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Combining Ability Analysis of Yield and Yield Components in Sunflower

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Abstract: An experiment was conducted to determine the combining ability of yield and yield components in sunflower. There was a significant difference for General Combining Ability (GCA), Specific Combining Ability (SCA) and Reciprocal Effect (RE) for all the traits studied except for 100-achene weight where the GCA effect was found non-significant. In the estimates of variances, the SCA for the traits were more than GCA showing non-additive effects for all the traits, GCA: SCA ratio also indicated predominance of non-additive gene effect for these traits. Additive and non-additive contributed equally to the inheritance of the achene number plant^{-1} and this can easily be judged from GCA: SCA ratio. Among the inbred lines, TF-1 was the best general combiner for head size and 100-achene weight though its GCA effect was not significant for the latter. Inbred line ARI was the best general combiner for the achene yield plant^{-1} and achene yield kg ha^{-1}, while TF-4 was the best combiner for achene number plant^{-1}. Different cross combinations showed different response with respect to GCA, SCA and RE for various traits studied. Only cross combination TF-335×PESH was consistent for having high SCA for head size and achene yield kg ha^{-1} and TF-335×TF-11 exhibited high RE effect for achene yield plant^{-1} and 100-achene weight.

Key words: Sunflower, GCA, SCA, RE, additive, non-additive, yield components

INTRODUCTION

The ability of an inbred to transmit desirable performance in its hybrid progenies is referred to as combining ability. Sprague and Tatum (1942) further refined the idea into general and specific combining ability which have significant impact on evolution of inbred line. General Combining Ability (GCA) is the average performance of a particular inbred in a series of hybrid combinations, whereas, specific combining ability, refers to the performance of a combination of specific inbreeds in a particular cross. The parental lines/genotypes are considered to be superior that prove as good donor and better combiner for desirable plant traits from breeding point of view. Breeding for various aspects needs the best combiners and desirable donors which could be helpful in evolving best hybrids/synthetics having high yield potential and good adopter for diversified agro-ecological zones.

Combining ability analysis is of special importance in cross-pollinated crops like sunflower as it helps in identifying potential inbred lines. It can be used for producing hybrid or synthetic composites variety and thus help in isolating base materials on which the success of any breeding programme initially depends. Some lines produce outstanding progenies on crossing, while others prove to be poor parents that were otherwise equally desirable (Griffing, 1956).

Present investigation was, therefore, set out to furnish information on combining ability in diallel cross experiment of selected inbreeds in sunflower (*Helianthus annuus* L.) for yield and yield components under conditions of Peshawar valley NWFP Pakistan.

MATERIAL AND METHODS

The research work was carried out at Malakandher Research farm NWFP Agricultural University Peshawar in the years of 2000-2004.

Five different sunflower selections from Tarnab Fertile (TF) Lines viz TF-1, TF-4, TF-7, TF-11 and TF-335 along with three hybrid cultivars viz., Gulshan-98, Aritar-93 and Peshawar-93 were taken.

The inbred lines were developed from all the genetic materials (TF-lines and hybrid cvs). For this purpose the materials were selfed for four generations and selections were made in each generation for various parameters. The inbred lines developed were re-named TF-1, TF-4, TF-7, TF-11, TF-335. GUL, ARI and PESH.

All the genetic materials (inbred lines) were crossed in 8×8 diallel fashion. To produce enough F_0 seeds, the crossings were made for two consecutive years i.e., from 2000-2002. The F_0 seed was harvested separately from each cross at maturity.

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Table 1: Mean Squares due to GCA, SCA and reciprocal effects in F_1 generation for various characters of Sunflower

Traits	GCA (7)	SCA (28)	Reciprocal (28)	Error (126)
Head size (cm^2)	31429.84**	14426.21**	13133.19**	233.969
Achene yield plant^{-1} (g)	150.75**	59.77**	39.58**	1.82
Achene No. plant^{-1}	112451.55*	19986.30**	15723.80**	20.54
100-achene wt. (g)	2.241**	0.518**	0.228**	0.0035
Yield (kg ha^{-1})	30999.36**	19241.020**	25428.65**	1.580

**Significant at 1% probability level, GCA = General Combining Ability, SCA = Specific Combining Ability

Table 2: Estimates of component of variance in F_1 generation for various characters of Sunflower

Traits	GCA	SCA	Recip.	Error	Total	Additive	Non-additive	GCA/SCA ratio
Head size (cm^2)	1078.28	7967.58	6449.61	233.97	15729.44	2156.58	7967.58	0.135
Yield of achene Plant^{-1} (g)	5.75	32.54	18.88	1.82	58.99	11.50	32.54	0.18
Achene's No.Plant^{-1}	5800.97	11208.85	8751.63	20.54	25781.99	11601.94	11208.85	0.518
100-achene wt. (g)	0.11	0.29	0.11	0.003	0.513	0.22	0.29	0.38
Yield (kg ha^{-1})	755.99	10801.09	12713.53	1.58	24272.20	1511.98	10801.09	0.07

Table 3: Estimates of GCA effects in F_1 generation for various characters of Sunflower

Inbred lines	Head size (cm^2)	Achene yield plant^{-1} (g)	Achene No. Plant^{-1} (no)	100-Achene wt. (g)	Achene yield (kg ha^{-1})
TF-1	87.567**	-2.982**	-138.350**	0.531	-11.028**
TF-4	20.338	-0.794**	146.400**	-0.63	5.670**
TF-7	-31.749*	-3.452**	-41.430**	-0.031	-17.748**
TF-11	6.442	-1.160**	5.651**	-0.118	-70.021**
TF-335	24.567	-1.189**	32.026**	-0.257	-8.621**
GUL	-46.619**	1.294**	14.734**	-0.014	40.522**
ARI	-28.120*	5.841**	42.693**	0.0756	78.571**
PESH	-32.432*	2.442**	-61.724**	0.452	-17.346**
SE(gi)	12.795	0.100	1.123	0.000	0.086
SE (gi-gj)	29.246	0.228	2.567	0.000	0.197

*Significant at 5% probability level. **Significant at 1% probability level

Hybrid seeds (F_1) of 56 crosses along with their eight parents were tested in an experiment in a Randomized Complete Block Design with three replications. In all the experiments one seed per hill was planted by dibbling. Each row was 4 meter long. Plant to plant and row-to-row distance was kept 25 and 60 cm, respectively. Normal cultural practices and plant protection measures were adopted during the crop season. The data on head size, achene yield plant^{-1}, achene number plant^{-1}, 100-achene weight and achene yield (kg ha^{-1}) the following parameters were recorded.

The data on F_1 hybrid and parental lines thus collected were subjected to combining ability analysis using procedures outlined by Griffing (1956) Method 1, Model

RESULTS AND DISCUSSION

Mean squares for GCA were significant ($p<0.05$) for all the characters (Table 1) indicating the importance of additive genetic variance. SCA mean squares were also significant for all the characters, showing that there is an importance of non-additive genetic variance too for these characters. The mean squares for reciprocals were also significant ($p<0.01$) for all the characters. The result indicated that non-additive gene effects were more important for the control of these characters alongwith significant role of cytoplasmic inheritance.

The Table 1 reveals that the General combining ability is more important than Specific Combining and Reciprocal (R) effects. The mean square of GCA for all the characters studied was more than that of specific and reciprocal effects. Therefore, general combining ability is more important than either of specific or reciprocal effects. The analysis of variance for combining ability showed that general combining ability effects were significant for all eight characters studied.

The variance components (Table 2) were estimated to determine precisely the importance of additive and dominance components in the control of characters under study. High SCA effects were observed for all the characters. These results indicated higher non-additive effect for these characters. Ratio of GCA: SCA for all characters is much smaller than one, showing that non-additive gene effect had a predominant role in inheritance of these characters. The achene yield with high reciprocal effects indicated the involvement of cytoplasmic inheritance alongwith non-additive gene effects in the control of these characters. Achene number per plant showed additive and non-additive gene effects and equally contributed for inheritance of this trait. This also be confirmed from GCA: SCA ratio, which is very close to

Table 4: Estimate of Specific Combining Ability (SCA) effects in F_1 generation for various characters of Sunflower

Character/Crosses	Head Size (cm^2)	Achene yield Plant^{-1}. (g)	Achene No.Plant^{-1} (no)	100-Achene weight (g)	Yield (kg ha^{-1})
TF-1×TF-4	153.162	1.75*	133.224**	-0.511**	12.191**
TF-1×TF-7	-15.256	4.14**	34.724**	0.183**	30.542**
TF-1×TF-11	26.724	-1.62*	-12.193**	-0.108**	41.486**
TF-1×TF-335	90.599	0.50	7.766**	-0.061**	-3.335**
TF-1×GUL	46.620	-4.61**	-36.943**	-0.253**	83.607**
TF-1×ARI	-9.547	9.80**	104.766**	0.135**	84.195**
TF-1×PESH	-53.234	-3.17**	34.682**	-0.342**	19.778**
TF-4×TF-7	-37.693	-6.60**	4.474	-0.552**	84.484**
TF-4×TF-11	-25.214	3.89**	-2.110	0.198**	85.271**
TF-4×TF-335	-87.839	-11.00**	-5.151	-0.572**	-118.46*
TF-4×GUL	82.182	5.98**	-83.860**	0.592**	43.062**
TF-4×ARI	83.014	10.15**	-104.818**	0.863**	53.942**
TF-4×PESH	3.66	0.51	-206.901**	0.963**	55.914**
TF-7×TF-11	-6.964	-1.47*	-16.609	-0.020**	52.672**
TF-7×TF-335	45.245	2.80**	25.516**	0.034**	31.440**
TF-7×GUL	25.766	7.23*	72.641**	0.164**	69.620**
TF-7×ARI	93.932	-4.37**	-67.318**	0.180**	-60.086**
TF-7×PESH	21.078	-0.86	16.766**	-0.248**	48.053**
TF-11×TF-335	-11.443	6.83**	114.599**	-0.049**	48.545**
TF-11×GUL	-23.256	-0.33	14.391	-0.156**	45.069**
TF-11×ARI	-1.756	-2.88**	-70.734**	0.362**	51.075**
TF-11×PESH	27.057	4.23**	96.349**	-0.178**	-378.2
TF-335×GUL	24.786	3.04**	-112.318**	0.793**	39.837**
TF-335×ARI	2.620	1.75*	-98.609**	0.241	*7.788**
TF-335×PESH	153.766	3.98**	-49.026**	0.241**	114.538**
GUL×ARI	-78.359	-3.72**	149.016**	-0.773**	57.356**
GUL×PESH	-133.05	0.41	24.266**	-0.064**	46.006**
ARI×PESH	25.547	-4.14**	-22.193**	-0.086**	3.512**
SE(Sij)	91.39	0.71	8.02	0.001	0.62
SE(Sij-Sik)	204.72	1.59	17.97	0.003	1.38
SE(Sij-ski)	175.48	1.37	15.40	0.003	1.19

*Significant at 5% probability level. **Significant at 1% probability level

0.50 for achene yield per plant. From Table 2, the variance of various components clearly indicated that specific combining ability (SCA) variances were higher than general combining ability (GCA) variances for all the traits except achene yield. This showed that majority of the characters were generally controlled by non-additive gene action. However, high reciprocal variances were detected for achene yield. These findings were totally in conformity with that of Hussain *et al.* (1998). Non-additive gene action for head diameter, number of seed head^{-1} and 100 seed weight was also confirmed by Kumar *et al.* (1998).

General Combining Ability (GCA) analysis: As cleared from the (Table 3), for head size, TF-1 was the only inbred line that showed maximum and highly significant GCA effect (87.57). The other four inbred lines showed negatively significant GCA effects. Such like report was also forwarded by Kandalkar (1997) who found that non of inbred cultivars exhibited significant GCA effects. In case of achene yield per plant, inbred line ARI exhibited the maximum GCA effect (5.84) followed by inbred line PESH with GCA effect of 2.44.

In case of achene number per plant all the eight inbreeds explicated significant GCA effect. TF-4 and ARI demonstrated positive GCA effects whereas TF-1 and Peshawar displayed high negative GCA effects. For 100-achene weight all the inbreeds depicted non-significant GCA effects. TF-1 and Peshawar were positive in their GCA effects while TF-4 and TF-335 were highly negative in their GCA effects. These findings were in agreement with that of Kumar *et al.* (1998) who reported non-significant GCA effect for the trait.

As far as the achene yield kg ha^{-1} is concerned, all the eight inbreeds demonstrated significant GCA effects. ARI and GUL showed the maximum positive GCA effects while the TF-11 and TF-7 showed the high negative GCA effects. Ortegon *et al.* (1995) also reported that additive effect were predominant in the control of achene yield and oil content, while Gangappa *et al.* (1997) reported that achene yield was under the control of both additive and non-additive gene action with the latter predominating.

In short we found that inbred line TF-1 indicated high general combining ability for the traits like head size and 100-achene weight, and was the best combiner for these traits. Inbred line TF-4 elucidated high general combing ability for achene number per plant was the best combiner for this character. Inbred ARI line exhibited high general combining ability for achene yield plant^{-1} followed by PESH was a good combiner for achene yield. Besides achene yield plant^{-1}, inbred line ARI also showed

Table 5: Estimates of reciprocal effects in F_1 generation for various characters of Sunflower

Inbred lines	Head size (cm^2)	Achene yield plant^{-1} (g)	Achene plant^{-1} No.	100-Achene wt. (g)	Achene yield (kg ha^{-1})
TF-4×F-1	24	-1.39	5.33	-0.165**	-36.27**
TF-7×TF-1	-78.50	-1.25	34.33**	-0.36**	-1.30
TF-7×TF-4	-19.17	-1.42	68.5**	-0.42**	-26.63**
TF-11×TF1	116.33	-7.85**	-86.17**	-0.21**	-96.97**
TF-11×TF-4	-25.50	-2.31*	28.67**	-0.22**	6.85**
TF-11×TF-7	38.67	4.19**	159.33**	-0.38**	62.50**
TF-335×TF-1	-33.00	-0.50	59.17**	-0.31**	-13.72**
TF-335×TF-4	40.67	1.42	211.33**	-0.52**	20.52**
TF-335×TF-7	114.33	-4.90**	51.17**	-0.52**	-51.00**
TF-335×TF-11	15.17	14.43**	20.00	0.78**	43.83**
GUL×TF-1	147.50	-4.31**	-22.83*	-0.31**	-61.52**
GUL×TF-4	180.50	2.13*	94.00**	-0.35**	24.18**
GUL×TF-7	89.67	3.66**	132.67**	-0.36**	58.67**
GUL×TF-11	19.83	-1.45*	37.83**	-0.19**	-21.50**
GUL×TF-335	96.33	-2.38*	-31.17**	0.05**	-6.33**
ARI×TF-1	74.50	6.74**	37.17**	0.21**	64.67**
ARI×TF-4	30.83	2.86**	88.33**	-0.07**	58.22**
ARI×TF-7	128.67	-6.93**	-176.33**	0.43**	-73.33**
ARI×TF-11	45.83	1.45	-76.67**	0.34**	-11.22**
ARI×TF-335	111.00	0.81**	39.83**	0.30**	-12.33**
ARI×GUL	-21.17	2.06*	-149.17**	0.61**	18.33**
PESH×TF-1	7.17	-7.23**	-112.67**	0.17**	-72.33**
PESH×TF-4	126.50	-3.88**	-94.17**	0.26**	-35.05**
PESH×TF-7	-24.83	-0.68	14.00	0.04**	-7.88**
PESH×TF-11	66.67	-0.51	-24.67*	0.10**	-553.33**
PESH×TF-335	63.50	-1.92	-68.33**	0.21**	-19.50**
PESH×GUL	41.00	0.04	-40.00	0.16**	-1.46
PESH×ARI	90.50	-2.20*	-37.83	0.09**	-18.00**
SE(rij)[a]	116.98	0.91	10.27	0.002	0.79
SE(ri-rij)[b]	233.97	1.82	20.54	0.003	1.58

*Significant at 5% probability level (T = 2.763), **Significant at 1% probability level

high general combining ability for achene yield kg ha^{-1} and was a good combiner for these traits. Inbred line PESH was a good combiner for 100-achene weight after TF-1 and was a poor combiner for head size. The inbred line ARI, has been identified as the best general combiners for achene yield plant^{-1} and achene yield kg ha^{-1}. Similarly, TF-7 was found good combiner for head size and 100-achene weight while TF-4 was found good combiner for achene number plant^{-1}.

Specific Combining Ability (SCA) effects: For head size no cross combination showed neither significantly positive nor negative specific combining ability effects. Cross combination TF-335×PESH in Table 4 indicated high positive SCA effect (153.766) followed by cross combination TF-1×TF-4 with SCA effect of 153.162. For achene yield per plant thirteen cross combinations demonstrated positive while ten cross combinations depicted negative significant specific combining ability effects. Cross combination TF-4×ARI demonstrated significantly high positive SCA effect followed by TF-1×ARI while TF-4×TF-335 showed highly negative specific combining ability effects. Similarly for achene number plant^{-1} ten cross combinations showed significant positive while twelve cross combinations showed significant negative specific combining ability effects. The maximum positive specific combining ability effect was depicted by GUL×ARI and TF-1×TF-4 followed by TF-1×TF-4 while the maximum negative specific combining ability effect was displayed by TF-4×PESH and TF-4×GUL (Table 4). Highly significant SCA were also found for these characters as reported by Radhika *et al.* (1999) and Sassikumar *et al.* (1999).

For 100-achene weight twelve cross combinations exhibited significant positive specific combining ability effects whereas fourteen cross combinations showed significant negative specific combining ability effect. The cross combination TF-4×PESH and TF-4×ARI exhibited the highest positive specific combining ability effect and cross combination GUL×ARI showed negative specific combining ability effect. For yield (kg ha^{-1}), twenty-one cross combinations demonstrated significantly positive effects while seven showed significantly negative specific combining ability effects. The cross combination TF-335×PESH displayed maximum positive specific combining ability effect. The lowest specific combining ability effect was expressed by TF-11×PESH.

The inferences drawn from the results described in the above paragraph elucidated that variable number of crosses for different parameters expressed positive specific combining ability effects. TF-335×PESH was found the only cross combination exhibited a high SCA effect for head size and achene yield kg ha^{-1}. All these crosses, showed good SCA for various traits, were obtained by the combinations of high × low or low × high general combiners but high SCA effect was observed in the hybrid of this cross. This might be due to the interaction of dominant alleles from good combiner and recessive alleles from poor combiner. All these combinations having maximum SCA effects for all the traits had at least one parent with high GCA. However for achene yield, the case was totally different. These results were contradictory to that of Liu *et al.* (1996) which might be due the different genetic materials used in the experiment.

Reciprocal combining ability (RE) effects: For head size only four cross combinations displayed significant positive reciprocal effect. The highest positive reciprocal effect was demonstrated by GUL×TF-4 (Table 5). For achene's yield $plant^{-1}$, eight cross combinations demonstrated significant positive whereas ten cross combinations showed significant negative reciprocal effects. The highest positive reciprocal effect was displayed by TF-335×TF-11 followed by ARI×TF-1 while the maximum negative reciprocal effect was displayed by cross combination TF-11×TF-1. There were thirteen cross combinations showed positive reciprocal effect for achene's number per plant. The highest significant reciprocal effect was demonstrated by TF-335×TF-4 followed by TF-11×TF-7 whereas the maximum negative reciprocal effect was demonstrated by ARIxTF-7.

For 100-achene weight fourteen cross combinations showed significant positive reciprocal effects. Cross combination TF-335×TF-11 demonstrated highest positive reciprocal while cross combination TF-7×TF-4 demonstrated maximum negative reciprocal effect. In case of achene yield kg ha^{-1}, nine crosses exhibited positive reciprocal effects. The highest reciprocal effect was demonstrated by ARI×TF-1, whereas the maximum negative effect was demonstrated by PESH×TF-11.

The conclusion drawn from the results (Table 5) manifested that only a single cross combination TF-335×TF-11 exhibited positive significant RE for two traits i.e., achene yield $plant^{-1}$ and 100-achene weight. Different cross combinations showed different effect for various traits. Reciprocal crosses indicated maximum positive heterosis for head size, achene yield per plant and achene number per plant. However, direct crosses expressed more profound results for 100-achene weight and achene yield. This showed that reciprocal effects might be totally different from that of the direct crosses.

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