demands and unsatisfying availability of desirable genotypes with better yield, it is therefore, the ultimate goal of plant breeders to develop desirable genotypes (Sabaghpuret al.; 2003). 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 inheritance(Farshadfar et al.; 2001). Identification of genetically superior parents is an important pre-requisite for developing promising strains. For this, combining ability analysis provides useful information to select the suitable parents for a hybridizing programme (Kakani et al.; 2007).Therefore, the present investigation was undertaken to study the effects of general and specific combining ability for yield and yield contributing traits.

MATERIALS AND METHODS

The experimental material comprised of pure breeding types obtained from division of genetics and plant breeding, IARI, New Delhi and CSA University, Kanpur. Ten varieties viz. Jyoti, K603 (Narmada), Azad, K226 (Lakhan),K560(Haritima), Manjula, K551(Ritambhara),K1149(Gitanjali), K508 (Prajapati) and Jagrati were selected on the basis of characteristics diversity among the plants. In the present investigation, these ten genetically diverse genotypes of *Hordeum vulgare* were crossed

[1]Corresponding Author

following diallel mating design, n(n-1)/2 excluding reciprocals during rabi season. In all 45 crosses were made from the parents. All these 45 F_1 hybrids along with their 10 parents were evaluated for their performance in RBD (Randomized Block Design) with three replication at KVK research farm Mathura, U.P., India. The row length was 3.0 m and spacing between and within rows was (20x10 cm) as agronomically recommended. All the recommended cultural practices were applied to raise good crops. Each treatment comprises of two rows of F_1 and four rows of parents and five competitive plants in each treatment in F_1 and parents were randomly selected for recording observations on yield and its contributing traits viz. days to flower, days to maturity, plant height, no. of effective tillers per plant, spike length excluding awns, number of grains per spikes, grain yield per plant, 1000 gramweight and harvest index (%). The mean data of each plot was used for statistical analysis of variance was carried out by RBD as suggested by Panse and Sukhatme (1967). The generalized model to estimate the general and specific combining ability effects of ijklth observations is given below (according to Griffing, 1956a).

$$Xijk=\mu+gi+gj+sij+\frac{1}{bc}\sum k\sum ieijkl$$

Where,

μ= Population means

gi= gca effect of ith male parent

gj= gca effect of jth female parent

sij= sca effect of ijth combinations

eijk= error associated with the observation Xijk

i= number of male parents

j= number of female parents

k= no of replications

RESULTS AND DISCUSSION

Perusals of table 1 revealed significant differences among the parents, crosses, parentvs cross for all the characters studied. All values were found significant except for days to maturity and 1000 seed weight for parents in the first year and for days to flower and seed yield per plant in the second year. Highly significant mean sum of squares were noted for days to maturity, plant height and 1000 seed weight in parent vs. hybrids.

Variances for diallel progenies were significant for all the characters studied indicating the presence of adequate amount of variability and there is an opportunity for selection of desirable plants for trait of interest.Analysis of variance for pooled estimates (for two consecutive seasons) of combining ability analysis indicated the variance due to GCA and SCA were highly significant for all the characters studied (Table 2 and 3). In table 4 pooled analysis of variance, the GCA: SCAratio indicated that days to flower, plant height, spike length, 1000 seed weight, seed yield per plant and biological yield per plant exhibited the dominance of additive gene effects. Similar results for these traits were also reported by Kakani et al.; 2008, Amer; 2011, Saad et al.;2013 and Singh et al.; 2013. Whereas days to maturity, tillers per plant, seed per spike and harvest index were under the influence of non-additive gene effects. Since the ratio of additive genetic variance to total genetics variance was less than unity therefore the role of non-additive gene effects has played predominant role in the inheritance of the later characters. These results were in consonance with that of Amer et al.; 2011. This demonstrated the contribution of both additive and non-additive gene effects in creating genetic variability present on the experimental material involved in this investigation. These results were in good agreement with those obtained by Bhatnagar and Sharma; 1995, Kakani et al.; 2007 and Potla et al.; 2013.

The parents Jyoti, Ritambhara, Jagrati were the best general combiner for plant height whereas Azad, Haritima, Manjula and Jagrati have shown desirable GCA effect and proved to be good general combiners for day to maturity. Jyoti, Haritima, Ritambhara, Lakhan were observed to be good general combiners for effective tillers per plant and for spike length (excluding own), Narmada and Ritambhara have shown good combining ability. Jyoti, Azad, Lakhan, Prajapati were good general combiners for no. of seeds per spike and for 1000 seed weight (grams), Jyoti, Narmada, Azad and Haritima were the good general combiners. Ritambhara, Gitanjali, Jagrati, Lakhan were observed to be good general combiners for grain yield per plant. Narmada, Azad, Haritima, Gitanjali were good general combiners for biological yield per plant and

Narmada, Ritambhara, Gitanjali and Lakhan have shown good combining ability for the harvest index percentage. The present investigation also revealed that some of the parents having significant positive GCA effects for grain yield per plant also showed positive GCA effect for one or more of yield contributing traits. The parents Ritambhara, Gitanjali, Lakhan and Jagrati exhibited positive and significant GCA effect for grain yield per plant and many of its contributing characters. The finding lends support from the studies of Yap and Harvey; 1972 , Sharma et al.; 2003, Joshi and Singh; 2004 and Kakaniet al.; 2007.

In all 14 crosses out of 45 F1 crosses Narmada X Haritima, Narmada X Jagrati, Gitanjali X Azad, Ritambhara X Lakhan, Jyoti X Ritambhara, Azad X Gitanjali, Gitanjali X Lakhan, Prajapati X Azad, Ritambhara X Prajapati, Azad X Jagrati and Haritima X Manjula have expressed positive and highly significant desirable SCA effect for seed yield per plant. Nine crosses out of 45 F1 crosses i.e. Haritima X Ritambhara, Ritambhara X Lakhan, Azad X Gitanjali and Haritima X Gitanjali revealed significant positive SCA effect for 1000 grain weight.

There for, based on good performance of selective parents and crosses in the present study can be concluded that desirable parent could be used as donors to get high yield and the selective crosses were identified as better for grain yield and it's contributing traits as they possess high SCA effect, may further be utilized in future breeding program.

S.N.	SOURCE OF VARATION	YEARS	CHARACTERS										
			DEGREE OF FREEDOM	DAYS TO FLOWER	DAYS TO MATURITY	PLANT HEIGHT	TILLERS/ PLANT	SPIKE LENGTH	SEEDS / SPIKE	1000 SEED WEIGHT	SEED YIELD/ PLANT	BIOLOGICAL YIELD / PLANT	HARVEST INDEX
1	REPLICATION	1	2	186.01	10.87	177.36**	9.01**	1.19**	117.89**	719.2	6.63	36.45*	59.4
		2	2	4171.88**	69.53	27.42	0.52	0.19	6.64	11.94	26.09	150.330**	1.87
2	DIALLLE PROGENTIES (GENOTYPE)	1	54	1867.30**	20.95**	72.25**	3.95**	0.94**	89.09**	765.22**	33.37**	108.84**	154.45**
		2	54	4052.53**	97.72*	71.53**	3.48**	0.84**	123.98**	24.18**	53.78**	100.19**	25.16**
3	PARENTS	1	9	379.31**	11.05	81.73**	2.47**	1.03**	39.49**	28.42	30.49**	109.91**	161.20**
		2	9	77.38	295.93**	97.50**	1.67**	0.75**	26.06**	16.10**	10.75**	98.41**	26.36***
4	HYBRIDS	1	44	2209.42**	22.66**	66.18**	4.33**	0.94**	99.87**	926.72**	34.72**	110.56**	34.95
		2	44	4938.82**	46.09	64.43**	3.93**	0.87**	146.83**	25.32**	62.94**	101.09**	25.42**
5	PARENTS VS HYBRIDS	1	1	205.9	34.88*	254.26**	0.64	0.46	60.41**	290.39**	0.17	23.3	351.17**
		2	1	832.37**	585.96**	150.20**	0.01	0.24	0.11	46.77**	38.22*	76.55	2.9
6	ERROR	1	108	53.12	7.07	6.98	0.56	0.26	4.59	41.73	3.45	10.51	74.49
		2	108	43.55	65.61	9.69	0.27	0.18	4.07	4.08	25613.34	22.12	9.41
* , ** = Significant at 5% level of significance													

Table 1: Analysis of variance for dialled progenies for yield and its contributing characters in Barley (*Hordeum vulgare*) in two consecutive years

S.N.	PARENTS	C H A R A C T E R S									
		DAYS TO FLOWER	DAYS TO MATURITY	PLANT HEIGHT	TILLERS/ PLANT	SPIKE LENGTH	SEEDS / SPIKE	1000 SEED WEIGHT	SEED YIELD/ PLANT	BIOLOGICAL YIELD / PLANT	HARVEST INDEX
P1	JYOTI	0.70**	-0.87**	-3.64**	0.82**	0.15	1.73**	0.89**	-1.86**	0.05	-0.62**
P2	K603 (NARMADA)	0.39	-0.3	2.65**	-0.06	0.35*	0.67*	0.85**	-0.58*	1.06**	0.50**
P3	AZAD	-0.65*	-1.23**	3.22**	-0.46**	-0.33*	1.84**	1.40**	-2.18**	1.66*	-0.41**
P4	K560 (HARITIMA)	-0.69*	-0.85**	1.82*	0.14*	-1.10	-2.51**	1.70**	3.19**	-1.26**	0.14*
P5	MANJULA	-2.17**	-0.29	-0.48	0.04	0.00	-0.72*	-0.04	-0.41	-0.16	0.07
P6	K551 (RITAMBHARA)	-1.61**	-0.14	-1.82*	0.18*	0.25*	-0.38*	-1.07**	1.52**	-0.32**	0.62**
P7	K1149 (GEETANJALI)	4.10**	0.64*	-0.13	-0.36**	-0.28*	-0.68*	-0.93**	1.55**	0.42	0.86**
P8	K226 (LAKHAN)	1.27**	0.87**	1.33*	0.34**	0.12	1.57**	-0.46*	2.51**	-0.18	0.90**
P9	K508 (PRAJAPTI)	-0.30	0.93**	-1.46*	0.03	0.04	1.22**	-1.52**	-1.96**	-0.83**	-1.20**
P10	JAGRATI	-1.05*	1.26**	-1.48*	0.01	-0.19	0.92**	-0.81**	-1.79**	-0.43**	-0.86**
	S.E. (gi)	0.11	0.14	0.24	-0.01	0.00	0.10	0.10	0.09	0.04	0.02
	S.E. (gi-gi)	0.25	0.31	0.54	-0.01	-0.01	0.23	0.23	0.2	0.08	0.05
* , ** = Significant at 5% and 1% level of significance											

Table 2:Pooled estimate of general ability effects of parents for yield and its contribution characters

in barley (*Hordeum vulgare*)

#	HYBRIDS	CHARACTERS									
		DAYS TO FLOWER	DAYS TO MATURITY	PLANT HEIGHT	TILLERS / PLANT	SPIKE LENGTH	SEEDS / SPIKE	1000 SEED WEIGHT	SEED YIELD / PLANT	BIOLOGICAL YIELD / PLANT	HARVEST INDEX
1	JYOTI X NARMADA	-0.88	-2.26	-4.69**	-0.07	0.03	-0.54	-4.79**	-6.08**	1.85**	-2.32**
2	JYOTI X AZAD	1.2	-3.84**	-5.18**	-0.44	-0.43*	-1.13	-0.71	-2.78**	1.38**	-0.55
3	JYOTI X HARTIMA	-2.53*	-3.95**	-6.29**	2.49**	0.28	1.67	0.39	-.781**	0.96*	-2.29**
4	JYOTI X MANJULA	1.45	2.27	-0.15	1.60**	0.45*	-4.35**	0.69	-0.71	1.54**	-0.02
5	JYOTI X RITAMBHARA	-0.77	-2.76	-2.21	-0.08	0.56*	-2.26**	0.82	6.69**	1.23*	3.15**
6	JYOTI X GEETANJALI	-0.69	-0.77	2.4	1	0.52*	2.34*	2.49*	-0.88	2.25**	0.45
7	JYOTI X LAKHAN	-0.95	0.2	0.11	0.71	0.73**	6.06**	0.21	3.67**	1.16*	2.15**
8	JYOTI X PRAJAPATI	2.88**	0.18	7.33**	0.3	-0.53*	4.01**	-0.2	-2.73*	-0.13	-1.26*
9	JYOTI X JAGRATI	2.13**	0.78	0.39	-0.01	-0.3	-0.39	2.23	-4.46**	-0.33	-2.09**
10	NARMADA X AZAD	1.64	-0.62	-1.55	0.11	0.34	1.42	-0.53	-3.86**	1.98**	-1.03
11	NARMADA X HARITIMA	0.48	-1.82	-5.38**	1.71**	-0.48*	5.20**	0.59	8.87**	-1.77**	3.23**
12	NARMADA X MANJULA	0.73	-2.61	0.12	-0.19	0.45*	2.18	1.03	-4.69**	-0.99*	-3.00**
13	NARMADA X RITAMBHARA	-3.23**	0.57	-1.34	-0.63	-0.04	1.17	2.46*	-0.52	0.66	-0.26
14	NARMADA X GEETANJALI	-3.65**	-1.57	1.57	0.28	0.36	2.74*	-0.68	-11.04**	1.52*	-4.49**
15	NARMADA X LAKHAN	-1.51	-1.87	-2.82	-0.61	-0.80**	-0.32	2.42*	-4.14**	-0.6	-2.06**
16	NARMADA X PRAJPATI	-1.38	-1.89	2.77	-0.38	0.60**	4.73**	-0.39	0.23	0.87*	0.23
17	NARMADA X JAGRITI	2.67**	-1.56	4.29*	-0.86*	-0.93**	3.20*	-0.53	7.92**	-2.96**	1.43*
18	AZAD X HARITIMA	-0.81	-2.06	1.49	0.48	-0.17	0.75	-1.59	0.28	0.43	1.23*
19	AZAD X MANJULA	1.11	-1.35	2.02	1.18*	0.2	4.72**	1.02	1.82	2.34**	1.80*
20	AZAD X RITAMBHARA	-2.38*	-0.64	-1.21	0.07	0.21	2.58*	2.78*	-0.18	2.89**	1.38*
21	AZAD X GEETANJALI	-3.40**	-2.08	0.41	0.31	0.07	2.82*	3.51**	6.35**	-3.21**	1.58*

22	AZAD X LAKHAN	-0.83	-2.97*	-0.92	0.56	0.01	11.23**	1.24	1.36	1.36*	1.57*
23	AZAD X PRAJPATI	2	-1.3	0.54	-1.28*	-0.32	3.85*	2.16	2.93	1.94**	2.36**
24	AZAD X JAGRATI	1.38	-0.97	2.96*	0.31	0.18	7.08**	-2.31	4.46**	0.67	2.43**
25	HARITIMA X MANJULA	1.02	-2.26	1.55	0.75*	-0.70**	1.89	-2.62*	4.28**	3.42**	3.96**
26	HARITIMA X RITAMBHARA	-2.41**	-1.81	-2.37	0.57	-0.65*	4.75**	3.81**	-4.85**	4.48**	0.53
27	HARITIMA X GEETANJALI	4.43**	-0.02	0.54	-0.92*	0.25	-1.88	3.31**	-5.69**	3.74**	-0.03
28	HARITIMA X LAKHAN	3.54**	-3.19**	-2.12	-0.44	0.52*	0.37	0.41	1.42	-0.19	1.13*
29	HARITIMA X PRAJPATI	2.54**	0.09	-0.4	-1.25**	-0.34	5.58**	-0.01	0.46	-1.21	-3.01**
30	HARITIMA X JAGRATI	0.35	-0.48	-2.64	-0.26	0.23	5.72**	-1.31	0.62	1.12	1.49*
31	MANJULA X RITAMBHARA	-0.66	-2.74*	-3.81*	-0.19	-0.25	1.8	-1.38	3.15*	-2.08**	-0.16
32	MANJULA X GEETANJALI	2.78**	-2.68*	2.97*	0.88*	0.08	8.93**	0.48	2.42*	-0.85	0.44
33	MANJULA X LAKHAN	-0.41	-0.74	0.04	0.23	0.32	5.01**	0.94	2.19	1.52*	1.60**
34	MANJULA X PRAJPATI	5.89**	-2.14	-3.50*	-1.28**	-0.14	4.66**	-1	-2.13	-0.99	-0.74
35	MANJULA X JAGRATI	1.44	1.5	1.19	0.35	0.46*	5.16**	-0.07	2.09	1.56*	1.29*
36	RITAMBHARA X GEETANJALI	5.39**	-2.67*	-0.26	-0.19	0.42*	-2.58	2.58*	-0.28	-0.47	-0.25
37	RITAMBHARA X LAKHAN	2.40*	0	-3.42*	1.02*	-0.03	0.84	3.77**	6.99**	1.61**	3.91**
38	RITAMBHARA X	4.80**	-0.26	-2.59	2.28*	-0.1	3.29*	-0.1	4.73**	3.08**	3.47**
39	RITAMBHARA X	-0.96	-2.52*	-3.07	0.34	-0.56*	0.96	-0.18	0.69	1.12*	0.67
40	GEETANJALI X	4.51**	0.09	-7.31**	-0.17	-0.44*	0.87	-1.36	5.09**	-2.93**	0.81
41	GEETANJALI X	-2.56**	-2.1	-2.28	1.22**	-0.3	-3.11*	-2.94*	0.9	-0.05	0.47
42	GEETANJALI X	0.21	-2.46*	4.84*	0.79	0.53*	3.36*	-4.68*	7.44**	2.53**	-2.27**
43	LAKHAN X	4.18**	-2.33	1.26	-0.5	0.30*	2.93*	-2.31	-2.46**	0.75	-0.57
44	LAKHAN X	-1.94	-3.66*	-1.29	0.49	-0.06	2.57	-3.65**	-4.00**	3.05**	-0.27
45	PRAJPATI X	-2.27	-3.06*	-8.92**	1.15**	-0.05	-5.25**	-0.69	4.84**	-1.27*	1.49*
S E (Sij)		1.25	1.57	2.74	0.07	0.05	1.15	1.15	0.99	0.39	0.26
S E (Sij-Sik)		2.71	3.39	5.92	0.16	0.11	2.48	2.49	2.14	0.86	0.56
S E (Sij-Skl)		2.47	3.08	5.38	0.14	0.09	2.26	2.27	1.95	0.78	0.51
Number of significant superior hybrids		7	11	9	9	10	23	9	14	21	18
* , ** = Significant at 5% and 1% level of significance											

Table 3:Pooled estimate of specific combining ability effects of hybrids for yield and its contributing characters in F_1 of barley (*Hordeum vulgare*)

S. N.	SOURCE OF VARATION	YEARS	CHARACTERS										
			DEGREE OF FREEDOM	DAYS TO FLOWER	DAYS TO MATURITY	PLANT HEIGHT	TILLERS/ PLANT	SPIKE LENGTH	SEEDS / SPIKE	1000 SEED WEIGHT	SEED YIELD/ PLANT	BIOLOGICAL YIELD / PLANT	HARVEST INDEX
1	GCA	1	9	1417.89**	25.30**	41.38**	2.73**	0.473**	62.99**	168.25	31.29***	72.23**	808.47*
		2		1210.40	100.89**	51.08**	2.37**	0.35**	127.60**	18.17**	6939.21	53.501**	18.87**
		P		39.93**	9.01**	58.23**	1.59**	0.61**	25.25**	15.42**	49.26*	8.94**	6.55**
2	SCA	1	45	463.34**	3.32	20.63**	1.034**	0.28**	23.04**	272.44	7.09***	29.09**	300.09
		2		1378.93	18.91	18.40**	0.92**	0.27**	24.07**	6.04**	8873.67	29.38**	6.29**
		P		7.37**	15.40**	16.96**	1.07**	0.21*	44.50**	6.58**	26.15**	6.93**	6.67**
3	ERROR	1	108	17.72	2.36	2.33	0.19	0.09	1.53	80.58	1.15	3.51	358.16
		2		1347.85	21.87	3.23	0.09	0.06	1.36	1.36	8537.78	7.37	3.14
		p	216	3.48	4.05	6.73	0.3	0.2	3.24	2.66	3.08	1.79	1.21
4	GCA : SCA	1		3.06 : 1	7.60 : 1	2.00 : 1	2.65 : 1	1.67 : 1	2.73 : 1	2.32 : 1	4.41 : 1	8.07 : 1	2.69 : 1
		2		0.87 : 1	5.33 : 1	2.77 : 1	2.57 : 1	1.29 : 1	5.30 : 1	2.76 : 1	0.78 : 1	0.82 : 1	2.82 : 1
		p		5.14 : 1	0.59 : 1	3.43 : 1	0.93 : 1	2.09 : 1	0.57 : 1	2.34 : 1	1.88 : 1	1.29 : 1	0.98 : 1
F_1 = 2009 – 2010, F_2 = 2010 – 2011, P = POOLED													
* , ** = Significant at 5% level of significance													

Table 4: Analysis of variance for diallel progenies for yield and its contributing characters in arley (*Hordeum vulgare*) in two consecutive years and their pooled values

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