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Study of economic heterosis and inbreeding depression in bread wheat (*Triticum aestivum* L.) under late sown condition

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Abstract: The present investigation was conducted to magnitude of economic heterosis and inbreeding depression in F_2s of bread wheat for identifying desirable cross combinations. The experimental materials comprised 100 genotypes which were consisted of 10 diallel parent and their F_1s and F_2s. The experimental material was conducted in randomized complete block deign with three replication at Economic Botanical Research Farm, Nawabganj of C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India 208 002. The analysis of variance revealed that the all components of variance had significant differences for almost the traits under studied over both generations. The result of economic heterosis revealed that the cross combinations, DBW 14 x K 0424, K 9162 x K 9423, K 9533 x K 0307, K 1114 x K 0424 and K 1114 x NW 2036 were good for grain yield per plant along with range of -88.54 (K 0424 x K 0911) to 28.52 per cent (DBW 14 x K 0424) and other traits compared to out of 45 F_1s whereas, all these cross combinations also had significant grain yield demission in F_2s results of increase of homozygosity among the crosses in advanced generations. The range of inbreeding depression varied from-50.36 (K 1114 x K 9423) to 49.12 % (K 0911 x K 0307) in F_2s. Therefore, it could be concluded that these cross combination exploited in future breeding programme for development of good heterotic gene pool as well as evolution of wheat by improving of grain yield as well as others heat tolerance traits.

Key words: Canopy temperature depression, Economic heterosis, Inbreeding depression, Grain yield

Introduction

Wheat is regarded as one of the most imperative crop, extensively cultivated throughout the global levels, with main purpose of human consumption, supporting approximately 35% of the world's population and which grown today is hexaploid (2n=6x=42), which is used in bread making and other bakery product (Debasis and Khurana, 2001). Importance of wheat as staple food crop is even more under changing climate scenario which at least partially due to rising temperature. Stresses due to high temperature as emerged major constraints for successful wheat production programme (Kumar *et. al.,* 2012). Breeders need to development of high yielding cultivar, these will be showed buffering fluctuation in heat stress condition either target environment for achieving food security for hundreds of millions of the rural poor who depends upon only template zone. Therefore, in progress of plant breeding, considerable efforts done by various plant scientists of countries for improving the grain yield of wheat emphasized that is only possible by crossing breeding programme among diverse parental materials.

The success of any breeding programme depends primarily upon the proper selection of parents, mating system employed and finally the breeder's keen judgment in selecting superior genotypes from more abundant and less desirable plants within the segregating populations. The study of heterosis and inbreeding depression in most of the crops including wheat is an important tool in interpreting genetic parameters. The nature and magnitude of heterosis and inbreeding depression could play a vital role for the plant breeder in formulating the appropriate breeding procedures. The present investigation was carried out to delineate the magnitude of heterosis and inbreeding depression in bread wheat and identified superior crosses would be gainfully utilized in further wheat improvement programmes.

Materials and Methods

The present investigation was carried out at Economic Botanical Research Farm, Nawabganj of C.S. Azad University of Agriculture and Technology, Kanpur, during *rabi* 2014-15. Ten diverse wheat genotypes namely K 9533, K 9162, K 1114, DBW 14, K 0607, K 0424, K 0911, K 0307, NW 2036 and K 9423 were selected as parents on the basis of their origin, adaptability, yield potential and heat tolerance characters. Crosses were attempted during *rabi*, 2013-14 to generate F_1s and during *kharif* 2014, F_1s were advanced in F_2s at IIWBR Regional Research Station, Dalang Maidan, Lahu Spiti (H.P.). Final experimental trial comprising 10 parents along with their 45 F_1s, and 45 F_2s were evaluated during *rabi*, 2014-15 in randomized block design with three replications. Normally, sowing was done by manually the seeds at a distance of 5 cm in the rows of 4 m length with row to row spacing of 22 centimeter. During crop period, all recommended agronomic practices were adopted to raise the good crop. Data were recorded on plot basis for days to 75% flowering, days to maturity, plant height (cm), canopy temperature depression (CTD) (^{0}c), chlorophyll intensity (%), chlorophyll fluorescence (Fv/Fm) and grain yield per plant were recorded on 5 randomly selected plants for parents, F_1s and 10 plants for F_2s. Canopy temperature depression (CTD) (^{0}c), chlorophyll intensity (%) and chlorophyll fluorescence (Fv/Fm) were measured by Infra Red Thermo-meter (Tele temp AG 42, USA), Chlorophyll SPAD-502 meter (Minolta, Japan) and Fluorescence Measurement System (handy PEA Hansatech Electronics Ltd. U.K.), respectively. Analysis of variance, heterosis and inbreeding depression were calculated as per standard procedures (Fonseca and Patterson, 1968 and Panse and Sukhatme, 1985).

Results and Discussion

In the present investigation, heterosis was estimated as deviation of the performance of hybrids over economic parent. The widely adopted and released variety K 0307 was considered as economic parent for the estimation of economic heterosis for all traits under studied and inbreeding depression of F_2 generation has also been studied. Analysis of variances revealed highly significant differences among genotypes and crosses all the characters under studied. Analysis of variance was given in table 1(a) and 1(b). Analysis of variances for parent *vs* F_1s and parents' *vs* F_2s also showed highly significant differences among traits over both generations at 1 per cent level of significance except of days to maturity and canopy temperature depression (CTD) (^{0}c) in F_1s at 5 per cent level of significance. The levels of significance of variances had desirable amount diversity among parents, therefore, produced

Table-1(a): Analysis of variance among 8th characters in a diallel cross (without reciprocal) of 10 parents and their F1s in wheat

Source of variation	*d.f.*	Days to 75% flowering	Days to maturity	Duration of reproductive phase	Plant height (cm)	CTD (^{0}C)	Chlorophyll intensity (%)	Chlorophyll fluorescence (Fv/Fm)	Grain yield per plant (g)
Replications	2	0.042	19.22**	1.024	5.656	0.075	1.30709	0.00003	0.107
Genotypes	54	154.25**	281.92**	55.67**	186.22**	1.75**	80.43430**	0.00893**	22.67**
Parents	9	39.72**	124.45**	74.74**	110.58**	0.58**	80.68819**	0.01916**	6.53**
F_1s	44	179.12**	320.06**	52.51**	205.38**	2.01**	81.14816**	0.00684**	24.93**
Parents *vs* F_1s	1	86.89**	20.71*	22.76**	23.55*	0.79*	46.71929**	0.00889**	69.21**
Error	108	2.68	3.78	0.993	5.06	0.135	2.72	0.0011	0.37

Table-1(b): Analysis of variance among 8th characters in a diallel cross (without reciprocal) of 10 parents and their F2s in wheat

Source of variation	*d.f.*	Days to 75% flowering	Days to maturity	Duration of reproductive phase	Plant height (cm)	CTD (^{0}C)	Chlorophyll intensity (%)	Chlorophyll fluorescence (Fv/Fm)	Grain yield per plant (g)
Replications	2	3.17	13.406	1.04	2.52	0.09	14.63169	0.0003	1.26
Genotypes	54	181.97**	331.63**	80.45**	149.75**	0.82**	70.24623**	0.00906**	5.42**
Parents	9	39.72**	124.46**	74.74**	110.58**	0.58**	80.68819**	0.01916**	6.52**
F_2s	44	215.024**	381.51**	83.05**	158.75**	0.88**	68.53520**	0.00695**	5.21**
Parents *vs* F_2s	1	8.19	1.75	17.51**	106.23**	0.39	51.55412**	0.01102**	4.45**
Error	108	3.95	7.13	1.84	8.95	0.15	5.42336	0.00014	0.55

Note: * significant at p=0.05 and ** significant at p=0.01

Table-2: Economic heterosis for grain yield per plant in relation to other genetic or physiological traits and grain yield attributing traits in bread wheat

Cross	Heterosis	Inbreeding depression	Sca effect	Gca effect P_1	Gca effect P_2	Desirable heterosis in grain yield attributing traits
DBW 14 x K 0424	28.52**	34.21**	7.44**	-0.73**	-0.52**	Days to 75% flowering (-13.20**), days to maturity (-11.38**), duration of reproductive phase (-13.11**), plant height (-9.89**), chlorophyll intensity (31.81**) and chlorophyll fluorescence (4.00**)
K 9162 x K 9423	26.14**	34.69**	5.73**	-0.08	-0.01	Duration of reproductive phase (-17.95**) and chlorophyll intensity (26.74**)
K 9533 x K 0307	22.91**	24.83**	3.48**	-0.29**	1.76**	Days to 75% flowering (-4.34**),days to maturity (-10.39**), duration of reproductive phase (-28.96**), plant height (-6.80**), CTD (29.15**) and chlorophyll intensity (34.86**)
K 1114 x K 0424	22.81**	47.79**	5.52**	-0.07	-0.52**	Days to 75% flowering (-10.60**), days to maturity (-21.18**), duration of reproductive phase (-53.33**) and plant height (-10.39**)
K 1114 x NW 2036	21.57**	34.43**	5.52**	-0.07	-0.76**	Days to 75% flowering (-15.94**), days to maturity (-16.98**), duration of reproductive phase (-24.32**) and chlorophyll intensity (18.95**)
K 0911 x K 0307	18.47**	49.12**	1.90**	0.43**	1.76**	chlorophyll intensity (21.71**)
K 9162 x K 0307	16.75**	34.90**	2.11**	-0.08	1.76**	Days to 75% flowering (-10.60**), days to maturity (-15.17**), duration of reproductive phase (-30.20**), plant height (-23.09) and chlorophyll intensity (19.92**)
K 0307 x K 9423	16.35**	36.74**	0.56	1.76**	-0.01	CTD (21.61**), chlorophyll intensity (22.69**) and chlorophyll fluorescence (4.00**)
K 0607 x K 0911	13.68**	35.62**	2.54**	0.29**	0.43**	Plant height (-26.35**), chlorophyll intensity (34.64**) and chlorophyll fluorescence (5.26**)
K 1114 x K 0911	10.38**	22.69**	2.38**	-0.07	0.43**	Duration of reproductive phase (-9.52**) and chlorophyll intensity (22.74**)

*Significant at 5 per cent and ** Significant at 1 per cent level.

of results by inter-mating of these parents showed significant and desirable heterosis along with inbreeding depression in F_2s.

The estimates of heterosis and inbreeding depression were given in table 2 revealed that the crosses response to economic heterosis and inbreeding depression were differ in character to character well as parent to parent in different generation. The ranged of economic heterosis varied from -26.32 (NW 2036 x K 9423) to 11.44 (K 0607 x K 0911) for days to 75 per cent flowering, -21.18 (K 1114 x K 0424) to 8.82 (K 1114 x K 0307) for days to maturity, -53.33 (K 1114 x K 0424) to 2.81 (K 1114 x DBW 14) for duration of reproduction phase, -26.35 (K 0424 x K 0911) to 9.77 (K 1114 x K 0911) for plant height, -58.82 (K 9533 x K 0911) to 55.25 (K 9533 x K 0424) for canopy temperature depression (CTD), -0.39 (NW 2036 x K 9423) to 38.06 (DBW 14 x NW 2036) for chlorophyll intensity, -24.14 (K 1114 x K 0307) to 6.49 (K 0911 x NW 2036) for chlorophyll fluorescence and -88.44 (K 0424 x K 0911) to 28.52

Table-3: Estimates of heterosis over economic parent (per cent) and inbreeding depression (per cent) in a 10 parent diallel cross for 8th characters in bread wheat

Crosses	Days to 75 % flowering		Days to maturity		Duration of reproductive phase		Plant Height (cm)	
	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression
K 9533 x K 9162	1.23	1.65	-7.20**	3.46	-32.68**	7.69	-16.66**	-7.63
K 9533 x K 1114	2.83	-8.10 **	-4.79**	-6.76	-27.78**	0.00	-10.85**	-5.39
K 9533 x DBW 14	-1.69	-7.20 *	-8.77**	-9.94 **	-30.20**	0.00	-4.80*	-10.01
K 9533 x K 0607	8.75**	6.08 *	2.62	7.33 **	-15.96**	10.08 **	4.27*	9.18
K 9533 x K 0424	-7.63**	4.04	-12.39**	3.32	-27.78**	0.00	-9.73**	6.09 *
K 9533 x K 0911	2.44	0.00	3.88*	3.10 **	2.13	7.09 **	-13.48**	-3.65
K 9533 x K 0307	-4.34*	0.00	-10.39**	-2.67	-28.96**	0.93	-6.80**	-1.35
K 9533 x NW 2036	-7.14**	2.68	-6.28**	0.00	-9.52**	-0.79	-19.76**	-10.17 **
K 9533 x K 9423	0.41	-7.05 *	-4.20*	-3.92 *	-18.96**	2.59	-8.39**	-8.28 **
K 9162 x K 1114	-1.69	0.00	-5.38**	-2.55	-17.95**	0.00	6.05**	-2.45
K 9162 x DBW 14	3.23*	-10.48 **	1.06	-7.18 *	-7.80**	-0.78	-18.41**	-10.58 **
K 9162 x K 0607	8.75**	2.66	4.86**	2.30	-7.80**	1.56	-8.79**	-11.29 **
K 9162 x K 0424	-11.62**	-9.30 *	-14.11**	-5.52 **	-24.32**	1.80	-21.81**	-0.29
K 9162 x K 0911	4.39**	-9.16 **	0.27	-7.51 *	-13.11**	-4.10	-6.49**	4.78
K9162 x K 0307	-10.60***	-4.15	-15.17**	-5.88 *	-30.20**	-9.43	-23.09**	-2.91
K 9162 x NW 2036	5.88**	0.00	1.33	-2.12	-13.11**	-2.46	-0.41	4.09
K 9162 x K 9423	-2.56	0.00	-5.98	0.00	-17.95**	0.00	2.74	2.17
K 1114 x DBW 14	-4.81**	3.49	-0.27	2.70	2.81	1.41	-5.45**	-2.09
K 1114 x K 0607	9.43**	14.72 **	3.63**	17.88 **	-14.06**	24.79 **	4.89**	18.14 **
K 1114 x K 0424	-10.60**	-19.35 **	-21.18**	-22.48 **	-53.33**	0.00	-10.39**	-8.88 **
K 1114 x K 0 911	10.11**	-2.62	5.34**	-1.53	-9.52**	0.79	9.77**	6.58 *
K 1114 x K 0307	10.11**	0.00	8.82**	0.00	2.13	0.00	-7.58**	-8.55 **
K 1114 x NW 2036	-15.94**	-3.86	-16.98**	-6.60 **	-24.32**	-11.71 *	3.35	9.10 **
K 1114 x K 9423	3.23*	0.00	1.59	5.82 **	-6.16**	22.31 **	-15.73**	-1.15
DBW 14 x K 0607	-14.83**	5.26	-12.39**	0.00	-13.11**	-13.11 *	-6.80**	-3.00
DBW 14 x K 0424	-13.20**	-3.77 *	-11.38**	-4.19 **	-13.11**	-4.92 *	-9.89**	2.03
DBW 14 x K 0911	5.88**	0.00	5.10**	-5.36 *	-0.72	2.19	-1.67	-0.24
DBW 14 x K 0307	11.11**	0.00	8.15**	1.23	-2.22	10.37	-1.14	-3.19
DBW 14 x NW 2036	-13.20**	0.00	-17.35**	-3.15	-31.43**	-11.43 *	-17.59**	-2.78
DBW 14 x K 9423	-10.60**	-1.84	-7.20**	-5.19 *	-6.16**	0.00	-20.50**	-8.54 **
K 0607 x K 0424	-13.75**	0.00	-15.89**	0.00	-25.44**	0.00	-0.65	0.97
K 0607 x K 0911	11.44**	4.80	8.82**	0.00	-0.72	-2.92	-2.92	-2.26
K 0607 x K 0307	10.11**	-5.24	3.63**	-10.36 **	-15.96**	-21.85 **	-8.59**	7.51 *
K 0607 x NW 2036	-6.20**	0.00	-9.73**	6.49 **	-22.11**	0.00	-21.40**	-2.00
K 0607 x K 9423	-11.11**	3.24	-9.41**	2.94	-11.30**	2.42	-15.77**	-6.19 **
K 0424 x K 0911	-20.61**	-3.02	-14.47**	3.08	-9.52**	12.70 **	-26.35**	-0.04
K 0424 x K 0307	-11.11**	0.00	-7.52**	11.27 **	-6.16**	30.00 **	-23.88**	-2.25
K 0424 x NW 2036	-18.22**	0.00	-15.89**	0.00	-16.96**	0.00	-19.38**	0.49
K 0424 x K 9423	-19.40**	0.00	-20.39**	0.00	-27.78**	0.00	-25.75**	-3.14
K 0911 x K 0307	6.62**	-1.56	5.34**	-2.04	-1.48	-2.94	8.58**	20.13 **
K 0911 x NW 2036	-17.08**	-14.63 **	-20.78**	-12.99 **	-33.99**	-9.71 **	-18.55**	-10.23 *
K 0911 x K 9423	-8.59**	-18.55 **	-17.35**	-21.14 **	-43.75**	-27.08 **	0.00	-9.93 **
K 0307 x NW 2036	-18.82**	-5.94	-16.98**	1.57	-18.96**	0.00	-18.70**	-13.58 **
K 0307 x K 9423	4.39**	11.16 **	4.37**	17.99 **	0.00	30.43 **	1.82	1.88
NW 2036 x K 9423	-26.32**	0.00	-18.85**	1.60	-12.20**	0.00	-9.57**	-2.66
SE±	**1.33**		**1.58**		**0.81**		**1.81**	
+(sig)	4(15)	24(3)	5(11)	17(7)	4(0)	24(7)	4(5)	8(6)
-(sig)	3(23)	8(10)	2(27)	7(14)	5(36)	7(7)	5(31)	20(11)

(DBW 14 x K 0424) for grain yield per plant whereas, inbreeding depression ranged from -19.35 (K 1114 x K 0424) to 14.72 (K 1114 x K 0607) for days to 75 per cent flowering, -22.48 (K 1114 x K 0424) to 17.99 (K 0307 x K 9423) for days to maturity, -27.08 (K 0911 x K 9423) to 30.43 (K 0307 x K 9423) for duration of reproductive phase, -13.58 (K 0307 x NW 2036) to 20.13 (K 0911 x K 0307) for plant height, -43.04 (NW 2036 x K 9423) to 43.87 (K 9162 x DBW 14) for canopy temperature depression, -15.52 (K 9162 x K 0911) to 11.26 (K 9533 x K 9423) for chlorophyll intensity, -8.96 (K 1114 x K 0607) to 2.41 (K 0911 x K 0307) for chlorophyll fluorescence and -50.36 (K 1114 x K 9423) to 49.12 (K 0911 x K 0307) for grain yield per plant.

Significant and desirable heterosis was found in forty five crosses for days to 75% flowering, twenty seven for days to maturity, thirty six for duration of reproduction phase, thirty one for plant height (cm), twenty two for canopy temperature depression (CTD) (^{0}c),

Continued Table 3

Crosses	CTD (^{0}C)		Chlorophyll Intensity %		Chlorophyll fluorscene (Fv/Fm)		Grain yield /plant (g)	
	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression	Heterosis	Inbreeding depression
K 9533 x K 9162	43.49**	20.93	28.46**	1.92	4.00**	0.444	-7.50	25.50 **
K 9533 x K 1114	40.73**	15.45 *	34.77**	-3.17	5.26**	-0.881	-10.23*	26.12 **
K 9533 x DBW 14	37.21**	3.45	33.34**	-0.92	2.70**	-1.345	-42.12**	10.70 *
K 9533 x K 0607	46.36**	29.41 *	21.71**	-0.23	0.00	0.463	7.16	24.83 **
K 9533 x K 0424	55.25**	41.72 **	31.89**	4.13	1.37	-0.917	-40.97**	14.54 *
K 9533 x K 0911	-58.82**	-41.30	30.58**	6.90 *	-4.35**	0.481	-1.16	16.05
K 9533 x K 0307	29.15**	16.50	34.86**	-0.71	-2.86*	0.948	22.91**	24.83 **
K 9533 x NW 2036	10.99	-10.98	22.56**	3.61	4.00**	0.897	-47.28**	2.86
K 9533 x K 9423	-5.65	-17.39	29.22**	11.26 **	4.00**	0.889	-17.91**	0.71
K 9162 x K 1114	3.95	-14.47	16.86**	-2.06	-5.88**	0.000	-42.46**	12.16
K 9162 x DBW 14	53.00**	43.87 **	24.48**	-3.97	-1.41	0.000	-53.79**	-1.09
K 9162 x K 0607	43.49**	40.31 **	3.57	-7.38	-18.03*	-1.648	-10.43*	9.15 *
K 9162 x K 0424	34.85**	14.29	0.89	-10.14	-5.88**	-0.493	-2.53	25.59 *
K 9162 x K 0911	36.55**	13.04	19.20**	-11.24 *	0.00	-1.860	-15.01**	14.60
K9162 x K 0307	0.00	-9.59	19.92**	-15.52 *	-20.00**	-1.657	16.75**	34.90 **
K 9162 x NW 2036	29.15**	20.39 *	25.60**	5.39	0.00	-0.465	-113.31**	-45.16
K 9162 x K 9423	1.62	-10.81	26.74**	1.52	1.37	-0.909	26.14**	34.69 **
K 1114 x DBW 14	7.60	5.06	31.99**	3.85	-5.88**	0.000	-36.85**	14.71 *
K 1114 x K 0607	6.54	30.77 *	2.61	-7.74	-1.41	-8.962 **	-83.16**	-18.20
K 1114 x K 0424	13.21	13.10	4.93	1.22	-20.00**	-0.559	22.81**	47.79 **
K 1114 x K 0 911	8.99	3.75	22.74**	3.84	1.37	0.000	10.38**	22.69 **
K 1114 x K 0307	37.21	18.97	30.25**	2.63	-24.14**	0.000	-21.19**	8.49
K 1114 x NW 2036	27.89	0.99	18.95**	-6.60	-5.88**	0.000	21.57**	34.43 **
K 1114 x K 9423	37.21**	22.41	23.10**	3.89	4.00**	0.000	-88.25**	-50.36 *
DBW 14 x K 0607	27.03**	29.00 *	28.92**	1.34	5.26**	0.000	0.90	16.14 **
DBW 14 x K 0424	-49.08**	-10.20	31.81**	-3.18	4.00**	0.000	28.52**	34.21 **
DBW 14 x K 0911	0.00	42.47**	17.47**	0.00	4.00**	0.000	-55.36**	-25.21 *
DBW 14 x K 0307	12.27	-13.25	22.62**	2.38	5.26**	-1.316	-16.11**	21.55 **
DBW 14 x NW 2036	20.85*	-9.78	38.06**	4.68	4.00**	0.444	-35.03**	-13.22
DBW 14 x K 9423	34.32**	12.61	36.58**	2.77	0.00	-0.461	-1.84	38.18 **
K 0607 x K 0424	17.06	-3.41	32.30**	-0.06	4.00**	0.000	-13.20**	3.69
K 0607 x K 0911	10.00	-23.46	21.29**	3.20	5.26**	0.441	13.68**	35.62 **
K 0607 x K 0307	23.34*	-2.11	20.79**	9.21 *	-1.41	0.467	6.52	39.80 **
K 0607 x NW 2036	31.16**	-10.38	27.42**	-0.21	5.26**	0.000	-1.92	39.79 **
K 0607 x K 9423	20.85*	0.00	19.40**	-12.34**	5.26**	0.000	-21.80**	29.97 **
K 0424 x K 0911	0.00	-6.85	34.64**	-7.14	4.00**	0.000	-88.54**	-24.77
K 0424 x K 0307	3.95	-2.63	35.11**	1.29	-7.46**	-0.495	-17.00**	15.97
K 0424 x NW 2036	-7.05	-8.82	21.97**	-0.54	4.00**	-0.444	-44.14**	-7.45
K 0424 x K 9423	28.53**	31.37	27.27**	-2.16	5.26**	2.193	-36.55**	11.70
K 0911 x K 0307	2.80	30.67	21.71**	2.49	-4.35**	2.415	18.47**	49.12 **
K 0911 x NW 2036	19.80*	-1.10	32.17**	8.56	6.49**	-0.873	5.87	24.68 **
K 0911 x K 9423	19.00	5.56	15.96**	3.34	-7.46**	0.000	-3.05	2.43
K 0307 x NW 2036	32.50**	7.41	23.92**	-1.81	2.70**	0.448	0.25	3.85
K 0307 x K 9423	21.61*	8.60	22.69**	-1.38	4.00**	-0.893	16.35**	36.74 **
NW 2036 x K 9423	7.60	-43.04 **	-0.39	-11.27	5.26**	-1.747 *	-22.54**	19.44 *
SE±	**0.29**		**1.34**		**0.0084**		**0.49**	
+(sig)	19(22)	18(9)	4(40)	20(3)	7(22)	27(0)	5(10)	11(26)
-(sig)	2(2)	17(1)	1(0)	19(3)	3(13)	16(2)	6(24)	6(2)

forty for chlorophyll intensity (%), twenty two for chlorophyll fluorescence (Fv/Fm) and ten cross combination indentified for grain yield per plant (g). Top cross combination NW 2036 x K 9423, K 0424 x K 0911 for days to 75 per cent flowering, K 1114 x K 0424, K 0911 x NW 2036 for earliness in maturity, K 1114 x K 0424, K 0911 x K 9423 for duration of reproductive phase, K 0424 x K 0911, K 0424 x K 9423 for reduced plant height, K 9533 x K 0424, K 9162 x DBW 14 for canopy temperature depression, DBW 14 x NW 2036, DBW 14 x K 9423 for chlorophyll intensity, K 0911 x NW 2036, K 9533 x K 1114 for chlorophyll fluorescence. The findings were supported by Prakash *et al.* (2006), Singh *et al.* (2008), Kumar *et al.* (2011) and Kumar and Maloo (2011). In F_2 generation, inbreeding depression is also given in table 2 revealed that ten cross combinations were found desirable for days to 75% flowering, fourteen for days to maturity, seven for duration of reproductive phase, eleven for plant height (cm), eighteen for CTD (^{0}c), twenty two for chlorophyll intensity (%), eighteen for chlorophyll fluorescence (Fv/Fm), and eight cross combinations for grain yield per plant. Desirable and significant cross combinations for inbreeding depression were *viz.,* K 1114 x K 0607, K 0307 x K 9423 for days to 75% flowering and days to maturity, K 0307 x K 9423, K 0424 x K 030 7 for duration of reproductive phase, K 0307 x NW 2036, K 9162 x K 0607 for plant height, NW 2036 x K 9423 for canopy temperature depression, K 9162 x K 0307, K 0607 x K 9423 for chlorophyll intensity, K 1114 x K 0607, K 9162 x K 0911 for chlorophyll fluorescence, and K 1114 x K 9423, K 9162 x NW 2036 for grain yield per plant.

Heterosis and inbreeding depression indicated that the crosses producing desirable heterosis also produced high inbreeding depression. Brim and Cockerham (1961) reported that when the additive gene effects were large, the inbreeding depression in F_2 generation would be small and *vice versa.* The linearity among the per cent homozygosity of the parent and the performance indicated that economic increase in grain yield in most of the combinations was due to non additive genetic components, had been cited as a major factor for the manifestation of hybrid vigour. As far as, the heterosis for grain yield per plant is concerned, it was observed that out of 45, only ten cross combinations showed positive heterosis over economic parent. These cross combinations were ranking in table 3 along with their sca and gca effect. Accordingly crosses, heterosis respond by high sca effect along with detonation in their performance in F_2 generation for most all crosses. The heterosis in these crosses resulted also due to low x low or high x high gca effects point out the role of additive x additive or non additive x non additive gene interactions supported by Budak and Yalderin (1996), Despandey and Nayeem (1999), Joshi *et al.* (2001), Singh (2001), Jaiswal *et al.* (2010) and Beche *et al.* (2013). Only one cross combination namely, DBW 14 x K 0424 had low x low general combining ability effects and significant specific combining ability effect indicated reflected highly significant and desirable heterosis over economic parent, highly significant inbreeding depression, significant sca effect and desirable greater *per se* performance over the populations. The economic increase in such cross could be attributed to non-additive genetic effects. Such combination might be utilized in heterosis breeding programme provided that stable cytoplasmic sterile line could be available.

In view of others crosses for different parameters, cross combination involved one parent had high and other low general combining effects indicated that both the additive and non additive gene effects were responsible for increase in grain yield and such hybrids could be utilized for heterotic and desirable recombinants could be obtained as a sustainable part of additive genetic variance, which was considered as fixable one. Whereas, parents involved the cross had high gca effect means, high x high indicated that heterosis might be attributed to pre-ponderance of both additive and non-additive gene effects. In view of suitable breeding approaches based on superior cross combination as per breeder interest, it could be suggested that the cross combination isolates from desirable segregants and used diallel selective mating system or inter crossing among superior F_2s is likely to helpful in identification of high yielding genotypes for further wheat improvement programme in future.

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