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Economic Heterosis in Sunflower Hybrids Based on Different Cytoplasmic Combinations for Seed Yield and its Component Traits

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ABSTRACT

Many of the current hybrids of sunflower are based on only one CMS source (*i.e.,* PET-1) identified from *Helianthus petiolaris,* resulting in a crop with an extremely narrow genetic base. Therefore, the present study was conducted to evaluate different cytoplasmic combinations in sunflower hybrids using cytoplasmic male sterile (CMS) sources as female parents. There were 40 single cross hybrids produced by crossing among four diversified cytoplasmic male sterile lines from *Helianthus argophyllus* and *H. annuus* with ten restorer lines evaluated in *kharif* 2016 and *rabi / summer* 2016-17. For earliness hybrids ARG-2-1-2 x GKVK 2, ARG-2-1-2 x RHA 93 and MUT2-8-3-2 x M-17R can be exploited while for seed yield (kg/ha) hybrid MUT-2-8-3-2 x GKVK 3 exhibited significant positive standard heterosis followed by cross combination ARG-2-1-2 x LTRR-822. As sunflower is an oilseed crop high heterosis for oil content is desired, hybrid ARG-2-1-2 x RHA 6D-1 showed significant positive heterosis for this trait. There was considerable heterosis in desired direction for other phenological and agronomic traits too which indicated that highly heterotic crosses may be selected to expand yield potential and cytoplasmic base of the sunflower hybrids.

Keywords : Sunflower, Economic heterosis, Cytoplasmic male sterility, Seed yield

Sunflower (*Helianthus annuus* L.) is one of the most prominent oilseed crop of the world containing 38 to 42 per cent edible oil, which is used for culinary purposes. (Prakash *et al*., 2017). Sunflower was introduced to India during 1969 from Russia in view of its distinct advantages, *viz.,* photo insensitivity, short duration, high seed multiplication ratio, high seed yield and better quality of oil. However, commercial cultivation of sunflower in India started during 1972 with the introduction of four Russian varieties *viz.,* EC 68413 (Vniimk), EC 68414 (Perdovik), EC 68415 (Armavirskii) and EC 69874 (Armaverts). In the initial year of its introduction sunflower cultivation suffered a setback due to poor seed set and other related problems in these open pollinated varieties.

The discovery of PET 1 CMS source (cytoplasmic male sterility) in the progeny of cross between *Helianthus petiolaris* Nutt and cultivated sunflower (cv. Armavirskii 9345) and subsequent identification of genes for fertility restoration resulted in the development of several sunflower hybrids. In India the first ever CMS based sunflower hybrid BSH 1 was released from the University of Agricultural Sciences, Bangalore (Seetharam *et al*., 1980) which provided the required fillip to expand sunflower cultivation in the country. Since then, many hybrids have been released for commercial cultivation by utilizing cytoplasmic genetic male sterility system.

Till date, mostly PET 1 cytoplasm was used in the commercial hybrid production resulting in the genetic uniformity for the cytoplasmic background in the crop. Prevalence of genetic uniformity of this kind over a large area could result in genetic vulnerability of hybrids which can be avoided by using alien cytoplasmic sources in future hybrid production. Economic heterosis is the increase or decrease in vigour of F_1 over commercial checks. By utilizing different cytoplasmic backgrounds in hybrid development, the objective of present study was set to estimate the extent of economic heterosis for various characters and to isolate promising hybrids over standard check hybrids for seed yield and oil content for commercial exploitation.

Material and Methods

The experimental material consisted of 4 diversified cytoplasmic male sterile lines derived from *Helianthus argophyllus* and *H. annuus*, crossed with ten restorers to obtain 40 experimental hybrids during *kharif* 2015. Hybrids along with three standard checks *viz.,* KBSH 44 (National check), KBSH 53 and KBSH 78 (Local checks) were evaluated in *kharif* 2016 and *rabi / summer* 2016-17 with two replications each and the experiment was laid out in randomized block design. Each genotype was represented by single row of 3.0 meter length with a spacing of 60 cm between rows and 30 cm between plants. Observations were recorded in each entry on randomly selected five plants for characters *viz*., days to 50 per cent flowering, plant height (cm), days to maturity, head diameter (cm), seed filling (%), 100 seed weight, hull content (%), seed yield (kg/ha) and oil content (%). Heterosis over standard checks (SC) was computed by the method suggested by Turner (1953) and Hayes *et al.* (1955).

Results and Discussion

Exploitation of heterosis, which is quick and convenient way of combining desirable characters assumes greater significance in the production of hybrids and often exploited to increase the yield potential of crop plants. In the present study, negative heterosis is desirable for attributes like days to 50 per cent flowering and days to maturity for developing early maturing hybrids. Highest significant negative heterosis of -15.08 per cent and -18.94 per cent over KBSH 44 and KBSH 53 was shown by the hybrid ARG-2-1-2 x GKVK 2 for days to 50 per cent flowering and for days to maturity also this hybrid ranked first with significant standard heterosis of -9.79 per cent and -11.66 per cent over these two checks (Table 1). While none of the hybrids showed significant negative heterosis over check KBSH 78. Hladini *et al.* (2011) and Lakshman *et al*. (2020) also reported significant negative heterosis for days to 50 per cent flowering.

Cross combination ARG 3 x RHA 93 was the most dwarf hybrid with significant negative heterosis of -27.33 per cent, -30.69 per cent and -8.59 per cent over the checks KBSH 44, KBSH 53 and KBSH 78 respectively. While the hybrids E002 x RHA-93 and ARG 3 x GKVK 2 ranked second and third for this trait (Table 4). These results are in agreement with those obtained by Chandra *et al*. (2014) and Nandini *et al.* (2017).

Head diameter in case of sunflower is an important yield attributing character since there is a positive correlation of head size with number of seeds per head and in turn with seed yield but in present study none of the hybrids showed significant desirable (positive) standard heterosis for head diameter (Table 2) over any of the checks while the hybrids MUT-2-8-3-2 x GKVK 3, ARG-2-1-2 x RHA 6D-1 and ARG-2-1-2 x RHA95-C-1 ranked as top three hybrids and were on par with the commercial checks. More number of filled seeds per head is important for getting higher seed yield in sunflower. For this trait none of the hybrids exhibited significant positive heterosis over any of the checks though the cross ARG-2-1-2 x RHA-93 expressed highest positive heterosis of 1.05 per cent and 0.45 per cent over KBSH 53 and KBSH 78, respectively. Similar results were obtained by Rathi *et al*. (2016) in sunflower.

The seed weight of a genotype serves as an indicator to the expression of an end product *i.e.,* seed yield as it is an important character contributing to seed yield. Maximun standard heterosis for 100 seed weight (g) was recorded in the cross combination ARG-2-1-2 x RHA95-C-1 (19.96%) (Table 2) followed by ARG-2-1-2 x RHA 6D-1 (16.98%) and MUT-2-8-3-2 x GKVK 3 (13.98%) over KBSH 53. For hull content heterosis in negative direction is desirable and the cross ARG-2-1-2 x RHA-93 exhibited highest significant negative heterosis of -22.50 per cent over KBSH 44, -23.84 per cent over KBSH 53 and -18.34 per cent over KBSH 78 followed by the hybrid ARG-2-1-2 x LTRR-822 with -17.31 per cent, -18.75 per cent and -12.88 per cent heterosis over standard checks KBSH 44, KBSH 53 and KBSH 78, respectively. The results were in agreement with Lakshman *et al*. (2018) and Ghaffari *et al*. (2020).

TABLE 1

Estimation of standard heterosis over KBSH 44, KBSH 53 and KBSH 78 for days to 50 per cent flowering, plant height and days to maturity

Hybrids	Days to 50 per cent Flowering			Plant Height (cm)			Days to Maturity		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
ARG-2-1-2 x GKVK 3	-5.16 **	-9.47 **	9.13 **	-12.50 **	-16.54 **	10.07 **	-3.70 **	-5.70 **	6.74 **
ARG-2-1-2 x RHA 6D-1	-9.13 **	-13.26 **	4.57 **	-11.43 **	-15.52 **	11.41 **	-7.41 **	-9.33 **	2.64 *
ARG-2-1-2 x 95-C-1	-7.94 **	-12.12 **	5.94 **	-4.23	-8.65 **	20.47 **	-6.88 **	-8.81 **	3.23 **
ARG-2-1-2 x LTRR-822	-7.54 **	-11.74 **	6.39 **	-10.31 **	-14.45 **	12.82 **	-4.76 **	-6.74 **	5.57 **
ARG-2-1-2 x M-17-R	-10.71 **	-14.77 **	2.74	-18.71 **	-22.47 **	2.25	-8.99 **	-10.88 **	0.88
ARG-2-1-2 x MR 1	-11.51 **	-15.53 **	1.83	-9.62 **	-13.79 **	13.69 **	-7.67 **	-9.59 **	2.35 *
ARG-2-1-2 x RHA 272-II	-11.51 **	-15.53 **	1.83	-12.39 **	-16.44 **	10.20 **	-6.35 **	-8.29 **	3.81 **
ARG-2-1-2 x X-15-NB-10	-9.52 **	-13.64 **	4.11 **	-7.70 **	-11.96 **	16.11 **	-5.56 **	-7.51 **	4.69 **
ARG-2-1-2 x GKVK 2	-15.08 **	-18.94 **	-2.28	-8.94 **	-13.14 **	14.55 **	-9.79 **	-11.66 **	0.00
ARG-2-1-2 x RHA-93	-13.49 **	-17.42 **	-0.46	-20.84 **	-24.49 **	-0.42	-8.99 **	-10.88 **	0.88
MUT-2-8-3-2 x GKVK 3	-2.38 **	-6.82 **	12.33 **	-11.36 **	-15.46 **	11.49 **	-0.53	-2.59 *	10.26 **
MUT-2-8-3-2 x RHA 6D-1	-4.37 **	-8.71 **	10.05 **	-8.87 **	-13.08 **	14.63 **	-1.06	-3.11 **	9.68 **
MUT-2-8-3-2 x 95-C-1	-5.95 **	-10.23 **	8.22 **	-5.10 *	-9.48 **	19.38 **	-2.65 *	-4.66 **	7.92 **
MUT-2-8-3-2 x LTRR-822	-5.95 **	-10.23 **	8.22 **	-8.87 **	-13.08 **	14.63 **	-4.50 **	-6.48 **	5.87 **
MUT-2-8-3-2 x M-17-R	-13.49 **	-17.42 **	-0.46	-16.98 **	-20.81 **	4.43	-7.14 **	-9.07 **	2.93 **
MUT-2-8-3-2 x MR 1	-9.52 **	-13.64 **	4.11 **	-15.91 **	-19.80 **	5.77	-4.23 **	-6.22 **	6.16 **
MUT-2-8-3-2 x RHA 272-II	-8.73 **	-12.88 **	5.02 **	-9.30 **	-13.49 **	14.09 **	-5.03 **	-6.99 **	5.28 **
MUT-2-8-3-2 x X-15-NB-10	-7.94 **	-12.12 **	5.94 **	-14.07 **	-18.04 **	8.09 **	-4.23 **	-6.22 **	6.16 **
MUT-2-8-3-2 x GKVK 2	-4.76 **	-9.09 **	9.59 **	-7.64 **	-11.91 **	16.17 **	-2.65 *	-4.66 **	7.92 **
MUT-2-8-3-2 x RHA-93	-9.52 **	-13.64 **	4.11 **	-16.73 **	-20.57 **	4.75	-3.70 **	-5.70 **	6.74 **
E002 x GKVK 3	-2.38	-6.82 **	12.33 **	-12.02 **	-16.08 **	10.67 **	-0.79	-2.85 **	9.97 **
E002 x RHA 6D-1	-9.13 **	-13.26 **	4.57 **	-13.19 **	-17.20 **	9.19 **	-4.76 **	-6.74 **	5.57 **
E002 x 95-C-1	-6.75 **	-10.98 **	7.31 **	-8.68 **	-12.90 **	14.87 **	-2.91 **	-4.92 **	7.62 **
E002 x LTRR-822	-5.56 **	-9.85 **	8.68 **	-14.07 **	-18.04 **	8.09 **	-1.32	-3.37 **	9.38 **
E002 x M-17-R	-13.10 **	-17.05 **	0.00	-17.66 **	-21.46 **	3.57	-9.52 **	-11.40 **	0.29

Table 1 (Contd.)

Hybrids	Days to 50 per cent Flowering			Plant Height (cm)			Days to Maturity		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
E002 x MR 1	-10.32 **	-14.39 **	3.20 *	-18.83 **	-22.58 **	2.10	-5.29 **	-7.25 **	4.99 **
E002 x RHA 272-II	-13.10 **	-17.05 **	0.00	-20.34 **	-24.02 **	0.20	-7.94 **	-9.84 **	2.05
E002 x X-15-NB-10	-9.52 **	-13.64 **	4.11 **	-17.78 **	-21.58 **	3.42	-5.29 **	-7.25 **	4.99 **
E002 x GKVK 2	-10.32 **	-14.39 **	3.20 *	-19.75 **	-23.46 **	0.94	-5.82 **	-7.77 **	4.40 **
E002 x RHA-93	-10.71 **	-14.77 **	2.74	-26.61 **	-30.00 **	-7.68 *	-5.82 **	-7.77 **	4.40 **
ARG 3 x GKVK 3	1.59	-3.03 **	16.89 **	-19.45 **	-23.17 **	1.33	3.17 **	1.04	14.37 **
ARG 3 x RHA 6D-1	-4.76 **	-9.09 **	9.59 **	-17.19 **	-21.02 **	4.16	3.17 **	1.04	14.37 **
ARG 3 x 95-C-1	-3.17 **	-7.58 **	11.42 **	-15.89 **	-19.77 **	5.81	0.00	-2.07	10.85 **
ARG 3 x LTRR-822	-3.17 **	-7.58 **	11.42 **	-17.34 **	-21.16 **	3.98	-4.76 **	-6.74 **	5.57 **
ARG 3 x M-17-R	-10.32 **	-14.39 **	3.20 *	-18.91 **	-22.66 **	2.00	-6.88 **	-8.81 **	3.23 **
ARG 3 x MR 1	-10.71 **	-14.77 **	2.74	-19.79 **	-23.50 **	0.89	-6.35 **	-8.29 **	3.81 **
ARG 3 x RHA 272-II	-10.32 **	-14.39 **	3.20 *	-18.71 **	-22.47 **	2.25	-7.14 **	-9.07 **	2.93 **
ARG 3 x X-15-NB-10	-6.75 **	-10.98 **	7.31 **	-19.18 **	-22.91 **	1.66	-3.17 **	-5.18 **	7.33 **
ARG 3 x GKVK 2	-11.51 **	-15.53 **	1.83	-25.44 **	-28.88 **	-6.21 *	-8.20 **	-10.10 **	1.76
ARG 3 x RHA-93	-7.54 **	-11.74 **	6.39 **	-27.33 **	-30.69 **	-8.59 **	-4.23 **	-6.22 **	6.16 **

** Significant at P ≤ 0.01 * Significant at P ≤ 0.05

TABLE 2

Estimation of standard heterosis over KBSH 44, KBSH 53 and KBSH 78 for head diameter, seed filling per cent and 100 seed weight

Hybrids	Head Diameter (cm)			Seed Filling Per cent (%)			Seed Weight (gm)		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
ARG-2-1-2 x GKVK 3	-9.36 **	-7.07 **	-4.08	-4.20 **	-2.74 **	-3.32 **	-9.99 **	9.82 *	-1.18
ARG-2-1-2 x RHA 6D-1	-2.13	0.34	3.56	-2.56 **	-1.07	-1.66	-4.12	16.98 **	5.26
ARG-2-1-2 x 95-C-1	-3.12	-0.67	2.52	-0.94	0.57	-0.03	-1.68	19.96 **	7.94 *
ARG-2-1-2 x LTRR-822	-5.75 **	-3.37	-0.26	-0.64	0.88	0.28	-7.85 *	12.43 **	1.16
ARG-2-1-2 x M-17-R	-12.32 **	-10.10 **	-7.21 **	-3.22 **	-1.75 *	-2.33 **	-23.23 **	-6.33	-15.71 **
ARG-2-1-2 x MR 1	-6.08 **	-3.70	-0.61	-5.19 **	-3.75 **	-4.32 **	-19.93 **	-2.31	-12.09 **
ARG-2-1-2 x RHA 272-II	-4.43 *	-2.02	1.13	-6.68 **	-5.25 **	-5.82 **	-7.25	13.17 **	1.83
ARG-2-1-2 x X-15-NB-10	-8.05 **	-5.72 **	-2.69	-4.49 **	-3.04 **	-3.61 **	-24.34 **	-7.69 -	16.94 **
ARG-2-1-2 x GKVK 2	-7.39 **	-5.05 *	-2.00	-7.21 **	-5.80 **	-6.36 **	-12.18 **	7.15	-3.58
ARG-2-1-2 x RHA-93	-6.40 **	-4.04	-0.96	-0.47	1.05	0.45	-8.57 *	11.55 **	0.37
MUT-2-8-3-2 x GKVK 3	-1.81	0.67	3.91	-1.03	0.48	-0.12	-6.60	13.95 **	2.54
MUT-2-8-3-2 x RHA 6D-1	-8.05 **	-5.72 **	-2.69	-5.56 **	-4.13 **	-4.69 **	-26.48 **	-10.30 **	-19.29 **
MUT-2-8-3-2 x 95-C-1	-9.03 **	-6.73 **	-3.74	-6.57 **	-5.14 **	-5.71 **	-9.60 *	10.29 **	-0.76
MUT-2-8-3-2 x LTRR-822	-8.70 **	-6.40 **	-3.39	-4.83 **	-3.38 **	-3.95 **	-17.70 **	0.41	-9.65 *
MUT-2-8-3-2 x M-17-R	-14.12 **	-11.95 **	-9.12 **	-10.49 **	-9.13 **	-9.67 **	-34.58 **	-20.18 **	-28.18 **
MUT-2-8-3-2 x MR 1	-10.51 **	-8.25 **	-5.30 *	-2.76 **	-1.28	-1.86 *	-20.66 **	-3.19	-12.89 **
MUT-2-8-3-2 x RHA 272-II	-8.54 **	-6.23 **	-3.21	-3.23 **	-1.75 *	-2.34 **	-9.82 *	10.03 **	-0.99
MUT-2-8-3-2 x X-15-NB-10	-6.73 **	-4.38 *	-1.30	-4.64 **	-3.19 **	-3.76 **	-11.10 **	8.47 *	-2.40
MUT-2-8-3-2 x GKVK 2	-11.99 **	-9.76 **	-6.86 **	-5.87 **	-4.43 **	-5.00 **	-24.90 **	-8.37 *	-17.55 **
MUT-2-8-3-2 x RHA-93	-8.21 **	-5.89 **	-2.87	-2.77 **	-1.29	-1.87 *	-12.04 **	7.31	-3.44
E002 x GKVK 3	-8.70 **	-6.40 **	-3.39	-5.02 **	-3.57 **	-4.15 **	-21.42 **	-4.13	-13.73 **
E002 x RHA 6D-1	-9.20 **	-6.90 **	-3.91	-2.34 **	-0.86	-1.44	-24.25 **	-7.58	-16.84 **
E002 x 95-C-1	-3.61	-1.18	2.00	-2.99 **	-1.52	-2.10 *	-18.94 **	-1.10	-11.01 **
E002 x LTRR-822	-7.72 **	-5.39 *	-2.35	-8.06 **	-6.66 **	-7.22 **	-22.93 **	-5.96	-15.39 **
E002 x M-17-R	-9.20 **	-6.90 **	-3.91	-4.26 **	-2.80 **	-3.38 **	-24.17 **	-7.48	-16.75 **

Table 2 (Contd.)

Hybrids	Head Diameter (cm)			Seed Filling Per cent (%)			Seed Weight (gm)		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
E002 x MR 1	-7.88 **	-5.56 *	-2.52	-3.73 **	-2.26 **	-2.84 **	-18.42 **	-0.47	-10.44 **
E002 x RHA 272-II	-8.21 **	-5.89 **	-2.87	-13.53 **	-12.2 **	-12.73 **	-18.68 **	-0.78	-10.72 **
E002 x X-15-NB-10	-8.87 **	-6.57 **	-3.56	-0.85	0.66	0.06	-25.07 **	-8.58*	-17.74 **
E002 x GKVK 2	-11.33 **	-9.09 **	-6.17 **	-4.22 **	-2.76 **	-3.34 **	-16.84 **	1.46	-8.70 *
E002 x RHA-93	-10.34 **	-8.08 **	-5.13 *	-4.26 **	-2.80 **	-3.38 **	-26.87 **	-10.77 **	-19.71 **
ARG 3 x GKVK 3	-8.37 **	-6.06 **	-3.04	-4.85 **	-3.40 **	-3.97 **	-28.11 **	-12.28 **	-21.07 **
ARG 3 x RHA 6D-1	-6.90 **	-4.55 *	-1.48	-6.00 **	-4.57 **	-5.13 **	-21.68 **	-4.44	-14.02 **
ARG 3 x 95-C-1	-4.76 *	-2.36	0.78	-6.06 **	-4.62 **	-5.19 **	-22.79 **	-5.80	-15.24 **
ARG 3 x LTRR-822	-10.67 **	-8.42 **	-5.47 *	-8.93 **	-7.54 **	-8.09 **	-23.39 **	-6.53	-15.90 **
ARG 3 x M-17-R	-9.85 **	-7.58 **	-4.60 *	-7.54 **	-6.13 **	-6.69 **	-25.63 **	-9.26 *	-18.35 **
ARG 3 x MR 1	-10.34 **	-8.08 **	-5.13 *	-7.82 **	-6.42 **	-6.97 **	-25.63 **	-9.26 *	-18.35 **
ARG 3 x RHA 272-II	-8.70 **	-6.40 **	-3.39	-14.81 **	-13.51 **	-14.02 **	-20.23 **	-2.68	-12.43 **
ARG 3 x X-15-NB-10	-11.99 **	-9.76 **	-6.86 **	-7.34 **	-5.93 **	-6.48 **	-19.79 **	-2.14	-11.95 **
ARG 3 x GKVK 2	-17.24 **	-15.15 **	-12.42 **	-11.49 **	-10.15 **	-10.68 **	-18.00 **	0.05	-9.98 **
ARG 3 x RHA-93	-11.82 **	-9.60 **	-6.69 **	-10.75 **	-9.39 **	-9.93 **	-14.65 **	4.13	-6.30

** Significant at $P \leq 0.01$ * Significant at $P \leq 0.05$

TABLE 3

Estimation of standard heterosis over KBSH 44, KBSH 53 and KBSH 78 for hull content, seed yield and oil content

Hybrids	Hull Content (%)			Seed Yield (kg / ha)			Oil Content (%)		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
ARG-2-1-2 x GKVK 3	-1.86	-3.56	3.41	-7.62	-8.63	-3.97	-6.07 **	-8.79 **	-10.01 **
ARG-2-1-2 x RHA 6D-1	-3.66	-5.34 *	1.51	-4.05	-5.10	-0.25	2.55 **	-0.42	-1.75 *
ARG-2-1-2 x 95-C-1	-6.81 **	-8.43 **	-1.81	6.60	5.43	10.81	-1.90 **	-4.74 **	-6.01 **
ARG-2-1-2 x LTRR-822	-17.31 **	-18.75 **	-12.88 **	15.04 *	13.78	19.59 **	-2.52 **	-5.35 **	-6.61 **
ARG-2-1-2 x M-17-R	-0.57	-2.30	4.76 *	-15.24 *	-16.17 *	-11.89	1.04	-1.89 *	-3.20 **
ARG-2-1-2 x MR 1	1.18	-0.58	6.61 **	-1.96	-3.03	1.92	1.96 *	-1.00	-2.32 **
ARG-2-1-2 x RHA 272-II	8.59 **	6.70 **	14.41 **	-1.15	-2.23	2.76	-8.37 **	-11.03 **	-12.22 **
ARG-2-1-2 x X-15-NB-10	5.34 *	3.50	10.99 **	-8.43	-9.43	-4.81	-0.61	-3.49 **	-4.78 **
ARG-2-1-2 x GKVK 2	5.25 *	3.42	10.90 **	4.79	3.64	8.93	-2.26 **	-5.09 **	-6.36 **
ARG-2-1-2 x RHA-93	-22.50 **	-23.84 **	-18.34 **	12.00	10.78	16.43 *	0.69	-2.23 **	-3.54 **
MUT-2-8-3-2 x GKVK 3	-8.37 **	-9.96 **	-3.45	16.39 *	15.11 *	20.99 **	-14.96 **	-17.42 **	-18.53 **
MUT-2-8-3-2 x RHA 6D-1	1.83	0.06	7.29 **	-21.85 **	-22.70 **	-18.76 *	-21.21 **	-23.49 **	-24.51 **
MUT-2-8-3-2 x 95-C-1	-1.46	-3.18	3.82	-3.98	-5.03	-0.18	-15.59 **	-18.03 **	-19.13 **
MUT-2-8-3-2 x LTRR-822	-14.22 **	-15.72 **	-9.63 **	-13.15	-14.10	-9.72	-21.95 **	-24.22 **	-25.23 **
MUT-2-8-3-2 x M-17-R	-10.03 **	-11.60 **	-5.21 *	-26.57 **	-27.37 **	-23.67 **	-18.61 **	-20.97 **	-22.03 **
MUT-2-8-3-2 x MR 1	0.61	-1.14	6.00 **	0.81	-0.29	4.79	-19.58 **	-21.91 **	-22.95 **
MUT-2-8-3-2 x RHA 272-II	18.31 **	16.25 **	24.66 **	-12.07	-13.03	-8.59	-21.05 **	-23.34 **	-24.36 **
MUT-2-8-3-2 x X-15-NB-10	16.00 **	13.99 **	22.22 **	-6.34	-7.36	-2.64	-20.23 **	-22.54 **	-23.58 **
MUT-2-8-3-2 x GKVK 2	-6.08 **	-7.72 **	-1.05	-18.48 *	-19.37 **	-15.25 *	-16.56 **	-18.98 **	-20.06 **
MUT-2-8-3-2 x RHA-93	-2.28	-3.98	2.97	10.18	8.98	14.54	-18.56 **	-20.92 **	-21.98 **
E002 x GKVK 3	1.35	-0.41	6.79 **	-9.31	-10.30	-5.72	-7.10 **	-9.80 **	-11.00 **
E002 x RHA 6D-1	0.12	-1.62	5.49 *	-11.19	-12.16	-7.67	-4.01 **	-6.79 **	-8.04 **
E002 x 95-C-1	9.02 **	7.13 **	14.87 **	-2.76	-3.83	1.08	-10.37 **	-12.97 **	-14.13 **
E002 x LTRR-822	-1.60	-3.31	3.68	-9.85	-10.83	-6.28	-3.72 **	-6.51 **	-7.76 **
E002 x M-17-R	9.10 **	7.20 **	14.95 **	-1.15	-2.23	2.76	-10.79 **	-13.38 **	-14.53 **

Table 3 (Contd.)

Hybrids	Hull Content (%)			Seed Yield (kg / ha)			Oil Content (%)		
	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78	KBSH 44	KBSH 53	KBSH 78
E002 x MR 1	7.47 **	5.60 *	13.23 **	-2.36	-3.43	1.50	-7.66 **	-10.34 **	-11.54 **
E002 x RHA 272-II	8.03 **	6.15 **	13.82 **	-12.81	-13.77	-9.37	-6.84 **	-9.55 **	-10.75 **
E002 x X-15-NB-10	0.68	-1.07	6.08 **	-11.94	-12.90	-8.45	0.02	-2.88 **	-4.18 **
E002 x GKVK 2	10.65 **	8.72 **	16.58 **	-3.30	-4.36	0.52	-6.62 **	-9.33 **	-10.54 **
E002 x RHA-93	6.11 **	4.26	11.80 **	-5.35	-6.39	-1.61	-14.62 **	-17.10 **	-18.20 **
ARG 3 x GKVK 3	2.52	0.74	8.02 **	0.54	-0.56	4.51	-16.83 **	-19.25 **	-20.32 **
ARG 3 x RHA 6D-1	6.36 **	4.50 *	12.06 **	-7.01	-8.03	-3.34	-14.29 **	-16.78 **	-17.89 **
ARG 3 x 95-C-1	11.99 **	10.04 **	18.00 **	-8.90	-9.90	-5.30	-9.85 **	-12.46 **	-13.63 **
ARG 3 x LTRR-822	6.59 **	4.74 *	12.31 **	-9.55	-10.54	-5.97	-16.80 **	-19.21 **	-20.29 **
ARG 3 x M-17-R	12.27 **	10.32 **	18.29 **	-10.23	-11.22	-6.68	-12.11 **	-14.66 **	-15.80 **
ARG 3 x MR 1	1.67	-0.10	7.12 **	-4.18	-5.23	-0.39	-14.86 **	-17.33 **	-18.43 **
ARG 3 x RHA 272-II	5.29 *	3.46	10.94 **	-20.84 **	-21.70 **	-17.71 *	-15.72 **	-18.17 **	-19.26 **
ARG 3 x X-15-NB-10	-2.12	-3.82	3.13	-13.15	-14.10	-9.72	-15.87 **	-18.31 **	-19.40 **
ARG 3 x GKVK 2	12.36 **	10.41 **	18.39 **	-9.10	-10.10	-5.51	-13.06 **	-15.58 **	-16.71 **
ARG 3 x RHA-93	3.56	1.76	9.11 **	-5.87	-6.90	-2.15	-25.07 **	-27.25 **	-28.22 **

** Significant at $P \leq 0.01$ * Significant at $P \leq 0.05$

TABLE 4

Top ranking hybrids with desirable standard heterosis over KBSH 44, KBSH 53 and KBSH 78 for different yield and yield attributing characters

Characters	Crosses	Per cent Standard heterosis over KBSH 44	Per cent Standard heterosis over KBSH 53	Per cent Standard heterosis over KBSH 78
Days to 50% flowering	ARG-2-1-2 x GKVK 2	-15.08 **	-18.94 **	-2.28
	MUT-2-8-3-2 x M-17-R	-13.49 **	-17.42 **	-0.46
	ARG-2-1-2 x RHA-93	-13.49 **	-17.42 **	-0.46
Plant height (cm)	ARG 3 x RHA-93	-27.33 **	-30.69 **	-8.59 **
	E002 x RHA-93	-26.61 **	-30.00 **	-7.68 *
	ARG 3 x GKVK 2	-25.44 **	-28.88 **	-6.21 *
Days to maturity	ARG-2-1-2 x GKVK 2	-9.79 **	-11.66 **	0.00
	E002 x M-17-R	-9.52 **	-11.40 **	0.29
	ARG-2-1-2 x RHA-93	-8.99 **	-10.88 **	0.88
Head diameter (cm)	MUT-2-8-3-2 x GKVK 3	-1.81	0.67	3.91
	ARG-2-1-2 x RHA 6D-1	-2.13	0.34	3.56
	ARG-2-1-2 x RHA95-C-1	-3.12	-0.67	2.52
Seed filling per cent	ARG-2-1-2 x RHA-93	-0.47	1.05	0.45
	ARG-2-1-2 x LTRR-822	-0.64	0.88	0.28
	E002 x X-15-NB-10	-0.85	0.66	0.06
100 seed weight (g)	ARG-2-1-2 x RHA95-C-1	-1.68	19.96 **	7.94 *
	ARG-2-1-2 x RHA 6D-1	-4.12	16.98 **	5.26
	MUT-2-8-3-2 x GKVK 3	-6.60	13.95 **	2.54
Hull content (%))	ARG-2-1-2 x RHA 93	-22.50 **	-23.84 **	-18.34 **
	ARG-2-1-2 x LTRR-822	-17.31 **	-18.75 **	-12.88 **
	MUT-2-8-3-2 x LTRR-822	-14.22 **	-15.72 **	-9.63 **
Seed yield (kg/ha)	MUT-2-8-3-2 x GKVK 3	16.39 *	15.11 *	20.99 **
	ARG-2-1-2 x LTRR-822	15.04 *	13.78	19.59 **
	ARG-2-1-2 x RHA 93	12.00	10.78	16.43 *
Oil content (%)	ARG-2-1-2 x RHA 6D-1	2.55 **	-0.42	-1.75 *
	ARG-2-1-2 x M-17-R	1.04	-1.89 *	-3.20 **
	ARG-2-1-2 x RHA 93	0.69	-2.23 **	-3.54 **

** Significant at P ≤ 0.01 * Significant at P ≤ 0.05

For seed yield (kg/ha) (Table 3) only two hybrids exhibited significant positive heterosis over KBSH 44. The cross combination MUT-2-8-3-2 x GKVK 3 (16.39%) exhibited highest significant positive heterosis followed by ARG-2-1-2 x LTRR-822 (15.04%). With respect to check KBSH 53 and KBSH 78, the standard heterosis of the cross combination MUT-2-8-3-2 x GKVK 3 was 15.11 per cent and 20.99 per cent, respectively. Hybrid ARG-2-1-2 x LTRR-822 ranked second for this trait with standard heterosis of 15.04, 13.78 and 19.59 per cent over the checks KBSH 44, KBSH 53 and KBSH 78, respectively. The presence of significant positive heterosis among the newly developed sunflower hybrid based on alien cytoplasmic lines was also observed by Nandini *et al.* (2017) and Tyagi *et al.* (2020).

As Sunflower is an oilseed crop, oil is the ultimate end product and hence, increasing oil content is of prime most important. The cross combination ARG-2-1-2 x RHA 6D-1 had highest significant standard heterosis of 2.55 per cent over the check KBSH 53 while it was on par with other two checks. Similar results were also obtained by Rathi *et al*. (2016) and Ailwar *et al.* (2020).

Exploitation of heterosis or hybrid vigour is an important method of crop improvement and is adopted in many of the cross pollinated crops all over the world. In sunflower, hybrids are more vigorous, uniform, productive and also resistant to disease and insect pests and are preferred for their better yield and contributing traits. In the present study, by using diverse cytoplasmic male sterile sources, high-yielding hybrids *viz.* MUT-2-8-3-2 x GKVK 3 and ARG-2-1-2 x LTRR-822 were obtained which were significantly better for seed yield than the commercial checks and hence can be utilized to overcome the genetic vulnerability which is present in Sunflower due to dependency on use of PET 1 as the sole CMS source for hybrid production.

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