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GENERATION MEAN ANALYSIS FOR GRAIN YIELD IN MAIZE

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ABSTRACT

The present study was conducted to evaluate genetic and epistatic effects governing the inheritance of grain yield and yield components. Parental material comprising of six genetically different maize inbred lines were crossed to produce F_1, F_2 and backcross generations. The analysis of variance showed significant differences among generations. Generation mean analysis revealed the preponderance of non-additive effects for all the characters under study. Please revisit. l (dom×dom) component was significant in all three traits with exceptions of few crosses. While i (ad × ad) was significant only for grain yield and in only one cross for 100-grain weight. The opposite of sign of h and l indicated the presence of duplicate epistasis. Significant role of dominance variance along with duplicate epistasis in the inheritance of said characters favours the use of research material (maize inbred lines) for the development of single cross hybrids.

Key words: Inbred lines, Generation mean analysis, Dominance, Additive, Epistasis.

INTRODUCTION

Maize (*Zea mays* L.), a major cereal crop, provides raw material for the food, starch industry and animal feed. Its cultivation extends over a wide range of geographical and environmental conditions ranging from 58^o N to 40^o S. Though Pakistan is not a food insecure country but is still far from ensuring sustained food production. With shrinking land resources and alarming increase in population, Pakistan is left with no option but to strive continuously for progressive yield growth in all crops especially food grains (Hussain *et al*. (2006). Maize being a highest yield potential crop amongst cereals, offers the best option to greatly enhance the food and feed availability in the country.

In the past, considerable efforts were made to discuss maize productivity but still lot of work is needed to exploit the genetic potential of maize crop. Grain yield and yield components are quantitative characters controlled by large number of genes in maize. The phenotypic expression of these traits mainly depends upon the type of gene action i.e., dominance and additive. Researcher likeHinz and Lamkey (2003); Azizi *et al*. (2006); Ravikant *et al*. (2006); Sofi *et al*. (2006). observed the important role of non allelic interactions in the inheritance of quantitative characters. The present study was conducted to get such information on grain yield and yield components in the parental material used here.

MATERIALS AND METHODS

The experimental material comprised of six maize inbred lines (i.e. FR-37, NYP-8, NYP-8-1,NCQPM-1, NCQPM-2, NCQPM-4) All the inbred lines were sown in the research area of Maize, Sorghum and Millet programme, NARC, Islamabad, during spring 2005. At the time of flowering crosses were made to produce F_1 generation.

Two rows of five meter length of each F_1 hybrid and their parents were sown during first week of July 2005. Parental lines were crossed to develop fresh F_1 hybrids (only direct crosses). To produce F_2 generation, four F_1 plants in each cross were selfed. At the same time BC_1 and BC_2 generations were also developed by crossing two F_1 hybrid plants with either of the parents.

Seed of hybrid generations i.e. F_1, F_2, BC_1 and BC_2 along with parents were sown in the research area of Maize, Sorghum and Millet programme, National Agricultural Research Centre, Islamabad, during last week of February, 2006. Randomized complete block design was followed with three replications. A single row for parental lines and F_1 hybrids, two for each back cross and four for F_2 generations were planted in each replication. The length of each row was five meter with row to row and plant to plant distances as 75 cm and 25 cm, respectively. Dose of fertilizer NPK (@ 206 kg N, 85 kg P and 62 kg K per hectare) was applied in the field to meet the nutritional requirements of the crop. Furadan insecticide @ 20 kg per hectare at the time of sowing and six weeks after sowing was applied to save the crop from borer attack

Data were recorded for number of grains per row, 100-grain weight and grain yield per plant. An observation were taken on ten plants in F1s and parents each, on 70 plants in F_2 progenies and 15 in BC_1 and BC_2 in each repeat. Analysis of variance was conducted for individual cross for each character using average values following the method of Steel and Torrie (1980) to find out significant differences among different generations. A computerized programme based on the procedures outlined by Singh and Narayanan (2000); Singh and Chaudhary (2004). has been used in the present study.

RESULTS AND DISCUSSIONS

Mean square values obtained from analysis of variance for said characters are given in Table 1.

Table 1.Analysis of variance of various plant characteristics in different crosses of maize (Mean squares)

Crosses	S.O.V	d.f	Grains per row	100- grain weight	Grain yield /plant
NCQPM-2 ×NYP-8	Generations	5	77.72**	26.47**	4342.26**
	Replication	2	0.62	0.30	1.13
	Error	10	0.50	0.37	11.38
NCQPM-2 ×NYP-8-1	Generations	5	20.83**	52.94**	3710.18**
	Replication	2	0.53	0.19	5.0
	Error	10	0.77	0.55	5.98
NCQPM-2 ×FR-37	Generations	5	38.53**	16.62**	4096.93**
	Replication	2	0.33	0.06	8.7
	Error	10	0.68	0.48	9.17
NCQPM-2 ×NCQPM-4	Generations	5	32.77**	56.85**	4358.73**
	Replication	2	0.21	0.16	5.7
	Error	10	0.70	0.17	14.07
NCQPM-2 ×NCQPM-1	Generations	5	44.18**	53.29**	4486.14**
	Replication	2	3.31	0.67	25.09
	Error	10	2.60	0.41	16.29
NYP-8×NYP-8-1	Generations	5	36.25**	41.50**	3336.42**
	Replication	2	0.05	0.42	2.66
	Error	10	0.40	0.25	14.31
NYP-8 ×FR-37	Generations	5	48.20**	40.52**	3711.96**
	Replication	2	0.10	0.07	2.20
	Error	10	0.36	0.20	14.55
NYP-8 ×NCQPM-4	Generations	5	45.07**	38.27**	3675.21**
	Replication	2	0.26	0.12	3.77
	Error	10	0.34	0.25	16.35
NYP-8 ×NCQPM-1	Generations	5	106.77**	34.52**	2958.37**
	Replication	2	0.12	0.30	1.09
	Error	10	0.34	0.36	11.52
NYP-8-1 ×FR-37	Generations	5	49.60**	24.11**	3388.28**
	Replication	2	0.14	0.15	1.38
	Error	10	0.34	0.32	8.39
NYP-8-1 ×NCQPM-4	Generations	5	47.42**	22.94**	3764.02**
	Replication	2	0.30	0.17	5.6
	Error	10	0.41	0.61	9.78
NYP-8-1 ×NCQPM-1	Generations	5	70.76**	16.56**	3806.16**
	Replication	2	0.10	0.13	8.9
	Error	10	0.62	0.68	16.90
FR-37 ×NCQPM-4	Generations	5	57.32**	21.21**	3659.84**
	Replication	2	0.50	0.14	3.04
	Error	10	0.57	0.26	10.24
FR-37 ×NCQPM-1	Generations	5	52.82**	27.22**	4418.80**
	Replication	2	0.37	0.13	1.60
	Error	10	0.39	0.28	18.48
NCQPM-4 ×NCQPM-1	Generations	5	65.26**	30.33**	4361.03**
	Replication	2	0.53	0.08	1.00
	Error	10	0.33	0.28	12.73

** = Significant at 1% probability level.

Number of grains per row: It is evident from Table-1 that significant genetic variability was present among different generation for number of grains per row. Significant values for all scaling tests (Table 2) indicated the presence of non-allelic interactions. Hence six parameter model was used to explain the nature of gene action and types of epistasis for the expression of number of grains per row. It is evident from the estimates of generation mean (Table 3) that due to significance of h, non additive genetic effects were responsible for the inheritance of this trait. These results are in accordance with Amer *et al*. (2002) while conducting combining analysis; Mosa (2004) studying testers; Jebaraj *et al*.(2010); Khodarahmpour(2011) in diallel graphic analysis. However, additive type of gene action was reported by Amer (2004) which differed from the present findings. Regarding the non allelic interactions, the dominance × dominance (*l)* interaction was significant in almost 50% crosses whereas cross NYP-8 ×NYP-8-1 showed the presence of both additive ×additive (*i)* and dominance ×dominance (*l)* of interactions. Results also revealed the absence of non allelic interactions in crosses NCQPM-2 × NCQPM-4, NCQPM-2 × NCQPM-1, NYP-8-1 ×FR-37, NYP-8-1 ×NCQPM-4, FR-37 ×NCQPM-1 and NCQPM-4 ×NCQPM-1. Positive sign of dominance effect h and opposite sign of dominance×dominance interaction *l* suggested presence of duplicate epistasis.

100-grain weight: Significant differences among generations were detected through analysis of variance (Table 1). This genetic variability paves the way for further analysis. The results of scaling tests (Table 4) divulged the presence of non allelic interaction in crosses included in the experiment indicating the role of non allelic interactions for the expression of 100-grain weight.

Estimates of generation mean analysis are presented in Table 5.Significant dominant genetic effects (h) in all the crosses suggested the preponderance of non-additive genetic effects in the inheritance of 100 grain weight. Results also showed the presence of maximum number of dominant genes due to significant value of dominance estimates in all crosses. Preponderance of dominance effects is also evident from the tester studies of Mosa (2004); Sofi *et al*. (2006); Jebaraj *et al* (2010) and Khodarahmpour (2011) in diallel graphical analysis. Scaling test displayed that the additive- dominance model was unable to describe the nature and magnitude of inter genic interaction, therefore, six parameter model was used to have unbiased explanation of genetic effects.

Regarding gene interactions, only dominance × dominance type of non allelic interaction was found for 100-grain. Sign of the dominance effects (h) was positive while the sign of dominance × dominance interaction (l) was negative which indicated that duplicate type of gene interaction was present confirming the importance of dominance effects.

Grain yield per plant: Results of analysis of variance (Table 1) depicted sufficient genetic variability among the different generations for grain yield per plant which helped in further analysis.Significant values of all scaling tests (Table 6) indicated the presence of epistasis. Therefore, six parameter model was used to estimate the non-allelic interactions along with their magnitude.

Table 2. Scaling tests for grains per row in different generations of maize hybrids.

Cross	A	B	C	D
NCQPM-2×NYP-8	5.70±0.85*	8.33±0.84*	-8.51±1.25*	-11.28±0.67*
NCQPM-2×NYP-8-1	1.82±0.80*	3.43±0.77*	-17.33±1.15*	-11.49±0.56*
NCQPM-2×FR-37	3.05±0.77*	6.68±0.74*	-9.45±1.12*	-9.59±0.56*
NCQPM-2×NCQPM-4	3.01±0.81*	5.96±0.84*	-13.72±1.22*	-11.34±0.62*
NCQPM-2×NCQPM-1	1.43±0.87	7.77±0.86*	-13.47±1.20*	-11.33±0.66*
NYP-8×NYP-8-1	5.69±0.77*	4.36±0.80*	-14.0±1.11*	-12.02±0.57*
NYP-8×FR-37	6.53±0.78*	7.74±0.78*	-6.11±1.07*	-10.19±0.58*
NYP-8×NCQPM-4	5.68±0.77*	5.47±0.79*	-11.71±1.09*	-11.43±0.56*
NYP-8×NCQPM-1	8.04±0.99*	10.06±0.98*	-9.58±1.31*	-13.84±0.74*
NYP-8-1×FR-37	6.69±0.91*	8.61±0.90*	-6.91±1.27*	-11.10±0.70*
NYP-8-1×NCQPM-4	6.32±0.93*	7.21±0.90*	-9.30±1.26*	-11.42±0.67*
NYP-8-1×NCQPM-1	6.59±0.96*	8.73±0.98*	-11.89±1.37*	-13.60±0.71*
FR-37×NCQPM-4	8.72±0.87*	7.69±0.94*	-4.93±1.29*	-10.67±0.66*
FR-37×NCQPM-1	4.92±0.93*	6.34±0.96*	-10.28±1.30*	10.77±0.68*
NCQPM-4×NCQPM-1	6.63±0.99*	6.2±1.0*	-9.09±1.34*	-10.96±0.72*

Perusal of Table 7 showed that non additive genetic effects and maximum number of dominant genes were controlling the mechanism of inheritance of grain yield per plant due to significant dominance estimate h in all crosses. These results are in agreement with the findings of Balc *et al*. (2004); Mosa (2004) from testers study; Singh and Roy (2007) conducting diallel; Haq *et al*. (2010) estimating combining ability analysis. While additive type of genetic effect was reported by Amer (2004); Ma *et al*. (2007). which are contradictory to the present study. As for as epistasis is concerned, presence of both additive × additive and dominance × dominance interactions were found in all the crosses except NCQPM-2 ×NYP-8-1, and NYP-8 × FR-37 in which additive ×additive interaction was present. Results also revealed that the involvement of duplicate epistasis where the dominance estimate and dominance × dominance interaction had opposite signs.

Table 3Estimates of generation mean parameters, mean (m), additive (d), dominance (h), additive × additive (i), additive × dominance (j) dominance × dominance (l) for grains per row in different generations of maize hybrids.

m	d	h	i	j	L
31.96±3.34*	0.53±3.27	33.77±15.04*	22.55±14.86	-1.32±3.99	-36.59±19.24*
26.24±2.68*	0.64±2.83	26.57±12.37*	22.98±12.13	-0.80±3.67	-28.24±14.32*
28.84±2.77*	0.69±2.72	25.91±12.55*	19.18±12.34	-1.81±3.60	-28.91±16.17
27.73±3.06*	0.58±3.07	28.43±13.89*	22.69±13.68	-1.47±3.86	-31.65±17.98
27.7±3.13*	-0.6±3.38	29.27±14.40*	22.67±14.22	-3.17±4.11	-31.87±18.98
26.97±2.71*	0.27±2.91	30.91±12.52*	24.04±12.22*	0.67±3.65	-34.09±16.55*
28.61±2.67*	0.04±2.97	28.70±12.40*	20.39±12.22	-0.61±3.71	-34.66±16.53*
27.67±2.55*	0.31±2.89	31.13±11.94*	22.87±11.72	0.11±3.63	-34.03±16.10*
30.25±3.35*	-0.29±3.91	41.13±15.72*	27.68±15.51	-1.00±4.49	-45.78±21.21*
28.71±3.34*	0.09±3.53	30.33±15.29*	22.21±15.10	-0.96±4.29	-37.51±20.00
28.59±3.04*	0.16±3.50	31.00±14.25*	22.84±14.02	-0.44±4.27	-36.37±19.23
28.42±3.32*	0.04±3.68	37.36±15.44*	27.21±15.19	-1.07±4.43	-42.53±20.59*
29.08±2.88*	0.07±3.51	30.39±**13.76***	21.34±13.48	0.52±4.24	-37.35±18.97*
27.38±3.04*	-0.64±3.58	30.91±14.39*	21.54±14.13	-0.71±4.31	-32.81±19.58
28.69±3.22*	0.73±3.84	32.41±15.24*	21.92±14.99	0.22±4.55	-34.76±20.79

* = Significant (if the value of parameter divided by its standard error exceeds 1.96)

Table 4. Scaling tests for 100 grain weight in different generations of maize hybrids

Cross	A	B	C	D
NCQPM-2×NYP-8	6.34±0.34*	5.75±0.36*	2.24±0.53*	-4.93±0.31*
NCQPM-2×NYP-8-1	8.5±0.35*	4.84±0.35*	7.59±0.58*	-2.87±0.30*
NCQPM-2×FR-37	5.80±0.30*	2.49±0.29*	-0.07±0.48*	-4.18±0.24*
NCQPM-2×NCQPM-4	9.75±0.33*	7.27±0.35*	8.55±0.53*	-4.15±0.29*
NCQPM-2×NCQPM-1	9.71±0.33*	6.27±0.32*	6.99±0.47*	-4.95±0.29*
NYP-8×NYP-8-1	8.36±0.35*	4.90±0.35*	4.95±0.53*	-4.16±0.29*
NYP-8×FR-37	8.20±0.35*	6.10±0.33*	7.56±0.51*	-3.37±0.29*
NYP-8×NCQPM-4	8.09±0.34*	6.71±0.34*	8.57±0.52*	-3.11±0.28*
NYP-8×NCQPM-1	7.99±0.33*	5.84±0.33*	6.30±0.50*	-3.76±0.28*
NYP-8-1×FR-37	3.73±0.33*	5.11±0.31*	3.12±0.47*	-2.86±0.07*
NYP-8-1×NCQPM-4	4.68±0.32*	6.10±0.30*	3.54±0.45*	-3.62±0.27*
NYP-8-1×NCQPM-1	4.42±0.33*	4.31±0.34*	0.95±0.51*	-3.89±0.28*
FR-37×NCQPM-4	5.11±0.33*	5.82±0.33*	1.54±0.55*	-4.69±0.31*
FR-37×NCQPM-1	6.30±0.33*	6.0±0.31*	3.15±0.46*	-4.57±0.28*
NCQPM-4×NCQPM-1	6.31±0.33*	5.60±0.33*	3.97±0.50*	-3.97±0.28*

Table 5Estimates of generation mean parameters, mean (m), additive (d), dominance (h), additive × additive (i), additive ×dominance (j) dominance × dominance (l) for 100 grain weight in different generations of maize hybrids.

m	d	h	I	j	L
26.48±1.58	-0.06±1.45	15.98±6.99*	9.85±6.95	0.29±1.73	-21.93±8.74*
30.78±1.64	-0.14±1.36	14.56±7.17*	5.74±7.09	1.83±1.66	-19.08±8.76*
26.27±1.25	-0.06±1.09	12.61±5.54*	8.36±5.47	1.65±1.45	-16.65±6.84*
30.14±1.52	-0.09±1.36	16.80±5.54*	8.29±6.67	1.15±1.65	-25.14±8.37*
30.14±1.47	0.08±1.37	17.42±6.50*	9.19±6.47	1.82±1.65	-25.36±8.13*
29.89±1.48	0.11±1.39	15.96±6.61*	8.31±6.54	1.73±1.63	-21.57±8.33*
29.91±1.45	-0.25±1.38	13.75±6.49*	6.74±6.43	1.05±1.62	-21.04±8.21*

29.79±1.45	-0.20±1.37	13.33±6.45*	6.23±6.38	0.69±1.60	-21.03±8.15*
29.46±1.43	-0.31±1.35	14.11±6.37*	7.53±6.32	1.07±1.59	-21.36±8.03*
29.82±1.32	-0.13±1.27	12.04±5.93*	5.73±5.87	-0.69±1.58	-14.57±7.52*
29.32±1.40	0.02±1.30	12.68±6.19*	7.24±6.15	-0.71±1.59	-18.02±7.73*
28.86±1.43	0.29±1.34	12.61±6.36*	7.78±6.30	0.06±1.62	-16.51±8.01*
28.22±1.70	-0.18±1.35	14.75±7.34*	9.39±7.30	-0.35±1.64	-20.32±8.80*
29.57±1.44	-0.18±1.35	15.42±6.41*	9.16±6.38	0.15±1.64	-21.46±8.02*
29.84±1.44	-0.14±1.34	14.66±6.42*	7.94±6.37	0.35±1.60	-19.85±8.06*

* = Significant (if the value of parameter divided by its standard error exceeds 1.96)

Table 6. Scaling tests for grain yieldin different generations of maize hybrids

Cross	A	B	C	D
NCQPM-2×NYP-8	57.06±1.72*	53.60±1.66*	-52.84±3.67*	-81.75±1.94*
NCQPM-2×NYP-8-1	57.80±1.60*	63.47±1.61*	30.63±3.90*	-45.32±2.04*
NCQPM-2×FR-37	58.59±1.46*	72.60±1.47*	-45.93±3.60*	-88.56±1.86*
NCQPM-2×NCQPM-4	51.52±1.53*	55.90±1.55*	-33.60±3.77*	-70.37±1.94*
NCQPM-2×NCQPM-1	49.58±1.64*	57.71±1.61*	-29.88±2.72*	-68.58±1.41*
NYP-8×NYP-8-1	48.57±1.63*	53.25±1.63*	-40.96±3.79*	-71.39±1.96*
NYP-8×FR-37	56.40±1.66*	72.37±1.67*	33.36±3.61*	-47.71±1.91*
NYP-8×NCQPM-4	43.45±1.71*	54.58±1.70*	-72.16±3.62*	-85.15±1.89*
NYP-8×NCQPM-1	40.02±1.57*	41.40±1.62*	-43.40±3.83*	-62.41±1.99*
NYP-8-1×FR-37	42.66±1.71*	42.59±1.61*	-29.08±3.63*	-57.16±1.85*
NYP-8-1×NCQPM-4	49.81±1.67*	46.04±1.68*	-71.4±4.03*	-83.62±2.11*
NYP-8-1×NCQPM-1	55.60±1.59*	44.93±1.56*	-50.74±3.93*	-75.63±2.02*
FR-37×NCQPM-4	51.51±1.62*	42.49±1.70*	-52.21±3.86*	-73.10±1.98*
FR-37×NCQPM-1	64.13±1.66*	63.20±1.54*	-61.88±3.84*	-94.60±2.01*
NCQPM-4×NCQPM-1	53.11±1.53*	46.89±1.46	-80.34±3.60*	-90.17±1.87*

Table 7 Estimates of generation mean parameters, mean (m), additive (d), dominance (h), additive ×additivea (i), additive × dominance (j) dominance × dominance (l) for grain yield in different generations of maize hybrids.

m	d	h	i	j	L
123.52±11.98	2.70±6.77	249.48±49.98*	163.49±49.79*	1.73±7.80	-274.15±55.72*
136.93±13.05	1.63±6.37	168.71±53.87*	90.63±53.71	-2.83±7.48	-211.70±58.65*
112.84±11.99	1.32±5.67	253.0±49.43*	177.13±49.27*	-6.99±6.91	-318.32±53.61*
123.33±12.47	4.04±5.93	227.54±51.45*	140.75±51.28*	-2.33±7.13	-247.89±55.89*
123.78±7.71	1.06±6.22	220.52±33.59*	137.17±33.26*	-4.07±7.33	-244.46±40.71*
116.5±12.43	1.15±6.40	217.71±51.53*	142.78±51.34*	-2.34±7.49	-244.60±56.61*
129.82±11.81	0.35±6.67	169.51±49.27*	95.42±49.09	-7.98±7.74	-224.19±54.90*
108.27±11.60	-0.21±6.68	248.18±48.50*	170.30±48.29*	-5.62±3.75	-268.44±54.33*
114.33±12.71	3.47±6.28	197.96±52.54*	124.83±52.37*	-0.69±7.37	-206.25±57.34*
112.95±11.52	4.88±6.31	192.89±48.01*	114.33±47.77*	-0.04±7.50	-199.58±53.41*
105.94±13.51	3.79±6.68	247.08±55.81*	167.25±55.66*	1.89±7.80	-263.60±60.86*
114.05±13.06	6.00±6.11	234.50±53.81*	151.26±53.64*	5.34±7.27	-251.78±58.30*
106.22±12.57	1.57±6.40	226.68±52.09*	146.21±51.88*	4.51±7.63	-240.20±57.17*
105.42±12.84	-3.71±6.36	270.44±53.07*	189.21±52.92*	0.47±7.57	-316.54±57.90*
106.48±11.98	1.87±5.83	267.05±49.46*	180.34±49.30*	3.11±7.13	-280.33±53.85*

* = Significant (if the value of parameter divided by its standard error exceeds 1.96).

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