S. K. Dhillon and Vikrant Tyagi*

Combining Ability Studies for Development of New Sunflower Hybrids Based on Diverse Cytoplasmic Sources

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Abstract: The experiment involved 7 different *cms* analogues as a female parent and 6 restores lines as male parent to synthesis of a set of these 42 hybrids. The experiment was conducted during spring season 2012 in Line × Tester breeding design and evaluated for combining ability of 7 morphological, physiological and important sunflower yield components traits. The results based on GCA effects of parents for different characters revealed that among the lines DV-10A and among testers P93R, P143R and RHA83R6 were found to be the good general combiners for seed yield and oil content with early maturing except P143R, which is good combiner for flowering and late maturity. The crosses CMS-XA × RHA83R6 and PRUN-29A × RHA83R6 were found to be superior and exhibited highest SCA effects with highest mean values for oil content but for seed yield having negative SCA effects with average for seed yield. The hybrids PKU-2A × RHA83R6 and E002-91A × P93R having high mean seed yield with high SCA effects.

Keywords: sunflower, combining ability effect, *cms* sources and morpho-physiological traits

Introduction

Sunflower, highly cross pollinated crop is ideally suited for exploitation of heterosis. The discovery of cytoplasmic male sterility by Leclereq (1969) and fertility restoration by Kinman (1970) provided the desired breakthrough in the development of hybrids. However, the cytoplasmic uniformity or narrow genetic base represents a potential risk and high degree of genetic vulnerability in

***Corresponding author: Vikrant Tyagi,** Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India, E-mail: vikranttyagi97@gmail.com
S. K. Dhillon, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India

hybrid sunflower. In order to reduce the probable chances of occurrence of these problems diversification of cytoplasmic male sterility in sunflower is the urgent need. Several sunflower researchers have attempted to identify new, diverse sources of cytoplasmic male sterility to widen the genetic base of cultivated sunflower (Heiser, 1982; Serieys, 1994; Christov, 1992). In addition to the continuing search for new *cms* sources, identification of new restorer lines and selection of parent/inbreeds based on their *per se* performance and combining ability for economic traits is very important in producing superior hybrids.

The line × tester analysis (Kempthare, 1957) is one of the simplest and efficient method to evaluate a large number of inbreeds for their combining ability and *per se* performance.

Analysis of general combining ability (*gca)* and specific combining ability (*sca)* also helps in knowing the type of gene action controlling various characters and development of suitable breeding strategies. With this background the present study was carried out involving different *cms* sources and restorers to develop superior hybrids with the objective to estimate *gca* of parents and *sca* of hybrids and gene action governing various morpho-physiological and yield traits.

Materials and methods

The materials for the present study included 42 hybrids, seven *cms* lines from diverse cytoplasmic sources viz; ARG-2, ARG-3 *(H. argophyllus)*, *cms*-XA (Unknown), PRUN-29A *(H. praecox spp. runyonic)*, DV-10A (*H. debilis* spp. *vestitus)* and E002-91A, PKU-2A (*H. annuus*), six restores lines (P93R, P75R, P138R, P137R, P143R and RHA83R6) and two check hybrids PSH-569 and PSH-996. The experiment was carried out during spring season 2012 in the experimental area of oilseed section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab, India. The experiment was designed according to the line × tester method. The parental lines and hybrids were planted manually at an optimum time, during first week of February in a well-prepared field. The plots consisted of two rows of 3 m length. The row-to-row spacing was 60 cm and the plants were spaced at 30 cm intervals within the rows. The data were recorded on morphological and physiological traits viz: days to 50% flowering (days), days to maturity (days), plant height (cm), head diameter (cm), 100 seed weight (g), grain yield per plant (g) and oil content (%). The mean values of the inbred lines and F_1 hybrids were used to calculate the values of the combining abilities and assess the gene effects for morpho-physiological and yield traits using the line × tester method (Singh and Choudhary, 1976).

Results and discussion

The analysis of variance for the characters studied in a line × tester (7 × 6) design is presented in Table 1. Highly significant differences for female vs male, females and males were recorded for all the traits however, the mean square due to females were non-significant for seed yield. Mean square due to males were non significant for 100 seed weight. The differences among the parents, parents vs crosses and crosses were observed to be highly significant for all the characters indicating the existence of wider genetic differences among parents and crosses. The mean squares due to female × male interactions were recorded highly significant for all the traits. Non-additive component of genetic variance played major role in their inheritance which is evident from analysis of variance for combining abilities and analysis of genetic variance components. Further supporting this conclusion was the fact that the *gca*/*sca* ratio in F_1 generation was below the value of one (*gca*/*sca* ratio = < 1.0) for all the traits except plant height which was governed by additive component of genetic variance for which the value of *gca*/*sca* ratio was 1.14. Non additive gene effects for oil content have been reported earlier by Shekar *et al.* (1998) and Parameshwari *et al.* (2004). Significant differences for yield and it's component traits have also been reported among sunflower genotypes by Gvozdenovic *et al.* (2005) and Habib *et al.* (2007).

The importance of combining ability in selection of parents for hybridization has been emphasized earlier by many research workers in sunflower (Gejli *et al.*, 2011; Syeda *et al.*, 2014). The estimates of *gca* and *sca* effects for the nine morphological and yield traits presented in Tables 2 to 8 are discussed below. Analysis of the combining abilities showed that the A lines and testers differed significantly in their *gca* for all the traits studied.

For the identification of early flowering genotypes, negative *gca* effects are desirable therefore the female parents DV-10A (−0.69) and E002-91A (−0.94) having significant negative *gca* effects were identified as good combiners for early flowering, while in male parents except two i. e. P75R (2.73) and P143R (1.80) all were good combiners for early flowering having negative *gca* effects. P75R (2.73) and P143R (1.80) were good combiners for late flowering. Among hybrids nine of them showed significant negative *sca* values for early flowering (Table 2).

For days to maturity the female parents DV-10A and E002-91A were recorded as early maturing while, ARG-3A, PRUN-29A and P143R were recorded as late maturing (Table 3). Out of forty two, twelve hybrids were recorded as early maturing having significant negative *sca* values.

Table 1: Analysis of variance for combining ability and estimates of genetic components of sunflower.

Source	d.f	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Seed yield (g)	Oil content (%)
Replicates	2	−0.020	0.578	73.243	1.633	0.001	40646.800**	0.088
Parents	12	32.414**	103.840**	2627.95**6	68.175**	1.853**	31942.850**	21.391**
Lines	6	44.159**	25.381**	1372.492**	47.325**	1.622**	389.017	29.185**
Testers	5	16.100**	45.125**	1232.900**	3.462*	0.098	23169.290**	2.455**
Lines vs testers	1	43.516**	868.172**	17136.020**	516.840**	12.009**	265133.700**	69.306**
Parents vs hybrids	1	539.406**	203.000**	39059.280**	50.324**	5.507**	4569229.000**	912.883**
Hybrids	41	21.174**	31.219**	926.545**	3.640**	1.365**	40963.530**	6.961**
Lines	6	14.209**	26.174**	568.519**	4.126**	0.550	7068.111**	1.469**
Testers	5	74.701**	83.123**	4623.600**	4.830**	6.129**	168415.300**	38.144**
Lines × testers	30	13.646**	23.577**	381.974**	3.344**	0.734**	26500.650**	2.863**
Error	108	2.275	1.872	82.731	1.223	0.275	1922.768	0.133
Estimates of genetic components								
Sigma-square(f)		0.03	0.14	10.36	0.04	−0.01	−1079.59	−0.08
Sigma-square(m)		2.91	2.84	201.98	0.07	0.26	6757.84	1.68
Sigma-square(f × m) *sca*		3.79	7.23	99.75	0.71	0.15	8192.63	0.91
Covariance(half-sibs) *gca*		1.58	1.59	113.54	0.06	0.13	3140.57	0.87
gca/*sca*		0.42	0.22	1.14	0.08	0.87	0.38	0.95

Table 2: Estimation of combining ability effects and mean performance of hybrids for days to 50% flowering.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	67	73	69	69	70	69	1.40*
	sca	−1.97*	1.1	2.17*	0.13	−1.47*	0.03	
ARG-3A	Mean	69	70	64	69	70	69	0.56
	sca	1.37	−1.56*	−1.99*	1.46*	−0.13	0.87	
cms-XA	Mean	67	69	63	65	69	70	−0.63
	sca	0.56	−0.87	−1.80*	−1.01	0.06	3.06*	
PRUN-29A	Mean	69	65	65	68	69	70	−0.44
	sca	2.37*	−5.56*	−0.49	0.96	−0.13	2.87*	
DV-10A	Mean	68	73	66	65	69	63	−0.69*
	sca	1.12	2.69*	1.26	−1.29	−0.38	−3.38*	
E002-91A	Mean	66	72	65	66	71	64	−0.94*
	sca	−0.63	1.94*	0.01	−0.54	1.87*	−2.63*	
PKU-2A	Mean	65	74	67	68	71	67	0.73*
	sca	−2.80*	2.27*	0.84	0.29	0.2	−0.8	
gca		−0.70*	2.73*	−2.34*	−0.79*	1.80*	−0.70*	

Table 3: Estimation of combining ability effects and mean performance of hybrids for days to maturity.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	96	99	99	98	104	99	0.29
	sca	−2.43*	−0.15	0.78	0.31	0.57	0.92	
ARG-3A	Mean	99	99	97	99	108	99	1.29*
	sca	0.07	−1.65*	−2.72*	0.31	4.07*	−0.08	
cms-XA	Mean	98	98	96	98	99	99	−0.74
	sca	1.1	−0.12	−1.69*	1.67*	−2.90*	1.95*	
PRUN-29A	Mean	99	99	108	96	98	99	1.04*
	sca	0.32	−0.9	9.03*	−2.44*	−5.68*	−0.33	
DV-10A	Mean	98	98	95	98	99	96	−1.54*
	sca	1.40*	0.69	−1.38*	1.64*	−2.10*	−0.24	
E002-91A	Mean	97	97	94	96	103	97	−1.38*
	sca	0.73	−0.48	−2.55*	−0.03	1.73*	0.59	
PKU-2A	Mean	98	103	98	97	108	96	1.04*
	sca	−1.18	2.60*	−1.47*	−1.44*	4.32*	−2.83*	
gca		−1.07*	0.15	−0.78*	−1.31*	3.93*	−0.92*	

One of the goals in sunflower breeding is to select for short plant height, so any genotype with a negative *gca* value for this trait is considered desirable in a breeding program. In the present study, the female lines ARG-2A (−9.67) and the male parents P138R (−24.90) and P137R (−4.39) had negative *gca* effects for plant

Table 4: Estimation of combining ability effects and mean performance of hybrids for plant height.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	144.50	129.50	138.40	120.00	141.50	133.50	−9.67*
	sca	0.89	−10.25*	28.73*	−10.18*	−11.54*	2.35	
ARG-3A	Mean	147.00	147.50	111.30	159.00	167.00	140.25	1.1
	sca	−7.39	−3.03	−9.14*	18.05*	3.18	−1.67	
cms-XA	Mean	166.50	154.00	112.00	135.95	169.00	145.50	2.92
	sca	10.30*	1.65	−10.26*	−6.82	3.37	1.76	
PRUN-29A	Mean	159.50	159.50	118.00	128.50	161.50	144.50	1.01
	sca	5.2	9.06*	−2.35	−12.36*	−2.22	2.67	
DV-10A	Mean	142.00	139.50	114.20	149.50	172.50	135.50	−2.04
	sca	−9.25*	−7.89	−3.1	11.69*	11.83*	−3.28	
E002-91A	Mean	152.00	164.00	127.50	133.00	153.50	123.00	−2.07
	sca	0.79	16.65*	10.23*	−4.78	−7.14	−15.75*	
PKU-2A	Mean	161.50	152.00	114.00	153.00	174.00	163.50	8.76*
	sca	−0.55	−6.19	−14.10*	4.39	2.53	13.92*	
gca		9.05*	5.19*	−24.90*	−4.39*	18.47*	−3.42	

height and were identified as good general combiners for dwarf plant type. On the other hand PKU-2A (8.76), P93R (9.05), P75R (5.19) and P143R (18.47) had highly significant positive *gca* values for plant height and therefore were rated as the good general combiners for tall plant type (Table 4). These findings are in agreement with those of Marinkovic (1982), who argues that in studding a particular trait advantage should be given to the line that is the best combiner for that particular trait regardless of whether the value is positive or negative, which depends on the direction of selection for that trait. For tall plant type and dwarf plant type nine hybrids were recorded as having significant positive and negative *sca* effects.

Highly significant positive *gca* for head size was found with the female line *cms*-XA (0.81) and the male line P93R (0.81) so these lines can be regarded as good general combiners for this trait. Seven hybrids recorded significant *sca* values for head diameter (Table 5).

As far as 100-seed weight is concerned no female parent was recorded as good combiner whereas, male parent P93R (1.00) was observed as good combiner for this trait (Table 6). Among the hybrids four hybrids showed significant positive *sca* values for this trait.

Highly significant positive *gca* values for seed yield were observed for the female parent DV-10A (16.64) and male parents P93R (99.43), P143R (82.00) and RHA83R6 (44.00), so these lines can be considered as good general combiners

Table 5: Estimation of combining ability effects and mean performance of hybrids for head diameter.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	17.15	14.70	14.10	15.50	14.90	14.60	−0.12
	sca	1.18*	−0.13	−0.57	0.65	−0.44	−0.69	
ARG-3A	Mean	14.70	14.80	14.05	14.90	16.70	17.45	0.15
	sca	−1.54*	−0.3	−0.89	−0.23	1.08*	1.88*	
cms-XA	Mean	17.20	15.65	17.15	15.25	16.50	14.80	0.81*
	sca	0.3	−0.11	1.55*	−0.54	0.23	−1.42*	
PRUN-29A	Mean	16.60	15.30	15.20	14.00	15.90	15.15	0.08
	sca	0.43	0.27	0.33	−1.05*	0.36	−0.34	
DV-10A	Mean	15.70	14.30	14.15	15.70	15.10	14.80	−0.32
	sca	−0.07	−0.33	−0.32	1.05*	−0.04	−0.29	
E002-91A	Mean	15.80	16.00	14.20	13.50	14.45	13.30	−0.74*
	sca	0.45	1.79*	0.15	−0.74	−0.27	−1.37*	
PKU-2A	Mean	15.50	13.90	14.70	16.00	14.70	17.80	0.15
	sca	−0.74	−1.20*	−0.24	0.87	−0.92	2.23*	
gca		0.81*	−0.33	−0.49*	−0.3	0.18	0.13	

Table 6: Estimation of combining ability effects and mean performance of hybrids for 100 seed weight.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	6.00	4.20	5.00	4.55	3.95	4.15	0.04
	sca	0.36	−0.02	0.31	0.41	−0.71*	−0.35	
ARG-3A	Mean	5.05	3.95	4.50	4.50	5.05	4.40	−0.03
	sca	−0.53*	−0.2	−0.13	0.43	0.46	−0.03	
cms-XA	Mean	5.25	4.75	5.20	4.30	4.55	4.45	0.15
	sca	−0.50*	0.43	0.40	0.05	−0.22	−0.16	
PRUN-29A	Mean	6.45	3.95	5.00	3.50	5.20	4.00	0.08
	sca	0.77*	−0.31	0.26	−0.68*	0.50*	−0.54*	
DV-10A	Mean	5.55	4.30	4.15	3.75	4.05	3.60	−0.37*
	sca	0.32	0.49	−0.14	0.02	−0.2	−0.49	
E002-91A	Mean	5.83	4.30	4.20	3.90	4.50	5.65	0.13
	sca	0.1	0.01	−0.58*	−0.33	−0.25	1.06*	
PKU-2A	Mean	5.10	3.80	4.55	4.20	5.05	5.00	0.01
	sca	−0.52*	−0.39	−0.12	0.09	0.42	0.52*	
gca		1.00*	−0.43*	0.05	−0.50*	0.02	−0.14	

Table 7: Estimation of combining ability effects and mean performance of hybrids for seed yield.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	688.00	167.33	350.00	462.00	507.00	542.00	−41.13*
	sca	135.85*	−184.10*	1.71	28.99	−27.72	45.28*	
ARG-3A	Mean	492.00	490.33	435.00	542.00	565.00	469.00	5.03
	sca	−106.32*	92.73*	40.54	62.83*	−15.89	−73.89*	
cms-XA	Mean	541.00	406.33	488.00	411.00	653.00	430.00	−5.63
	sca	−46.65*	19.4	104.21*	−57.51*	82.78*	−102.22*	
PRUN-29A	Mean	573.00	541.00	399.00	446.00	607.00	469.00	11.98
	sca	−32.26	136.45*	−2.40	−40.12	19.17	−80.83*	
DV-10A	Mean	518.00	431.00	397.00	575.00	621.00	521.00	16.64*
	sca	−91.93*	21.79	−9.07	84.21*	28.5	−33.5	
E002-91A	Mean	727.00	445.00	342.00	436.00	513.00	582.00	13.64
	sca	120.07*	38.79	−61.07*	−51.79*	−76.50*	30.5	
PKU-2A	Mean	614.00	267.00	315.00	447.00	565.00	752.00	−0.52
	sca	21.24	−125.05*	−73.90*	−26.62	−10.33	214.67*	
gca		99.43*	−101.29*	−104.43*	−19.71*	82.00*	44.00*	

for this trait as shown in Table 7. Highly significant negative *gca* effects and the lowest grain yield means were recorded in the female inbred line ARG-2A (−41.13). ARG-2A along with restorer lines P75R (−101.29), P138R (−104.43) and P137R (−19.71) may be considered as poor general combiners for seed yield. The ten hybrid combinations ARG-2A × P93R (135.85), ARG-2A × RHA83R6 (45.28), ARG-3A × P75R (92.73), ARG-3A × P137R (62.83), *cms-XA* × P138R (104.21), *cms-XA* × P143R (82.78), PRUN-29A × P75R (136.45), DV-10A × P137R (84.21), E002-91A × P93R (120.07) and PKU-2A × RHA83R6 (214.67) had highly significant positive significant *sca* values for seed yield.

PRUN-29A (0.33), DV-10A (0.40), P93R (1.18), P143R (0.31) and RHA83R6 (1.88) were recorded as good combiners for oil content. Out of forty two hybrids evaluated fourteen hybrids recorded significant *sca* values for oil content (Table 8).

Among the female lines DV-10A was observed as good combiner for most of the traits like early flowering, maturity, seed yield and oil content while, among the male parents P93R and RHA83R6 were identified as good combiners for seed yield, oil content, early flowering and maturity. P143R was observed as good combiner for other traits but maturity.

Among the hybrids ten combinations ARG-2A × P93R (135.85), ARG-2A × RHA83R6 (45.28), ARG-3A × P75R (92.73), ARG-3A × P137R (62.83), *cms-XA* × P138R (104.21), *cms-XA* × P143R (82.78), PRUN-29A × P75R (136.45), DV-10A × P137R (84.21), E002-91A × P93R (120.07) and PKU-2A × RHA83R6 (214.67) had highly significant positive significant *sca* values for seed yield.

Table 8: Estimation of combining ability effects and mean performance of hybrids for oil content.

		P93R	P75R	P138R	P137R	P143R	RHA83R6	*gca*
ARG-2A	Mean	38.05	36.24	34.77	36.28	36.15	39.01	−0.27*
	sca	0.12	0.31	−0.44*	0.53*	−0.91*	0.38*	
ARG-3A	Mean	37.50	35.89	35.75	38.45	36.20	38.79	0.07
	sca	−0.77*	−0.38*	0.19	2.36*	−1.21*	−0.18	
cms-XA	Mean	37.34	35.84	34.97	35.67	38.42	39.33	−0.1
	sca	−0.77*	−0.26	−0.42*	−0.25	1.18*	0.52*	
PRUN-29A	Mean	39.12	37.52	36.38	33.23	38.21	39.68	0.33*
	sca	0.59*	0.99*	0.56*	−3.12*	0.54*	0.45*	
DV-10A	Mean	37.83	37.21	35.64	36.34	38.00	39.54	0.40*
	sca	−0.77*	0.61*	−0.25	−0.08	0.26	0.24	
E002-91A	Mean	38.53	35.38	35.25	35.76	37.06	38.13	−0.34*
	sca	0.67*	−0.48*	0.1	0.08	0.06	−0.43*	
PKU-2A	Mean	39.05	35.32	35.64	36.42	37.32	37.84	−0.09
	sca	0.94*	−0.79*	0.25	0.49*	0.08	−0.97*	
gca		1.18*	−0.82*	−1.54*	−1.00*	0.31*	1.88*	

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