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Detection of Gene Action Through Generation Mean Analysis for Yield and Yield attributes in Sunflower (*Helianthus annus* L.)

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ABSTRACT

The study on gene effects for eight quantitative traits viz., days to 50% flowering, plant height, head diameter, filled seeds per head, seed yield per plant, 100 seed weight, oil content and oil yield per plant in sunflower was studied by employing generation mean analysis. The results revealed that day to 50% flowering, plant height, head diameter, filled seeds per head, 100 seed weight and oil content characters were governed by dominance and epistatic gene interactions. It clearly indicated that traits can be exploited through heterosis breeding as well to break the gene constellation and release of free variability, biparental mating design can be used. However in cross PFMS 400 A x GP 9-1-163-8 and IMSWGA x GP9-163-8 for days to 50% flowering, where in ARM 245 A x 856 R (plant height), IMS WGA x GP 9-1-163-8 (seed yield) and IMS WGA x GP 9-1-163-8 and PET 2-7-1 A x ARM 239 (oil yield) additive gene action is found to be significant. These traits can be improved through simple selection processes in passing generations to accumulate the positive alleles to develop in the form of inbred. In the present study gene action differed cross wise and also character to character. Since the parents involved were differing, thus the gene action controlled the traits also differ significantly.

Key words : Additive, Epistasis, Generation mean, Gene effects, Joint scaling.

Sunflower is one of the most important oilseed crops of India. The heterosis exploited in hybrids due to male sterility system for high productivity and oil yield. There is a need to do concerted efforts to know the gene action controlling the traits, so that appropriate breeding methods can be employed in the years to come. The L x T design estimates additive and dominance components only, but it cannot estimate epistasis, through epistasis is an integral component of genetic architecture of population, therefore for few selected crosses involving diversified cytoplasmic source of CMS lines *i.e.*, *Helianthus petiolaris sub spp fallax* (CMSPEF), *Helianthus lenticularis* (CMS l), *Helianthus petioloris* (PET2) and *Helianthus annuus* (PET 1) were subjected to generation mean analysis (Joint scaling test of Cavalli 1952). This method not only provides the estimates of additive and dominance gene effects but also provides estimates of magnitude of all three types of digenic interactions i.e. additive x additive (i), additive x dominance (j) and dominance x dominance (l) gene effects. By using such estimates appropriate breeding procedure can be employed to improve different traits in sunflower.

MATERIAL AND METHODS

The experimental material comprised of parents (P_1 and P_2) and their F_1, F_2, B_1 (F_1xP_1) and B_2(F_1xP_2) generations of six fully fertile crosses (cross 1 : ARM 245 A X 856R, cross 2:PFMS 400 A X GP9-163-8, cross 3: IMSWGA X GP 9-163-8, cross 4:PFMS 400 A X 89 B, cross 5: PET 2-7-1A X ARM 239, cross 6:ARM 245A X 6D-1 R) derived from different cytoplasmic backgrounds were taken to study the gene action through generation mean analysis. In all the six crosses B_1, B_2, F_1 and F_2 generations were developed during *kharif* and *rabi* 2006 and those families *i.e.*, P_1, P_2, B_1, B_2, F_1 and F_2 were raised in compact block design in RBD replicated twice during *kharif* 2007 at College of Agriculture, Rajendranagar, Hyderabad. The parents P_1 and P_2 were sown in

Table 1. Mean performance and standard error of six crosses for yield and yield attributes in sunflower.

Generation	Days to 50% flowering Mean ± SE	Plant height(cm) Mean ± SE	Head diameter(cm) Mean ± SE	Filled seeds / Head Mean ± SE	Seed yield / plant (g) Mean ± SE	100 seed weight Mean ± SE	Oil content(%) Mean ± SE	Oil yield per plant (g/pl) Mean ± SE
Cross 1								
ARM 245 A X 856 R								
P1	68.50 ± 0.50	180.20 ± 1.80	17.90 ± 1.80	487.02 ± 6.62	23.20 ± 1.00	4.76 ± 0.03	38.93 ± 0.50	9.03 ± 0.51
P2	68.00 ± 1.00	168.30 ± 1.70	9.95 ± 0.38	275.70 ± 6.55	6.91 ± 0.25	2.51 ± 0.02	38.42 ± 0.83	2.65 ± 0.15
F1	66.50 ± 0.50	170.20 ± 1.80	19.95 ± 0.25	688.53 ± 4.97	41.41 ± 0.80	6.01 ± 0.05	37.32 ± 0.32	15.61 ± 0.55
F2	67.50 ± 0.50	157.65 ± 2.85	19.25 ± 0.35	446.95 ± 8.59	26.41 ± 0.99	5.91 ± 0.03	41.19 ± 0.62	10.87 ± 0.24
B1	70.50 ± 0.50	163.40 ± 3.00	16.75 ± 0.25	635.23 ± 5.61	31.65 ± 0.83	5.02 ± 0.03	38.42 ± 0.36	12.16 ± 0.44
B2	66.25 ± 0.25	175.45 ± 2.05	15.70 ± 0.20	808.72 ± 6.49	33.10 ± 0.67	4.11 ± 0.03	35.92 ± 0.08	11.89 ± 0.27
Cross 2								
PFMS 400 A X GP 9-163-8								
P1	64.25 ± 0.25	139.60 ± 3.00	13.90 ± 0.80	500.49 ± 9.51	20.56 ± 1.00	4.16 ± 0.14	40.93 ± 0.48	8.37 ± 0.46
P2	66.50 ± 0.50	168.30 ± 1.70	15.10 ± 0.50	557.25 ± 16.34	27.76 ± 1.80	5.05 ± 0.07	39.90 ± 0.05	11.08 ± 0.73
F1	64.50 ± 0.50	170.20 ± 1.80	19.00 ± 0.20	1430.68 ± 6.79	77.50 ± 1.94	5.42 ± 0.02	42.75 ± 0.19	33.14 ± 0.97
F2	65.00 ± 1.00	157.65 ± 2.85	15.95 ± 0.55	503.76 ± 9.98	27.06 ± 0.43	5.39 ± 0.10	40.81 ± 0.22	11.05 ± 0.11
B1	64.25 ± 0.75	163.40 ± 3.00	17.10 ± 0.60	654.34 ± 5.76	39.56 ± 3.07	5.72 ± 0.20	41.99 ± 0.01	16.61 ± 1.33
B2	66.25 ± 0.25	175.45 ± 2.05	17.75 ± 0.35	786.26 ± 4.27	44.03 ± 1.04	5.60 ± 0.18	40.56 ± 0.52	20.52 ± 0.86
Cross 3								
IMS WGA X GP 9-163-8								
P1	62.75 ± 0.25	123.75 ± 2.75	12.00 ± 0.60	257.03 ± 9.53	15.06 ± 0.50	5.89 ± 0.09	35.85 ± 0.44	5.40 ± 0.11
P2	66.50 ± 0.50	167.80 ± 4.00	15.70 ± 0.10	638.73 ± 7.43	30.70 ± 2.50	4.86 ± 0.10	37.99 ± 0.83	11.65 ± 0.69
F1	63.50 ± 0.50	189.80 ± 1.20	16.00 ± 0.20	867.75 ± 7.37	55.53 ± 0.77	6.41 ± 0.16	42.11 ± 0.62	23.39 ± 0.66
F2	62.75 ± 0.25	162.60 ± 1.90	14.30 ± 0.50	506.75 ± 9.55	29.74 ± 0.75	5.89 ± 0.03	40.11 ± 0.39	11.92 ± 0.19
B1	62.50 ± 0.50	161.50 ± 3.00	14.70 ± 0.60	357.96 ± 7.73	23.99 ± 1.73	6.74 ± 0.24	35.73 ± 1.13	8.59 ± 0.88

Table 1 cont........

Generation	Days to 50% flowering Mean ± SE	Plant height(cm) Mean ± SE	Head diameter(cm) Mean ± SE	Filled seeds / Head Mean ± SE	Seed yield / plant (g) Mean ± SE	100 seed weight Mean ± SE	Oil content(%) Mean ± SE	Oil yield per plant (g/pl) Mean ± SE
Cross 4								
PFMS 400 A X 89-B								
P1	64.25 ± 0.25	129.80 ± 2.20	14.00 ± 0.50	410.88 ± 4.58	21.38 ± 1.22	5.26 ± 0.10	35.60 ± 0.24	7.61 ± 0.74
P2	64.25 ± 0.25	118.30 ± 2.50	12.70 ± 0.10	650.33 ± 7.27	16.86 ± 0.50	2.59 ± 0.03	37.97 ± 0.53	6.40 ± 0.28
F1	70.75 ± 0.25	179.10 ± 3.50	19.95 ± 0.55	1405.03 ± 21.62	66.84 ± 1.77	4.52 ± 0.07	43.33 ± 0.38	28.99 ± 0.52
F2	65.00 ± 0.50	132.60 ± 1.60	16.55 ± 0.55	468.39 ± 3.59	26.99 ± 1.50	5.73 ± 0.03	38.38 ± 0.73	10.34 ± 0.38
B1	62.25 ± 0.25	147.00 ± 1.30	16.45 ± 0.75	482.35 ± 6.23	30.16 ± 1.00	6.26 ± 0.00	41.94 ± 0.65	12.66 ± 0.61
B2	71.25 ± 0.25	166.05 ± 1.65	17.35 ± 0.55	879.01 ± 6.41	34.58 ± 0.47	3.97 ± 0.02	39.55 ± 0.45	13.68 ± 0.34
Cross 5								
PET 27-1 A X ARM-239								
P1	64.25 ± 0.25	112.70 ± 3.30	12.65 ± 0.45	368.37 ± 6.19	13.64 ± 0.52	3.59 ± 0.20	36.48 ± 0.84	4.97 ± 0.08
P2	72.50 ± 0.50	177.55 ± 2.95	14.90 ± 0.10	479.99 ± 9.11	25.66 ± 1.10	5.38 ± 0.16	36.84 ± 0.61	9.44 ± 0.62
F1	67.25 ± 0.25	184.10 ± 5.50	17.80 ± 0.60	776.22 ± 7.57	44.56 ± 1.00	5.76 ± 0.14	32.87 ± 0.60	14.66 ± 0.59
F2	66.25 ± 0.25	150.15 ± 2.55	17.00 ± 0.10	816.51 ± 8.24	43.49 ± 1.50	5.34 ± 0.05	34.72 ± 0.94	15.11 ± 0.93
B1	64.75 ± 0.25	149.90 ± 4.00	15.75 ± 0.35	675.21 ± 5.57	34.58 ± 2.19	5.20 ± 0.12	35.49 ± 0.63	12.28 ± 0.99
B2	71.25 ± 0.50	163.15 ± 4.45	16.75 ± 0.75	683.13 ± 3.24	38.44 ± 1.00	5.62 ± 0.10	35.47 ± 0.59	13.65 ± 0.85
Cross 6								
ARM 245 A X 6 D-1 R								
P1	68.00 ± 1.00	177.60 ± 3.60	16.00 ± 0.20	474.17 ± 8.78	26.56 ± 1.00	5.45 ± 0.11	37.76 ± 0.27	10.0. ± 0.45
P2	68.50 ± 0.50	151.00 ± 3.00	8.40 ± 0.40	656.35 ± 9.36	18.56 ± 1.20	2.83 ± 0.03	41.85 ± 0.51	7.76 ± 0.41
F1	66.50 ± 0.50	206.45 ± 4.05	21.10 ± 0.90	947.91 ± 12.17	58.56 ± 1.00	6.28 ± 0.07	40.89 ± 0.38	23.99 ± 0.14
F2	68.25 ± 0.25	189.20 ± 4.68	16.85 ± 0.55	625.72 ± 9.14	35.04 ± 0.45	5.65 ± 0.13	40.49 ± 0.26	14.19 ± 0.27
B1	67.25 ± 0.25	194.65 ± 2.85	17.20 ± 0.50	600.49 ± 9.84	36.29 ± 1.81	6.18 ± 0.04	40.17 ± 0.16	14.57 ± 0.66
B2	69.25 ± 0.25	184.05 ± 3.55	15.15 ± 1.05	926.80 ± 11.33	40.82 ± 1.00	4.40 ± 0.08	42.89 ± 0.78	17.51 ± 0.75

single row, F_1 in 2 rows, B_1 and B_2 in 3 rows each and F_2 in 5 rows with 4 m. row length. A spacing of 60 cm between rows and 30 cm between plants with in the row was maintained. Recommended cultural and management practices were followed to raise the crop. Observations were recorded for days to 50% flowering, plant height, head diameter, filled seeds per head, seed yield per plant, 100 seed weight , oil content and oil yield per plant on ten randomly selected plants in each replication for P_1, P_2 and F_1. Similarly observations were recorded by using 20 plants in each replication for B_1 and B_2 and 60 randomly chosen plants per replication in F_2. The data on seed yield and all possible ancillary traits were analyzed with the help of Joint scaling test (Cavelli 1952 and Mather and Jinks 1982) of three and five parameter models where sequential fit scheme was employed and the best fit scheme was searched.

RESULTS and DISCUSSION

The mean, standard errors of mean of two parents and four generations (F_1, F_2, $B_1$and B_2) of six sunflower crosses for eight characters is presented in Table-1. The hybrids exhibited superiority over the parents for days to 50% flowering, plant height, head diameter filled seeds per head, seed yield and oil yield except plant height in ARM245A x 856 R, 100 seed weight in PFMS 400 A x 89 B and oil content in ARM 245 A x 856 R and PET-2-7-1 A x ARM 239.

The results of joint scaling test with least square technique of the mean data of different traits revealed the importance of epistasis. The three parameter model m, [d] and [h] exhibited good fit $X^2_{(3)}$ being non significant for three characters only in few crosses. *viz*., IMS WGA x GP 9-163-8 and ARM 245 A X 6 D-1 R for plant height, cross PFMS 400 A X 89-B and ARM 245 A X 6 D-1 R for head diameter and PFMS 400 A X GP 9-163-8 for filled seeds per head and for other characters in all cross combinations this model does not appear to be appropriate. It indicates the involvement of other parameters such as digenic epistatic gene effects in the inheritance of these traits. However inadequacy of 3 parameter model allowed to proceed for 2 parameter model. It was observed that 2 parameter model was adequate in PFMS 400 A X GP 9-163-8 for days to 50% flowering, head diameter, whereas in PET 2-7-1 A X ARM-239 for oil content. When the data was subjected to five parameter model a considerable reduction of $X^2{}_{[1]}$ value was noticed for each character. Hence the estimates of genetic parameters obtained under this model appears to be relatively more reliable (Table-2).

For days to 50% flowering, under five parameter model two crosses (IMS WGA X GP 9-163-8 and PFMS 400 A X 89-B) exhibited good fit, $\times^2{}_{[1]}$ being non significant. In majority of the crosses additive component is prevalent and possessed negative sign suggested that the alleles for earliness were more frequent and dominant over the alleles for lateness. Among the epistatic gene actions(additive x dominance) and (dominance x dominance) played significant role in the inheritance of days to 50% flowering. The additive dominance model was found to be adequate for plant height in two crosses (IMS WGA X GP 9-163-8 and ARM 245 A X 6 D-1 R) with predominance of dominance effect than the additive effect. In majority of the crosses three types of epistatic effects ([i] [j] [l]) were found to contribute for the expression of plant height.

PFMS 400 A X 89-B and ARM 245 A X 6 D-1 R exhibited good fit for additive dominance model for head diameter whereas in PFMS 400 A X GP 9-163-8, dominance component [h] was found to be significant. The five parameter model indicating predominance of non fixable genetical effects, dominance based epistatic gene effects were showed good fit for IMS WGA X GP 9-163-8 with [d], [h] [i] and [l] genetic components were important. While the h and l posses opposite sign indicating the presence of duplicate gene action. The magnitude of dominance effect was higher than additive for head diameter in most of the crosses. Similar results were reported by Gangappa *et al.,* (1997).

For filled seeds per head only in IMS WGA X GP 9-163-8 five parameter model showed good fit where in m, [d] [h] [j] and [l] genetic components were important and [h] and [l] with opposite sign for rest of the crosses (ARM 245 A X 856 R, PFMS 400 A X GP 9-163-8, PFMS 400 A X 89-B, PET 27-1 A X ARM-239 and ARM 245 A X 6 D-1 R) indicated higher order of gene interaction or linkage was found to be involved in sunflower.

Table 2. Estimates of gene effects based on joint scaling test for three and five parameters model / sequential model for yield and yield components in sunflower.

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -1								
ARM 245 A X 856 R								
m	67.7 ± 0.38**	136.7 ± 1.29**	14.3 ± 0.17**	430.6 ± 4.15**	3.71 ± 0.2**	14.36 ± 0.45**	37.09 ± 0.29**	5.90 ± 0.21**
[d]	1.83 ± 0.34**	41.6 ± 1.25**	3.20 ± 0.16**	50.60 ± 4.08**	1.15 ± 0.018**	7.0 ± 0.45**	2.42 ± 0.24**	2.86 ± 2.2**
[h]	-0.69 ± 0.71**	24.8 ± 2.34**	5.14 ± 0.31**	314.6 ± 6.80**	2.72 ± 0.040**	30.44 ± 0.86**	0.33 ± 0.51**	10.16 ± 0.29**
$\chi^2_{(3)}$	30.20**	8.60*	112.88**	2085.29**	1734.8**	149.53**	64.25**	90.81**
m								
[d]								
[h]								
$\chi^2_{(2)}$								
m	64.90 ± 2.34**	136.9 ± 1.46**	16.9 ± 0.29**	-714 ± 38.67**	8.87 ± 1.4**	15.05 ± 0.52**	54.85 ± 2.65**	5.85 ± 0.26**
[d]	-	43.2 ± 1.46**	4.08 ± 0.20**	-	1.09 ± 0.02**	8.14 ± 0.52**	-	3.19 ± 0.26**
[h]	8.60 ± 5.41 NS	20.4 ± 6.42**	-	3241.3 ± 87.06**	-9.25 ± 0.35**	37.60 ± 2.56**	-37.54 ± 5.64**	12.53 ± 1.07**
[i]	3.50 ± 2.29 NS	-	-3.26 ± 0.39**	1094.1 ± 38.39**	-5.35 ± 0.14**	-	-16.05 ± 2.61**	-
[j]	8.50 ± 1.12**	13.5 ± 5.75**	-5.60 ± 0.76**	-341.0 ± 17.12 NS	-	-20.37 ± 2.35**	4.98 ± 0.75**	-6.94 ± 1.09**
[l]	-7.20 ± 3.29*	5.3 ± 6.43 NS	2.37 ± 0.45**	1838.7 ± 50.38**	6.29 ± 0.23**	-11.26 ± 2.67**	20.41 ± 3.10**	-2.76 ± 0.94**
$\chi^2_{(1)}$	0.20 NS	2.16 NS	35.25**	514.6**	18.69**	28.20**	0.28 NS	10.80**
m	68.59 ± 0.28**	136.4 ± 1.30**						
[d]	-	43.3 ± 1.45**						
[h]	-	25.3 ± 2.35**						
[i]	-	-						
[j]	7.82 ± 1.02**	-13.7 ± 5.74**						
[l]	-2.01 ± 0.64**	-						
$\chi^2_{(6-p)}$	2.84 NS	2.85 NS						

*, ** Significant at 5% and 1% level

P= Number of parameters included and eliminated for analysis

NS= Non significant

Table 2 cont ....

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -2								
PFMS 400 A X GP 9-163-8								
m	65.63 ± 0.24**	155.3 ± 1.54**	14.6 ± 0.38**	294.4 ± 6.25**	4.78 ± 0.07**	16.77 ± 0.91**	40.45 ± 0.09**	6.63 ± 0.41**
[d]	-1.40 ± 0.25**	-14.0 ± 1.54**	-0.74 ± 0.39 NS	-20.07 ± 5.39**	-0.32 ± 0.07**	1.63 ± 0.93**	0.53 ± 0.08**	-0.94 ± 0.42**
[h]	0.69 ± 0.54 NS	16.6 ± 2.45**	4.37 ± 0.46**	978.7 ± 10.70**	0.72 ± 0.08**	29.3 ± 1.86**	2.57 ± 0.26**	10.11 ± 0.82**
$\chi^2_{(3)}$	3.31 NS	16.64**	6.42 NS	2540.0**	27.96**	499.9**	138.78**	476.6**
m	65.39 ± 0.16**		15.0 ± 0.34**					
[d]	-1.25 ± 0.21**		-					
[h]	-		4.06 ± 0.43**					
$\chi^2_{(2)}$	4.95 NS		10.12*					
m		108.4 ± 13.35**		-347.3 ± 43.2**	4.61 ± 0.08**	-35.7 ± 5.74**	25.90 ± 1.30**	-22.16 ± 2.97**
[d]		-13.9 ± 1.56**		-	-0.44 ± 0.08**	-3.67 ± 0.99**	-	-1.53 ± 0.43**
[h]		135.11 ± 30.9**		1630.3 ± 94.20**	2.61 ± 0.41**	138.09 ± 16.9**	42.67 ± 3.36**	77.50 ± 8.91**
[i]		45.7 ± 13.3**		862.1 ± 42.4**	-	59.98 ± 5.53**	13.99 ± 1.30**	31.98 ± 0.92**
[j]		-		-263.8 ± 14.34**	1.06 ± 0.56* NS	-	-9.25 ± 0.94**	-
[l]		-73.3 ± 18.3**		147.68 ± 53.6**	-1.81 ± 0.37**	-24.8 ± 11.75**	-25.92 ± 2.12**	-22.21 ± 6.20**
$\chi^2_{(1)}$		0.33 NS		9.02**	2.60 NS	0.06 NS	36.77** NS	2.56 NS
m					4.63 ± 0.08**			
[d]					-0.40 ± 0.08**			
[h]					2.56 ± 0.40**			
[i]					-			
[j]					-			
[l]					1.72 ± 0.37**			
$\chi^2_{(6-p)}$					6.19*			

*, ** Significant at 5% and 1% level

P= Number of parameters included and eliminated for analysis

NS= Non significant

Table 2 cont ....

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -3								
IMS WGA X GP 9-163-8								
m	63.77 ± 0.24**	143.8 ± 1.87**	13.8 ± 0.27**	383.7 ± 5.41**	5.47 ± 0.06**	17.39 ± 0.95**	36.69 ± 0.39**	7.64 ± 0.31**
[d]	0.97 ± 0.21**	-20.18 ± 2.04**	-1.84 ± 0.26**	-228.90 ± 5.44**	-0.30 ± 0.06**	3.29 ± 0.98**	-0.82 ± 0.40*	-2.35 ± 0.31**
[h]	1.64 ± 0.48**	45.58 ± 2.43**	2.23 ± 0.35**	397.2 ± 9.45**	1.47 ± 0.13**	34.92 ± 1.35**	5.20 ± 0.75**	10.41 ± 0.63**
$\chi^2_{(3)}$	35.90**	8.31*	16.10**	574.9**	499.39**	121.3**	17.40**	125.11**
m								
[d]								
[h]								
$\chi^2_{(2)}$								
m	61.69 ± 0.32**		5.7 ± 2.53**	447.8 ± 6.04**	5.29 ± 0.24**	3.81 ± 1.66**	47.02 ± 2.64**	8.14 ± 0.33**
[d]	-1.84 ± 0.28**		-2.0 ± 0.28**	-190.8 ± 6.04**	0.46 ± 00	-7.69 ± 1.25**	-1.28 ± 0.44**	-3.18 ± 0.35**
[h]	-		23.9 ± 6.13**	-237.0 ± 30.4**	16.29 ± 0.69**	51.67 ± 2.14**	-22.47 ± 7.14**	-
[i]	2.88 ± 0.45**		7.9 ± 2.5**	-	5.09 ± 0.23**	18.93 ± 2.11**	-9.98 ± 2.55**	0.44 ± 0.48 NS
[j]	3.68 ± 0.89**		-	-143.60 ± 30.77**	-	-24.10 ± 5.94**	-	-10.57 ± 2.23**
[l]	1.75 ± 0.74*		13.7 ± 3.71**	656.8 ± 30.11**	-	-	17.84 ± 4.70**	15.32 ± 0.92**
$\chi^2_{(1)}$	0.60 NS		1.88 NS	3.02 NS	8.2**	0.27 NS	1.69 NS	1.17 NS
m								8.35 ± 0.24**
[d]								-2.96 ± 0.25**
[h]								-
[i]								-
[j]								-11.04 ± 2.17**
[l]								14.84 ± 0.75**
$\chi^2_{(6-p)}$								2.00 NS

*, ** Significant at 5% and 1% level
P= Number of parameters included and eliminated for analysis
NS= Non significant

Table 2 cont ....

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -4								
PFMS 400 A X 89-B								
m	66.89 ± 0.22**	123.3 ± 1.52**	13.2 ± 0.24**	528.0 ± 4.15**	4.77 ± 0.04**	16.59 ± 0.60**	36.50 ± 0.26**	5.84 ± 0.23**
[d]	-4.60 ± 0.21**	-1.87 ± 1.29 NS	0.56 ± 0.24**	-162.40 ± 3.89**	2.13 ± 0.03**	0.05 ± 0.56 NS	-0.77 ± 0.26**	0.28 ± 0.22**
[h]	2.15 ± 0.36**	43.32 ± 3.12**	6.89 ± 0.54**	226.5 ± 10.40**	0.80 ± 0.07**	36.36 ± 1.19**	6.76 ± 0.47**	17.51 ± 0.49**
$\chi^2_{(3)}$	377.18**	307.49**	3.65 NS	2570.3**	876.78**	126.07**	23.10**	286.22**
m								
[d]								
[h]								
$\chi^2_{(2)}$								
m	57.75 ± 0.73**	29.0 ± 6.30**		-411.6 ± 22.56**	6.10 ± 0.04**	16.49 ± 3.19**	35.90 ± 1.21**	-5.92 ± 1.95**
[d]	-3.15 ± 0.28**	-		-118.4 ± 4.29**	1.30 ± 0.05**	2.07 ± 0.66**	-1.25 ± 0.29**	0.44 ± 0.22**
[h]	13.03 ± 0.89**	269.05 ± 16.52**		1740.9 ± 37.0**	-	81.52 ± 4.60**	7.60 ± 1.41**	30.11 ± 4.78**
[i]	9.67 ± 0.83**	95.7 ± 6.08**		939.2 ± 22.6**	-2.21 ± 0.07**	35.35 ± 3.30**	0.99 ± 1.27 NS	12.87 ± 1.94**
[j]	-11.70 ± 0.89**	-38.1 ± 4.2**		-557.9 ± 19.8**	2.04 ± 0.13**	-11.10 ± 2.4**	6.17 ± 1.65**	-
[l]	-	124.04 ± 2.24**		-	-1.60 ± 0.10**	-	-	4.80 ± 3.06**
$\chi^2_{(1)}$	0.47 NS	11.93**		25.2**	3.69 NS	6.37*	7.83**	4.81*
m							36.82 ± 0.27**	8.63 ± 0.89**
[d]							-1.21 ± 0.25**	0.48 ± 0.22**
[h]							-6.56 ± 0.47**	37.24 ± 1.28**
[i]							-	15.54 ± 0.93**
[j]							6.29 ± 1.64**	-
[l]							-	-
$\chi^2_{(6-p)}$							8.44*	7.28*

*, ** Significant at 5% and 1% level
P= Number of parameters included and eliminated for analysis
NS= Non significant

Table 2 cont ....

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -5								
PET 27-1 A X ARM-239								
m	68.05 ± 0.24**	143.0 ± 2.10**	13.9 ± 0.21**	461.7 ± 4.54**	4.67 ± 0.10**	20.62 ± 0.58**	36.92 ± 0.46**	7.27 ± 0.13**
[d]	-4.31 ± 0.24**	-30.45 ± 2.07**	0.97 ± 0.21**	48.90 ± 3.96**	-0.70 ± 0.09**	6.58 ± 0.58**	-0.09 ± 0.44 NS	-2.28 ± 0.13**
[h]	-1.35 ± 0.37**	-26.86 ± 4.73**	5.74 ± 0.44**	402.0 ± 8.97**	1.29 ± 0.19**	26.68 ± 1.14**	3.71 ± 0.78**	8.67 ± 0.54**
$\chi^2_{(3)}$	48.39**	22.05**	17.03**	590.21**	9.55**	54.12**	1.65 NS	23.65**
m								
[d]								
[h]								
$\chi^2_{(2)}$								
m	65.75 ± 0.54**	116.3 ± 7.49**	16.7 ± 0.24**	809.1 ± 15.54**	4.48 ± 0.13**	42.39 ± 1.67**		15.51 ± 1.70**
[d]	-4.25 ± 0.28**	-32.4 ± 2.21**	-1.13 ± 0.23**	-53.32 ± 5.49**	-0.89 ± 0.13**	-5.99 ± 0.61**		-2.24 ± 1.13**
[h]	1.67 ± 0.70**	66.2 ± 11.88**	-	45.6 ± 21.3**	2.23 ± 0.44**	-		-0.87 ± 2.04 NS
[i]	2.83 ± 0.62**	28.6 ± 7.79**	-2.96 ± 0.33**	391.7 ± 17.1**	-	-22.78 ± 1.81**		-8.31 ± 1.71**
[j]	-3.00 ± 1.06**	35.97 ± 12.7**	0.23 ± 1.41 NS	109.0 ± 16.76**	0.91 ± 0.4**	5.00 ± 5.54 NS		1.78 ± 2.56 NS
[l]	-	-	1.06 ± 0.81 NS	-	-0.95 ± 0.42**	2.14 ± 2.14 NS		-
$\chi^2_{(1)}$	11.67 NS	0.14 NS	0.01 NS	25.93**	0.59 NS	0.42 NS		0.01 NS
m			17.03 ± 0.09**			43.80 ± 0.76**	36.94 ± 0.44**	14.87 ± 0.43**
[d]			-1.10 ± 0.21**			-5.83 ± 0.59**	-	-2.23 ± 0.13**
[h]			-			-	-3.74 ± 0.77**	-
[i]			-3.23 ± 0.24**			-24.32 ± 0.99**	-	-7.58 ± 0.46**
[j]			-			-	-	-
[l]			-			-	-	-
$\chi^2_{(6-p)}$			1.80 NS			2.44 NS	1.69 NS	0.63 NS

*, ** Significant at 5% and 1% level

P= Number of parameters included and eliminated for analysis

NS= Non significant

Table 2 cont ....

Crosses	Days to 50% flowering	Plant height (cm)	Head diameter(cm)	No. of filled seeds / head	100 Seed weight (g)	Seed yield (g/ plant)	Oil content (%)	Oil yield (kg/ha)
Cross -6								
ARM 245 A X 6 D-1 R								
m	68.53 ± 0.37**	165.3 ± 2.15**	12.23 ± 0.22**	484.8 ± 9.2**	4.31 ± 0.04**	20.41 ± 0.66**	39.97 ± 0.26**	7.92 ± 0.26**
[d]	-1.26 ± 0.29**	13.0 ± 2.07**	3.71 ± 0.22**	191.1 ± 8.96**	1.49 ± 0.04**	2.76 ± 0.71**	-1.85 ± 0.25**	0.71 ± 0.29**
[h]	-0.92 ± 0.69 NS	44.4 ± 4.34**	8.21 ± 0.64**	448.9 ± 16.55**	2.07 ± 0.08**	34.13 ± 1.24**	1.62 ± 0.44**	15.66 ± 0.34**
$\chi^2_{(3)}$	18.05**	1.79 NS	5.92 NS	246.58**	29.83**	81.84**	12.58**	61.24**
m								
[d]								
[h]								
$\chi^2_{(2)}$								
m	68.25 ± 0.56**			338.39 ± 21.4**	5.39 ± 0.09**	11.49 ± 1.35**	36.79 ± 1.29**	4.61 ± 0.56**
[d]	-0.25 ± 0.56**			-68.6 ± 12.4**	1.31 ± 0.05**	3.98 ± 0.78**	-2.12 ± 0.07**	1.14 ± 0.30**
[h]	1.75 ± 1.84 NS			637.2 ± 30.4**	-	47.23 ± 2.18**	10.71 ± 3.10**	19.35 ± 0.65**
[i]	-			257.4 ± 25.3**	-1.25 ± 0.12**	11.16 ± 1.55**	3.06 ± 1.32**	4.34 ± 0.66**
[j]	-3.50 ± 1.32**			-491.40 ± 39.3**	0.93 ± 0.21**	-18.42 ± 3.94**	-	-7.86 ± 2.08**
[l]	-3.50 ± 1.16*			-	0.89 ± 0.13**	-	-6.61 ± 1.99**	-
$\chi^2_{(1)}$	0.10 NS			54.39**	0.09 NS	0.47 NS	0.64 NS	1.99 NS
m	68.73 ± 0.22**							
[d]	-							
[h]	-							
[i]	-							
[j]	-4.00 ± 0.71**							
[l]	-2.09 ± 0.63**							
$\chi^2_{(6-p)}$	0.91 NS							

*, ** Significant at 5% and 1% level
P= Number of parameters included and eliminated for analysis
NS= Non significant

For the character test weight, dominance gene action was found to be prevalent as revealed from the greater magnitude of dominance gene effects than additive gene effects. The joint scaling test of five parameter model was found to be adequate in crosses (PFMS 400 A X 89-B , PET 27-1 A X ARM-239 and ARM 245 A X 6 D-1 R) with genetic components *viz.*, m [d] [i] [j] and [l] were found to be important for the PFMS 400 A X 89-B and ARM 245 A X 6 D-1 R.

For seed yield joint scaling test of 5 parameter model in which four crosses (PFMS 400 A X GP 9-163-8, IMS WGA X GP 9-163-8, PFMS 400 A X 89-B and ARM 245 A X 6 D-1 R) showed good fit. The genetic components *viz.*, m [d] [h] [i] and [l] were predominant in PFMS 400 A X GP 9-163-8 and ARM 245 A X 6 D-1 R while m [d] [h] [i] and [j] were important for IMS WGA X GP 9-163-8 and PFMS 400 A X 89-B . Under sequential best fit model for IMS WGA X GP 9-163-8 additive and additive x additive components were important. Since both dominance and dominance x dominance gene effects are in the same direction, it follows that dominance at individual loci complement each other resulting in an increased manifestation of this trait. For oil content in IMS WGA X GP 9-163-8 and ARM 245 A X 6 D-1 R the genetic parameters m[d] [h] [i] and [l] were important while ARM 245 A X 856 R showed significance of m [h] [i] [j] and [l] genetic parameters. For PFMS 400 A X 89-B , additive, dominance and additive x dominance component was in higher magnitude.

Joint scaling test of five parameter model was adequate for oil yield per plant in PFMS 400 A X GP 9-163-8 and ARM 245 A X 6 D-1 R. Under sequential fit scheme four parameters m [d] [j] and [l] for IMS WGA X GP 9-163-8 and m [d] [h] and [i] for PFMS 400 A X 89-B were important. The role of dominance [h] component was relatively higher as compared to that of additive [d] in most of the cross combinations.

The presence of epistasis in sunflower population has been reported for plant height (Gangappa *et al.,* 1997 and Satyanarayana, 2000), 100 seed weight (Singh *et al.,* 1987, Satyanarayana, 2000) Seed yield per plant (Dua and Yadava, 1982. El-Hamid - El Hity, 1992; Kendalkar 1997 and Gangappa *et al.,* 1997) and oil content (Merinovic *et al.,*2006).

Additive gene action was found to be important for days to 50 per cent flowering (PFMS 400 A X GP 9-163-8 and IMS WGA X GP 9-163-8), plant height (ARM 245 A X 856 R) 100 seed weight (PFMS 400 A X 89-B), seed yield (IMS WGA X GP 9-163-8) and oil yield (IMS WGA X GP 9-163-8 and PET 2-7-1 A X ARM-239), this indicates that it could be easier to select and isolate high performing inbred lines for most of these traits are happens to be important since they contribute to the seed yield. Hence, selection for transgressive segregants for these traits is possible in the early generations would be more effective for obtaining genetic gain of these characters. Additive gene action for different characters in sunflower reported by various workers for days to 50% flowering (Dua and Yadava 1983; Goksoy *et al.,* 2000) and seed yield (Ortegonn Morales and Scobedo Mendoza, 1993).

Besides additive, epistatic component of additive x additive (i) significance indicates the role of preponderance of additivity over non additivity. In such cases in a particular cross to improve the trait pedigree method or SSD method will be a rewarding. Such interactions were noticed in certain crosses for various characters *i.e.*, head diameter (PET 27-1 A X ARM-239), 100 seed weight (ARM 245 A X 6 D-1 R), seed yield and oil yield (PFMS 400 A X GP 9-163-8, PFMS 400 A X 89-B and PET 27-1 A X ARM-239) and these interactions would enhance for making improvement through selection. Gupta and Khanna (1982) also observed similar type of [i] gene effects for seed yield in Sunflower.

The overall perusal of generation mean analysis results indicated that epistasis is the integral part of genetic architecture of the present material used in the investigation and breeder cannot ignore it. The presence of dominance and epistatic effects for most of the traits in majority of the crosses would slow down the progress of selection. Hence, suggested the use of intermating of selector followed by visual selection in early segregating generations which would simultaneously exploit both type of gene effects. Further, this approach is likely to break some undesirable linkages resulting in the establishment of rare useful recombinations.

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