Electronic Journal of Plant Breeding, 7(3): 602-610 (September 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00077.6

Research Article

Comparing of Self-Incompatibility and Cytoplasmic Male Sterility Systems for the performance of F_1 hybrids in cabbage (*Brassica oleracea* var. *capitata* L.)

Hament Thakur[1] and Vidyasagar[2]
[1]M.Sc. Student, [2]Professor, Department of Vegetable Science & Floriculture, CSKHPKV, Palampur (HP) 176 062
E-mail: hemantt114@gmail.com

(Received:06 Sep 2015; Accepted:14 Aug 2016)

Abstract
Four cytoplasmic male sterile (CMS) and three self-incompatible (SI) lines of cabbage were used as females for crossing with four cabbage testers (males) as per line × tester mating design during 2012-13 to produce the F_1 seeds of 28 hybrids. These hybrids were evaluated in Randomized Block Design with two standard checks Varun and KGMR-1 at the Vegetable Research Farm, CSKHPKV Palampur (mid-hills, sub-temperate with high rainfall) during 2013-14. Based on the performance, the hybrids CMS GAP x E-1-3 and II-12-4-10 x SC 2008-09 were either at par with the standard check 1 (Varun) and standard check 2 (KGMR-1) or significantly superior to both the checks for marketable head yield and most of the component traits. The hybrids which involved CMS lines as one of the parents have excelled in their performance for majority of the characters *viz.*, plant spread, non-wrapper leaves, polar diameter, days to harvest, head shape index and head compactness, whereas for the characters *viz.*, gross head weight, net head weight, equatorial diameter and marketable head yield per plot the hybrids developed using SI system excelled. Among the top five hybrids, four were of CMS system and one was of SI system. So, CMS system was considered more effective for production of F_1 hybrids by using the genetic material used in this study.

Key words
Performance, SI, CMS, cabbage

Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.), a member of *Brassicaceae* family is one of the most important cole-group vegetable crops. Hybrids are preferred over open pollinated varieties on account of their higher productivity and better quality produce. Commercialization of hybrids becomes possible due to the use of genetic mechanisms in reducing the cost of hybrid seed. In cole crops, the genetic mechanisms such as sporophytic self-incompatibility (SSI) and cytoplasmic male sterility (CMS) are prevalent and have been used commercially (Parkash, 2008). In developed countries, more than 90% cabbage growing area is under hybrid whereas it is 31 per cent in India (Kumar *et al.*, 2013). This is due to the cultivation of traditional open-pollinated varieties, higher cost and inconsistent performance of hybrids released by private companies and non-availability of potential hybrids from the public sector institutions. This necessitates the development and release of improved and widely adaptable hybrids from public sector institutions for the benefit of vegetable growers. Commercialization of hybrids becomes possible due to the use of genetic mechanisms in reducing the cost of hybrid seed. In cole crops, the genetic mechanisms of sporophytic self incompatibility (SSI) and cytoplasmic male sterility (CMS) are prevalent and have been used commercially. Till now, only limited research work has been carried out to improve cabbage in our country since breeding work has remained confined to a few research centers in the hills. Hence, it was considered to be a desirable proposition to use the self-incompatible (SI) and cytoplasmic male sterile (CMS) lines in combination with elite pollen parental lines to develop hybrids and to compare their effectiveness on the horticultural performance of F_1 hybrids.

Materials and method

Four CMS (CMS I, CMS II, CMS III and CMS GAP) and three SI lines (SI I-4-6, SI 2008-09-03-01 and II-12-4-10) were used as females to cross with four testers (males) *viz.*, Glory-1, E-1-3, E-1-10 and SC 2008-09 by following line x tester mating design to develop 28 F_1 hybrids. After heading and selection, the parental lines were covered with insect proof nylon net enclosures at the time of bolting and initiation of flowering during 2012-13. Pollination work was started when majority of the plants in parents had about 20-25% flowering. Pooled pollen of each tester was collected and applied to the opened flowers of self-incompatible plants (after removing anthers and petals just before pollination) and male sterile lines. The parental lines were also maintained through manual sibmating carried out in bud stage (Cabin *et al*., 1996) and open flower stage. However, the self-incompatible parental plants were sprayed common salt (3%) after about 15-20 minutes of pollination (Singh and Vidyasagar, 2012). The matured siliquas of respective hybrids and parental lines were harvested separately during the period May end to early June, 2013 and the seeds were extracted after about a week and kept for evaluation during 2013-14. The hybrids were then evaluated along with parents, standard check

1 (Varun) and standard check 2 (KGMR-1) in RBD with 3 replications at the Vegetable Research Farm, CSKHPKV Palampur (mid-hills, sub-temperate with high rainfall) during 2013-14. Observations were recorded on 5 randomly selected plants in each treatment per plot and replication for plant spread (cm), number of non-wrapper leaves, gross head weight (g), net head weight (g), polar and equatorial diameters of head (cm), days to harvest, head shape index, compactness of head (g/cm^3), number of marketable heads per plot, heading percentage (%) and marketable head yield/plot (kg). Head shape index was worked out by dividing the polar diameter with equatorial diameter (Odland and Noll, 1954). Compactness of head was determined as per the procedure suggested by Pearson (1931). The data were statistically analysed as per the procedure given by Panse and Sukhatme (1984).

Result and discussion

Analysis of variance: The analysis of variance for the characters plant spread (cm), non-wrapper leaves, gross head weight (g), net head weight (g), polar and equatorial diameter (cm), days to harvest, head shape index, compactness of head (g/cm^3), marketable heads per plot, heading percentage (%) and marketable head yield per plot (kg) have been presented in Table 1. The analysis of variance indicated significant differences among treatments for all the characters.

Performance of hybrids and parents: Performance of 28 crosses, 11 parents (7 lines and 4 testers) and 2 standard checks *i.e.*, standard check-1(SC1)-Varun and standard check-2 (SC2)-KGMR-1 for all the traits studied are presented in Table 2, 3 and 4. For plant spread, the breeders are in search of the combinations having shorter plant spread. Varieties with shorter plant spread are desired by the farmers also so that they may accommodate more number of plants per unit area. Plant spread varied from 31.16 cm (E-1-10) to 52.30 cm (SC1). All the hybrids had significantly lesser plant spread as compared to SC1 (Varun). The hybrid CMS I x E-1-10 (35.83 cm) and CMS GAP x E-1-10 (35.96 cm) had the shortest plant frame among all the hybrids. All the remaining hybrids except two *i.e.*, II-12-4-10 x E-1-3 (45.80 cm) and SI-I-4-6 x SC-2008-09 (45.70 cm) were at par with SC2 (Table 2). These results are in contrast to Parkash (2008) who found that none of the hybrids exhibited significantly smaller frame size than the check variety, whereas in this study all the hybrids showed significantly lesser plant frame compared to SC1. Relatively less number of non-wrapper leaves is desired in cabbage so as to have higher net head yield in relation to the gross head yield. *Yoon et al.* (1988) reported slow initial development of hybrids of Chinese cabbage with Ogura cytoplasm, affecting the number of leaves. The non-wrapper leaves varied from 11.53 (CMS III) to 18.00 (SI-I-4-6). The hybrid CMS GAP x E-1-3 (12.40) had the minimum number of non-wrapper leaves. As many as 23 hybrids were at par with SC2 (KGMR-1) whereas only 10 hybrids were at par with SC1 (Varun) (Table 2). Melo and Giordano (1994) and Parkash (2008) also reported hybrids developed by CMS lines with lesser number of non-wrapper leaves which were statistically at par with check variety. The gross head weight varied from 602.00 g (E-1-10) to 1395.33 g (II-12-4-10). Three of the hybrids *viz.*, II-12-4-10 x SC-2008-09 (1207 g), II-12-4-10 x E-1-3 (1062 g) and CMS GAP x E-1-3 (1032 g) had gross head weight at par with both the standard checks (Varun and KGMR-1) whereas all the remaining hybrids had gross head weight significantly lower than standard checks (Table 2). Plants with higher net head weight are required by the farmers in order to get more marketable yield per unit area. The range for net head weight varied from 223.33 g (Glory-1) to 637.00g (II-12-4-10 x SC 2008-09). The hybrids II-12-4-10 x SC 2008-09 (637 g) and CMS GAP x E-1-3 (564.66 g) had significantly higher net head weight as compared to SC1 whereas these were at par with SC2 (KGMR-1). Eleven hybrids were at par with SC1 (Table 2). Parkash (2008) reported that hybrids developed by self-incompatible lines had of higher net head weight than the hybrids developed by CMS lines.

In this study, the hybrid with the highest net weight was of SI system but, in general, the hybrids developed by CMS system showed more net head weight compared to SI system. Polar and equatorial diameters have direct influence on net head weight. The Polar diameter varied from 9.24 cm (CMS I x Glory-1) to 13.23 cm (II-12-4-10). Nine and 15 hybrids were at par with SC1 and SC2, respectively. The hybrid CMS GAP x SC 2008-09 (12.32 cm) exhibited the highest polar diameter among all the hybrids (Table 3). The equatorial diameter varied from 8.41 cm (SI-I-4-6) to 13.77 cm (II-12-4-10 x SC 2008-09). The hybrid II-12-4-10 x SC 2008-09 had the highest equatorial diameter of 13.77 cm. Generated hybrids were of less polar and equatorial diameter than those developed by Wang (2007) who developed an F_1 hybrid Chunkui by crossing self-incompatible line 9701-2 with HT502 which had about 22 cm height and 14 cm diameter. Ren (2008) developed a new cabbage F_1 hybrid Xiyuan No. 10, (cytoplasmic male sterile line 2002041 x inbred line 2002070), with flat round and compact head (11.0-13.0cm in height, 21.5-23.5cm in diameter). This may be due to the difference in the genotypes used in these two studies and also may be due to preference of consumer for large heads in their country whereas, small heads are preferred in a country like India as the families are small now a days. Fourteen hybrids were at par where as all other hybrids had significantly less equatorial diameter as compared to both SC1 and SC2 (Table 3).

Earliness is a highly desirable attribute in vegetables in the sense that the prevailing prices in the market are invariably higher in early season. So, hybrids with lesser number of days to harvest are desirable. Days to harvest varied from 112.80 (SC2) to 135.00 (II-12-4-10). The hybrid CMS I x Glory-1 (113.73 days) was the earliest among all the hybrids. Ren (2008) developed a new cabbage F_1 hybrid Xiyuan No. 10, (cytoplasmic male sterile line 2002041 x inbred line 2002070) with 105-120 days of maturing period. As many as 16 hybrids were earlier and 12 hybrids were at par with SC1 (Varun) whereas all the hybrids were at par with SC2 (KGMR-1) (Table 3).

Head shape index value (polar: equatorial diameter) determines the shape of cabbage heads. In case of round heads, shape index value is between 0.8-1.0. The value below 0.8 indicates flat or drumhead type heads whereas the values > 1.0 indicate pointed heads. Although round heads are preferred in India, but higher head shape index values have been considered better while discussing this trait. The head shape index varied from 0.83 (II-12-4-10 x SC 2008-09 and II-12-4-10 x Glory-1) to 1.33 (SI-I-4-6). The hybrid CMS III x SC 2008-09 exhibited the highest head shape index of 1.20. Three hybrids had significantly higher head shape index and 21 hybrids were at par with SC1. Eight hybrids had significantly higher head shape index and 20 hybrids were at par with SC2 (Table 3).

Head compactness is a desirable attribute in the sense that a compact head will have less volume and more weight per unit area. Besides, compact heads have better storage and are less prone to post harvest handling. The compactness of head varies from 22.65 g/cm^3 (II-12-4-10) to 37.88 g/cm^3 (E-1-10). The hybrid CMS GAP x E-1-10 showed the highest compactness (37.04 g/cm^3) among all the hybrids. As many as 21 hybrids were significantly more compact and 7 hybrids were at par with SC1 whereas 25 hybrids were at par with SC2. Tang (2010) developed a new cabbage F_1 hybrid Chenggan No 1 [self incompatible line Cai (05-01) X self-incompatible line Jinbei (05-02)]. The hybrid produced round and compact heads with excellent taste with a net weight of 0.75 kg (Table 4). Marketable heads per plot contribute directly towards marketable yield. The range varied from 6.00 (Glory-1) to 14.00 (CMS I). The hybrids, II-12-4-10 x E-1-10 and CMS GAP x E-1-3 had the highest number of marketable heads per plot (13.66) among all the hybrids. All the hybrids were at par with both SC1 and SC2 (Table 4). Heading percentage also contributes toward the total marketable yield. It varied from 57.14 (Glory-1) to 100.00 (SI-I-4-6 x SC 2008-09, CMS GAP x Glory-1, CMS GAP x E-1-3, CMS GAP x E-1-10, II-12-4-10 x E-1-3, II-12-4-10 x E-1-10 and CMS I). All the hybrids were at par with both SC1 and SC2 (Table 4). Marketable head yield is the dependent variable which is of economic concern to breeders and farmers. The hybrid II-12-4-10 x SC 2008-09 (6.92) showed the highest marketable head yield per plot among all the hybrids. Ding *et al.* (2011) developed a new red cabbage F_1 hybrid Zigan No. 3 by crossing a CMS line (CMSZ95-7) with an inbred line (Z97-18) with average head weight 1.5-2.0 kg and a yield of 66 t /hm^2. The hybrids CMS GAP x E-1-3 (6.56 kg/plot) and II-12-4-10 x SC 2008-09 (6.92 kg/plot) had significantly higher yield than SC1 (Varun) and 10 hybrids were at par with SC1. No hybrid could surpass but 5 hybrids were at par with SC2. Chen *et al.* (2011) developed a new cabbage F_1 hybrid Xiahua No.2 by crossing cytoplasmic male sterile line NBB10-87 C and inbred line 107-1with average head weight of 1.1 kg and a mean yield of 37.5-45.0 t /hm^2 (Table 4). The comparison of top five hybrids on the basis of their performance with standard check 1 (SC1) -Varun and standard check 2 (SC2) -KGMR-1 have been presented in Table 5. All the top 5 hybrids were significantly superior or either at par with standard check 1 (SC1) –Varun and standard check 2 (SC2) –KGMR-1 for most of the yield contributing traits.

Conclusion

The analysis of variance indicated significant differences among the treatments for all the characters studied which implied that the breeding materials used in this study had sufficient amount of genetic diversity. Based on the performance, the hybrids *viz.*, II-12-4-10 x SC 2008-09, CMS GAP x E-1-3, CMS GAP x SC 2008-09, CMS II x SC 2008-09 and CMS GAP x Glory-1 were found to be the top five hybrids (Table 5). Out of the top five hybrids four were of CMS system and one was of SI system. It can be concluded from (Table 5) that the hybrids CMS GAP x E-1-3 and II-12-4-10 x SC 2008-09 were either at par with the standard check 1 (Varun) and standard check 2 (KGMR-1) or significantly superior to both the checks for marketable head yield and most of the component traits. The hybrids developed by CMS lines showed better performance for majority of the characters *viz.*, plant spread, non-wrapper leaves, polar diameter, days to harvest, head shape index and head compactness. While for the characters *viz.*, gross head weight, net head weight, equatorial diameter and marketable head yield per plot, the hybrids developed using SI lines excelled in their performance. No doubt the hybrids made by SI system excelled the CMS system in major yield contributing traits but the yield can be increased by accommodating more number of plants per unit area by using hybrids which have shorter plant frame and less number of non-wrapper leaves *i.e.* hybrids developed by CMS system in this case.

Although the CMS lines are less liked by pollinators due to smaller flower size and lesser developed nectarines. In case of SI system, the SI lines with weak S allele interaction may break down later in the season, their maintenance is more tedious and requires more labour yet the problem can be eased by using SI lines with strong S allele interaction, by the use of CO_2 (Niikura and Matsuura, 2000) or adopting microspore culture (Palmer *et. al*, 1996; Rudolf *et. al*, 1999) to get the homozygous plants. So, it can be concluded from the results that CMS system can be considered better option than the SI system for the development of F1 hybrids if the lines used are stable.

References

Cabin, R.J., Evans, A.S., Jennings, D.L., Marshall, D.L., Mitchell, R.J., and Sher, A.A. 1996. Using bud pollinations to avoid self-incompatibility: implications from studies of three mustards. *Can. J. Bot.,* **74**: 285-289.

Chen, W.H., Fang, S.G., and Shao, G.R. 2011. A new cabbage F_1 hybrid 'Xiahua No.2'. *China Veg.,* **16**: 101-102

Ding, Y.H., Kang, J.G., and Jian, Y.C. 2011. A new red cabbage F_1 hybrid 'Zigan No. 3'. *China Veg.,* **12**: 91-93.

Kumar, C., Raturi, H.C., and Uniyal, S.P. 2013. Performance of cabbage hybrids under rainfed mid hills conditions of Uttrakhand. *Asian J. Hort.,* **8**: 110-113

Melo, P., and Giordano, L. 1994. Effect of Ogura male-sterile cytoplasm on the performance of cabbage hybrid variety. *Euphytica,* **76**: 117-123

Odland, M.L. and Noll, C.J. 1954. Vegetable variety trials 1953. Progressive Report Pennsylvania Agricultural Experiment Station. p114

Panse, V.G., and Sukhatme, P.V. 1984. Statistical Methods for Agricultural Workers. ICAR, New Delhi, p 381.

Parkash, C. 2008. Effectiveness of self-incompatibility and cytoplasmic male sterility systems in developing F_1 hybrids of cabbage. *Internat. J. Plant Sci.,* **3**: 468-470

Pearson, O.H. 1931. Methods of determining the solidarity of cabbage heads. *Hilgardia,* **5**: 383-393

Ren, X.S., Li, C.Q., and Song, H.Y. 2008. A new cabbage F1 hybrid 'Xiyuan No. 10'. *China Veg.,* **2**:33-34

Singh, S., and Vidyasagar. 2012. Effect of common salt (nacl) sprays to overcome the self-incompatibility in the s-allele lines of *Brassica oleracea* var. *capitata* L. *SABRAO J. Breed. Genet.,* **44**: 339-348.

Tang, Z.J., Kuang, C.B., and Su, L. 2010. A new cabbage F1 hybrid 'Chenggan No.1'. *China Veg.,* **6**: 80-81

Wang, C., Zhu, S., and Wang, S. 2007. A new cabbage F1 hybrid 'Chunkui'. *China Veg.,* **2**: 32-33

Yoon, J.Y., Opena, R.T., and Chang, L.C. 1988. Evaluation of radish derived cytoplasmic male sterility for use in tropical heading Chinese cabbage . *Cruciferae Newsl.,* **13**: 70-71.

Table 1. Analysis of variance for randomized block design

S.No.	Sources of variation → Traits df→	Replications 2	Treatments 40	Error 80
1	Plant spread (cm)	334.28	46.87*	7.86
2	Non wrapper leaves	7.51	8.19*	1.60
3	Gross head weight (g)	117333.20	84760.28*	5126.94
4	Net head weight (g)	12608.79	31769.24*	1711.31
5	Polar diameter (cm)	10.14	3.45*	0.47
6	Equatorial diameter (cm)	14.22	4.71*	1.03
7	Days to harvest	43.05	52.41*	14.91
8	Head shape index	0.01	0.04*	0.01
9	Compactness of head (g/cm^3)	6.97	29.41*	10.00
10	Marketable heads per plot	10.88	10.50*	2.18
11	Heading percentage (%)	222.01	302.89*	69.01
12	Marketable head yield (kg)	0.25	5.01*	0.25

* Significant at 5% level of significance

Table 2. Mean values of 28 crosses, 11 parents and 2 checks for plant spread, non-wrapper leaves, gross head weight and net head weight

Genotypes	Plant spread (cm)	Non wrapper leaves	Gross head weight (g)	Net head weight (g)
Crosses				
L1 x T1	43.13	17.66	792.66	298.00
L1 x T2	42.26	17.46	762.00	292.00
L1 x T3	43.66	17.06	834.66	345.33
L1 x T4	45.70	15.33	961.33	401.33
L2 x T1	41.30	13.86	805.33	383.33
L2 x T2	39.13	15.93	678.00	284.00
L2 x T3	38.16	14.60	614.00	281.00
L2 x T4	39.93	13.60	830.66	422.00
L3 x T1	40.16	15.40	778.00	334.00
L3 x T2	39.36	14.00	665.33	272.66
L3 x T3	35.83	17.00	722.00	345.33
L3 x T4	41.80	13.86	924.33	451.00
L4 x T1	42.80	15.06	757.33	314.00
L4 x T2	43.83	15.93	756.66	264.00
L4 x T3	39.43	14.53	895.33	480.00
L4 x T4	40.30	14.26	1002.66	499.33
L5 x T1	43.43	13.86	947.33	511.33
L5 x T2	43.33	15.00	849.33	393.00
L5 x T3	41.46	15.06	918.66	435.66
L5 x T4	44.10	13.80	928.66	430.00
L6 x T1	39.73	12.90	897.33	448.00
L6 x T2	42.36	12.40	1032.00	564.66
L6 x T3	35.96	14.53	806.00	396.66
L6 x T4	37.73	13.10	979.00	531.33
L7 x T1	43.93	13.60	985.00	430.00
L7 x T2	45.80	15.20	1062.00	446.00
L7 x T3	41.66	14.00	971.66	468.00
L7 x T4	43.93	12.90	1207.00	637.00
Lines				
L1	45.20	18.00	873.33	256.00
L2	38.60	16.00	656.00	241.33
L3	42.56	13.93	887.33	429.33
L4	40.13	15.86	675.00	285.33
L5	46.43	11.53	820.66	346.66
L6	35.80	12.40	733.00	321.00
L7	51.53	15.60	1395.33	434.66
Testers				
T1	40.80	17.80	716.66	223.33
T2	36.56	17.20	724.00	305.33
T3	31.16	16.06	602.00	290.66
T4	43.70	14.46	988.00	466.67
Checks				
Standard Check1(SC1)	52.30	11.93	1134.6670	494.00
Standard Check2(SC2)	40.70	13.80	1124.3330	609.66
CV (%)	6.74	8.55	8.2245	10.55
S.E (m)	1.61	0.73	41.33	23.88
C.D (5%)	4.55	2.05	116.3462	67.21

L1: SI I-4-6 L2: SI-2008-09-03-01 L3: CMS I L4: CMS II L5: CMS III L6: CMS GAP L7: II-12-4-10

T1: Glory-1 T2: E-1-3 T3: E-1-10 T4: SC 2008-09 SC1: Varun SC2: KGMR-1

Table 3. Mean values of 28 crosses, 11 parents and 2 checks for polar diameter,equatorial diameter, days to harvest and head shape index

Genotypes	Polar diameter (cm)	Equatorial diameter (cm)	Days to harvest	Head shape index
Crosses				
L1 x T1	9.34	9.64	115.06	0.96
L1 x T2	9.44	9.39	114.86	1.01
L1 x T3	10.68	9.14	117.13	1.17
L1 x T4	11.75	10.42	117.60	1.13
L2 x T1	10.39	10.27	114.60	1.01
L2 x T2	9.72	9.28	115.26	1.04
L2 x T3	9.83	9.06	117.53	1.09
L2 x T4	11.25	10.30	117.86	1.10
L3 x T1	9.24	10.27	113.73	0.90
L3 x T2	9.60	9.08	117.86	1.06
L3 x T3	9.86	9.14	117.26	1.08
L3 x T4	11.72	10.76	115.13	1.10
L4 x T1	9.57	9.67	116.40	1.00
L4 x T2	9.49	9.50	115.86	0.99
L4 x T3	10.46	10.89	114.00	0.93
L4 x T4	11.25	11.84	117.26	0.96
L5 x T1	10.91	11.93	114.80	0.92
L5 x T2	10.08	10.99	114.93	0.91
L5 x T3	11.07	10.46	114.73	1.05
L5 x T4	12.18	10.13	118.06	1.20
L6 x T1	11.31	10.95	116.00	1.01
L6 x T2	11.47	11.90	116.40	0.96
L6 x T3	10.10	10.14	116.86	1.01
L6 x T4	12.32	10.57	116.60	1.17
L7 x T1	10.03	11.95	114.70	0.83
L7 x T2	10.66	11.76	115.20	0.91
L7 x T3	10.04	11.82	114.26	0.84
L7 x T4	11.31	13.77	114.20	0.83
Lines				
L1	11.02	8.41	116.73	1.33
L2	9.84	8.45	117.80	1.17
L3	10.02	11.54	118.86	0.86
L4	9.54	9.94	120.80	0.95
L5	12.14	10.13	127.20	1.19
L6	11.09	9.17	121.50	1.21
L7	13.23	11.48	135.00	1.15
Testers				
T1	9.24	8.67	120.60	1.09
T2	9.95	9.24	117.66	1.09
T3	9.76	8.45	115.60	1.15
T4	13.04	10.06	126.66	1.30
Checks				
Standard check1(SC1)	12.26	12.16	122.60	1.01
Standard check2(SC2)	11.42	12.18	112.80	0.94
CV (%)	6.42	9.79	3.28	8.70
S.E (m)	0.39	0.58	2.23	0.05
C.D (5%)	1.11	1.65	6.27	0.14

L1: SI I-4-6 L2: SI-2008-09-03-01 L3: CMS I L4: CMS II L5: CMS III L6: CMS GAP

L7: II-12-4-10 T1: Glory-1 T2: E-1-3 T3: E-1-10 T4: SC 2008-09 SC1: Varun SC2: KGMR-1

Electronic Journal of Plant Breeding, 7(3): 602-610 (September 2016)
ISSN 0975-928X

Table 4. Mean values of 28 crosses, 11 parents and 2 checks for compactness of head, marketable heads per plot, heading percentage and marketable head yield

Genotypes	Compactness of head (g/cm^3)	Marketable heads per plot	Heading percentage (%)	Marketable head Yield (kg/plot)
Crosses				
L1 x T1	34.36	12.66	95.23 (79.62)	4.39
L1 x T2	34.19	12.66	92.85 (77.39)	3.32
L1 x T3	35.14	13.00	95.23 (79.62)	3.81
L1 x T4	29.26	13.33	100.00 (89.96)	4.76
L2 x T1	33.51	12.00	95.23 (79.62)	4.03
L2 x T2	33.03	11.66	90.47 (75.60)	3.12
L2 x T3	33.34	12.66	97.61 (84.79)	3.08
L2 x T4	32.34	11.66	89.74(78.73)	4.63
L3 x T1	34.26	12.00	92.85 (77.39)	3.84
L3 x T2	33.11	12.66	92.85 (77.39)	3.09
L3 x T3	36.09	11.00	88.09 (73.37)	3.63
L3 x T4	30.22	12.00	97.61 (84.79)	5.25
L4 x T1	33.96	11.33	88.09 (73.37)	2.72
L4 x T2	30.97	10.33	85.71(71.79)	2.67
L4 x T3	36.33	12.00	90.10 (74.86)	4.92
L4 x T4	32.10	12.66	95.23 (79.62)	5.93
L5 x T1	32.15	12.00	92.85 (77.39)	4.86
L5 x T2	33.56	12.33	92.85 (77.39)	4.07
L5 x T3	34.20	11.66	92.85 (77.39)	4.65
L5 x T4	30.00	11.33	85.70 (71.76)	4.48
L6 x T1	32.06	13.33	100.00 (89.96)	5.47
L6 x T2	34.89	13.66	100.00 (89.96)	6.56
L6 x T3	37.04	13.33	100.00 (89.96)	4.43
L6 x T4	31.66	13.00	97.61 (84.79)	6.09
L7 x T1	32.33	13.00	95.23 (79.62)	5.24
L7 x T2	31.31	11.33	100.00 (89.96)	4.76
L7 x T3	35.66	13.66	100.00 (89.96)	4.84
L7 x T4	31.51	12.33	92.85 (77.39)	6.92
Lines				
L1	27.58	9.66	76.18 (61.14)	2.68
L2	30.17	8.66	71.42 (57.77)	2.43
L3	33.26	14.00	100.00 (89.96)	4.91
L4	31.34	8.00	73.80 (59.56)	2.30
L5	24.91	8.66	80.94 (64.83)	2.94
L6	29.17	9.00	76.18 (61.14)	2.85
L7	22.65	8.33	85.71 (71.74)	3.34
Testers				
T1	31.72	6.00	57.14 (49.11)	1.53
T2	34.00	7.66	68.67 (56.41)	2.13
T3	37.88	12.66	92.48 (77.10)	3.73
T4	30.01	10.33	73.80 (59.56)	4.85
Checks				
Standard check1 (SC1)	26.78	11.66	92.85 (77.39)	5.52
Standard check2 (SC2)	35.58	12.33	95.23 (79.62)	6.15
CV (%)	9.79	12.85	9.25 (12.60)	11.9893
S.E (m)	1.82	0.85	4.79 (3.19)	0.28
C.D (5%)	5.13	2.40	13.49 (15.56)	0.81

Values in parenthesis are arc sine transformed values

L1: SI I-4-6 L2: SI-2008-09-03-01 L3: CMS I L4: CMS II L5: CMS III L6: CMS GAP L7: II-12-4-10

T1: Glory-1 T2: E-1-3 T3: E-1-10 T4: SC 2008-09 SC1: Varun SC2: KGMR-1

Table 5. Mean values of top 5 hybrids and standard checks (SC1 and SC2) on the basis of horticultural performance for marketable yield per plot and component traits

S. No.	Traits	L7 x T4	L6 x T2	L6 x T4	L4 x T4	L6 x T1	SC1	SC2	CD (5%)
1	Plant spread (cm)	43.93	42.36	37.73	40.30	39.73	52.30	40.70	4.55
2	Non wrapper leaves	12.90	12.40	13.10	14.26	12.90	11.93	13.80	2.05
3	Gross weight (g)	1207.00	1032.00	979.00	1002.66	897.33	1134.66	1124.33	116.34
4	Net weight (g)	637.00	564.66	531.33	499.33	448.00	494.00	609.66	67.21
5	Polar diameter (cm)	11.31	11.47	12.32	11.25	11.31	12.26	11.42	1.11
6	Equatorial diameter (cm)	13.77	11.90	10.57	11.84	10.95	12.16	12.18	1.65
7	Days to harvest	114.20	116.40	116.60	117.26	116.00	122.60	112.80	6.27
8	Head shape index	0.83	0.96	1.17	0.96	1.02	1.01	0.94	0.14
9	Compactness of head (g/cm^3)	31.51	34.89	31.66	32.10	32.06	26.78	35.58	5.13
10	Marketable heads per plot	12.33	13.66	13.00	12.66	13.33	11.66	12.33	2.40
11	Heading percentage (%)	92.85	100.00	97.61	95.23	100.00	92.85	95.23	13.49
12	Marketable head yield (kg/plot)	6.92	6.56	6.09	5.93	5.47	5.52	6.15	0.81

Lines→ L1- SI I-4-6 L2- SI-2008-09-03-01 L3- CMS I L4- CMS II L5- CMS III L6- CMS GAP L7- II-12-4-10

Testers→ T1- Glory 1 T2- E-1-3 T3-E-1-10 T4- SC 2008-09 SC1- Varun SC2- KGMR-1