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Exploitation of heterosis for yield contributing traits of late group of cauliflower

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ABSTRACT

Cauliflower hybrids belonging to the late (Snowball) group were evaluated for their mean performance and heterosis using the Ogura cytoplasmic male sterility (CMS) system. A total of 30 F_1 hybrids were developed by crossing three CMS lines with ten diverse testers through a Line × Tester mating design. These hybrids were assessed for ten key morphometric traits related to yield performance. Among the CMS lines, UHF-CAU-CMS-2 exhibited superior performance for most traits, except for days to 50% curd maturity and harvest index. Among the testers, PSBK-1, PSBKT-25, and Early London showed promising results for the majority of the yield-contributing traits. Based on per se performance and significant heterotic effects, the hybrids UHF-CAU-CMS-1 × Snowball Super, UHF-CAU-CMS-1 × PSBK-1, and UHF-CAU-CMS-2 × Early London emerged as the top-performing combinations. These crosses demonstrated notable improvements in curd size index, marketable curd weight, and harvest index, making them promising candidates for commercial cultivation, needs further validation through multi-location trials.

Key words: Snowball, Ogura , cytoplasmic male sterility, line × tester analysis, yield traits.

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is a popular cole vegetable cultivated throughout the world. India is the second largest producer of cauliflower after China with a production of 9.90 metric tonnes from an area of 0.50 million hectares. West Bengal, Madhya Pradesh and Bihar are the top three cauliflower producing states in the country. As compared to other states, Himachal Pradesh is ranked 15th in area and 14th in production however, the productivity fares better with a ranking of 9th (Indiastat, 5). Cauliflower cultivation is one of the major source of income for small and marginal farmers in Himachal Pradesh (Lalenpuii *et al*., 10). The state offers varied agro-climatic conditions for production of cauliflower with a growing market. Cauliflower is highly temperature sensitive crop affecting quality of curds in early and late season (Giri *et al*., 4). Cauliflower hybrids have been popular over other cultivars for their uniformity, better curd yield and tolerance to environmental as well as biotic stresses. The development of hybrids was earlier done by utilizing the self compatibility mechanism which were strong and stable in the early, mid and mid-late groups however was weak in the temperate type late group (Singh *et al.*, 18).

Among five different maturity groups of cauliflower, the mid-late and late group is popular off-season crop in hilly terrains of Himachal Pradesh, India. This area is unique and compatible for seed production of the temperate types commonly known as snowball group (Singh and Sharma, 16). Dey *et al.* (2) opined the cytoplasmic male sterility (CMS) as the best method for hybrid seed production in cauliflower because it remains stable across a wide range of climates, unlike self incompatibility (SI) systems. CMS based F_1 hybrids are completely male sterile, ensuring 100 % genetically pure hybrid seed (Kumar *et al.,* 8). This is especially advantageous in cauliflower, where the harvested product is the curd, not the seed. Consequently, for late maturing “Snowball” cauliflowers, heterosis breeding is more efficient with the Ogura CMS system than with SI based approaches (Singh *et al*., 15). As the development of cauliflower hybrids by utilizing the heterosis and combining ability studies related to late group through Ogura CMS is meagre, looking into this research gap the present study was undertaken. This investigation aimed to identify suitable hybrids in the snowball /late maturity group exhibiting superior yield-contributing traits.

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MATERIALS AND METHODS

The experiment was conducted in Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during *Rabi* season of 2019-2021. The site is located between 35.5° North latitude and 77.8° East longitude with an altitude of 1,270 m above mean sea level characterized as the mid hill zone. The climatic conditions were sub humid to sub temperate with cool winters wherein December and January were the coldest months. The experiment comprised of three CMS lines *viz.,* UHF-CAU-CMS-1, UHF-CAU-CMS-2, UHF-CAU-CMS-3 (from YSPUHF Solan, India) and ten testers. Line and testers were crossed to generate 30 F_1 hybrids during the first season and evaluated in second season 2020 by Randomized Complete Block Design (RCBD) with 3 replications. The attributes were record by randomly selecting five plants from each plot and their means were worked out for statistical analysis. The mean performance of ten quantitative attributes *viz.,* plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI) were recorded. The harvest index was obtained by dividing weight of marketable curd per plant to gross plant weight and then multiplied by 100.

Better parent and standard heterosis were worked by the following formulas,

(i) Heterosis over better parent (%) = $[(F_1\text{-BP})/BP] \times 100$

(ii) Heterosis over standard check (%) = $[(F_1\text{-SC})/SC] \times 100$

where in F_1, BP and SC were the respective mean values of crosses, better parent and standard check respectively. The data recorded were analyzed using MS-Excel and OPSTAT software packages as per design of experiment.

RESULTS AND DISCUSSION

Perusal of the analysis of variance revealed significant differences for all characters under investigation (Table 1). Singh *et al.* (16) had reported significance in parents as well as crosses for days to 50 % curd maturity, number of leaves, curd weight, curd size index except for stalk length. Non-significant variances for stalk length and significant variances for number of leaves, days to curd maturity, curd size and curd weight have been reported by Varalakshmi (20). Verma and Kalia (21) had similarly reported significant differences for plant height, days to 50 % curd maturity, marketable curd weight and harvest index.

Table 1. Analysis of variance for various quantitative traits of late cauliflower.

Source	Mean sum of squares		
Character	Replications	Genotypes	Error
Df	2	43	86
PH	53.29	116.57*	10.25
CH	2.60	44.22*	1.37
NL	1.34	15.73*	0.60
LSI	7717.18	152,058.65*	5,052.27
PS	19.45	60.80*	6.97
SL	0.20	2.10*	0.06
CSI	27.24	2668.62*	80.53
CS	42.02	170.72*	22.66
MCW	8718.17	290736.60*	2516.27
HI	8.74	91.94*	8.76

*Significant at 5% level of significance

Plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI)

The selection of superior inbred lines and highly heterotic crosses is of vital importance for effective crop improvement and sustainable hybrid development (Singh *et al.,* 15; Singh *et al*., 17). In the present study, mean performance of parents and hybrids led to identification of superior parents and combinations (Table 2). Parental lines, CMS line UHF-CAU-CMS-2 was best for plant height, number of leaves per plant, curd size index, curd solidity and marketable curd weight. However CMS line, UHF-CAU-CMS-1 was found superior for traits *viz.,* days to 50 % curd harvesting, stalk length and harvest index. The UHF-CAU-CMS-3 was better line for leaf size index and lesser plant spread. White Heart proved to be best tester for plant height and leaf size index, Cambridge No 5 for curd size index and PSBK-1 for maximum days to 50 % curd harvesting. However, PSBK-1, Early London and PSBKT-25 were the top three testers for curd weight whereas, PSBKT-25, White Rock and Early London proved best for harvest index. One of the major marketing aspects in cauliflower is the curd solidity wherein the testers Early London, Olympus and Snowball Super were exemplary. Significant differences amongst genotypes has been confirmed by Varalakshmi (19) and Sharma *et al.* (13) for curd size index, Kumar (7) for plant height, days to 50 % curd harvesting and harvest index.

Table 2. Mean performance of parents, crosses for cauliflower yield contributing traits.

Parents	PH (cm)	CH	NL	LSI (cm)	PS	SL (cm)	CSI (cm)	CS g/cm	MCW (g)	HI %
Line(s)										
UHF-CAU-CMS-1	49.77	123.33	16.87	849.270	51.77	4.64	109.63	75.98	1070.67	66.29
UHF-CAU-CMS-2	59.87	117.67	16.27	906.525	54.03	5.34	115.28	79.27	1083.33	62.19
UHF-CAU-CMS-3	56.68	110.00	19.93	952.365	51.59	5.16	108.86	77.93	1000.67	63.26
Tester(s)										
PSB K-1	51.30	129.00	14.60	954.585	52.53	4.90	88.64	76.58	993.33	64.45
PSB KT-25	56.47	122.33	13.27	945.203	52.63	5.94	100.87	71.96	937.33	71.29
Early Snowball	52.97	116.67	14.81	1,087.153	51.43	4.37	98.34	54.80	760.00	54.11
Cambridge No. 5	36.60	121.00	19.67	462.633	40.20	5.61	109.02	76.80	821.33	63.16
Olympus	56.13	124.33	22.00	877.043	52.13	5.86	100.61	85.59	932.00	63.19
Snowball Super	52.53	121.33	23.13	766.490	52.78	5.33	92.39	79.02	931.33	55.78
White Heart	65.80	120.00	16.60	1,220.613	53.83	4.50	105.65	70.07	918.67	49.71
Champion	61.33	122.00	19.27	913.433	59.10	4.33	99.11	72.87	800.67	50.23
Early London	49.71	118.67	20.20	828.473	51.43	5.05	94.54	86.01	956.00	67.40
White Rock	39.27	114.67	13.47	452.930	42.13	6.50	73.87	61.71	734.67	71.08
SE (m)±	1.85	0.68	0.44	41.04	1.52	0.14	5.13	2.76	28.63	1.69
$C.D._{(0.05)}$	5.21	1.91	1.26	115.58	4.29	0.40	14.44	7.78	80.62	4.76

*Significant at 5% level of significance

Plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI)

The desirable crosses/ hybrids were identified by plant growth and curd attributes *viz*., maximum marketable curd weight and higher curd size index and harvest index. Evaluation trials on basis of mean performances revealed the crosses UHF-CAU-CMS-2 × PSBK-1 as best for morphological traits such as plant height, leaf size index and second best for bearing minimum number of leaves (Table 3). UHF-CAU-CMS-1 × White Heart with maximum plant height and minimum stalk length and UHF-CAU-CMS-1 × Champion for highest harvest index were the best for respective traits.

In case of yield traits, the crosses UHF-CAU-CMS-1 × Snowball Super UHF-CAU-CMS-1 × PSBK-1 and UHF-CAU-CMS-2 × Early London performed best for marketable curd weight, curd size index and curd solidity as well. However the crosses UHF-CAU-CMS-2 × Olympus, UHF-CAU-CMS-1 × Champion and UHF-CAU-CMS-2 × Early Snowball were best three for harvest index. Desirable F_1 hybrids *per se* mean performance have been reported by Garg and Lal (3), Dey *et al.* (2). Verma and Kalia (20) for growth and yield parameters such as plant height and marketable curd weight. For plant height, significant better parent heterosis (Table 4) and standard heterosis (Table 5) was observed in five and fifteen crosses respectively in positive direction (desirable) confirmed by earlier studies by Dey *et al.* (1), Yang *et al.* (21) and Ram (12).

Trait days to 50 % curd harvesting, late maturing curds were considered desirable. In this study, twenty one crosses recorded better parent heterosis in positive direction, the elite three being UHF-CAU-CMS-3 × White Heart, UHF-CAU-CMS-3 × PSBKT-25 and UHF-CAU-CMS-2 × White Rock. Further, thirteen crosses registered significantly positive standard heterosis, the top three performing crosses were UHF-CAU-CMS-2 × White Heart, UHF-CAU-CMS-2 × Early Snowball and UHF-CAU-CMS-2 × Cambridge No. 5. Significantly positive and negative heterosis over better parent and standard parent has been reported by Ram (12); Jindal and Thakur (6) and Garg and Lal (3). Significantly better parent heterosis for number of leaves was exhibited by only three crosses whereas, seventeen crosses showed significant standard heterosis. These findings are in line with Garg and Lal (3); Dey *et al.* (1) and Ram (9) for the above trait. Leaf size index is an important growth parameter which directly contributes to curd yield (Sheemar *et al.,* 14). UHF-CAU-CMS-2 × PSBK-1 showed maximum heterosis at both levels (BP and SC) for leaf size index. These results are supported

Table 3. Mean performance of cauliflower crosses for various yield contributing traits.

Parents	PH (cm)	CH (days)	NL	LSI (cm)	PS (cm)	SL (cm)	CSI (cm)	CS g/cm	MCW (g)	HI %
Cross(s)										
UHF-CAU-CMS-1 × PSB K-1	54.70	120.00	17.07	925.46	49.00	6.07	194.82	82.73	1446.67	63.93
UHF-CAU-CMS-1 × PSB KT-25	56.00	118.67	20.47	1,034.14	55.88	5.90	172.83	82.68	1330.00	65.19
UHF-CAU-CMS-1× Early Snowball	60.67	124.67	14.00	1,311.37	52.17	7.24	130.87	81.51	1140.00	55.16
UHF-CAU-CMS-1 × Cambridge No. 5	58.17	119.00	15.13	1,097.25	50.87	5.53	165.10	80.34	1353.33	60.96
UHF-CAU-CMS-1 × Olympus	56.47	118.33	21.73	1,060.55	58.77	5.77	154.09	81.20	1228.67	57.88
UHF-CAU-CMS-1 × Snowball Super	56.20	122.33	20.27	1,001.98	54.33	6.75	184.31	86.51	1470.00	61.43
UHF-CAU-CMS-1 × White Heart	67.17	116.67	17.80	1,161.63	57.68	4.67	158.94	81.19	1256.67	59.05
UHF-CAU-CMS-1 × Champion	62.20	124.67	16.20	1,005.65	58.33	5.79	145.67	76.12	1261.33	67.15
UHF-CAU-CMS-1 × Early London	58.47	118.33	16.67	943.45	54.67	6.05	148.52	77.58	1160.00	54.31
UHF-CAU-CMS-1 × White rock	58.23	117.67	18.07	1,114.82	55.77	7.89	135.48	78.48	1270.00	59.07
UHF-CAU-CMS-2 × PSB K-1	67.60	122.67	14.80	1,801.78	55.63	5.89	134.26	69.10	1176.67	58.64
UHF-CAU-CMS-2 × PSB KT-25	58.13	125.00	17.67	1,161.22	50.67	7.61	198.42	81.86	1343.33	62.27
UHF-CAU-CMS-2 × Early Snowball	61.43	126.33	19.07	1,352.83	56.87	5.65	161.46	81.11	1383.33	66.97
UHF-CAU-CMS-2 × Cambridge No. 5	57.17	125.67	19.73	1,068.45	53.23	6.53	144.46	80.35	1150.00	61.97
UHF-CAU-CMS-2 × Olympus	51.63	122.33	18.47	822.70	53.63	6.80	143.93	81.84	1332.67	72.59
UHF-CAU-CMS-2 × Snowball Super	59.47	117.33	19.00	1,007.84	53.57	5.51	157.09	75.82	1316.67	61.37
UHF-CAU-CMS-2 × White Heart	57.33	127.33	19.13	1,090.42	46.27	6.79	153.44	76.96	1303.33	60.97
UHF-CAU-CMS-2 × Champion	51.57	122.33	19.40	950.61	51.08	6.16	155.49	72.46	1136.67	51.84
UHF-CAU-CMS-2 × Early London	53.07	118.33	17.93	837.35	50.22	7.41	181.43	81.16	1446.67	65.48
UHF-CAU-CMS-2 × White rock	54.83	124.33	19.80	806.13	50.65	5.93	137.77	77.96	1230.00	58.60
UHF-CAU-CMS-3 × PSB K-1	50.13	117.00	17.67	854.99	43.87	5.57	131.94	69.28	1273.33	60.42
UHF-CAU-CMS-3 × PSB KT-25	57.83	122.67	18.13	911.37	49.13	5.63	129.28	69.28	1117.33	63.63
UHF-CAU-CMS-3 × Early Snowball	56.33	119.00	19.07	1,020.85	47.12	5.38	154.27	69.73	1139.33	64.88
UHF-CAU-CMS-3 × Cambridge No. 5	44.70	116.33	19.13	580.36	45.42	5.95	110.72	77.63	1156.67	66.50
UHF-CAU-CMS-3 × Olympus	48.50	117.33	19.13	814.37	55.20	5.49	143.94	58.57	1070.67	56.28
UHF-CAU-CMS-3 × Snowball Super	46.63	115.67	16.93	835.47	55.80	6.50	143.45	83.87	1302.67	64.29
UHF-CAU-CMS-3 × White Heart	58.73	125.33	17.60	1,087.16	55.23	5.31	128.68	77.35	1164.67	59.26
UHF-CAU-CMS-3 × Champion	54.92	118.00	19.60	1,098.44	53.95	5.34	126.70	59.79	1066.67	50.53
UHF-CAU-CMS-3 × Early London	54.27	116.67	16.20	1,077.56	55.57	6.10	159.99	76.07	1350.00	61.91
UHF-CAU-CMS-3 × White rock	53.37	119.00	15.33	754.17	58.75	5.12	141.00	62.57	1108.00	65.92
Pusa Snowball Hybrid-1 (Check)	51.20	119.67	19.93	1,066.89	62.03	6.70	125.70	75.82	1094.00	56.58
SE (m)±	1.85	0.68	0.44	41.04	1.52	0.14	5.13	2.76	28.63	1.69
$C.D._{(0.05)}$	5.21	1.91	1.26	115.58	4.29	0.40	14.44	7.78	80.62	4.76

*Significant at 5% level of significance, plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI)

by studies of Dey *et al.* (1); Mehra (11) and Yang *et al.* (22) for leaf length and breadth.

The stalk length, only standard heterosis was observed in twenty-one crosses. For trait curd size index, UHF-CAU-CMS-1 × PSBK-1, UHF-CAU-CMS-2 × PSBKT-25, UHF-CAU-CMS-1 × Snowball Super figured as the top three crosses both for better parent heterosis and standard heterosis. Better parent heterosis for respective trait was noted in twenty-nine crosses and standard heterosis noted in twenty-one crosses respectively. Garg and Lal (3), Varalakshmi (19), Mehra (11) had also reported

Table 4. Better parent heterosis for various traits of cauliflower.

Parents	PH (cm)	CH	NL	LSI (cm)	PS (cm)	SL (cm)	CSI (cm)	CS g/cm	MCW (g)	HI (%)
Cross(s)										
UHF-CAU-CMS-1 × PSB K-1	6.63	-2.70*	16.89*	-3.05	-5.34	30.89*	77.71*	8.88	35.12*	-3.56
UHF-CAU-CMS-1 × PSB KT-25	-0.83	-3.00*	54.27*	9.41	7.95	27.16*	57.65*	8.82	24.22*	-8.56*
UHF-CAU-CMS-1× Early Snowball	14.54*	6.86*	-5.49	20.62*	1.43	65.80*	19.38*	7.28	6.48	-16.79*
UHF-CAU-CMS-1 × Cambridge No. 5	16.88*	-1.65*	-10.29*	29.20*	26.53*	19.25*	50.60*	5.74	26.40*	-8.05*
UHF-CAU-CMS-1 × Olympus	0.59	-4.05*	28.83*	20.92*	13.52*	24.43*	40.56*	6.87	14.76*	-12.68*
UHF-CAU-CMS-1 × Snowball Super	6.98	0.82	20.13*	17.98*	4.96	45.55*	68.12*	13.87*	37.30*	-7.34*
UHF-CAU-CMS-1 × White Heart	2.08	-2.78*	7.23	-4.83	11.43*	3.70	44.98*	6.85	17.37*	-10.93*
UHF-CAU-CMS-1 × Champion	1.41	2.19*	-3.97	10.10	12.69*	33.90*	32.88*	0.19	17.81*	1.30
UHF-CAU-CMS-1 × Early London	17.48*	-0.28	-1.21	11.09	6.29	30.46*	35.47*	2.10	8.34*	-19.42*
UHF-CAU-CMS-1 × White rock	17.01*	2.62*	34.13*	31.27*	32.36*	70.11*	23.58*	3.30	18.62*	-16.89*
UHF-CAU-CMS-2 × PSB K-1	12.92*	4.25*	1.37	88.75*	5.90	20.27*	16.46*	-9.05	8.62*	-9.02*
UHF-CAU-CMS-2 × PSB KT-25	-2.90	6.23*	33.13*	22.85*	-3.74	42.45*	72.12*	7.73	24.00*	-12.65*
UHF-CAU-CMS-2 × Early Snowball	2.62	8.29*	28.74*	24.44*	10.56*	29.47*	40.06*	6.75	27.69*	7.69*
UHF-CAU-CMS-2 × Cambridge No. 5	-4.51	6.80*	21.29*	17.86*	32.42*	22.35*	25.31*	5.75	6.15	-1.89
UHF-CAU-CMS-2 × Olympus	-13.75*	3.97*	13.50*	-9.25	2.88	27.34*	24.85*	7.72	23.02*	14.88*
UHF-CAU-CMS-2 × Snowball Super	-0.67	-0.28	16.78*	11.18	1.48	3.25	36.27*	-0.21	21.54*	-1.32
UHF-CAU-CMS-2 × White Heart	-12.87*	8.22*	17.60*	-10.67*	-14.06*	50.81*	33.11*	1.30	20.31*	-1.96
UHF-CAU-CMS-2 × Champion	-15.92*	3.97*	19.24*	4.07	-5.46	42.45*	34.88*	-4.63	4.92	-16.64*
UHF-CAU-CMS-2 × Early London	-11.36*	0.57	10.22*	-7.63	-2.37	46.57*	57.12*	6.82	34.91*	-2.85
UHF-CAU-CMS-2 × White rock	-8.41	8.43*	46.99*	-11.08	20.21*	10.99*	19.51*	2.60	13.54*	-17.56*
UHF-CAU-CMS-3 × PSB K-1	-11.55*	6.36*	21.00*	-10.43	-14.98*	13.61*	21.20*	-8.82	27.25*	-6.25
UHF-CAU-CMS-3 × PSB KT-25	2.03	11.52*	36.65*	-3.58	-4.77	9.17*	18.76*	-8.81	11.66*	-10.75*
UHF-CAU-CMS-3 × Early Snowball	-0.61	8.18*	28.74*	-6.10	-8.39*	9.80*	41.72*	-8.22	13.86*	2.56
UHF-CAU-CMS-3 × Cambridge No. 5	-21.14*	5.76*	-2.73	-39.06*	12.98*	15.31*	1.71	2.17	15.59*	5.13
UHF-CAU-CMS-3 × Olympus	-14.43*	6.67*	-4.00	-14.49*	6.99	6.46	32.23*	-22.92*	7.00	-11.03*
UHF-CAU-CMS-3 × Snowball Super	-17.73*	5.15*	-15.04*	-12.27*	8.15	25.97*	31.77*	10.38*	30.18*	1.62
UHF-CAU-CMS-3 × White Heart	-10.74*	13.94*	6.02	-10.93*	7.06	18.07*	18.21*	1.80	16.39*	-6.33
UHF-CAU-CMS-3 × Champion	-10.46*	7.27*	1.71	15.34*	4.57	23.42*	16.39*	-21.31*	6.60	-20.12*
UHF-CAU-CMS-3 × Early London	-4.26	6.06*	-18.72*	13.15*	8.04	20.65*	46.96*	0.12	33.54*	-8.15*
UHF-CAU-CMS-3 × White rock	-5.85	8.18*	13.83*	-20.81*	39.44*	-0.78	29.53*	-17.64*	10.73*	-7.26*
SE (m)±	1.85	0.68	0.44	1.13	1.52	0.14	5.13	2.76	28.63	1.69
$C.D._{(0.05)}$	5.21	1.91	1.26	3.18	4.29	0.40	14.44	7.78	80.62	4.76
Desirable crosses over better parent	05	21	03	11	03	-	29	02	25	02

*Significant at 5% level of significance

Plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI)

crosses with significant positive heterosis over better parent and standard check for the trait stalk length and curd size index. The superior heterotic effects exhibited by crosses UHF-CAU-CMS-1 × Snowball Super and UHF-CAU-CMS-1 × PSBK-1 for curd size index was also noted in case of marketable curd weight wherein these crosses along with UHF-CAU-CMS-2 × Early London retained their positions as the top three elite crosses. Twenty-five crosses recorded better parent heterosis whereas nineteen

Table 5. Standard heterosis for traits of cauliflower.

Parents	PH (cm)	CH	NL	LSI (cm)	PS (cm)	SL (cm)	CSI (cm)	CS g/cm	MCW (g)	HI (%)
Cross (s)										
UHF-CAU-CMS-1 × PSB K-1	6.84	0.28	-14.38*	-13.26*	-21.01*	-9.35*	54.99*	9.11	32.26*	13.01*
UHF-CAU-CMS-1 × PSB KT-25	9.37	-0.84	2.68	-3.07	-9.91*	-11.94*	37.50*	9.05	21.59*	15.24*
UHF-CAU-CMS-1× Early Snowball	18.49*	4.18*	-29.77*	22.92*	-15.91*	8.06*	4.12	7.51	4.22	-2.49
UHF-CAU-CMS-1 × Cambridge No. 5	13.61*	-0.56	-24.08*	2.85	-18.00*	-17.41*	31.35*	5.96	23.72*	7.76
UHF-CAU-CMS-1 × Olympus	10.29*	-1.11	9.03*	-0.59	-5.27	-13.83*	22.59*	7.10	12.33*	2.33
UHF-CAU-CMS-1 × Snowball Super	9.77	2.23*	1.67	-6.08	-12.41*	0.80	46.63*	14.11*	34.39*	8.59*
UHF-CAU-CMS-1 × White Heart	31.18*	-2.51*	-10.70*	8.88	-7.01*	-30.35*	26.45*	7.08	14.89*	4.38
UHF-CAU-CMS-1 × Champion	21.48*	4.18*	-18.73*	-5.74	-5.96	-13.53*	15.89*	0.40	15.31*	18.71*
UHF-CAU-CMS-1 × Early London	14.19*	-1.11	-16.39*	-11.57*	-11.88*	-9.65*	18.16*	2.32	6.05	-3.99
UHF-CAU-CMS-1 × White rock	13.74*	-1.67*	-9.36*	4.49	-10.10*	17.81*	7.78	3.51	16.10*	4.43
UHF-CAU-CMS-2 × PSB K-1	32.03*	2.51*	-25.75*	68.88*	-10.32*	-12.04*	6.81	-8.86	7.57*	3.66
UHF-CAU-CMS-2 × PSB KT-25	13.54*	4.46*	-11.37*	8.84	-18.32*	13.53*	57.86*	7.96	22.81*	10.09*
UHF-CAU-CMS-2 × Early Snowball	19.99*	5.57*	-4.35	26.80*	-8.33*	-15.62*	28.46*	6.98	26.47*	18.40*
UHF-CAU-CMS-2 × Cambridge No. 5	11.65*	5.01*	-1.00	0.15	-14.19*	-2.49	14.93*	5.97	5.13	9.55*
UHF-CAU-CMS-2 × Olympus	0.85	2.23*	-7.36*	-22.89*	-13.54*	1.49	14.50*	7.94	21.83*	28.33*
UHF-CAU-CMS-2 × Snowball Super	16.15*	-1.95*	-4.68	-5.53	-13.65*	-17.81*	24.98*	0.00	20.37*	8.49*
UHF-CAU-CMS-2 × White Heart	11.98*	6.41*	-4.01	2.21	-25.42*	1.29	22.08*	1.51	19.15*	7.78
UHF-CAU-CMS-2 × Champion	0.72	2.23*	-2.68	-10.90*	-17.65*	-8.01*	23.70*	-4.43	3.92	-8.36*
UHF-CAU-CMS-2 × Early London	3.65	-1.11	-10.03*	-21.51*	-19.05*	10.55*	44.10*	7.05	32.26*	15.76*
UHF-CAU-CMS-2 × White rock	7.10	3.90*	-0.67	-24.44*	-18.35*	-11.54*	9.61	2.82	12.45*	3.59
UHF-CAU-CMS-3 × PSB K-1	-2.08	-2.23*	-11.37*	-19.86*	-29.29*	-16.92*	4.97	-8.63	16.41*	6.81
UHF-CAU-CMS-3 × PSB KT-25	12.96*	2.51*	-9.03*	-14.58*	-20.80*	-15.92*	2.85	-8.62	2.15	12.48*
UHF-CAU-CMS-3 × Early Snowball	10.03	-0.56	-4.35	-4.31	-24.05*	-19.70*	22.73*	-8.03	4.16	14.70*
UHF-CAU-CMS-3 × Cambridge No. 5	-12.70*	-2.79*	-4.01	-45.60*	-26.79*	-11.19*	-11.91*	2.38	5.74	17.57*
UHF-CAU-CMS-3 × Olympus	-5.27	-1.95*	-4.01	-23.67*	-11.02*	-18.01*	14.52*	-22.76*	-2.12	-0.50
UHF-CAU-CMS-3 × Snowball Super	-8.92	-3.34*	-15.05*	-21.69*	-10.05*	-2.99	14.12*	10.61*	19.09*	13.65*
UHF-CAU-CMS-3 × White Heart	14.71*	4.74*	-11.71*	1.90	-10.96*	-20.70*	2.37	2.02	6.48	4.76
UHF-CAU-CMS-3 × Champion	7.27	-1.39	-1.67	2.96	-13.03*	-20.30*	0.80	-21.15*	-2.48	-10.67*
UHF-CAU-CMS-3 × Early London	5.99	-2.51*	-18.73*	1.00	-10.42*	-9.00*	27.28*	0.33	23.42*	9.44*
UHF-CAU-CMS-3 × White rock	4.23	-0.56	-23.08*	-29.31*	-5.29	-23.58*	12.18*	-17.47*	1.29	16.53*
SE (m)±	1.85	0.68	0.44	41.04	1.52	0.14	5.13	2.76	28.63	1.69
$C.D._{(0.05)}$	5.21	1.91	1.26	58.04	4.29	0.40	14.44	7.78	80.62	4.76
No of desirable crosses over Standard check (Pusa Snowball hybrid-1)	15	13	17	03	27	21	21	02	19	16

*Significant at 5% level of significance

Plant height (PH), days to 50 % curd harvesting (CH), number of leaves (NL), leaf size index (LSI), plant spread (PS), stalk length (SL), curd size index (CSI), curd solidity (CS), marketable curd weight (MCW) and harvest index (HI)

crosses showed standard heterosis over standard check. These results are in confirmation with the findings by Jindal and Thakur (6) and Kumari (9) for various maturity groups of cauliflower.

The crosses UHF-CAU-CMS-1 × Snowball Super and UHF-CAU-CMS-3 × Snowball Super were ideal for curd solidity as compared to better parent and standard check (Pusa Snowball Hybrid-1).

These results are in concurrence with Garg and Lal (3).

The harvest index, only two crosses *viz.,* UHF-CAU-CMS-2 × Olympus and UHF-CAU-CMS-2 × Early Snowball exhibited better parent heterosis in positive direction (desirable). On the contrary, sixteen crosses showed desirable significantly standard heterosis, the top three crosses among these were UHF-CAU-CMS-2 × Olympus, UHF-CAU-CMS-1 × Champion and UHF-CAU-CMS-2 × Early Snowball. These results are in concurrence with Dey *et al.* (2) and Ram (12).

Thus for yield related traits the lines UHF-CAU-CMS-1 and UHF-CAU-CMS-2 whereas testers PSBK-1, Early London and PSBKT-25 were found best and may be utilized as suitable parents in breeding programme. The best three cross combinations were UHF-CAU-CMS-1 × Snowball Super, UHF-CAU-CMS-1 × PSBK-1 and UHF-CAU-CMS-2 × Early London due to their superior heterotic effects displayed over better parent and standard check. Thus, these crosses could replace existing cultivated F_1 hybrids and may be recommended for commercial release subject to evaluation results of the multi-location trials.

AUTHORS' CONTRIBUTION

Conceptualization of research (SAN, DKM); Designing of the experiments (DKM, RKD); Contribution of experimental materials (DKM); Execution of field/lab experiments and data collection (RK, SK VV); Analysis of data and interpretation (BS, VS); Preparation of the manuscript (DKM, RKD, VV).

DECLARATION

The authors declare that they do not have any conflict of interest.

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