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Genetic expression of CMS based hybrids for yield and its attributing traits in chilli (*Capsicum annuum* L.)

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Abstract

Eight chilli genotypes including four lines (CCA-4261, CCA-4257, IC-395318 and VR-339) and four testers (DSL-2, EC-519636, EC-566320 and Pusa Jwala) were crossed to obtain 16 F_1 hybrids. The lines (females) included three cytoplasmic male sterile (CMS) lines (CCA-4261, CCA-4257 and IC-395318) and one fertile line (VR-339). The 24 genotypes (4 lines, 4 testers and 16 resulting F_1 hybrids) were evaluated for growth and yield contributing traits. Correlation studies indicated that yield per plant was significantly correlated with fruit weight, total fruit weight per plant and plant height at both genotypic and phenotypic levels, whereas, it was positively associated with fruit length, fruit diameter and number of fruits per plant. The lines CCA-4261, CCA-4257, VR-339 and EC-566320 were grouped under cluster I while IC-395318 and EC-519636 grouped in cluster II. Analysis of variance for combining ability revealed that lines and testers exhibit adequate variation for all the characters. Highest phenotypic coefficients of variability obtained from fruit yield and the lowest from fruit diameter. Based on *per se* performance, heterosis and SCA effects, the hybrids IC-395318 × EC-566320, CCA-4261 × EC-519636 and VR-339 × EC-566320 were found superior hybrids for yield and its attributing traits. These elite hybrids may be tested for yield and other quality traits under different agro-climatic conditions for commercial exploitation of hybrid vigour.

Key words: Chilli, CMS lines, cluster analysis, combining ability, hybrid

Introduction

The genus *Capsicum* consists of a diverse range of plants and fruits and varies enormously with respect to morphology, yield and nutritional parameters. Chillies are grown as annual crop, although it can be grown as perennial shrub in suitable climatic conditions. Among the five cultivated species, *Capsicum annuum* L. is most widely cultivated for its pungent (hot) and non pungent (sweet pepper) fruits throughout the world (Bosland and Votava, 2000).

The fruits have as many versatile and innovative uses as its diversity (Kumar *et al.*, 2006). Utilization of chillies is attributed to its wide spectrum of inherent chemicals including steam-volatile oil, fatty oils, capsaicinoids, carotenoids, vitamins, protein, fiber, and mineral elements (Bosland and Votava, 2000; Krishna De, 2003). The presence of capsaicinoids is specific to the genus *Capsicum*, which varies widely among varieties, seasons, places of origin, etc. The chilli fruits are consumed at different ripening stage (green, red or partial red-ripe). This immense horticultural and biological diversity has helped to make *C. annuum* globally important as a fresh and cooked vegetable (*e.g*. for salads, warm dishes, pickled) and a source of food ingredients for sauces and powders and as a colourant, which is used in cosmetics as well (Andrews, 1995; Bosland and Votava, 2000). Moreover, the species is used for medicinal purposes and provides the ingredient for a non-lethal deterrent or repellent to some human and animal behaviour (Cichewicz and Thorpe, 1996; Reilly *et al.*, 2001).

Chillies have been classified as self-pollinated, however, the extent of cross pollination in chillies varies from 2 -96% (Pickersgill 1997) which may change the genetic identity of the land races forever (Votava *et al.,* 2005). It has substantial amount of non-additive genetic variance, hybrid vigour for yield (Gopalakrishnan *et al.*, 1987; Doshi and Shukla, 2000), which can be exploited profitably through heterosis breeding. According to the FAOSTAT (2011), India ranks on the top in dry chilli production in the world whereas, for the green chillies the value is too low as compared to the world production. Hybrid breeding has been advantageous for increased chilli production. Hybrid/heterosis breeding is comparatively easy for vegetable breeders as it is easy to incorporate desirable horticultural traits along with resistance to various stresses in F_1 hybrid and also to protect the right of the bred variety in terms of parental lines. For effective transfer of desirable genes, controlling both quantitative and qualitative traits in the resultant progenies, it is necessary to locate the better combining breeding materials.

The major focus of any breeding programme remains on the yield of the desired product. In chillies, fruit (dry and green) is the major component affecting crop yield and is governed by many quantitative traits. Since, yield is a complex trait, governed by a large number of component traits, it is imperative to know the interrelationship between yield and its component traits to arrive at an optimal selection index for improvement of yield. Several hybrids have been developed in hot chillies; however, the hybrid development programme should be the continuous so as to make the seeds available to the growers at the affordable cost. This investigation was planned to identify good combiners and heterotic cross combinations for yield, its component traits and quality in CMS-based and manually developed crosses in chilli.

Materials and methods

Eight genotypes including four lines and four testers (DSL-2, EC-519636, EC-566320, and Pusa Jwala) were crossed to obtain 16 F_1 hybrids. The lines (females) included three cytoplasmic male sterile lines (CCA-4261, CCA-4257 and IC-395318) and one fertile line (VR-339). The 24 genotypes (4 lines, 4 testers and 16 resulting F_1 hybrids) were evaluated in a randomized complete block design with three replications at Indian Institute of Vegetable Research, Varanasi during the chilli growing season of 2010 -2011. The observations were recorded on seven horticultural traits, *viz.,* fruit length (cm), fruit diameter (cm), number of fruits per plant, plant height (cm), ten fruit weight (g), fruit weight per plant (g) and fruit yield (q/ha).

The heterosis of F_1s over the better parent (BPH) and mid parent (MPH) was calculated by using the formula:

$$\text{Heterosis over mid parent (\%)} = \frac{F_1\text{-MP}}{\text{MP}} \times 100$$

$$\text{Heterosis over better parent (\%)} = \frac{F_1\text{-BP}}{\text{BP}} \times 100$$

Where, F_1 = Mean value of F_1s, BP= Mean of better parent and MP= mean of mid parent value.

Analysis of combining ability was carried out using the method proposed by Kempthorne (1957). The genetic parameters, such as phenotypic, genotypic and environmental coefficients of variation (GCV, PCV and ECV), heritability in broad sense (h^2_b), genetics advance and correlation coefficients for each character were estimated as suggested by Tsegaye *et al.* (2007).

Results and discussion

The results revealed that the magnitude of phenotypic coefficient of variation (PCV) values for all the traits were higher than the corresponding (GCV) values indicating that these characters may be under influence of the environmental effect to some extent. Phenotypic coefficients of variability ranged from 20.59 to 29.71% and the highest PCV obtained from fruit yield and the lowest from fruit diameter (Table 1).

Estimates of heritability obtained in the present investigation were very high for the character *viz.,* fruit length, ten fruit weight, yield per plant, plant height, total fruit weight per plant and number of fruits per plant (Table 1). In general, higher heritability estimates for these traits indicate that environmental factors did not greatly affect phenotypic variation in the characters. High estimates of heritability for above characters suggested that selection based on phenotypic performance would be effective as propounded by Johnson *et al.* (1955). Low heritability was noted for an important character that is number of fruits per plant. Therefore, it is obvious that selection for number of fruits per plant alone may not be effective in the early generation when the individual plants are selected on the basis of phenotypic performance. High heritability coupled with high genetic advance has been reported for yield and total fruit weight per plant in chillies (Munshi and Behra, 2000; Singh and Yadav, 2008).

Hybrid vigour is of paramount importance in chillies for increasing the productivity of the crop vertically as the land is shrinking. In present study, we found that heterosis over better parent and mid parent were significant for fruit yield and its component traits *viz.,* number of fruits per plant, fruit length, ten fruit weight, fruit weight per plant and yield per plant (Table 2). Considering fruit length, the cross combinations, CCA4261 × EC-566320, IC-395318 × DSL-2, IC-395318 × EC-519636 showed 9.92, 7.72 and 6.44% heterosis, respectively over better parent. The corresponding values for these crosses for mid-parent heterosis were 11.30, 16.75 and 15.77%, respectively. Regarding fruit diameter, CCA-4261 × DSL-2, CCA-4257 × Pusa Jwala, CCA-4257 × EC-566320 showed 1.11, 0.91 and 0.08% heterosis over better parent, respectively. For these crosses, heterosis over mid-parent for fruit diameter was observed to be 3.12, 12.88 and 11.01, respectively. Higher hybrid vigour for number of fruits per plant over better parent was observed for the crosses IC-395318 × EC-519636, CCA-4257 × Pusa Jwala, CCA-4261 × EC-519636 were 23.08, 19.33 and 13.89 %, respectively. It was interestingly noted that highest heterosis over better parent was observed for fruit yield by the crosses IC-395318 × EC-519636 (49.40%), VR-339 × EC519636 (48.39%) and CCA-4261 × EC-519636 (41.73%), respectively while mid-parent heterosis was 57.52, 60.33 and 68.93%, respectively.

We used three cytoplasmic male sterile lines as female parent and found that the resulting F_1 hybrids from the CMS system were more heterotic as compared to the normal counterparts. It is suggested that CCA-4257 × EC-566320 and IC-395318 × EC-519636 hybrid expressed appreciable heterosis over better and mid parent for most of the characters. Therefore, these hybrids are worthwhile to exploit for yield heterosis on commercial scale.

Analysis of variance for combining ability revealed that lines and testers showed adequate variation for all the characters. Promising general combiner for different character were CCA-4261 (for five characters: fruit length, fruit diameter, plant height, ten fruit weight, fruit weight per plant), EC-566320 (for five characters: fruit length, plant height, ten fruit weight, fruit weight per plant) and Pusa Jwala for fruit length. Genotypes CCA-4261 and EC-566320 were found good general combiner for fruit length while CCA-4257 and EC-519636 were found to be better general combiners for fruit diameter. Better specific combiner for fruit diameter, number of fruits per plant, fruit weight per plant were

Table 1. Mean, range, genotypic and phenotypic coefficient of variation heritability and genetic advance in hybrids of chilli

S.N.	Character	Grand mean	Range	Coefficient of variation		Heritability (%)	Genetic advance as % of mean
				GCV	PCV		
1.	Fruit length (cm)	8.58	5.42 - 10.81	19.70	20.69	90.60	36.48
2.	Fruit diameter (cm)	1.11	0.68 - 1.40	19.31	20.59	88.00	36.93
3.	Number of fruits/ plant (g)	94.55	66.50 - 136.50	21.27	23.32	83.10	38.98
4.	Plant height (cm)	63.50	54.55 - 91.00	20.63	22.43	84.60	39.25
5.	Ten fruit weight (g)	54.45	31.28 - 91.55	27.52	28.13	95.70	51.99
6.	Fruit weight per plant (g)	501.36	348.59 - 784.27	27.12	29.71	83.30	47.02
7.	Fruit yield (q/ha)	150.48	104.58 - 235.28	27.12	29.71	83.00	47.00

VR-339 × EC-519636, CCA-4261 × EC-519636 and CCA-4257 × Pusa Jwala, involved both the high general combiner for fruit length, ten fruit weight, fruit weight per plant, and could therefore be due to additive and additive × additive type of gene interaction which are fixable in nature. High general combining ability (GCA) of the parents, therefore, seems to be reliable criterion for the prediction of specific combining ability (SCA) for fruit length. The combinations IC-395318 × EC-519636 and CCA-4257 × Pusa Jwala involved low × high general combiners, while CCA-4257 × EC-566320 and VR-339 × Pusa Jwala involved low × low general combiner. Heterosis in the crosses involving low × high general combiners might be due to dominant × additive type of interaction which is partially fixable and the crosses involving both the poor combining parents and showing high SCA may be due to intra and inter-allelic interaction. The crosses CCA-4261 × EC-519636, VR-339 × EC-519636, CCA-4257 × EC-566320 showing high SCA for yield also exhibited high or average SCA effects for yield component traits. Therefore, it can be concluded that the crosses CCA-4261 × EC-519636, VR-339 × EC-519636, CCA-4257 × EC-566320 may be exploited for hybrid vigour in chilli (Solankey *et al.*, 2013).

Correlation studies indicated that yield per plant was significantly correlated with ten fruit weight, total fruit weight per plant and plant height at both genotypic and phenotypic levels whereas it was positively associated with fruit length, fruit diameter and number of fruits per plant (Table 3). Further breeding considering the importance of these traits would be fruitful for chilli improvement. Ten fruit weight showed negative correlation with number of fruits per plant at both genotypic and phenotypic levels which indicated that increase in number of fruits per plant would result in decrease in fruit weight. Similar results have been reported in chillies by Pasudesai *et al.* (2006), Hosamani and Shivkumar (2008) and Ganeshreddy *et al.* (2008), who observed significant correlation of various yield attributing traits with fruit yield.

In the present study, based on *per se* performance, heterosis and SCA effects, hybrids IC-395318 × EC-566320, CCA-4261 × EC-519636 and VR-339 × EC-566320 were found superior for yield and yield attributing traits. These three hybrids may be tested for yield and other quality traits under different agro-climatic conditions for commercial exploitation of hybrid vigour.

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Table 2. Best three heterotic F_1s and GCA and SCA effects for seven characters in chilli

Characters	Hybrids (F_1)	BP (%)	MP (%)	Parents	GCA	Hybrids (F_1)	SCA
Fruit length (cm)	CCA- 4257 × EC-566320	9.92	11.30	CCA- 4261	1.17	VR-339 × DSL-2	1.27
	IC- 395318 × DSL-2	7.72	16.75	EC-566320	1.04	VR-339 × EC-566320	0.71
	IC- 395318 × EC-519636	6.44	15.77	Pusa Jwala	0.73	CCA- 4261 × EC-519636	0.63
Fruit diameter (cm)	CCA- 4261 × DSL-2	1.11	3.12	CCA- 4261	0.12	VR-339 × EC-519636	0.15
	CCA- 4257 × Pusa Jwala	0.91	12.88	CCA- 4257	0.08	CCA- 4261 × EC-566320	0.10
	CCA- 4257 × EC-566320	0.08	11.01	EC-519636	0.08	CCA- 4257 × EC-566320	0.06
Number of fruits per plant	IC- 395318 × EC-519636	23.08	35.21	EC-519636	17.95	VR-339 × EC-519636	20.05
	CCA- 4257 × Pusa Jwala	19.93	1.17	IC- 395318	17.78	CCA- 4257 × EC-566320	11.72
	CCA- 4261 × EC-519636	13.89	16.92	VR-339	3.95	CCA- 4257 × DSL-2	9.26
Plant height (cm)	CCA- 4257 × EC-566320	26.98	47.17	EC-566320	4.28	CCA- 4257 × EC-566320	20.84
	CCA- 4261 × EC-519636	-36.63	-10.40	CCA- 4261	2.89	IC- 395318 × DSL-2	10.74
	CCA- 4261 × DSL-2	-36.46	-17.87	CCA- 4257	2.56	CCA- 4261 × Pusa Jwala	7.56
Ten fruit weight (g)	CCA- 4261 × Ec-566320	49.27	52.17	CCA- 4261	15.92	CCA- 4257 × Pusa Jwala	12.15
	CCA- 4257 × Pusa Jwala	28.89	34.42	EC-566320	11.27	VR-339 × DSL-2	12.10
	CCA- 4257 × EC-566320	27.63	17.93	CCA- 4257	2.53	CCA- 4261 × EC-566320	9.91
Fruit weight per plant (g)	IC- 395318 × EC-519636	164.67	57.52	CCA- 4261	105.09	CCA- 4261 × EC-519636	82.84
	VR-339 × EC-519636	48.40	60.33	EC-519636	94.97	VR-339 × EC-519636	79.08
	CCA- 4257 × EC-566320	45.87	15.61	EC-566320	70.00	CCA- 4257 × Pusa Jwala	69.03

Table 3. Genotypic correlation coefficient for various characters in chilli

Characters		Fruit diameter (cm)	No. of fruits per plant	Plant height (cm)	Ten fruit weight (g)	Fruit weight per plant (g)	Fruit yield per plant (g)
Fruit length (cm)	P	-0.142	-0.319	0.390*	0.627**	0.344	0.344
	G	-0.166	-0.371	0.447*	0.675**	0.390*	0.390*
Fruit diameter (cm)	P		-0.029	-0.206	0.441*	0.401*	0.401*
	G		-0.52	-0.223	0.482*	0.449*	0.449*
Number of fruits/plant	P			0.067	-0.299	0.439*	0.439*
	G			0.083	-0.351	0.354	0.359*
Plant height (cm)	P				0.117	0.138	0.138
	G				0.127	0.158	0.158
Ten fruit weight (g)	P					0.710**	0.710**
	G					0.742**	0.742**

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