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Genetic Analysis of Yield and Some other Quantitative Traits in Bread Wheat

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ABSTRACT

The significant differences among six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) were observed for all the studied plant traits of crosses V-95199 x PARI-73 and Chakwal-86 x V-8060. The F_1 means for flag leaf area, spike length and 1000-grain weight exhibited heterosis in both crosses. Generation means analysis indicated that additive, dominance and epistatic genetic effects seemed to have played role in the inheritance of all studied plant parameters. A single parameter model [m] was only adequate for grain yield per plant in cross Chakwal-86 x V-8060. To study gene action in this trait F_3 or further generations are needed. Two-parameter model [md] provided the best fit for number of grains per spike in cross V-95199 x PARI-73 and for plant height, spikelets per spike and biomass per plant in cross Chakawal-86 x V-8060. The additive or additive x additive gene effects were found for plant height and number of grains per spike in cross V-95199 x PARI-73.While dominance or dominance x dominance effects were noticed for flag leaf area and 1000-grain weight in cross Chakwal-86 x V-8060. Number of tillers per plant in Chakwal-86 x V-8060 showed [i], [j] and [l] type of epistatic effects together which indicated complex inheritance for this trait.

Key Words: Wheat; Genetic analysis; Generation means; Gene effects

INTRODUCTION

Information regarding nature and magnitude of genetic effects prevailing in the breeding material is necessary to decide the kind of breeding procedure to be chosen for better exploitation of the genetic potential of different plant traits in a crop. Among these characters plant height is a very important trait to improve the production of wheat. Wheat plant can be tall, intermediate in height or dwarf in stature.

The green revolutions i.e. significant increment in wheat yield has primarily been realized through the introduction of Norin-10 dwarfing genes. Presently most of the wheat cultivars possess the dwarfing genes derived from the Norin-10 source (Rht-1 and Rht-2) either singly or together (Mishra & Kushwaha, 1995). The drastic reduction in height also causes reduction in grain yield.

Keeping this in view, generation mean analysis was carried out in crosses of two tall and two dwarf locally adopted wheat varieties/lines along with their reciprocals to study gene effects of plant height on grain yield and other yield components.

MATERIALS AND METHODS

The experimental material comprised of four parental wheat varieties/lines. Two of them namely Chakwal-86 and V-95199 were taken as tall and the other two i.e. PARI-73 and V-8060 as dwarf variety/line. These varieties/lines were grown in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad to develop six generations for each cross as under:

	Cross I		Cross II	
Population	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
P_1	V-95199	PARI-73	Chakwal-86	V-8060
P_2	PARI-73	V-95199	V-8060	Chakwal-86
F_1	P_1 x P_2	P_1 x P_2	P_1 x P_2	P_1 x P_2
F_2	Self F_1	Self F_1	Self F_1	Self F_1
BC_1	P_1 x F_1	P_1 x F_1	P_1 x F_1	P_1 x F_1
BC_2	P_2 x F_1	P_2 x F_2	P_2 x F_1	P_2 x F_1

Fifty plants were selected from each tall and dwarf wheat variety/line and they were used as parents. Tall wheat line V-95199 was crossed with dwarf wheat variety PARI-73 to produce F_1 and its reciprocal. The F_1s, their reciprocals and parental seed was harvested separately at maturity. In the 2nd year a part of seed obtained from each of parents, two hybrids and their reciprocals were sown in the field to produce F_2 generation and back cross (BC_1 and BC_2) seed. At maturity seed from parents, F_1, BC_1 and BC_2 and their reciprocals were harvested.

The parents, F_1, F_2 and backcross (BC_1 and BC_2) generations and their reciprocals were sown in the field in triplicate by using randomized complete block design. A single row of 5 m length for parental and F_1 generations, two for each backcross and three for F_2 generations were planted. Ten plants were selected at random from each parent and each F_1, 20 from each backcross (BC_1 and BC_2) and 30 from each F_2 generation in each replication to record the data on individual plant basis for the plant traits like flag leaf area, plant height, number of tillers per plant, spike length, spikelets per spike, number of grains per spike, 1000-grain weight, biomass per plant, grain yield per plant and harvest index.

Analysis of variance was performed using the formula given by Steel and Torrie (1980) to assess significant differences among generation means.

Generation means analysis was performed following the procedure of Mather and Jinks (1982). Standard errors (S.E.) of generation means were computed by performing a nested analysis of variance (Snedecor & Cochran, 1989) with partitioning of total variation into (i) between replications, (ii) between rows within replications and (iii) between plants within rows within replications. The significant mean squares were divided by the total number of plants in rows and replications (N) to obtain the variance of generation means and its square root provided the standard error of means. Pooling of non-significant mean squares was done wherever required. The best fitting models were chosen on the basis of significant parameters and non-significant chi-squares at 5%.

RESULTS AND DISCUSSION

Generation means. There were significant differences among six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) for all the studied plant parameters of cross combinations V-95199 x PARI-73 and Chakwal-96 x V-8060 (Tables I & II). The magnitude and direction of heterosis varied from cross to cross. The F_1 hybrid showed intermediate plant height than the parents in both crosses. In cross V-95199 x PARI-73, the F_1 means of flag leaf area, number of tillers per plant, spike length, spikelets per spike and 1000-grain weight were outside the parental range indicating considerable heterosis for these plant traits.

Similarly in cross Chakwal-86 x V-8060 the F_1 means of flag leaf area, spike length, 1000-grain weight and harvest index exhibited heterosis. In general, for 1000-grain weight the F_1 exceeded the better parent indicating over-dominance in both crosses. Munir *et al*. (1999) reported that 1000-grain weight was the main factor for improving grain yield in wheat.

The findings of Walia *et al*. (1995) and Kowalczyk (1998) also supported the results of present study regarding heterosis for different plant parameters. Thus flag leaf area, spike length and 1000-grain weight can be used for selection and development of high yielding genotypes from the present material.

Genetic effects for yield and yield components. The knowledge about the nature and magnitude of genetic effects prevailing in breeding material is necessary to decide for further breeding strategies. In order to determine kind and amount of genetic effects involved in the control of yield and its parameters, the generation mean analysis procedure was used following the model and assumptions outlined by Mather and Jinks (1982).

In case of flag leaf area five-parameter model [mdhlj] was best fitted from observed to the expected generation means of the cross V-95199 x PARI-73 (Table III). The dominance effects [h] were found to be greater than additive effects [d]. This may be due to overdominance or unidirectional or dispersion of genes in the parents which are responsible for this reduced estimation of additive component [d] than dominance component [h]. The dominance effects were negative for flag leaf area showing thereby that decrease for this trait was dominant of the non-allelic interaction, the [l] component was only important. The negative value of [j] i.e., additive x dominance interaction showed that it is possible to obtain less flag leaf area in infinity generation.

Model [mh] was the best fitted from observed to the expected generation means for flag leaf area of the cross Chakwal-86 x V-8060 (Table IV). The dominant effects [h] were present significantly.

The results get support from the findings of Awaad (1996) and Chowdhry *et al*. (1999) who reported that additive genetic variance was predominant for flag leaf area in wheat. However, Singh *et al*. (1986) and Chowdhry *et al*. (1992) reported dominance genetic effects for flag leaf area in wheat.

In case of plant height four-parameter model [mdhi] was the best fitted from the observed to the expected generation means of the cross V-95199 x PARI-73 (Table III). The additive effects [d] were found to be greater than dominance effects [h]. The negative value of [i] for plant height showed that it was possible to obtain less plant height in the infinity generation.

In the cross Chakwal-86 x V-8060 two-parameter model [md] was best fitted from observed to expected generation means (Table IV). The additive effects [d] were predominant for plant height in this cross.

The results are in accordance with Sharma and Ahmad (1980) and Awaad (1996) who reported that additive genetic effects were predominant for plant height in wheat. Chowdhry *et al*. (1992) revealed that additive and partial dominance genetic effects were important for this trait. Amawate and Behl (1995) disclosed that plant height was governed by additive x additive [i] gene interaction.

Five parameter model [mhilj] was the best fitted from observed to the expected generation means in the cross V-95199 x PARI-73 for number of tillers per plant (Table III). The dominance effects [h] were greater than [i], [l] and [j] interaction effects. The positive [l] means that it is possible to fix dominance x dominance interaction to increase number of tillers per plant. The inheritance of this trait is polygenic and not found to be so simple.

Similarly five-parameter model [mdhil] was the best fitted from observed to the expected generation means of the cross Chakwal-86 x V-8060 (Table IV). The data was transformed into logarithm for number of tillers per plant because model was not fitted for that trait. The dominance

Table I. Generation means and S.E. of various quantitative traits of the cross V-95199 (P_1) x PARI-73 (P_2) of wheat.

	P_1		P_2		F_1		F_2		BC_1		BC_2	
PlantTraits	**Mean**	**±S.E**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**
Flagleafarea	35.10bc	1.08	38.57a	1.50	34.99bc	1.53	37.10ab	0.94	33.09c	0.90	34.99bc	0.82
Plantheight	127.77a	1.40	78.10f	0.84	102.40d	0.97	108.29c	1.99	120.43b	1.53	93.93e	1.94
Numberoftillersperplant	10.53a	0.21	10.67a	0.25	8.87bc	0.22	11.10a	0.29	8.17c	0.32	9.28b	0.40
Spikelength	12.86a	0.12	12.74ab	0.18	12.18c	0.18	12.78ab	0.12	12.54b	0.15	12.81a	0.11
Spikeletsperspike	21.30b	0.28	22.90a	0.30	21.27b	0.29	22.69a	0.22	21.60b	0.21	22.77a	0.22
Numberofgrainsperspike	69.90a	1.71	61.20c	1.88	62.33bc	2.13	65.97abc	1.20	66.67ab	1.17	66.40abc	1.43
1000-grainweight	46.54b	0.57	44.90bc	0.51	52.15a	0.63	45.27bc	0.75	45.88bc	0.60	44.48c	0.50
Biomassperplant	62.79a	4.45	37.57c	2.07	40.41c	2.87	54.77ab	2.22	48.09bc	2.55	40.11c	2.36
Grainyieldperplant	25.47a	1.72	17.63b	1.02	18.28b	1.34	23.74a	0.89	18.95b	0.91	18.58b	1.05
Harvestindex	41.19b	1.09	46.81a	0.81	45.41a	1.05	45.92a	1.81	40.47b	0.82	47.11a	0.94

Table II. Generation means and S.E. of various quantitative traits of the cross Chakwal-86 (P_1) x V-8060 (P_2) of wheat.

	P_1		P_2		F_1		F_2		BC_1		BC_2	
PlantTraits	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**	**Mean**	**±S.E.**
Flagleafarea	34.01c	1.32	34.77bc	1.43	46.56a	1.60	38.45bc	0.97	39.72b	1.13	38.69bc	1.03
Plantheight	110.90a	1.14	72.80e	0.95	89.60c	1.03	94.25c	1.70	102.58b	1.43	83.27d	1.26
Numberoftillersperplant	9.60c	0.34	14.93a	0.31	10.27bc	0.36	11.47b	0.29	10.23bc	0.36	10.63bc	0.38
Spikelength	13.18b	0.12	13.53ab	0.12	13.77a	1.13	13.33b	0.13	13.86a	0.13	13.87a	0.14
Spikeletsperspike	24.73a	0.33	20.80d	0.24	22.87bc	0.24	22.77c	0.20	23.90ab	0.20	22.30c	0.22
Numberofgrainsperspike	77.67a	1.54	53.00c	1.62	70.47b	1.44	70.14b	1.21	75.03ab	1.16	71.07b	1.46
1000-grainweight	46.44ab	0.71	43.89bc	1.08	49.09a	0.77	45.42bc	0.63	44.76bc	0.49	42.75c	0.78
Biomassperplant	60.20a	2.79	49.79b	2.68	52.02b	3.61	59.33a	2.06	61.09a	2.79	50.23b	2.33
Grainyieldperplant	25.40b	1.46	22.29c	1.22	23.82bc	1.55	25.81ab	0.92	26.80a	1.18	24.27abc	1.05
Harvestindex	41.89c	1.16	44.84b	0.73	46.60b	1.08	43.95bc	0.86	44.54bc	0.70	49.45a	0.93

Note: Means sharing the same letters are non-significant.

effects [h] were found greater than additive effects in this cross. Chowdhry *et al*. (1999) reported additive and dominance components for genetic variance for number of tillers per plant. However, Chowdhry *et al*. (1992) found non-additive type of gene action for number of tillers per plant in wheat.

In case of spike length three parameter model [mdh] was the best fitted from observed to the expected generation means of the cross V-95199 x PARI-73 (Table III). The dominance effects [h] were found to be greater than the additive effects [d], which can arise if there is over dominance or unidirectional dominance or dispersion of genes in parents leading to reduced estimation of [d] component in relation to [h] component.

In the cross Chakwal-86 x V-8060 five-parameter model [mdhil] was the best fitted from observed to expected generation means (Table IV). The dominance effects [h] were greater than additive effects [d]. This may be possible due to over dominance or unidirectional dominance or dispersion of genes in the parents which are responsible for this reduced estimation of additive component [d] than dominance component [h].

Walia (1995) and Awaad (1996) revealed that additive genetic effects [d] were more important than dominance effects [h] for spike length in wheat. While Chowdhry *et al*. (1999) reported that spike length was controlled by partial dominance with additive gene action in wheat.

As regards spikelets per spike five parameter model [mdhij] was best fitted from observed to the expected generation means of the cross V-95199 x PARI-73 (Table III). The dominance [h] effects were greater than additive effects. This can arise if there is overdominance, or unidirectional dominance or dispersion of genes in the parents leading to reduced estimation of [d] component in relation to [h] component. The negative [i] for spikelets per spike shows that it is possible to obtain less spikelets per spike in F-infinity generation. The negative value of [j] also shows that there will be a decrease in spikelets per spike in infinity generation.

The two parameter model [md] was best fitted from observed to the expected generation means of the cross Chakwal-86 x V-8060 (Table IV). In this cross additive effects were important. The results are in agreement with the findings of Sharma and Ahmad (1980) and Walia *et al*. (1995). They reported that the estimates of additive genetic effects were important for spikelets per spike in wheat.

In case of number of grains per spike two parameter model [md] provided the best fit from observed to the expected generation means of the cross V-95199 x PARI-73.The additive [d] effects were important in this cross and played significant role. The results of this cross are in accordance with Awaad (1996) who reported that additive genetic effects [d] were predominant for number of grains per spike in wheat.

The four parameter model [mdhl) was best fitted from observed to the expected generation means of the cross

Table III. Best model fit estimates for generation mean parameters by weighted least squares analysis of various quantitative traits of the cross V-95199 x PARI-73 of wheat.

						Parameters.							
Planttraits	**M**	**±S.E.**	**[d]**	**±S.E.**	**[h]**	**±S.E.**	**[i]**	**±S.E.**	**[j]**	**±S.E.**	**[l]**	**±S.E.**	**X^2(df)**
Flagleafarea	37.22	0.91	1.86*	0.92	-5.70**	2.21	-	-	-5.96**	1.96	4.52*	2.12	3.81(1)
Plantheight	116.89	3.38	25.06**	0.77	-14.32**	3.86	-13.78**	3.55	-	-	-	-	1.74(2)
Numberoftillersperplant	15.55	0.86	-	-	-11.21**	1.57	-4.97**	0.86	-3.41**	0.58	4.52**	0.80	0.18(1)
Spikelength	12.91	0.10	-	-	-0.5**	0.19	-	-	-	-	-	-	5.93(3)
Spikeletsperspike	24.07	0.51	0.80**	0.21	-2.79**	0.73	-1.98**	0.56	-1.90**	0.36	-	-	0.06(1)
Numberofgrainsperspike	65.71	0.59	3.07**	1.05	-	-	-	-	-	-	-	-	6.33(4)
1000-grainweight	39.84	1.81	-	-	8.24**	2.75	5.75**	1.85	-	-	3.96**	1.03	5.56(2)
Biomassperplant	1.83	0.05	0.10**	0.02	-0.30**	0.08	-0.19**	0.05	-	-	-	-	5.45(2)
Grainyieldperplant	1.45	0.07	0.06**	0.02	-0.25**	0.09	-0.16*	0.07	-	-	-	-	5.27(2)
Harvestindex	44.22	0.41	2.75**	0.66	-	-	-	-	-9.50**	1.39	-	-	2.74(3)

Table IV. Best model fit estimates for generation mean parameters by weighted least squares analysis of various quantitative traits of the cross Chakwal-86 x V-8060 of wheat.

						Parameters							
Planttraits	**M**	**±S.E.**	**[d]**	**±S.E.**	**[h]**	**±S.E.**	**[i]**	**±S.E.**	**[j]**	**±S.E.**	**[l]**	**±S.E.**	**X^2(df)**
Flagleafarea	33.75	0.87	-	-	11.14**	1.71	-	-	-	-	-	-	3.24(4)
Plantheight	91.83	0.49	19.05**	0.69	-	-	-	-	-	-	-	-	8.03(4)
Numberoftillersperplant	1.17	0.03	-0.10**	0.01	-0.29**	0.06	-0.10**	0.04	-	-	0.13**	0.03	0.55(1)
Spikelength	12.56	0.34	0.21**	0.08	2.09**	0.57	0.81*	0.35	-	-	-.85**	0.27	2.08(1)
Spikeletsperspike	22.89	0.09	1.89**	0.16	-	-	-	-	-	-	-	-	3.39(4)
Numberofgrainsperspike	65.00	1.07	11.71**	1.01	16.66**	2.78	-	-	-	-	-11.80**	2.38	1.71(2)
1000-grainweight	45.37	0.56	-	-	-3.11*	1.43	-	-	-	-	6.32**	1.22	6.74(3)
Biomassperplant	56.01	1.06	6.52**	1.70	-	-	-	-	-	-	-	-	6.21(4)
Grainyieldperplant	25.32	0.42	-	-	-	-	-	-	-	-	-	-	4.47(5)
Harvestindex	1.58	0.02	-	-	0.15**	0.04	0.06**	0.02	-	-	-0.07**	0.02	4.14(2)

m = Mean, [d] = Additive effects, [h] = Dominance effects, [i] = Additive x additive effects, [l] = Dominance x dominance effects.
* = $P \leq 0.05$** = $P \leq 0.01$

Chakwal-86 x V-8060 (Table IV). The dominance [h] effects were greater than additive [d] and dominance x dominance effects in both crosses. This is due to over dominance or unidirectional dominance or dispersion of genes in parents leading to reduce estimates of [d] component in relation to [h] component. The negative values of [l] in this cross indicate that there is not any breeding importance in proceeding generations. The component of [h] and [l] for number of grains per spike shows that there exist duplicate gene interaction for this trait and are likely to be very difficult to exploit for the improvement of line/variety. Chowdhry *et al*. (1992) found that dominance effects [h] were predominant for number of grains per spike. Epistatic effect was significant for this trait.

Four parameter model [mhil] was best fitted from observed to the expected generation means of the cross V-95199 x PARI-73 for 1000-grain weight (Table III). The dominance [h] gene effects were greater than additive x additive [i] and dominance x dominance [l]. The comparison of [h] and [l] for 1000-grain weight showed that there existed duplicate gene interaction for this trait and likely to be very difficult to exploit for the improvement of wheat line/variety.

Three parameter model [mhl] was the best fitted from observed to the expected generation means of the cross Chakwal-86 x V-8060 (Table IV). The dominance x dominance [l] effects were greater than dominance [h] effects. The positive [l] interaction indicates that 1000-grain weight is an important plant trait in developing a variety and can be fixed in proceeding generations. Tsenov (1996) and Chowdhry *et al*. (1999) found dominant and over-dominant types of inheritance for 1000-grain weight.

In case of biomass per plant four parameter model [mdhi] was found to be the best fitted from observed to expected generation means of the cross V-95199 x PARI-73 (Table III). The additive effects [d] were important than dominance effects [h] in this cross. The negative [i] interaction for biomass per plant indicated that it is possible to obtain less biomass per plant in infinity generation.

In the cross Chakwal-86 x V-8060, the two parameter model [md] was found to be the best fitted from observed and expected generation means (Table IV). The additive effects [d] were significantly present and showed simple inheritance. Singh *et al*. (1986) reported that biomass per plant in wheat was mainly controlled by dominance gene action.

The four-parameter model [mdhi] was found to be the best fitted from observed to the expected generation means of the cross V-95199 x PARI-73 for grain yield per plant (Table III). The dominance effects [h] were greater than additive [d] and additive x additive [i] effects. This may be due to over dominance or unidirectional or dispersion of genes in the parents.

Model [m] was best fitted from observed to expected generation means of the cross Chakwal-86 x V-8060 (Table IV). It means that none of gene effect or non-allelic interaction seems to be significant for grain yield per plant in this cross. To study gene action in this trait F_3 or further generations are needed. Walia *et al*. (1995) and Chowdhry *et al*. (1999) revealed that dominance genetic effects were more important than additive gene action for grain yield per plant in wheat. While Kamboj *et al*. (2000) reported that additive genetic effects were important for grain yield per plant. Mehla *et al*. (2000) reported that additive x additive [i] and dominance x dominance [l] type of epistasis were important for grain yield per plant in wheat.

In case of harvest index two parameter model [md] was best fitted from observed to expected generation means of the cross V-95199 x PARI-73 (Table III). The additive effects were significantly present and showed simple inheritance for this trait.

The four parameter model [mhil] was best fitted from observed to expected generation means of the cross Chakwal-86 x V-8060 (Table IV). The dominance effects [h] were greater than additive x additive [i] and dominance x dominance effects. The dominance x dominance interaction was found to be negative and showed no breeding importance in the preceding generations. Srivastava and Nema (1993) reported partial dominance effects for harvest index. Singh *et al*. (1986) revealed significant additive and dominance genetic effects for this trait in wheat. Mehla *et al*. (2000) also reported that additive x additive [i] and dominance x dominance [l] types of epistasis were important for harvest index in wheat.

It is concluded that most of the plant traits exhibited simple inheritance with additive dominance model. The additive or additive x additive gene effects were important for plant height to improve grain yield in both crosses as well as their reciprocals.

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