HELIA, **20**, Nr. 27, p.p. 73-84, (1997) UDC 631.527.5:633.854.78

STUDIES ON COMBINING ABILITY IN SUNFLOWER (*Helianthus annuus* L.)

E. Gangappa*, K.M. Channakrishnaiah, M.S. Harini and S. Ramesh

AICORPO (Sunflower), University of Agricultural Sciences, G.K.V.K., Bangalore, 560 065, Karnataka, India

Received: July 19, 1996
Accepted: October 20, 1997

SUMMARY

An investigation was undertaken to assess the magnitude and direction of combining ability of six cytoplasmic male sterile lines and twelve fertility restorer lines in sunflower. The study revealed that the parental lines RHA-99RTNBr, RHA-284, RHA-299 and CMS-302 possessed genes for earliness. The hybrid CMS-852 x RHA-99RTNBr was found to be the best combination for days to 50 per cent flowering. The lines CMS-207 and CMS-852 and the testers RHA-6D-5-3-6 and RHA-214Br appear to transmit genes for higher seed yield and hence they are suggested for utilization in hybridization programme to obtain better yields. The hybrids CMS-302 x RHA-273 and CMS-234 x RHA-284 were found to be the best combinations for seed yield and oil content, respectively. All the characters were found to be under control of both additive and non-additive gene action with the predomiance of the latter.

Kew words: Sunflower, combining ability, line x tester.

INTRODUCTION

Sunflower is one of the most important oilseed crops of India. It is also a crop in which heterosis is exploited for better seed and oil yield. The value of hybrids and the importance of heterosis breeding was recognized very early in sunflower. The discovery of cytoplasmic male sterility (Leclercq, 1966) in France and fertility restoration (Kinman, 1970) in USA has provided the required break through for heterosis breeding in sunflower. As a result, plant breeders have extensively used and exploited heterosis to improve seed and oil yield in sunflower. Hybrids are generally more vigorous, uniform, self fertile and also resistant to important foliar diseases (Seetharam, 1980). In a systematic breeding programme it is essential to identify superior parents for hybridization and crosses to expand the variability reservoir for selection of superior genotypes. Combining ability analysis helps the breeder in selecting desirable parents and provides information on the relative

* Corresponding author

Table 1: Analysis of variance for the ten quantitative characters in sunflower

Source	D.F.	Days to 50% flowering	Plant height	Stem girth	Head diameter	Days to maturity	100 seed weight	Seed filling	Oil content	Seed yield per ha.	Oil yield per ha.
					MEAN SUM OF SQUARES						
Replications	2	54.44	8531.13**	1.7*	144.84**	98.13**	1.98	29.75	159.05**	1182688.00**	2231564.00**
Treatments	89	40.14**	1060.60**	0.21**	16.60**	42.08**	2.28**	66.14**	36.63**	944699.69**	199491.86**
Parents	17	24.24	366.46**	0.16**	15.23**	23.11**	3.06**	56.56*	19.40*	335192.25**	56864.79*
Crosses	71	44.24**	569.34**	0.16**	8.45**	47.06**	1.82**	69.28**	36.14**	445307.50**	103434.42**
Parents Vs. crosses	1	19.28	47740.41**	4.61**	618.77**	11.69	21.07**	6.13	275.51**	46763176.00**	9408730.00**
Lines	5	119.90**	3809.80**	0.73**	50.36**	209.87**	5.38**	58.98	107.91**	1563164.00**	261430.41*
Testers	11	84.06**	528.70	0.29**	10.53**	71.94**	3.13*	133.53*	92.47**	587979.63	157294.55*
Line x Tester	55	30.12**	282.88**	0.08**	4.23*	27.28**	1.24*	57.37**	18.35**	316058.75**	78944.58**
Error	178	18.385	145.75	0.04	2.75	6.87	0.65	28.21	10.02	128906.79	32289.93
S.Em+		2.48	6.97	0.07	0.96	1.51	0.47	3.07	1.83	207.29	103.75
C.V. (%)		6.53	10.08	13.23	12.79	2.74	17.95	5.75	7.56	21.80	25.55
C.D. (5%)		6.88	19.33	0.19	2.67	4.19	1.29	8.49	5.76	547.77	287.57
C.D. (1%)		9.05	25.44	0.25	3.51	5.52	1.70	11.20	6.68	756.33	418.69

** P<0.01; * P<0.05

importance of GCA and SCA for interpreting the genetic basis of important traits. In the present study an attempt was made to assess the combining ability and gene action governing the quantitative traits in sunflower for six cytoplasmic lines and twelve fertility restorer lines by employing line x tester analysis.

MATERIALS AND METHODS

Six cytoplasmic male sterile lines and 12 fertility restorer lines were mated in line x tester fashion to generate 72 single cross hybrids. These crosses along with their 15 parents were grown in randomized block design with three replications. The experiment was conducted at GKVK Campus, University of Agricultural Science, Bangalore. The crossing was carried out during kharif 1994 and the evaluation of the crosses and their parents was done during summer 1995. Each entry was grown in a single row of 3 m length with a spacing of 60 cm between rows and 30 cm between plants in row. Fertilizers were applied at the rate of 60:90:60 NPK kg/ha. A standard package of practices was followed for raising the crop. Observations were recorded on five randomly selected plants in each tretment of all replications for ten quantitative traits, days to 50 per cent flowering, plant height, stem girth, head diameter, days to maturity, 100-seed weight, per cent seed filling, oil content, seed yield and oil yield. Mean values of the ten characters for different entries were subjected to line x tester analysis (Kempthorne, 1957) to estimate general combining ability (GCA), specific combining ability (SCA) effects and their respective variances.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) indicated that the lines, testers and line x testers exhibited significant differences among themseves for all the characters except for per cent seed filling in lines and seed yield/ha in testers. Further, crosses were also found to be significantly different from each other for all the characters. It could be because of the diverse nature of testers and the significant interacition between lines and testers.

The estimates of GCA and SCA effects of 18 parents and 72 hybrids, respectively, for ten quantitative charactes are furnished in Table 2. Days to 50 per cent flowering, oil content and seed yield are of much practical significance in sunflower. Therefore, the discussion in this study centers mainly around theses characters. The lines CMS-302 and RHA-99RTNBr, RHA-284 and RHA-299 among cytoplasmic male sterile (CMS) lines and restorer lines, respectively, exhibited significant GCA effects for days to 50 per cent flowering in the desirable direction (negative direction). Among the testers, the line RHA-99RTNBr exhibited significant GCA effects for per cent seed filling and oil content also. This indicates that this particular line seemed to posses decreasing alleles for days to 50 per cent flowering and increasing

Table 2: Estimates of general combining ability and specific combining ability effects for parents and hybrids in sunflower (Days to 50 per cent flowering and plant height)

Days to 50 per cent flowering		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-2.15	-1.10	-1.16	3.79	4.34	-0.10	-4.99*	0.79	0.73	-2.60	2.07	0.40	1.10
	302	2.07	0.79	-0.94	-0.99	2.57	-4.21	3.23	-1.99	-0.71	-2.05	3.95	-1.71	-2.79**
	851	-0.05	-2.66	-1.71	-3.44	2.12	2.34	-0.55	-0.44	0.84	0.51	0.51	2.51	0.66
	852	2.70	4.76	3.37	0.65	-14.80**	0.76	1.20	3.98	-2.41	2.59	-0.07	-2.74	2.24**
	400	-2.69	-0.63	-0.68	0.93	3.15	-0.30	-0.19	-1.74	2.20	1.54	-2.46	0.87	-1.04
	234	0.12	-1.16	1.12	-0.94	2.62	1.51	1.29	-0.60	-0.66	0.01	-3.99	0.68	-0.18
GCA effects		3.19**	1.13	1.52	-0.75	-3.32**	1.13	2.69*	-0.76	-2.70*	-1.70	1.63	-2.04*	
S.E. (GCA for lines) = 0.71				S.E. (GCA for testers) = 1.01				S.E. (SCA) = 2.48						

Plant height		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	0.53	2.75	4.75	1.82	18.98**	10.09	-26.49**	3.15	12.07	-5.86	12.62	-10.28	7.50**
	302	6.67	0.43	5.82	4.26	-6.15	-16.97	21.55**	-4.31	-2.60	-6.59	-1.23	-3.34	-13.57
	851	-8.02	-1.72	-3.32	-13.63	-13.77	25.34**	2.60	7.74	8.39	6.60	-15.46*	5.24	2.51
	852	-2.17	-11.68	-3.75	10.55	5.41	0.65	-2.29	3.19	6.44	4.91	4.79	-3.18	10.47**
	400	-4.72	5.83	-0.97	-2.19	-3.50	-9.39	3.93	-1.86	8.92	-2.27	0.07	6.11	-12.09**
	234	7.72	4.35	2.52	-0.82	-0.96	-9.72	0.68	-7.92	3.80	3.20	-3.25	5.45	5.17*
GCA effects		8.93**	9.64**	1.31	-0.40	-6.65*	4.17	0.71	-1.43	-4.94	0.85	-4.43	-7.13*	
S.E. (GCA for lines) = 0.84				S.E. (GCA for testers) = 1.39				S.E. (SCA) = 2.78						

** P<0.01: * P<0.05

Table 2: Estimates of general combining ability and specific combining ability effects for parents and hybrids in sunflower (Stem girth and head diameter)

Stem girth		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-0.03	-0.03	0.01	0.77**	0.13	0.06	-0.30*	-0.19	-0.09	-0.07	-0.13	-0.12	0.14**
	302	0.11	0.04	0.06	-0.13	-0.01	-0.32*	0.22*	0.04	-0.01	0.02	-0.17	0.06	-0.15**
	851	-0.07	-0.07	-0.06	-0.25*	0.06	0.36**	0.06	0.01	0.17	0.03	0.10	-0.04	-0.01
	852	-0.03	-0.01	-0.17	-0.04	0.02	0.16	-0.04	0.01	0.05	0.05	-0.06	0.09	0.20**
	400	-0.05	0.01	0.15	-0.02	-0.11	-0.08	0.06	0.12	0.02	-0.05	0.03	-0.10	-0.06
	234	0.08	0.07	0.01	-0.33**	0.03	-0.08	-0.01	0.01	0.02	0.02	0.06	0.11	-0.12**
GCA effects		0.24**	0.06	0.11*	0.18**	-0.16**	0.01	-0.04	-0.08	-0.12*	-0.10*	-0.06	-0.06	
S.E. (GCA for lines) = 0.03				S.E. (GCA for testers) = 0.05				S.E. (SCA) = 0.18						

Head diameter		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	0.28	0.52	0.47	1.91*	2.04*	1.02	-3.54*	-0.02	-0.43	-0.16	-0.38	-1.74	0.78*
	302	-0.02	1.29	0.16	-0.66	-0.09	-2.64*	3.29**	-0.38	-0.49	0.04	0.11	-0.61	-1.33**
	851	0.60	-0.62	-0.64	-0.27	-0.64	1.61	-0.15	-1.43	-0.31	0.63	0.87	0.35	0.65**
	852	-0.35	-1.24	-0.86	0.08	0.21	-0.41	-0.30	1.15	0.61	0.81	-0.42	0.73	1.61**
	400	-1.59	0.79	0.17	-0.63	-1.97	-0.15	1.12	1.14	1.23	-1.07	-0.26	1.23	-0.55
	234	1.07	-0.75	0.69	-0.43	0.46	0.58	-0.42	-0.46	-0.60	-0.24	-0.03	0.05	-1.15**
GCA effects		0.82	1.30**	0.39	-0.01	-1.41**	0.41	0.24	-0.22	-0.87**	-0.67	0.49	-0.46	
S.E. (GCA for lines) = 0.28				S.E. (GCA for testers) = 0.39				S.E. (SCA) = 0.96						

** P<0.01: * P<0.05

Table 2: Estimates of general combining ability and specific combining ability effects for parents and hybrids in sunflower (Days to maturity and hundred seed weight)

Days to maturity		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-2.16	-1.10	-1.16	3.79*	1.01	3.23**	-5.00**	0.79	0.73	-2.60	2.06	0.40	1.01*
	302	2.06	0.79	-0.94	-0.99*	-0.77	-0.88	3.23*	-1.99	-0.72	-2.05	3.95**	1.71	-2.79**
	851	-0.05	-2.66	-1.71	-3.43*	-1.21	5.68**	-0.54*	0.44	0.84	0.51	0.51	2.51	0.66
	852	1.04	3.09*	1.70	-1.02	0.20	2.43	-0.46	2.32	-4.07**	0.93	-1.74	-4.41**	3.91*
	400	-2.69	-0.63	-0.69	0.93	-0.19	3.04*	-0.19	-1.74	2.20	1.54	-2.46	0.87	-1.04*
	234	1.9	0.51	2.79	0.73	0.95	-13.49**	2.95	1.06	1.00	1.68	-2.32	2.34	-1.84**
GCA effects		3.19**	1.13	1.52*	-0.76	0.02	-2.20**	2.69**	-0.76	-2.70**	-1.70*	1.63*	-2.04**	
S.E. (GCA for lines) = 0.44				S.E. (GCA for testers) = 0.62				S.E. (SCA) = 0.151						

Hundred seed weight		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-0.32	-0.72	0.06	1.93**	0.33	1.29**	-0.26	0.97*	0.27	0.26	0.66	-0.62	-0.59**
	302	-1.12*	0.83	0.48	0.51	0.11	-0.83	0.85	-0.49	0.71	0.27	-1.63**	0.29	0.16
	851	-1.28	-0.02	-0.38	1.10*	0.02	0.09	0.14	-0.44	0.50	0.22	0.12	-0.07	-0.56**
	852	0.87	-0.08	-0.19	0.05	-0.09	-0.16	-0.47	0.28	-0.32	-0.69	0.82	0.10	0.08
	400	-0.12	0.03	0.07	0.16	-0.70	-0.15	-0.14	-0.20	0.27	-0.05	0.12	0.72	-0.15
	234	0.98*	-0.04	-0.04	0.20	0.34	-0.25	-0.12	-0.12	-0.42	-0.01	-0.10	-0.42	-0.13
GCA effects		0.09	0.55*	0.48*	0.01	0.07	0.35	0.85**	0.27	-0.08	-0.63**	-0.03	-0.24	
S.E. (GCA for lines) = 0.13				S.E. (GCA for testers) = 0.19				S.E. (SCA) = 0.47						

** P<0.01: * P<0.05

Table 2: Estimates of general combining ability and specific combining ability effects for parents and hybrids in sunflower (Seed filling and oil content))

Seed filling		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-0.06	-5.14	-7.74*	1.47	1.99	-4.13	2.14	-2.38	5.02	1.54	3.20	3.61	0.75
	302	1.47	3.46	-6.01	-0.47	-3.62	0.82	0.92	4.90	4.36	4.48	-12.27**	1.79	-0.35
	851	-1.36	3.14	-4.04	4.43	4.07	4.74	-1.51	-5.07	-7.25*	-3.30	4.32	1.84	-1.26
	852	3.64	4.28	2.71	0.44	-0.69	1.59	-0.07	-4.89	-1.80	-6.03*	2.88	-2.07	-0.54
	400	-3.34	-4.61	6.93*	-3.94	-1.41	-1.43	1.54	2.90	3.40	0.22	1.67	-1.94	2.29*
	234	0.25	-1.31	8.15**	-2.20	-0.35	-1.60	-3.81	4.56	-3.74	3.10	0.19	3.24	0.61
GCA effects		2.16	1.33	-4.67**	2.11	2.86*	1.51	1.62	-3.34*	-2.01	-4.04**	0.46	2.01	
S.E. (GCA for lines) = 0.89				S.E. (GCA for testers) = 1.25				S.E. (SCA) = 3.07						

Oil content		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	-0.45	-8.51**	2.49	0.51	0.79	0.15	-1.89	-1.13	5.18**	1.71	1.75	4.37	-2.51**
	302	1.70	3.44	0.81	-0.09	-0.61	-0.53	0.75	0.21	-0.79	0.13	-5.71**	0.69	0.25
	851	1.00	-0.54	-2.69	2.31	3.73*	2.39	-1.13	-0.70	-1.49	-2.21	0.90	-1.58	-0.42
	852	-0.29	1.26	0.99	-2.14	-0.97	-0.48	1.33	0.59	-0.17	1.05	-0.99	-0.17	-0.88
	400	-2.43	1.11	2.14	-1.41	-2.04	-1.46	1.08	1.76	2.53	-1.41	2.72	-2.59	2.64**
	234	0.47	3.23	1.24	0.83	-0.90	-0.08	-0.14	-0.72	5.26**	0.72	1.32	0.72	-0.83
GCA effects		2.25**	0.19	-0.04	1.88*	2.59**	-0.40	0.99	-3.82**	-3.21**	-3.32**	1.36	1.51	
S.E. (GCA for lines) = 0.53				S.E. (GCA for testers) = 0.75					S.E. (SCA) = 1.83					

** P<0.01: * P<0.05

Table 2: Estimates of general combining ability and specific combining ability effects for parents and hybrids in sunflower (Seed yield per hectare and oil yield per hectare)

Seed yield per hectare		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	340.22	-27.34	-342.48	361.20	583.19**	689.90**	-677.71**	-436.91*	-323.32	-129.88	307.15	-352.99	245.18**
	302	246.15	-35.39	-29.57	-355.26	6.66	-488.62*	919.73**	-10.74	108.57	260.58	-397.64	267.84	-277.19**
	851	1.45	14.46	26.86	13.91	-354.67	285.47	154.75	-196.52	-137.15	-50.73	-232.19	-9.88	0.56
	852	-14.50	-40.28	-129.50	388.33	199.83	-217.38	-128.38	-350.81	8.13	-86.84	-179.62	-150.00	231.77**
	400	-397.71	75.27	103.35	-233.31	-234.44	167.35	114.35	340.53	388.43	-239.83	65.77	184.65	-150.07*
	234	316.69	13.27	371.35	-174.85	-200.57	-111.31	-382.16	-47.26	-44.65	246.71	-27.85	40.64	-50.25
GCA effects		49.97	308.27**	12.58	128.68	-104.54	323.44**	-139.13	-1023.88	-164.73	-159.19	56.97	-209.44*	
S.E. (GCA for lines) = 59.84				S.E. (GCA for testers) = 84.63				S.E. (SCA) = 207.29						

Oil yield per hectare		RHA 6D-1	RHA 6D-5-3-6	RHA 17	RHA 99RTBr	RHA 99RTNBr	RHA 214Br	RHA 273	RHA 274	RHA 284	RHA 297	RHA 298	RHA 299	GCA effects
		SCA EFFECT												
CMS	207	144.62	-209.79*	-178.05	169.80	210.39*	276.35**	-294.21**	-188.28	-40.92	-20.00	185.47	-55.38	44.26
	302	-96.30	-48.75	17.34	-144.06	-70.88	-198.38	407.15**	10.21	31.50	125.17	-252.31*	119.81	-112.69**
	851	33.52	7.89	-39.30	57.25	-168.05	181.47	27.33	-85.30	-74.60	-50.04	118.23	-28.40	-10.50
	852	-34.55	-1.28	-65.21	96.22	392.91**	-122.17	-62.63	144.97	-41.00	-49.57	-124.61	-102.98	140.12**
	400	-212.58*	76.69	84.50	-119.80	-206.27	-85.73	62.28	176.68	220.75*	-114.42	66.72	51.07	-26.35
	234	165.30	177.74	180.72	-61.41	-158.10	-51.55	-159.91	-28.40	-95.73	108.96	6.50	15.87	-34.84
GCA effects		51.25	123.36**	0.71	82.93	58.68	116.79*	-44.70	-116.23*	-126.60**	-126.70**	147.43	-66.93	
S.E. (GCA for lines) = 29.95				S.E. (GCA for testers) = 42.35				S.E. (SCA) = 103.75						

** P<0.01: * P<0.05

alleles with additive effects for per cent seed filling and oil content. Significant GCA effects for days to 50 per cent flowering, per cent seed filling and oil content had also been reported (Tuberose *et al.*, 1982). With respect to plant height, three CMS lines viz., CMS-207, CMS-852, and CMS-234, and two testers, RHA-6D-1 and RHA-6D-5-3-6 registered significant postive GCA effects. Further, the lines CMS-207 and CMS-852, appeared to possess favorable alleles with additive effect for stem diameter, head diameter, days to maturity and seed yield/ha also, as evident from significant positive GCA effects of these two lines for the above traits. The restorer line 6D-1 manifested significant GCA effects for stem diameter, days to maturity and oil content also.

In general, no single line or tester expressed significant GCA effect for all the characters. For example, the lines CMS-207, CMS-852, RHA-6D-1, RHA-99RTBr and RHA-17 for stem diameter; CMS-207, CMS-851, CMS-852 and RHA-6D-5-3-6 for head diameter; CMS-207, CMS-852, RHA-6D-1, RHA-17, RHA-273 and RHA-298 for days to maturity; CMS-207, RHA-6D-5-3-6, RHA-17 and RHA-273 for 100-seed weight and CMS-400 and RHA-99RTNBr for per cent seed filling manifested significant GCA effects.

The lines CMS-207 and CMS-852 which recorded highest GCA effects for seed yield seemed to possess unfavorable alleles for oil content as evident form the significant negative GCA effects exhibited by these lines for oil content. The lines CMS-400RHA-6D-1, RHA-99RTBr and 99RTNBr appear to combine favorably for oil content as revealed from their significant positive GCS effect. Oil yeld is the function of both seed yield and oil content. In this regard, although, the lines CMS-852, RHA-6D-5-3-6 and RHA-214Br which did not possess favorable genes for oil content, by virtue of their good combining ability for seed yield, expressed a fairly high magnitude of GCA effects for oil yield. Significant postive GCA effect for oil yield has been reported by earlier workers (Kadkol *et al.*, 1984.).

Among 72 hybrids, only two, CMS-852 x RHA-99RTNBr and CMS-207 x RHA-273, expressed significant negative SCA effects for days to 50 per cent flowering. Of the parental lines involved in the former combination, CMS-852 had significant positive GCA effect; whereas RHA-99RTNBr had significant negative GCA effects; in spite of the GCA effects of these two parental lines in opposite direction, the significant SCA effects of this combination in the desirable direction may be due to a high frequency of dominant alleles for earliness. Both parental lines in the latter combination did not seem to possess favorable genes for earliness. The negative SCA effects of this combination may be attributed to the favorable epistatic interaciton of genes from these two lines.

Only three hybrids, CMS-207 x 99RTNBr, CMS-207 x 214Br and CMS 302 x RHA-273, recorded significant positive SCA effects for seed yield. In addition, these hybrids have exhibited significant positive SCA effects for several other traits also. For example, the hybrid CMS-207 x RHA-99RTNBr for plant height and head diameter; CMS-207 x RHA-214Br for 100-seed weight and oil yield and CMS-302 x RHA-

273 for days to 50 per cent flowering, stem dimeter, head diameter and oil yield. The hybrids CMS-207 x RHA-284, CMS-234 x RHA-284 and CMS-851 x RHA-99RTNBr were found best specific combinations for oil content as evident from their significant positive SCA effects.

The parental lines RHA-99RTNBr, RHA-284, RHA-299 and CMS-302 were found to possess genes for earliness as evident from their significant negative GCA effects for days to 50 per cent flowering. The hybrid CMS-852 x RHA-99RTNBr was adjudged to be the best specific combination for earliness. The lines CMS-207 and CMD-852 and the testers RHA-6D-5-3-6 and RHA-214Br appeared to transmit additive genes for higher seed yield in their progenies and hence could be used as parents advantageously in hybridization programmes to obtain better yields. The combination CMS-302 x RHA-273 registered the highest positive SCA effect for seed yield. The parental lines CMS-400, RHA-6D-1, RHA-99RTBr and RHA-99RTNBr were found to inherit genes for higher oil content. The hybrid CMS-234 x RHA-284 was found to be the best as it expressed the highest positive SCA effect for oil content.

Table 3: Variance due to general and specific combining ability for the characters in sunflower

Character	Variance due to GCA	Variance due to SCA	GCA:SCA
Days to 50% flowering	0.17	3.91	1 : 23.61
Plant height	3.36	45.71	1 : 13.59
Stem girth	0.001	0.013	1 : 14.50
Head diameter	0.05	0.49	1 : 9.90
Days to maturity	0.23	6.80	1 : 29.30
Hundred seed weight	0.01	0.20	1 : 28.64
Seed filling	0.14	9.72	1 : 69.48
Oil content	0.21	2.78	1 : 13.29
Seed yield per ha	1571.31	62383.99	1 : 41.12
Oil yield per ha	293.37	15551.55	1 : 53.01

Predominance of dominance gene action was evident from the ratio of GCA to SCA variances (< 1) of all the characters (Table 3). Non-additive gene action had been reported by earlier workers (Ibrahim, 1985; Rudra Naik, 1985; Manjunath, 1986; Giriraj *et al.*, 1987; Gupta and Singh, 1988). However, additive gene action for these traits has also been reported (Ananda Rao, 1979; Shankar, 1981; Sudhakar *et al.*, 1984; Singh *et al.*, 1989).

It was interesting to note that the line CMS-207 was involved as a common female parent in most hybrids which exhibited significant SCA effects in favorable direction for days to 50 per cent flowering, plant height, stem diameter, head diameter, days to maturity, 100-seed weight, oil content, seed yield and oil yield. Similarly, RHA-99RTNBr was involved as male line in most hybrids which exhibited significant SCA effects in favorable direction for days to 50 per cent flowering, plant height, head diameter, oil content and seed yield. From this, it could be ascertained that these two lines are the most versatile in their ability to combine among the parental lines.

From the present study it could be concluded that the lines CMS-207, CMS-852, RHA-6D-5-3-6 adn RHA-214Br may be further evaluated for the confirmation of their superiority with respect to their general combining ability for seed yield. The lines CMS-400, RHA-6D-1, RHA-99RTBr and RHA-99RTNBr are also suggested for further evaluation for oil content. The hybrid CMS-302 x RHA-273 which exhibited the highest SCA effect for seed yield needs to be critically evaluated over different seasons and locations to confirm its superiority and stability.

REFERENCES

Ananda Rao, P.K., 1979. Diallel analysis of the quantitative characters in sunflower (*Helianthus annuus* L.). M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

Giriraj, K., Shantha R. Hiremath and Seenappa, K., 1987. Combining ability of converted male sterile lines of sunflower (*Helianthus annuus* L.). Indian J. Genet., 47: 315-317.

Gupta, R.K. and Singh, S.P., 1988. Diallel analysis for seed yield, oil content and other economic traits in sunflower. Genetica, 20: 161-173.

Ibrahim, 1985. Studies on heterosis and path coefficient analysis in sunflower (*Helianthus annuus* L.). M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

Kadkol, G.P., Ananad, I.J. and Sharma, R.P., 1984. Combining ability and heterosis in sunflower. Ind. J. Genet., 44: 447-451.

Kempthorne, O., 1957. An Introduction to Genetic Statistics. The IOWA State University Press.

Kinman, M.L., 1970. New developments in the USDA and state experiment station sunflower breeding programme. Proc. Fourth Int. Sunflower Conf. Memphis, Tennessee. pp. 181-183.

Leclercq, P., 1966. An utilizable male sterile line for the production of hybrid sunflower. Ann. Amelior. Planta., 76: 135-139.

Manjunath, M.E., 1986. Evaluation of male sterile and fertility restorer lines for combining ability in sunflower (*Helianthus annuus* L.). M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

Rudra Naik, V., 1985. Studies on combining ability of inbreds in sunflower (*Helianthus annuus* L.) by line x tester analysis. M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

Seetharam, A., 1980. Hybrid sunflowers. Indian Fmg., 24(12): 15.

Shankar, A.C., 1981. Evaluation of sunflower hybrids for combining ability by line x tester analysis. M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

Sing, S. B., Labana, K.S. and Virk, D.S., 1989. Detection of epistatic, additive and dominance variantion in sunflower (*Helianthus annuus* L.). Indian J. Genet., 47(3): 243-247.

Sudhakar, D., Seetharam, A. and Sindagi, S.S., 1984. Analysis of combining ability in sunflower. J. Oilseeds., 1: 157-166.

Tuberosa, R., Alba, E., Greco, I. and Paradisi, V., 1982. Evaluation of combining ability in pure lines of sunflower. Sementi Elette., 28(5): 19-22.

ETUDE DE LA VALEUR EN COMBINAISON CHEZ LE TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

Une étude a été entreprise pour préciser l'importance et le sens de l'aptitude à la combinaison de six lignées mâle stériles cytoplasmiques et de douze lignées restauratrices de tournesol. L'étude a révélé que les lignées parentales RHA-99RTNBr, RHA-284, RHA-299 et CMS-302 possédaient des gènes de précocité. L'hybride CMS-852 x RHA-99RTNBr s'est révélé le meilleur pour le nombre de jours nécessaires à 50% de floraison. Les lignées CMS-207 et CMS-852 ainsi que les testeurs RHA-6D-5-3-6 et RHA-214Br montrent qu'ils possèdent les gènes pour les rendements élevés en grains, ce qui permet de suggérer leur utilisation dans les programmes d'amélioration du rendement. Les hybrides CMS-302 x RHA-273 et CMS-234 x RHA-284 correspondent respectivement aux meilleures combinaisons pour le rendement en grains et la teneur en huile. On a trouvé que tous ces caractères sont à la fois sous contrôle de gènes à effets additifs et non additifs avec une prédominance de gènes à effets non additifs.

ESTUDIOS SOBRE APTITUD COMBINATORIA EN GIRASOL (*Helianthus annuus* L.)

RESUMEN

Se llevó a cabo una investigación para determinar la magnitud y dirección de la aptitud combinatoria de seis líneas androestériles citoplásmicas y doce líneas restauradoras en girasol. El estudio reveló que las líneas parentales RHA-99RTNBr, RHA-284, RHA-299 y CMS-302 poseen genes para precocidad. El híbrido CMS-852 x RHA-99RTNBr fué la mejor combinación para días haste 50% de floración. Las líneas CMS-207 y CMS-852 y los probadores RHA-6D-5-3-6 y RHA-214Br parecen transmitir genes para rendimiento más alto y por tanto se sugiere su utilización para programas para obtener mejores rendimientos. Los híbridos CMS-302 x RHA-273 y CMS-234 x RHA-284 fueron las mejores combinaciones para rendimiento y contenido en aceite respectivamente. Todos los caracteres estuvieron bajo el control de acción génica aditiva y no aditiva con predominancia de la no aditiva.