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Research Article

Heterosis and combining ability analysis for yield and its component traits in wheat [*Triticum aestivum* (L.)]

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Abstract
In present study four lines were crossed with eight testers, to determine the nature of gene action, combining ability and heterosis for yield and yield contributing traits in wheat using line × tester analysis. Both additive and non-additive gene action were found to control the expression of the traits under study. The magnitude of general combining ability variances was higher than the specific combining ability variances for all the characters which indicated preponderance of additive gene action in the inheritance of these traits. Among female, GW 11 and male, GW 322 were found to be good general combiners for grain yield per plant, harvest index and protein content. The highest heterosis over standard check variety (GW 496) for grain yield per plant was registered by the cross GW 503 x GW 190 followed by GW 173 x GW 190, GW 11 x GW 190 and GW 503 x GW 322.

Keywords:
Wheat, combining ability, heterosis, line × tester analysis, gene action

Introduction:

Wheat (*Triticum astevium L.*) is second important staple food crop in India next to rice. It is widely cultivated due to its remarkable adaptation to a wide range of environment. *Triticum* spp. originated from Middle–East region of Asia and is a member of family *Poaceae.* It covers about 32 per cent of the total acreage under cereals in the world. The bread wheat (Hexaploid 2n=42), the macaroni wheat (Tetraploid 2n=28) is mostly grown in the central and the southern states and also in the North–West while, emmer wheat (Tetraploid 2n=28) is confined to southern states of India and some part of Gujarat**.** India is the second largest producer of wheat in the world (Kundan *et al*., 2010). Heterosis breeding has proved to be a potential method of increasing yield in the self as well as cross fertilizing crops. However, commercial exploitation of heterosis in self-pollinated crops like wheat has been limited owing to difficulties of genetical and technical nature involved in commercial hybrid seed production. Hybrid technology has been attempted in wheat by varied sterility induction techniques encompassing genetic male sterility, cytoplasmic genetic male sterility and through chemical hybridizing agents (Mahajan *et al.*, 1999). Among these, chemical hybridizing agents have been reported to be impressive particular under less endowed areas (Jernej *et al*., 2013). However, the utility of the technique in enhancing productivity in crop like wheat is still quite moot owing to polyploidy status of the crop and technical intricacies involved in hybrid seed production at commercial scale. Therefore, an early identification of superior, potential crosses is quite necessary to handle the material in advanced generations, effectively and gainfully.There is need to improve the yield potential of wheat varieties as the genetic potential of present day cultivars of wheat appears to be fast reaching plateau due to short span of cool season substantiated by global warming. *Aestivum* wheat has narrow genetic base. In this endeavour, new methods and techniques have been suggested to broaden the genetic base to evolve the elite genetic stock to maintain upward trend in the yield level. According to Jain and Sastry (2012) heterosis studies in wheat gives idea about different types of gene effects which can be utilised further for improvement in production. The success of breeding procedure is determined by the useful gene combinations organised in the form of good combining lines and isolation of valuable germplasm. Some lines produce outstanding progenies on crossing with others, while others may look equally desirable, but may not produce good progenies on crossing. The lines, which perform well in combination, are eventually of great importance to the plant breeders (Gami *et al*., 2010). Hence, investigation on general and specific combining ability would yield very useful information. Accordingly, a good knowledge of gene action involved in the inheritance of quantitative characters of economic importance is required in order to frame an efficient breeding plan leading to rapid improvement. Line × Tester analysis is a useful technique for screening large number of lines for identification of best combiner (Jain and Sastry., 2012). Similarly, knowledge about nature of gene action governing the expression of various traits could help in predicting the effectiveness of selection. The partitioning of genetic variances into its components helps in formulation of an effective and sound breeding programme. Thus, the present study aims to assess the relative magnitude of GCA and SCA for the yield and yield contributing traits and to select the best combiner for successful wheat hybridization.

Material and Methods

Twelve wheat genotypes representing four lines and eight testers were crossed in a Line x Tester mating design to develop 32 F_1 hybrids during Rabi 2012 (Table 1). The experiment was laid out with 32 hybrids and 12 parents in a randomized block design with two replications with 23 x 10 cm of 3.5 M length during Rabi 2012-13. Fertilizer was applied at the rate of 120-60-00 NPK kg ha^{-1}. Five competitive plants were randomly selected to record the observations on eleven characters (days to 50% heading, days to maturity, plant height, no. of effective tillers, length of main spike, grain yield per plant, spikelets per spike, grain yield per spike, 100-grain weight, harvest index and protein content) and the protein was estimated by Kjeldal method as described by Johan Kjeldal, the mean values were subjected to statistical analysis. The analysis of variance was carried out based on the model proposed by Panse and Sukhatme (1964). The analysis of the experimental material was done according to Griffing (1956a and b).

Results and Discussion

The parents and hybrids exhibited considerable genetic variation for all the traits under study corroborated by analysis of variance for various characters (Table 2). Comparison of mean squares due to parent vs. hybrids indicated presence of overall heterosis for all the characters except length of main spike, spikelets per spike, 100-grain weight and protein content indicating that the performance of hybrids was different than that of the parents for most of the characters.

The analysis of variance for combining ability and the estimates of variance components (Table 2) indicated that the mean squares due to lines were significant for all characters except days to 50 per cent heading and 100- grain weight indicated significant contribution of lines towards general combining ability variance components for most of the traits. The mean sum of squares due to testers was also significant for all the characters, suggesting larger contribution of testers towards component of gca variance. The mean sum of squares due to line × testers interaction were significant for plant height, number of effective tillers and grain yield per spike, revealed the significant contribution of hybrids for specific combining ability variance components.The magnitude of gca variance were higher than the sca variance for all the characters, which indicated preponderance of additive gene action in the inheritance of these traits. Therefore, selection for these traits in early generations would be effective to developing the varieties in wheat breeding programme. This was further supported by high magnitude of σ^2_{gca} / σ^2_{sca} ratios. Preponderance of additive variance in the expression for these traits in wheat has also been reported by Joshi *et al.* (2004).

General and specific combining ability effects were estimated for parents and crosses, respectively. The summary of general combining ability effects of the parents (Table 3) revealed that none of the parent was found to be good general combiner for all the characters. These results are akin to the findings of Dhadhal and Dobariya (2006). An overall appraisal of general combining ability effects revealed that among the females, GW 503 was found to be good general combiner for length of main spike, grain yield per plant, spikelets per spike and grain yield per spike, Lok 1 for plant height and 100-grain weight, GW 173 for days to maturity and number of effective tillers per plant, GW 11 for plant height, grain yield per plant, grain yield per spike, harvest index and protein content. Among the males, the good general combiner was GW 496 for days to 50 per cent heading, days to maturity, plant height, length of main spike, 100-grain weight and protein content, GW 190 for days to 50 per cent heading, number of effective tillers, length of main spike, grain yield per plant and grain yield per spike, GW 273 for number of effective tillers, length of main spike, spikelets per spike and harvest index, GW 322 for number of effective tillers, grain yield per plant, spikelets per spike, 100-grain weight, harvest index and protein content, GW 366 for days to maturity and number of effective tillers, GW 438 for grain yield per spike. Moreover, high *per se* performance exhibited by most of the characters of parents delineated good general combining ability effects. Hence, *per se* performance may be used effectively for the selection of parents. Similar result of positive association of *per se* performance and general combining ability and its use for selection of the parents were also reported by Kumar *et al*. (2011). In general, the line GW 11 and tester GW 322 was good general combiner for grain yield and most of the yield contributing traits evincing it as a good source for increasing grain yield as well as protein content in wheat. Hence, these parents can be a source to study favourable genes responsible for enhancing grain yield and protein content in wheat breeding programme.

According to Ping and Virmani (1990), sca effects are the index to determine the usefulness of a particular cross combination for exploitation of heterosis. The important criterion for the evaluation of hybrids is the specific combining ability effects which could be related with hybrid vigour. The sca effects signify the role of non-additive gene action in trait expression. The results of specific combining ability effects (Table 4) of different cross revealed that none of the crosses showed consistently significant and desirable specific combining ability effects for all the characters. None of the crosses expressed negative significant specific combining ability effects for days to 50 per cent heading, days to maturity and plant height while, positive significant specific combining ability effect were observed for number of effective tillers per plant, length of main spike and grain yield per spike. In general, the cross showing positive and negative combining ability effect, involved either good × good, good × average, good × poor, average × average, average × poor and poor × poor combining parents. Therefore, information of general combining ability effects alone may not be sufficient to predict the magnitude of heterosis. Hence, information of general combining ability effects of the parents need to be supplemented by that of specific combining ability effects. In crosses performance, marked negative specific combining ability effects in crosses between good × good and good × average combiners could be attributed to lack of co-adaptation between favourable alleles of the parents involved, whereas marked positive specific combining ability effects in cross between poor × poor, average × poor and average × average combiners could be ascribed to better complementation between favourable alleles of the involved parents.

Comparative study of promising crosses identified on the basis of heterosis, combining ability and per se performance for seed yield per plant (Table 5) revealed that hybrid *viz.*,GW 503 × GW 190, GW 173 × GW 190 and GW 503 × GW 322 showed positive significant relative heterosis (13.17, 11.60 and 11.06 %) and economic heterosis (28.40, 25.93 and 21.48 %) for grain yield per plant, respectively. The significant economic heterosis in desirable direction was observed in most of the high heterotic hybrid of a grain yield per plant and number of effective tillers per plant, which indicating yield heterosis. All the four crosses had recorded significant value of standard heterosis for grain yield per plant. The hybrids GW 503 × GW 190, GW 11 × GW 190 and GW 503 × GW 322 (with non-significant sca effects and parents with significant gca effects) is recommended to exploit additive and non additive type of gene action by high volume crossing like diallel selective mating design (Jensen, 1970) and bi-parental mating as non significant specific combining ability effects (absence of dominance) and parents with significant general combining ability effects (presence of additive gene action) are useful in identification of superior segregants.

From the ongoing discussion, it can be concluded that the cross GW 503 × GW 190 followed by GW 173 × GW 190, GW 11 × GW 190 and GW 503 × GW 322 were registered significant economic heterosis. The analysis of variance for combining ability indicated preponderance of additive gene action in the inheritance of all the traits studied. Among females, GW 11 and among males, GW 322 was found to be good general combiner for seed yield per plant, harvest index and protein content. The three hybrids viz., GW 503 × GW 190, GW 11 × GW 190 and GW 503 × GW 322 showed significant positive relative heterosis and economic heterosis for seed yield per plant with non-significant specific combining ability effects and parents with significant general combining ability effects. Normally, the specific combining ability effects do not contribute tangibly in the improvement of self pollinated crops but useful in commercial exploitation of heterosis. Breeder's interest therefore rests in obtaining transgressive segregants through crosses by producing more potent homozygous lines.

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Table 1. Particulars of wheat parent materials used in study

Sr. No.		Name of parent	Pedigree	Source
[A]	**Line (Female parents) :**			
	1.	GW 503	CPAN 1582/J 142	SDAU, Vijapur
	2.	LOK 1	S 308/S 331	Lok Bharati, Seva Sansthan, Sanosara, Bhavnagar
	3.	GW 173	TW 275-7-7-1/Lok 1	SDAU, Vijapur
	4.	GW 11	Lok 1/HW 1042//Lok 1	SDAU, Vijapur
[B]	**Tester (Male parents) :**			
	1.	GW 496 (check)	HD 2258/CPAN 1861	GAU, Junagadh
	2.	GW 190	VEE'S'/VA 6	SDAU, Vijapur
	3.	GW 273	CPAN 2084/GW 205	SDAU, Vijapur
	4.	GW 322	DL 285/CPAN 426/J 431	SDAU, Vijapur
	5.	GW 366	DL 802-3/GW 232	SDAU, Vijapur
	6.	GW 439	GW 293/NIAW 725	SDAU, Vijapur
	7.	GW 428	CPAN 1905/J 405//WR 8849	SDAU, Vijapur
	8.	GW 438	BORL95/SPET//J429/CC518/3/GW324	SDAU, Vijapur

Table 2 . Analysis of variance (mean square) for parents and hybrids for seed yield along with its component characters, combining ability and estimates of components of variance in wheat

Source of variation	d.f.	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
Replication	1	0.28	0.011	3.68	1.47	0.62	0.03	0.05	0.08	0.25	1.13	0.14
Genotype	43	27.15**	11.51**	52.69**	9.71**	1.78**	22.76**	3.40**	0.51**	0.18*	37.81**	0.42**
Parents	11	61.67**	22.59**	103.68**	5.60**	3.85**	35.37**	6.97**	0.59**	0.31**	58.18**	0.78**
Female	3	19.45*	9.33	222.45**	0.11	4.95**	16.85**	5.84**	0.44**	0.39*	43.98**	1.14**
Male	7	28.57**	13.39*	50.84**	7.39**	3.93**	47.16**	4.02**	0.70**	0.32**	66.36**	0.74**
Female vs. Male	1	420.08**	126.75**	117.18**	9.54**	0.05	8.41*	31.04**	0.29*	0.004	43.51**	0.005
Parents vs. Hybrid	1	47.28**	21.48*	83.52*	35.15**	0.00	6.95*	1.11	1.29**	0.06	12.81*	0.004
Hybrids	31	14.25**	7.26	33.60*	10.35**	1.11**	18.79**	2.21**	0.46**	0.14	31.40**	0.30**
Error	43	4.88	5.05	15.63	0.48	0.21	1.41	0.92	0.05	0.09	2.73	0.06
COMBINING ABILITY:												
Replication	1	1.56	0.76	7.56*	1.59	0.50	1.82	0.003	0.26**	0.49*	0.15	0.003
Crosses	31	14.25**	7.26*	33.60*	10.35**	1.11**	18.79**	2.21**	0.46**	0.14	31.40**	0.30**
Females (Line)	3	5.75	3.43**	60.08**	16.53**	1.77*	39.08**	4.00**	1.51**	0.08	35.60**	0.75**
Males (Tester)	7	46.96**	26.33**	102.78**	29.05**	3.06**	64.60**	7.43**	0.99**	0.51**	118.95**	0.77**
Females x Males	21	4.55	1.45	6.76**	3.23**	0.36	0.62	0.21	0.13**	0.02	1.61	0.08
Error	31	4.53	3.63	15.43	0.49	0.21	1.34	0.79	0.03	0.08	2.93	0.07
COMPONENTS OF VARIANCES :												
σ^2 Females		0.07	0.12	3.33**	0.83**	0.08*	2.40**	0.23**	0.08**	0.003	2.12**	0.04**
σ^2 Males		5.30**	3.11**	12.00**	3.22**	0.33**	7.99**	0.90**	0.10**	0.06**	14.66**	0.08**
σ^2_{gca}		1.81**	1.11**	6.22**	1.62**	0.17**	4.26**	0.45**	0.09**	0.02**	6.30**	0.05**
σ^2_{sca}		-0.16	-1.80	-4.43	1.37**	0.07	-0.39	-0.35	0.04**	-0.03	-0.56	0.01
$\sigma^2_{gca}/\sigma^2_{sca}$		1.05	5.28	1.55	1.18	2.25	1.05	1.63	2.18	2.00	1.05	5.20

** significant at P≤ = 0.05 *P ≤= 0.01 levels

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Table 3. Summary table showing general combining ability effects of parents for various characters in wheat

Parents	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
LINES (FEMALES) :											
GW 503	A	A	P	P	G*	G*	G*	G*	P	P	A
LOK 1	A	A	G*	A	A	P	P	P	G*	P	P
GW 173	A	G*	A	G*	P	A	A	P	A	A	A
GW 11	A	P	G*	P	A	G*	A	G*	A	G*	G*
TESTERS (MALES) :											
GW 496	G*	G*	G*	A	G*	A	A	A	G*	A	G*
GW 190	G*	A	A	G*	G*	G*	A	G*	A	A	P
GW 273	A	P	A	G*	G*	A	G*	P	P	G*	P
GW 322	A	P	A	G*	A	G*	G*	P	G*	G*	G*
GW 366	A	G*	P	G*	P	P	P	P	A	P	A
GW 439	A	A	A	P	P	P	P	A	A	A	A
GW 428	A	G*	P	P	P	P	A	A	A	P	P
GW 438	P	A	P	P	A	P	P	G*	A	P	A

*G = Good parents having significant gca effects in desired direction,
*A = Average parent having either positive or negative but non-significant gca effect, and
*P = Poor parents having gca effect in the undesired direction.

Table 4. The estimates of specific combining ability (sca) for various characters in wheat

Crosses	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
GW 503 x GW 496	0.81	0.10	1.31	-0.74	0.55	0.18	0.72	0.28	0.006	-0.52	-0.10
GW 503 x GW 190	0.31	-0.64	-0.93	-0.14	-0.02	0.33	0.08	0.01	0.11	-0.29	-0.07
GW 503 x GW 273	0.31	-0.39	1.31	-0.18	0.84*	-1.20	0.07	-0.17	0.10	0.08	0.36
GW 503 x GW 322	-0.68	-0.26	-0.43	-0.38	-0.15	0.65	0.23	0.02	0.09	0.20	-0.22
GW 503 x GW 366	-2.43	1.60	0.18	-0.08	0.23	0.24	-0.02	0.05	-0.15	-0.43	0.01
GW 503 x GW 439	2.06	1.48	0.81	0.51	-0.29	-0.01	-0.36	-0.07	0.08	-0.48	0.06
GW 503 x GW 428	-0.68	-1.01	-1.43	0.74	-0.44	0.19	-0.42	-0.11	-0.06	-0.40	0.02
GW 503 x GW 438	0.31	-0.89	-0.81	0.28	-0.70*	-0.38	-0.30	-0.02	-0.18	1.85	-0.05
Lok 1 x GW 496	0.06	-0.76	-2.68	0.46	0.16	0.00	-0.52	-0.10	0.05	0.46	-0.08
Lok 1 x GW 190	-0.43	0.48	1.06	-0.18	0.23	0.15	0.09	0.03	-0.08	0.48	0.04
Lok 1 x GW 273	-1.43	-0.26	-1.68	-0.22	-0.70*	-0.38	-0.07	0.005	-0.14	0.56	0.03
Lok 1 x GW 322	1.56	-0.64	0.56	0.38	-0.50	0.02	-0.05	-0.01	-0.006	-0.81	-0.008
Lok 1 x GW 366	-1.18	0.73	1.18	0.03	0.03	0.46	0.33	0.10	-0.006	0.49	-0.22
Lok 1 x GW 439	0.31	0.10	-0.68	-0.52	0.21	-0.3	-0.30	0.06	0.08	-0.15	0.28
Lok 1 x GW 428	0.56	0.60	1.06	0.005	0.26	-0.03	0.33	0.005	0.13	0.47	-0.05
Lok 1 x GW 438	0.56	-0.26	1.18	0.04	0.29	0.08	0.20	-0.09	-0.03	-1.51	0.01
GW 173 x GW 496	-2.06	0.29	-2.81	-0.21	-0.45	0.02	0.005	-0.04	-0.11	-0.02	-0.12
GW 173 x GW 190	0.43	0.04	-1.56	1.63**	-0.02	0.42	0.01	-0.40*	0.04	0.40	-0.002
GW 173 x GW 273	1.43	0.29	0.18	2.09**	0.08	0.48	-0.09	-0.26	-0.06	1.08	-0.26
GW 173 x GW 322	-1.56	0.42	0.43	1.89**	0.53	-0.8	-0.23	-0.31	0.01	0.70	0.09
GW 173 x GW 366	3.68*	-1.20	0.56	-1.30*	-0.27	-0.66	-0.09	0.15	0.16	-0.38	0.33
GW 173 x GW 439	-1.81	-0.82	-0.31	-1.20*	-0.10	0.32	0.21	0.26	-0.04	-0.03	0.08
GW 173 x GW 428	0.43	0.17	1.93	-1.47**	-0.05	-0.11	0.30	0.25	0.006	-0.75	-0.05
GW 173 x GW 438	-0.56	0.79	1.56	-1.43**	0.28	0.31	-0.12	0.34*	-0.006	-0.99	-0.07
GW 11 x GW 496	1.18	0.35	4.18	0.49	-0.26	-0.20	-0.20	-0.13	0.05	0.08	0.31
GW 11 x GW 190	-0.31	0.10	1.43	-1.30*	-0.18	-0.90	-0.19	0.35*	-0.08	-0.59	0.03
GW 11 x GW 273	-0.31	0.35	0.18	-1.69**	-0.22	1.10	0.09	0.42 *	0.10	-1.72	-0.12
GW 11 x GW 322	0.68	0.48	-0.56	-1.89**	0.12	0.11	0.05	0.29	-0.10	-0.09	0.13
GW 11 x GW 366	-0.06	-1.14	-1.93	1.35**	0.01	-0.04	-0.20	-0.31	-0.006	0.31	-0.12
GW 11 x GW 439	-0.56	-0.76	0.18	1.20*	0.18	-0.006	0.45	-0.25	-0.11	0.66	-0.42*
GW 11 x GW 428	-0.31	0.23	-1.56	0.73	0.23	-0.04	-0.20	-0.14	-0.06	0.69	0.08
GW 11 x GW 438	-0.31	0.35	-1.93	1.11*	0.12	-0.02	0.21	-0.22	0.21	0.65	0.11
S.E. (s_{ij}) ±	2.21	2.24	3.95	0.69	0.46	1.18	0.96	0.22	0.30	1.65	0.25

* and** indicates significant at $p \leq 0.05$ and $p \leq 0.01$ levels, respectively.

Table 5. Promising crosses identified on the basis of heterosis, combining ability and *per se* performance

	GW 503 x GW 190	GW 173 x GW 190	GW 11 x GW 190	GW 503 x GW 322
Seed yield per plant (g)	26.00	25.50	24.65	24.60
Relative heterosis for seed yield (%)	13.17**	11.60 *	3.79	11.06 *
Heterobeltiosis for seed yield (%)	-2.44	-4.32	-7.5	-1.6
Standard heterosis for seed yield (%)	28.40**	25.93 **	21.73 **	21.48 **
Sca effect for seed yield	0.33	0.42	-0.90	0.65
Gca effect for grain yield :				
(i) Female parent	1.00 **	0.41	0.89 **	1.00 **
(ii) Male parent	4.85 **	4.85 **	4.85 **	3.13 **

***** and ** significant at p ≤=0.05 and p ≤= 0.01 levels, respectively.***

Table 6 : Mean performance of parents and hybrids for various characters in wheat (*Triticum aestivum* L.)

Sr. No.	Genotypes	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike (g)	100-grain weight	Harvest index	Protein content
FEMALES (Lines) :												
1.	GW 503	54.50	108.00	77.00	6.80	9.65	19.30	15.95	2.85	4.65	25.90	11.55
2.	Lok 1	48.00	103.00	70.00	7.05	6.60	14.15	12.00	2.01	5.65	19.60	11.65
3.	GW 173	49.00	104.00	56.00	7.30	6.10	19.05	13.95	2.61	5.20	26.50	12.10
4.	GW 11	53.00	105.00	79.50	6.80	7.20	20.85	15.10	3.12	5.50	31.00	13.20
MALES (Testers) :												
5.	GW 496	52.00	107.00	66.00	7.50	8.50	20.25	16.80	2.71	5.70	26.40	13.05
6.	GW 190	59.00	111.00	72.00	8.80	7.80	26.65	17.15	3.05	5.21	29.85	11.80
7.	GW 273	61.00	112.00	78.50	9.50	9.15	20.55	18.30	2.16	4.70	35.05	11.65
8.	GW 322	62.00	113.00	75.00	9.65	8.90	25.00	18.80	2.59	5.75	38.50	13.10
9.	GW 366	58.00	106.00	80.00	11.50	6.35	19.70	14.50	1.71	5.40	24.45	12.20
10.	GW 439	63.00	110.00	73.50	6.50	6.25	12.25	15.80	1.90	5.25	27.50	12.15
11.	GW 428	61.00	112.00	82.00	7.65	5.25	14.25	16.30	1.86	5.12	26.45	11.55
12.	GW 438	64.00	108.00	75.50	5.50	7.70	18.10	15.65	3.31	4.65	20.65	11.75
HYBRIDS :												
1.	GW 503 x GW 496	55.00	108.00	72.00	7.75	8.85	21.50	16.95	2.77	5.50	26.00	12.30
2.	GW 503 x GW 190	58.00	109.00	73.00	9.50	8.30	26.00	17.30	2.74	5.35	28.00	11.70
3.	GW 503 x GW 273	61.00	111.00	77.00	10.50	9.50	19.50	18.00	1.86	5.00	32.00	12.20
4.	GW 503 x GW 322	60.00	112.00	77.50	11.50	7.90	24.60	18.50	2.15	5.65	34.50	12.40
5.	GW 503 x GW 366	57.00	109.00	80.00	9.50	7.65	19.90	15.80	2.10	5.10	24.45	12.05
6.	GW 503 x GW 439	63.00	111.00	75.00	7.50	6.80	17.00	15.65	2.27	5.35	26.05	12.20
7.	GW 503 x GW 428	59.00	110.00	79.50	8.50	6.50	18.50	16.10	2.18	4.95	25.10	11.80
8.	GW 503 x GW 438	62.00	107.00	79.00	6.50	7.10	19.50	15.50	3.01	4.70	24.35	11.85

Table 6 : Contd..

Sr. No.	Genotypes	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike (g)	100-grain weight	Harvest index	Protein content
9.	Lok 1 x GW 496	53.00	106.50	66.50	9.50	7.85	18.00	14.50	1.89	5.70	26.50	12.20
10.	Lok 1 x GW 190	56.00	109.50	73.50	10.00	7.95	22.50	16.10	2.26	5.30	28.30	11.70
11.	Lok 1 x GW 273	58.00	110.50	72.50	11.00	7.35	17.00	16.65	1.55	4.90	32.00	11.75
12.	Lok 1 x GW 322	61.00	111.00	77.00	12.80	6.95	20.65	17.00	1.61	5.70	33.00	12.50
13.	Lok 1 x GW 366	57.00	107.50	79.50	10.15	6.85	16.80	14.95	1.66	5.40	24.90	11.70
14.	Lok 1 x GW 439	60.00	109.00	72.00	7.00	6.70	13.40	14.50	1.91	5.50	25.90	12.30
15.	Lok 1 x GW 428	59.00	111.00	80.50	8.30	6.60	14.95	15.65	1.81	5.30	25.50	11.60
16.	Lok 1 x GW 438	61.00	107.00	79.50	6.80	7.50	16.65	14.80	2.45	5.00	20.50	11.80
17.	GW 173 x GW 496	51.00	107.50	65.00	10.00	7.15	20.75	15.50	2.11	5.45	28.00	12.40
18.	GW 173 x GW 190	57.00	109.00	69.50	13.00	7.60	25.50	16.50	1.97	5.35	30.20	11.90
19.	GW 173 x GW 273	61.00	111.00	73.00	14.50	8.05	20.60	17.10	1.42	4.90	34.50	11.70
20.	GW 173 x GW 322	58.00	112.00	75.50	15.50	7.90	22.55	17.30	1.45	5.65	36.50	12.85
21.	GW 173 x GW 366	62.00	105.50	77.50	10.00	6.45	18.40	15.00	1.84	5.50	26.00	12.50
22.	GW 173 x GW 439	58.00	108.00	71.00	7.50	6.30	16.75	15.50	2.25	5.30	28.00	12.35
23.	GW 173 x GW 428	59.00	110.50	80.00	8.00	6.20	17.60	16.10	2.20	5.10	26.25	11.85
24.	GW 173 x GW 438	60.00	108.00	78.50	6.50	7.40	19.60	14.95	3.03	4.95	23.00	11.95
25.	GW 11 x GW 496	55.00	108.50	76.50	8.30	7.85	21.00	15.50	2.54	5.70	29.40	13.10
26.	GW 11 x GW 190	57.00	110.00	77.00	7.65	7.95	24.65	16.50	3.26	5.30	30.50	12.20
27.	GW 11 x GW 273	60.00	112.00	77.50	8.30	8.25	21.70	17.50	2.64	5.15	33.00	12.10
28.	GW 11 x GW 322	61.00	113.00	79.00	9.30	8.00	23.95	17.80	2.58	5.60	37.00	13.15
29.	GW 11 x GW 366	59.00	106.50	79.50	10.25	7.25	19.50	15.10	1.90	5.40	28.00	12.30
30.	GW 11 x GW 439	60.00	109.00	76.00	7.50	7.10	16.90	15.95	2.26	5.30	30.00	12.10
31.	GW 11 x GW 428	59.00	111.50	81.00	7.80	7.00	18.15	15.80	2.33	5.10	29.00	12.25
32.	GW 11 x GW 438	61.00	108.50	79.50	6.65	7.75	19.75	15.50	2.98	5.25	25.95	12.40
	Mean	58.23	109.05	75.34	8.91	7.45	19.63	16.04	2.29	5.27	28.27	12.15
	S.Em. ±	1.58	1.58	2.80	0.49	0.33	0.83	0.69	0.16	0.22	1.16	0.18
	C.D %	4.49	4.50	7.97	1.39	0.94	2.38	1.95	0.45	0.61	3.30	0.51