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Identification of fertility restorer and sterility maintainer lines in Chilli (*Capsicum annuum* L.)

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Abstract
The eight CMS lines received from Asian Vegetable Research and development centre, Taiwan were crossed with twelve genotypes of chilli from Department of Agril. Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.). These twelve genotypes (male pollinators) of chilli were crossed with each of the CMS line during *rabi* 2014-15 and 96 hybrids were effected. Before crossing, sterility of female plants were checked and ensured to have 100 per cent sterile.
The seed from test cross hybrids were sown in the germination trays during summer 2015 at Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). 30-35 days old seedlings were transplanted in the pots and evaluation was carried out in the polyhouse. The observations on the pollen fertility were recorded to identify suitable restorer for different CMS lines.
Among the restorer, the six restorer *viz*. Pusa Jwala, DPLC-1, DPLC-2, DPLC-4, ACSS9818 and BC-28 were identified as common effective restorer for five CMS line AVPP0709S, AVPP0711S, AVPP0309S, AVPP0310S and AVPP0517S. BC-24 was identified as effective sterility maintainer for all the CMS lines. None of the chilli genotype under study was found to be effective restorer for CMS lines AVPP0710S.

Keywords: Chilli, restorer, maintainer and CMS lines

Introduction
Chilli (*Capsicum annuum* L.) vegetable-cum-spice is one of the most important commercial crop of India, valued for its industrial (oleoresin extraction) purposes. Chilli has its unique place in Asian diet as a spice as well as vegetable. It is also high valued crop grown commercially in almost all parts of the world. Asian countries produce nearly 9.7 mt of hot pepper annually and have a largest acreage planted under this crop (Greenleaf, 1986) [4]. The estimated acreage planted for hot pepper production in Asia is 1.6 m.ha. The leading countries are India, China and Korea have the largest hot pepper growing areas (Yamaguchi, 1983 and AVRDC, 1993) [15, 1].
Dry chilli production in world is 2.80 million tonnes with productivity 1584.9 kg/ha and area 1.77 m.ha. India is the largest producer of chilli in the world owing to the availability of improved varieties. According to an estimate for 2013, in India, dry chillies were cultivated on 7,93,590 ha with total production of 1.3 million tonnes of dry fruits and green chillies were cultivated on 8000 ha. with production6800 tonnes of fresh fruits. Average yield of dry chilli harvest was around 1.6 tonnes per hectare compared to those of 8.5 tonnes per hectare for green chilli (FAOSTAT, 2013) [3].
The role of hybrid seed in India is limited and the production of hybrid cultivar can be successful only if adequate quantities of hybrid seed are produced at reasonably low cost. The hybrid seed production in chili required tedious process of emasculation and pollination. Chilli flower are delicate in nature, resulting in flower drop or poor fruit set after emasculation. Moreover, hand pollination increases the cost of hybrid seed production due to high labour cost. In the recent years, hybrid cultivars have become popular and many farmers are producing hybrid seed of hot peppers based on nuclear male sterility (Dash *et al.*, 2001) [2]. Development of male sterility system is the only alternative to reduce the cost of seed production as it is being practices in other vegetable.

Materials and Methods
The eight CMS lines received from Asian Vegetable Research and Development Centre, Taiwan (Table 1) were crossed with twelve genotypes of chilli from Department of Agril. Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) (Table 2).

These twelve genotypes (male pollinators) of chilli were crossed with each of the CMS line during *rabi* 2014-15 and 96 hybrids were effected. Before crossing, sterility of female plants were checked and ensured to have 100 per cent sterile. The seed from test cross hybrids were sown in the germination trays during summer 2015 at Department of Agricultural Botany, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). 30-35 days old seedlings were transplanted in the pots and evaluation was carried out in the polyhouse. The observations on the pollen fertility were recorded to identify suitable restorer for different CMS lines. (Gulyas *et al.* 2006) [5].

Table 1: List of Genotypes (CMS line)

Sr. No.	Name of Genotypes (CMS line)		Origin	Source
1.	AVPP0711S	'A' line	Indonesia	AVRDC, Taiwan
	VI060630, C05671	'B' line		
2.	AVPP0516S	'A' line	Indonesia	AVRDC, Taiwan
	VI037614, TC06308	'B' line		
3.	AVPP0517S	'A' line	Sri Lanka	AVRDC, Taiwan
	VI060632, C05661	'B' line		
4.	AVPP9907S	'A' line	Korea	AVRDC, Taiwan
	AVPP9907	'B' line		
5.	AVPP0709S	'A' line	Korea	AVRDC, Taiwan
	VI060627, C05606	'B' line		
6.	AVPP0710S	'A' line	USA	AVRDC, Taiwan
	VI046838, TC06677	'B' line		
7.	AVPP0309S	'A' line	Indonesia	AVRDC, Taiwan
	AVPP0309	'B' line		
8.	AVPP0310S	'A' line	Indonesia	AVRDC, Taiwan
	VI060629, C05601	'B' line		

Table 2: List of male pollinators (Genotypes)

Sr. No.	Name of Genotypes	Origin / Source	Salient Features
1.	Pusa Jwala	IARI, New Delhi	Fruits are long, thin and pungent, National check
2.	Pant C-3	GBPAU, Pantnagar	Erect, small size light green fruit,
3.	LCA-334	RARS, Lam, Guntur	Highly pungent
4.	Jayanti	PDKV, Akola,(M.S.)	Pale green fruits, turned red after ripening
5.	Konkan Kirti	Dr. BSKKV, Dapoli, (M.S.)	Bushy plant, dark green fruit, mild pungent
6.	DPLC-1	Central Experiment Station, Wakawali, Dr. BSKKV, Dapoli,(M.S.)	Light green, medium sized.
7.	DPLC-2	Central Experiment Station, Wakawali, Dr. BSKKV, Dapoli,(M.S.)	Fruits are short, bold, point up word and straight
8.	DPLC-4	Central Experiment Station, Wakawali, Dr. BSKKV, Dapoli,(M.S.)	Fruits are short, bold, point up word and pendent
9.	ACSS 9818	Anand Agril. University, Gujarat	Yellowish green, Medium to long sized chilli.
10.	BC-24	Orissa University of Agril. & Technology, Bhubaneshwar (Odisha)	Fruits are short, light green
11.	BC-28	Orissa University of Agril. & Technology, Bhubaneshwar (Odisha)	Green fruits with pungency
12.	Parbhani Tejas	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, (M.S.)	Fruits are long and pungent

Table 3: Fertility reaction of hybrids

Sl. No	Lines used as male	F1 population	Female															
			AVPP0309S		AVPP9907S		AVPP0310S		AVPP0516S		AVPP0517S		AVPP0710S		AVPP0709S		AVPP0711S	
			Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1	Fertile	% fertile plants in F1
1	Pusa Jwala	10	10	100	10	100	10	100	4	40	10	100	4	40	10	100	10	100
2	Pant C-3	10	4	40	10	100	4	40	5	50	3	30	2	20	10	100	10	100
3	LCA 334	10	10	100	10	100	10	100	5	50	0	0	5	50	7	70	5	50
4	Jayanti	10	3	30	10	100	4	40	7	70	3	30	4	40	10	100	5	50
5	Konkan Kirti	10	4	40	3	30	7	70	10	100	10	100	3	30	10	100	10	100
6	DPLC-1	10	10	100	9	90	10	100	3	30	10	100	5	50	10	100	10	100
7	DPLC-2	10	10	100	7	70	10	100	5	50	10	100	3	30	10	100	10	100
8	DPLC-4	10	10	100	6	60	10	100	6	60	10	100	4	40	10	100	10	100
9	ACSS 9818	10	10	100	5	50	10	100	6	60	10	100	3	30	10	100	10	100
10	BC 24	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	BC 28	10	10	100	10	100	10	100	10	100	10	100	6	60	10	100	10	100
12	Parbhani Tejas	10	0	0	4	40	5	50	10	100	4	40	4	40	5	50	0	0

Results and Discussion

Male sterility in vegetable is never ending process due to rapid advancement in molecular techniques and their implementation. On global level, cytoplasmic male sterility (CMS) and cytoplasmic genetic male sterility (CGMS) are the most widely utilized in majority of vegetables. In India vegetable hybrids based on CMS and CGMS systems have been limited. Punjab Agricultural University (PAU), Ludhiana, India had released two chilli hybrids (CH-1 and CH-3) based on GMS system. In the recent past, chilli CGMS

lines were introduced at the Indian Institute of Vegetable Research (IIVR) from AVRD which are utilized directly or indirectly to produce CMS based hybrids i.e. Kashi Surkh (CCH-2) and Kashi Early (CCH-3). The Indian Institute of Horticultural Research (IIHR), Bengaluru, India has also released chilli hybrids based on CGMS system i.e. ArkaMeghna (MSH-172), MSH-149 and MSH-96. In India, research on the transgenic male sterility system has been initiated in selected vegetables but our first priority would be utilization of existing and established, but unexploited, male sterility systems. This will not only promote adoption of hybrid vegetable technology by economizing the cost of hybrid seeds but also provide basic material and scope for the development of more efficient male sterility system in respective vegetable crops.

In recent past, considerable emphasis has been given on the development of hybrids and high yielding in several vegetable crops. The phenomenon of heterosis has been attracted the attention of plant breeders due to its conspicuous effect on economic characters and the knowledge of combining ability provides a useful clue for selection of desirable parents for the development of better hybrids, which are superior in yield, quality and resistant to diseases and pests over present cultivated hybrids. Further for successful breeding programmes, the knowledge of genotype × environment interactions and stability parameters is of immense value and provides useful guidelines in selection of stable and high yielding genotypes. The genotypes specifically adopted to better and poor management conditions and those showing general adaptation can be identified.

Thus, the information regarding heterosis, combining ability and stability are the basic requirements for a thorough understanding of genetic architecture of yield and its components. Keeping all these views in mind, the present study was undertaken to obtain the information pertaining to the extent of heterosis, combining ability and phenotypic stability of genotypes in various environments for 13 characters utilizing line × tester mating design, involving five females and six male parents (of diverse origin).The resultant 30 F_1 along with parents and one standard check were grown during *rabi* 2015-16 at Dapoli, Karjat and Mulde locations. The results obtained in the present investigation are presented and discussed in the following sub-heads:

1. Identification of restorer
2. Analysis of variance for the experimental design
3. Performance of parents and hybrids
4. Magnitude of heterosis
5. Combining ability studies

Stability analysis

The twelve chilli genotypes were crossed with eight cytoplasmic male sterile lines to produce 96 F_1 hybrids. Based on their fertility restoration the male parents of hybrids were categorized as (i) Fertility restorer (Rf), (ii) Sterility maintainer (rf) and (iii) Partial restorer (Rf/rf) (Yoo, 1990) [16]. The information on fertility reaction of hybrids and classification of genotypes in three categories is presented in Table 3 and 4 respectively. Out of 96 F_1, fertility was restored (Rf) in forty six F_1 hybrids, partially restored in forty F_1 hybrids and maintained sterility (rf) in ten F_1 hybrids. Woong, (1985) [14] also reported similar result in male sterile lines of chilli. The results shown in table 4 revealed that percentage of fertility restoration was 47.91 per cent, partial restoration 41.67 per cent and sterility maintainer was 10.42 per cent. It shows a lot of variation for the presence of fertility restorer gene in chilli genotypes used as male on CMS lines (Shifriss, 1995 and Zhang, 2000) [9, 17].

Among the 12 high yielding genotypes the occurrence of restorer was higher in CMS lines AVPP0709S (75%) followed by AVPP0711S (66.66%) and AVPP0309S, AVPP0310S and AVPP0517S with (58.33%) for each CMS lines. These findings are inconformity with those of Patel *et al.*, (2001) [8] and Wankhede *et al.*, (2004) [13]. In present investigation, none of the chilli genotypes under study was found to be effective restorer for CMS line AVPP0710S. This suggest that it is very complex mechanism to restore the fertility in this cytosterile source, possibly due to presence of excess sterility nuclear genes in female parent, which could act as inhibiter of pollen fertility restoration in the F_1 generation (Tembhurne and Rao, 2012) [12].

Out of twelve pollinators or male parents BC-24 was identified as effective sterility maintainer for all the CMS lines. The six pollinators *viz*. Pusa jwala, DPLC-1, DPLC-2, DPLC-4, ACSS9818 and BC-28 were identified as common effective restorer for five CMS lines except AVPP9907S, AVPP0516S and AVPP0710S. Pusa jwala behave as partial restorer for AVPP0516S and AVPP0710S and restorer for AVPP9907S whereas DPLC-1, DPLC-2, DPLC-4, ACSS-9818 act as partial restorer for AVPP9907S, AVPP0516S and AVPP0710S. Among all the pollinators BC-28 act as a restorer for all CMS lines except AVPP0710S, Pant C-3 which was identified as effective restorer for the CMS lines AVPP9907S, AVPP0709S and AVPP0711S whereas for remaining CMS lines it act as partial restorer, LCA-334 behave as sterility maintainer for AVPP0517S and restorer for AVPP0309S, AVPP9907S and AVPP0310S and for remaining CMS lines it act as a partial restorer. Jayanti was found to be effective restorer with AVPP9907S and AVPP0709S while it was partial restorer for remaining six lines. Konkan kirti was identified as effective restorer for AVPP0516S, AVPP0517S, AVPP0709S and AVPP0711S whereas ParbhaniTejas was effective restorer for AVPP0516S and sterility maintainer for AVPP0309S and AVPP0711S. The variation in the restoration ability of genotypes for the CMS lines have also been confirmed by the studies of earlier worker *viz*., Singh *et al.*,(2006) [10], Kumar *et al.*,(2007) [6], Ma *et al.*, (2013) [7] and Suryawanshi *et al.*,(2013) [11].

In general, six pollinators *viz.* Pusa jwala, DPLC-1, DPLC-2, DPLC-4, ACSS9818 and BC-28 were identified as common effective restorer for five CMS lines *viz.* AVPP0309S, AVPP0310S, AVPP0517S, AVPP0709S and AVPP0711S.

Table 4: Fertility restoration of different pollinator (%)

CMS line	Restorer	Partial restorer	Maintainer	Total
AVPP0309S	7(58.33)	3(25.00)	2(16.66)	12
AVPP9907S	5(41.66)	6(50.00)	1(8.33)	12
AVPP0310S	7(58.33)	4(33.33)	1(8.33)	12
AVPP0516S	3(25.00)	8(66.66)	1(8.33)	12
AVPP0517S	7(58.33)	3(25.00)	2(16.66)	12
AVPP0710S	--	11(91.66)	1(8.33)	12
AVPP0709S	9(75.00)	2(16.66)	1(8.33)	12
AVPP0711S	8(66.66)	2(41.66)	2(16.66)	12
Total	46(47.91)	40(41.67)	10(10.42)	12

(Figures in the parentheses are percentage)

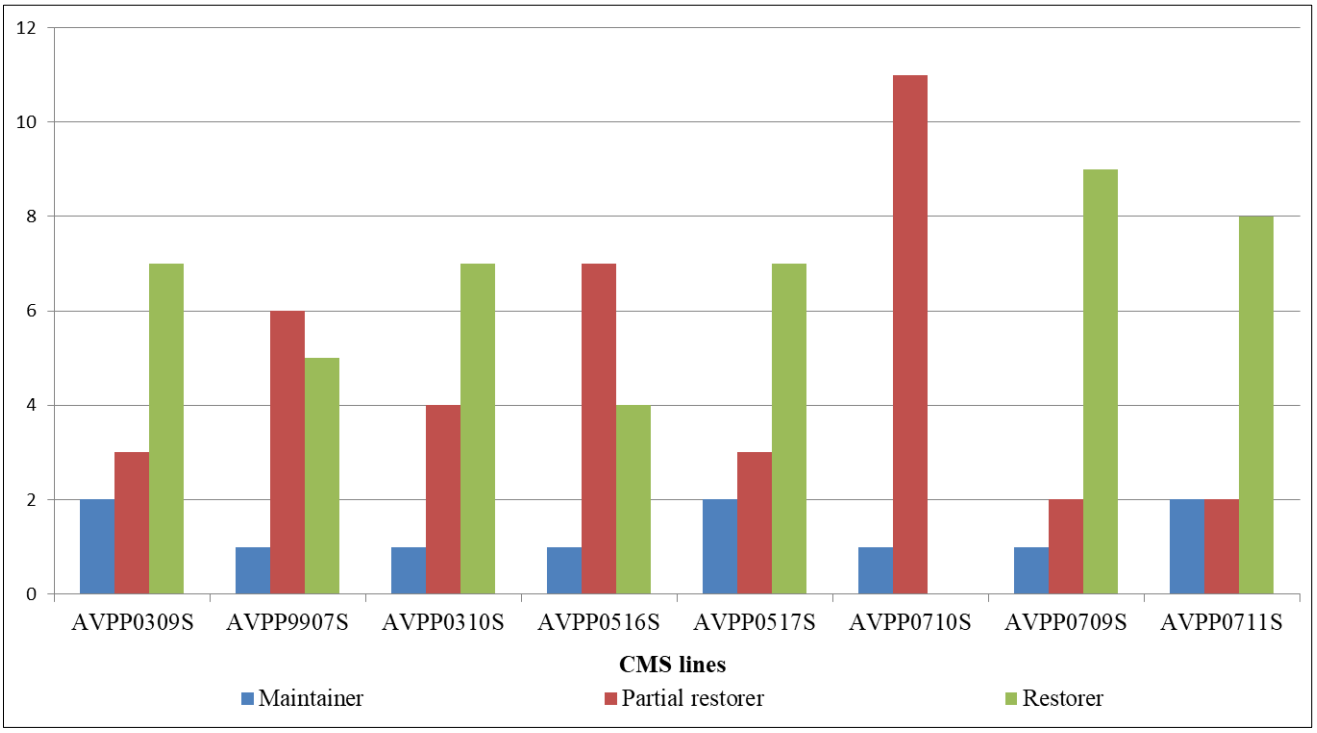

Fig 1: Indicating frequency of restorer, partial restorer and maintainer of genotypes for different CMS lines

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