ARTICLE

Estimation of mean performance and heterosis in cytoplasmic male sterility (CMS) based hybrids in cabbage

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Abstract: *The successful transfer of R-cytoplasm (Ogura)-induced cytoplasmic male sterility has aroused great interest in the development of hybrids in cabbage. An experiment was conducted from 2018 to 2020 to study the per se performance and estimate heterosis in cabbage (Brassica oleracea L. var. capitata L.), This crop is highly cross-pollinated; thus, exploitation of heterosis is an additional advantage. The experimental material consisted of an F_1 population of 18 crosses, resulting from three lines (CMS) crossed with six testers in a Line × Tester design, plus a standard check (Pusa Cabbage Hybrid-1). The per se performance and estimates of heterosis of the cross combinations L1 × T2, L2 × T2, L2 × T5, L3 × T2 and L3 × T5 were high for various horticultural parameters. Hence, after multilocation testing, these parents and crosses can be released to substitute existing cabbage varieties/hybrids.*

Keywords: *R-cytoplasm, cabbage, cytoplasmic male sterility, heterosis, line × tester design*

INTRODUCTION

Cabbage (*Brassica oleracea* L. var*. capitata* L.), with a diploid chromosome number (2n = 2x = 18), is one of the most important cole crops grown in the world. Modern cabbage cultivars were derived from wild, non-heading Brassica (*Brassica oleraceae* L. var. *oleraceae* L.) by mutation, human selection and adaptation. The crop is grown for its leafy heads, which are commonly consumed as salad, cole slaw, or boiled, pickled or dehydrated vegetable. This vegetable contains the indole-3-carbinol compound, which serves as protection against bowel cancer (Thamburaj and Singh 2001).

Initially, only the sporophytic self-incompatibility system was used for commercial hybrid seed production. In the last decade, however, after the successful transfer of the R-cytoplasm (Ogura)-induced CMS system, the possibility of developing hybrids using cytoplasmic male sterility (CMS) has aroused great interest. Ogura CMS was inserted into cabbage by distant hybridization between radish and cabbage combined with embryo rescue, and OguraR1 CMS cabbage was created (Bannerot et al. 1974). However, because Ogura CMS cabbage lines have a radish cytoplasm, problems with nuclear–cytoplasmic incompatibility, chlorosis at low temperature (15 ºC), nectary dysplasia and poor seed set occur frequently. OguraR2 CMS materials were successfully established by protoplast fusion, by which the radish chloroplast was replaced by that of cauliflower in the OguraR1 CMS system (Walters et al. 1992). With Ogura CMSR3 material as

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the sterile source, several Ogura CMS cabbage lines with stable sterility and normal flowering and seed set have been bred and widely used in the development and production of cabbage hybrids (Ren et al. 2022).

Compared to the self-incompatible lines, cytoplasmic male sterile lines are more stable and could increase the cultivar purity of cabbage hybrids by 5-7% (Ding and Jian 2008). This is a promising alternative approach that could overcome the problem of selfs in hybrid seed due to the breakdown of self-incompatibility and vigor decline in S-allele lines, as a result of repeated selfing and sib-mating.

The rate of conversion from open-pollinated to hybrid varieties and seed replacement ratio are very high in cabbage. So far, of all coordinated research projects on vegetable crops in India, only the regional research station ICAR-IARI, in Katrain, Kullu Valley, Himachal Pradesh, India, developed one CMS-based hybrid KTCH-1 (Pusa Cabbage Hybrid-1). In, view of the above facts, this study has been undertaken to assess the *per se* performance and heterosis for various horticultural traits of F_1 population of 18 crosses, resulting from three CMS lines crossed with six testers in a Line × Tester design, plus a standard check.

MATERIAL AND METHODS

The experiment was carried out on an experimental farm of the Vegetable Science Department, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India, from 2018 to 2020. The parental lines were selected for their variability in various horticultural characteristics and practical applicability in heterosis breeding. The healthy seedlings of three lines *viz.,* L1, L2 and L3, and six testers *viz.,* T1, T2, T3, T4, T5 and T6, were transplanted to the main field on September 25, 2018. Details of the studied plant material are listed in Table 1. At proper head maturity in the last week of December 2018, the compact heads were incised crosswise, to facilitate bolting and flowering stalk emergence from the center of the heads. Crosses between the lines (three CMS lines) and testers (six) were initiated in February, 2019. Eighteen F_1 hybrid combinations were developed by standard procedures of crossing and bud pollination, according to the Line × Tester mating design (Kempthorne 1957). The matured siliquae of hybrids and parental lines were harvested separately from May to June, 2019. The seeds were dried and stored in a cool place for sowing in the following year.

On September 5, 2019, the seeds of the F_1 hybrids (18), parents (three lines and six testers) along with a standard check (Pusa Cabbage Hybrid-1) were sown in a nursery. Healthy seedlings were transplanted to the main field on September 26, 2019, in a randomized complete block design (RCBD), with three replications. The following horticultural parameters were recorded: days to 50% marketable maturity, number of non-wrapper leaves, plant spread (cm), head compactness (g cm^{-3}), head shape index, gross head weight (g), net head weight (g), stalk length (cm), harvest index (%), equatorial head diameter (cm), polar head diameter (cm), core size (cm), total soluble solids (°B), ascorbic acid (mg) and yield per plot (kg) and per hectare (q).

Table 1. Identification of cabbage genotypes used in the study

Sl. No.	Genotypes	Designation	Sl. No.	Genotypes	Designation
1.	UHF-CAB-CMS-20	L1	6.	UHF CAB -12	T3
2.	UHF-CAB-CMS-21	L2	7.	UHF CAB -13	T4
3.	UHF-CAB-CMS-22	L3	8.	UHF CAB -14	T5
4.	UHF CAB -10	T1	9.	UHF CAB -15	T6
5.	UHF CAB -11	T2	10.	Pusa Cabbage Hybrid -1	SC

RESULTS AND DISCUSSION

The mean performances of nine parents, 18 crosses and the standard check are shown in Tables 2-4. The mean squares due to parents and hybrids were found to be significant for all traits, which indicates the existence of sufficient variation among parents and hybrids, a prerequisite to improve traits through breeding. The mean and range of the parents were greater than of the hybrids for days to 50% maturity, number of wrapper leaves, plant spread (Table 2) and core size (Table 3), as shown by the desirable negative heterosis.

The mean and range of the F_1 hybrids were found to be greater than those of the parents for head compactness, head shape index, gross head weight (Table 2), net head weight, polar diameter (Table 3), total soluble solids, ascorbic acid and yield per plot (Table 4). This can also be explained by the positive heterosis, which is desirable for these traits. The parental mean and range were lower than the mean and range of hybrids for stalk length (for which negative heterosis is desirable) and greater than the mean and range of hybrids for harvest index, equatorial diameter (Table 3) and total soluble solids (Table 4), which indicated superiority of the parents over hybrids.

The significant superiority of 11 and 16 hybrids over the better parent and standard check, respectively, for days to 50% marketable maturity (for which negative heterosis is desirable) indicated dominant earliness and prospects to

Table 2. Mean performance of parents, hybrids and standard check for the traits days to 50% marketable maturity, number of non-wrapper leaves, plant spread, head compactness, head shape index and gross head weight

Genotypes	Days to 50% marketable maturity	Number of non-wrapper leaves	Plant spread	Head compactness	Head shape index	Gross head weight
Lines						
L1	86.67	15.53	56.93	29.92	0.88	1573.33
L2	97.33	15.43	52.80	41.25	1.00	1492.67
L3	111.00	13.47	55.97	54.95	0.83	1382.00
T1	111.33	13.07	49.80	38.91	0.89	1329.33
T2	97.00	13.47	48.40	40.15	0.91	1071.33
T3	107.00	16.20	50.13	37.25	0.84	1195.00
T4	106.67	14.63	52.23	45.13	0.85	1126.67
T5	110.67	13.37	53.13	28.06	0.85	1052.00
T6	109.33	15.97	55.07	22.30	0.80	1233.33
Range	86.67-111.33	13.07-16.20	48.40-56.93	22.30-54.95	0.80-1.00	1052.00-1573.33
Mean	104.11	14.57	52.72	37.55	0.87	1272.85
Crosses						
L1×T1	95.33	12.11	51.47	38.80	0.91	1340.00
L1×T2	95.00	13.28	51.33	64.27	0.90	1481.67
L1×T3	90.33	13.18	46.37	42.75	0.87	1529.00
L1×T4	90.00	12.54	54.10	45.38	0.92	1274.33
L1×T5	89.33	12.11	52.53	42.41	0.83	1609.00
L1×T6	95.33	12.98	50.07	37.82	0.92	1522.33
L2×T1	89.00	12.38	52.87	41.83	0.91	1478.67
L2×T2	86.00	12.14	52.70	38.72	1.17	1480.00
L2×T3	85.33	14.48	52.33	34.11	0.95	1541.00
L2×T4	86.00	15.01	53.87	43.08	0.92	1501.00
L2×T5	87.00	14.94	57.40	33.13	0.89	1628.67
L2×T6	94.33	13.51	52.73	42.98	0.98	1396.00
L3×T1	95.00	11.18	53.07	47.99	0.83	1444.00
L3×T2	87.33	11.01	51.63	62.04	1.05	1344.67
L3×T3	94.33	12.31	53.40	49.74	1.02	1262.67
L3×T4	85.67	12.44	53.80	51.35	0.99	1456.00
L3×T5	85.67	13.61	50.50	37.39	0.83	1434.00
L3×T6	87.00	13.31	52.93	38.44	0.80	1626.00
Range	85.33-95.33	11.01-15.01	46.37-57.40	33.13-64.27	0.80-1.17	1262.67-1628.67
Mean	89.89	12.92	52.39	44.01	0.93	1463.83
SC	98.33	12.27	43.55	32.40	0.92	1257.67
S.E. (m)±	1.15	0.39	0.62	1.31	0.02	36.03
C.D. $_{(0.05)}$	3.28	1.10	1.76	3.71	0.07	102.44
#	18	5	0	18	5	18

[*] Significant at 5% level of significance, [#] No. of desirable cross-combinations over standard check
SC - Standard check, S.E. (m) - Standard error (mean), C.D. - Critical difference

breed short duration hybrids to drive up the market price (Table 5). Significant desirable negative heterosis estimates for heterobeltiosis and standard heterosis were found for 11 cross combinations. Similar results were described by Parkash et al. (2015). Comparatively, a smaller number of non-wrapper leaves is considered desirable in cabbage which generally has shorter frame leaves. Significant desirable negative heterosis was recorded for heterobeltiosis and standard heterosis, respectively, in nine and one crosses. For one cross combination, significant desirable negative heterosis was estimated for heterobeltiosis and standard heterosis. These findings are in line with those of Thakur and Vidyasagar (2016a) and Kumar et al. (2019).

Cabbage lines with reduced plant spread are desirable, since a greater number of plants per square meter can be accommodated, resulting in higher yields. Significant desirable negative heterosis for heterobeltiosis was recorded in

Table 3. Mean performance of parents, hybrids and standard check for net head weight, stalk length, harvest index, equatorial head diameter, polar head diameter and core size

Genotypes	Net head weight	Stalk length	Harvest index	Equatorial head diameter	Polar head diameter	Core size
Lines						
L1	477.33	3.50	30.35	12.47	10.90	10.95
L2	577.00	3.87	38.68	11.17	11.20	10.24
L3	707.67	4.07	51.23	11.90	9.87	11.92
T1	674.67	3.93	50.78	12.73	11.30	14.35
T2	628.33	4.17	58.69	12.17	11.07	12.41
T3	493.33	4.50	41.32	11.93	10.03	13.43
T4	567.67	4.80	50.44	11.67	9.93	12.47
T5	469.00	5.17	44.60	12.87	10.87	11.74
T6	458.33	4.43	37.22	14.10	11.33	13.08
Range	458.33-707.67	3.50-5.17	30.35-58.69	11.17-14.10	9.87-11.33	10.24-14.35
Mean	561.48	4.27	44.81	12.33	10.72	12.29
Crosses						
L1×T1	516.00	4.83	38.59	11.50	10.50	10.78
L1×T2	676.67	4.03	45.72	10.73	9.63	8.68
L1×T3	550.00	5.63	35.99	11.63	10.13	12.67
L1×T4	571.33	4.00	44.90	11.27	10.33	10.43
L1×T5	519.33	3.80	32.34	11.67	9.72	8.50
L1×T6	639.67	4.47	42.05	12.43	11.40	12.85
L2×T1	573.67	4.27	38.82	11.63	10.60	11.41
L2×T2	580.67	4.63	39.26	10.57	12.33	12.42
L2×T3	548.67	5.50	35.59	12.00	11.43	10.63
L2×T4	555.00	4.63	36.99	11.33	10.43	10.15
L2×T5	715.67	4.67	43.95	13.67	12.20	11.11
L2×T6	670.00	4.50	48.01	11.70	11.50	12.63
L3×T1	750.33	4.10	51.99	12.67	10.57	15.27
L3×T2	780.33	4.03	58.08	10.53	11.07	11.36
L3×T3	617.33	3.80	48.93	10.67	10.83	11.59
L3×T4	622.00	4.03	42.79	10.70	10.63	15.91
L3×T5	492.67	3.33	34.40	11.97	9.97	8.21
L3×T6	708.33	3.60	43.58	13.63	10.90	10.07
Range	492.67-780.33	3.33-5.63	32.34-58.08	10.53-13.67	9.63-12.33	8.21-15.91
Mean	615.98	4.33	42.33	11.68	10.79	11.37
SC	573.33	5.30	45.60	12.57	11.63	12.47
S.E. (m)±	11.67	0.16	1.06	0.20	0.17	0.67
C.D. $_{(0.05)}$	33.19	0.46	3.01	0.56	0.48	1.91
#	11	16	5	3	2	13

[*] Significant at 5% level of significance, [#] No. of desirable cross-combinations over standard check

SC - Standard check, S.E. (m) - Standard error (mean), C.D. - Critical difference

five crosses. None of the cross combinations showed significant desirable negative heterosis estimates over standard check (Table 5). These findings are similar to those of Kumar et al. (2019). High head compactness is desirable since a more compact head will have less volume and more weight per unit area. Of the 18 F_1 hybrids, heterosis over the better parent and standard check, respectively, was significantly positive for 5 and 16 crosses. Five crosses showed significant desirable positive heterosis estimates for heterobeltiosis and standard heterosis, respectively. These findings were similarly reported by Singh et al. (2009) and Kumar et al. (2019). For head shape index, positive heterosis is desirable. Among the 18 F_1 hybrids, heterosis was significant and positive for four and three crosses, respectively, over the better parent and standard check. Three crosses showed significant desirable positive heterosis estimates for heterobeltiosis and economic heterosis. Similar results were also obtained by Kumar et al. (2019) and Thakur and Vidyasagar (2016b).

High gross head weight is the key trait that contributes to high yields. Significant desirable negative heterosis was recorded for 2 and 14 crosses, respectively, for heterobeltiosis and standard heterosis (Table 6). For two crosses, the (desirable) positive heterosis values, respectively, were significant for heterobeltiosis and standard heterosis. Significant positive heterosis (desirable) for gross head weight in cabbage was also reported by Singh et al. (2009) and Parkash et al. (2015).

Net head weight is an important yield-related horticultural trait. Among the 18 F_1 hybrids, for eight and nine crosses, respectively, heterosis was significant and positive over the better parent and standard check. For six crosses, heterosis for heterobeltiosis and standard heterosis was significant and positive (desirable). Similar results were obtained by Kumar et al. (2019). For stalk length, negative heterosis is desirable. Significant desirable negative heterosis was recorded in one and 15 crosses for heterobeltiosis and standard heterosis (Table 6). One cross combination showed significant desirable negative heterosis estimates for heterobeltiosis and standard heterosis. Significant negative heterosis (desirable) for stalk length in cabbage was also reported by Thakur and Vidyasagar (2016b). Among the 18 F_1 hybrids, two and three crosses showed desirable heterosis over the better parent and standard check, respectively, for harvest index (Table 5). Significant desirable positive heterosis values for heterobeltiosis and standard heterosis were not found for any of the crosses. These results are similar to those of Parkash et al. (2015).

For equatorial and polar head diameter, positive heterosis is desirable. Significant positive heterosis over the better parent and standard check, respectively, was recorded for equatorial diameter in one and two crosses (Table 6). One cross combination showed significant and positive heterosis (desirable) for heterobeltiosis and standard heterosis. Significant positive heterosis over the better parent and standard check was recorded in two and

Table 4. Mean performance of parents, hybrids and standard check for total soluble solids, ascorbic acid, yield per plot and yield per hectare

Genotypes	Total soluble solids	Ascorbic acid	Yield per plot	Yield per hectare
Lines				
L1	9.27	16.60	9.33	122.91
L2	9.33	16.78	11.24	148.02
L3	9.27	16.60	13.89	182.96
T1	9.47	5.69	13.42	176.73
T2	9.27	10.46	12.03	158.46
T3	10.03	9.01	9.45	124.49
T4	9.50	5.63	11.07	145.78
T5	8.90	7.29	9.20	121.20
T6	9.30	3.97	9.11	119.92
Range	8.90-10.03	3.97-16.78	9.11-13.89	119.92-182.96
Mean	9.35	9.82	10.97	144.4967
Crosses				
L1×T1	9.33	18.54	9.99	131.60
L1×T2	8.67	23.39	16.85	221.89
L1×T3	9.00	21.22	10.68	140.60
L1×T4	8.47	18.16	10.84	142.75
L1×T5	9.03	15.06	10.36	136.47
L1×T6	9.07	14.04	12.60	165.97
L2×T1	9.00	6.46	11.32	149.03
L2×T2	8.03	20.71	11.30	148.81
L2×T3	9.10	11.86	10.89	143.45
L2×T4	8.53	8.50	10.69	140.82
L2×T5	8.97	7.83	13.95	183.70
L2×T6	8.23	9.48	12.50	164.56
L3×T1	10.03	7.70	15.02	197.75
L3×T2	9.17	5.99	15.16	199.68
L3×T3	8.53	10.77	12.07	158.90
L3×T4	9.13	14.84	11.78	155.17
L3×T5	10.13	13.48	9.61	126.60
L3×T6	9.33	5.77	13.83	182.12
Range	8.03-10.13	5.77-23.39	9.61-16.85	126.60-221.89
Mean	8.99	12.99	12.19	160.55
SC	7.63	15.30	10.87	143.10
S.E. (m)±	0.14	0.21	0.22	2.89
C.D. $_{(0.05)}$	0.40	0.60	0.62	8.22
#	18	5	12	12

[*] Significant at 5% level of significance, [#] No. of desirable cross-combinations over standard check
SC - Standard check, S.E. (m) - Standard error (mean), C.D. - Critical difference

Table 5. Heterobeltiosis and standard heterosis for days to 50% maturity, number of non-wrapper leaves, plant spread, head compactness and head shape index

		Days to 50% marketable maturity	Number of non-wrapper leaves	Plant spread	Head compactness	Head shape index
Better parent heterosis	Range (%)	-22.59 to 10.00	18.26 to 11.77	9.09 to 8.88	-31.96 to 60.06	-10.75 to 20.92
	Mean (%)	-6.43 -9.60	-7.39	1.93	1.30	1.87
	No. of promising better parent hybrids	11	9	5	5	4
	Promising hybrid	L3 × T5 L3 × T6 L3 × T4 L3 × T1 L1 × T3	L3 × T2 L1 × T6 L1 × T3 L2 × T1 L1 × T4	L1 × T6 L1 × T3 L2 × T6 L3 × T5 L3 × T6	L1 × T2 L1 × T5 L1 × T6 L2 × T3 L3 × T2	L3 × T3 L3 × T4 L2 × T2 L3 × T2
Economic heterosis	Range (%)	-13.22 to -3.05	-10.27 to 22.33	6.47 to 31.80	2.24 to 98.35	-13.99 to 25.54
	Mean (%)	-9.60	5.28	20.31	35.84	-0.18
	No. of promising economic hybrids	16	1	0	16	3
	Promising hybrid	L2 × T3 L3 × T4 L3 × T5 L2 × T2 L2 × T4	L3 × T2		L1 × T2 L3 × T2 L3 × T4 L3 × T3 L3 × T1	L2 × T2 L3 × T2 L3 × T3

Table 6. Heterobeltiosis and standard heterosis for gross head weight, net head weight, stalk length, harvest index and equatorial head diameter

		Gross head weight	Net head weight	Stalk length	Harvest index	Equatorial head diameter
Better parent heterosis	Range (%)	-19.00 to 17.66	-30.38 to 34.01	-18.10 to 60.95	-33.10 to 24.12	-17.02 to 6.19
	Mean (%)	-1.05	0.51	14.43	-12.63	-7.73
	No. of promising better parent hybrids	2	8	1	2	1
	Promising hybrid	L3 × T6 L1 × T5	L1 × T6 L2 × T5 L2 × T6 L1 × T3 L3 × T2	L3 × T5	L2 × T6 L1 × T6	L2 × T5
Economic heterosis	Range (%)	0.40 to 29.50	-14.07 to 36.11	-37.11 to 6.29	-29.08 to 27.38	-16.20 to 8.72
	Mean (%)	16.39	7.44	-18.38	-7.16	-7.05
	No. of promising economic hybrids	14	9	15	3	2
	Promising hybrid	L2 × T5 L3 × T6 L1 × T5 L2 × T3 L1 × T3	L3 × T2 L3 × T1 L2 × T5 L3 × T6 L2 × T6	L3 × T5 L3 × T6 L3 × T3 L1 × T5 L1 × T4	L3 × T2 L3 × T1 L3 × T3	L2 × T5 L3 × T6

Table 7. Heterobeltiosis and standard heterosis for polar head diameter, core size, total soluble solids, ascorbic acid and yield per plot

		Polar head diameter	Core size	Total soluble solids	Ascorbic acid	Yield per plot
Better parent heterosis	Range (%)	-12.98 to 10.12	-30.10 to 33.47	-14.92 to 11.72	-61.52 to 40.90	-30.79 to 40.07
	Mean (%)	-3.19	3.31	-4.97	-16.58	1.94
	No. of promising better parent hybrids	2	3	1	6	8
	Promising hybrid	L2 × T2 L2 × T5	L3 × T5 L1 × T5 L1 × T2	L3 × T5	L1 × T2 L1× T3 L2 × T2 L3 × T4 L1 × T1	L1 × T2 L1 × T6 L2 × T5 L1 × T3 L2 × T6
Economic heterosis	Range (%)	-17.17 to 6.05	-34.19 to 27.59	5.29 to 32.81	-62.31 to 52.88	-11.56 to 55.01
	Mean (%)	-6.71	-8.82	17.79	-15.10	12.16
	No. of promising economic hybrids	2	6	18	5	9
	Promising hybrid	L2 × T2 L2 × T5	L3 × T5 L1 × T5 L1 × T2 L3 × T4 L1 × T4	L3 × T5 L3 × T1 L3 × T6 L3 × T2 L3 × T4	L1 × T2 L1 × T3 L2 × T2 L1 × T1 L1 × T4	L1 × T2 L3 × T2 L3 × T1 L2 × T5 L3 × T6

two crosses, respectively, for polar diameter (Table 7). For two crosses, significant positive heterosis (desirable) was estimated for heterobeltiosis and standard heterosis. These findings confirm those of Kibar et al. (2015) and Thakur and Vidyasagar (2016b).

A relatively smaller core size is desirable as it highly corrected with compact head**.** The significant superiority for core size of three and six hybrids over the better parent and standard check, respectively, indicate the dominance of compact head for better shelf life of cabbage (Table 7). For three crosses, significant negative heterosis (desirable) was estimated for heterobeltiosis and standard heterosis. Three crosses had significant negative heterosis values (desirable) for heterobeltiosis and standard heterosis. Significant negative heterosis (desirable) for core size in cabbage was also reported by Parkash et al. (2015), Thakur and Vidyasagar (2016b) and Kumar et al. (2019). For total soluble solids, positive heterosis is desirable. Significant positive heterosis over the better parent and standard check, respectively, was recorded in one and eighteen crosses. In one cross combination, significant desirable positive heterosis for this trait was estimated for heterobeltiosis and standard heterosis. These findings agree with those of Kumar et al. (2019). Significant positive heterosis (desirable) for ascorbic acid of six and five hybrids over the better parent and standard check, respectively, was recorded. Significant positive heterosis (desirable) was estimated for five crosses for heterobeltiosis and standard heterosis. Similar trends were reported by Parkash et al. (2015). Yield is the prime and complex trait. For yield per plot, positive heterosis is desirable. Significant positive heterosis over the better parent and standard check was recorded in eight and nine crosses, respectively, which enlightening that there is enough scope to increase the productivity. Significant positive heterosis (desirable) for heterobeltiosis and standard heterosis was found for six crosses, in agreement with findings of Thakur and Vidyasagar (2016b).

CONCLUSION

The *per se* performance and heterosis estimates (better parent and standard check) indicated that the crosses L1 × T2, L2 × T5, L3 × T5, L3 × T2 and L2 × T2 performed well for various horticulture parameters (Supplementary material I). Thus, the results of this study might be relevant and useful for developing hybrids with good head compactness, harvest index, equatorial and polar diameter, net head weight, total soluble solids and ascorbic acid, to possibly enhance the plant stand per square meter and biotic and abiotic stress tolerance, without losing vigour advantage of the yield. Hence, after multilocation testing, these parents and crosses can be released to replace existing cabbage varieties/hybrids.

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