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Uncovering the Genetic Basis of Combining Ability in *Capsicum annuum* for Yield Attributing Traits

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ABSTRACT: The current experiment was designed to determine the value of heterosis for fruit yield and its component traits in chilli. The crossing block comprised of 7 lines and 6 testers and their 42 hybrids developed using line × tester mating design which were assessed in randomized block design having three replications. The experiment was conducted at Main Vegetable Research Station, Anand Agricultural University, Anand during *kharif-rabi* 2020-21. In genetic combining ability analysis gca effects disclosed that among the female parents, ACGMS 2 and ACGMS 3 and among the males, ACS 13 – 03 and ACS 13 – 24 were found to be good general combiners for green fruit yield per plant. Hybrids ACCMS 1 × GAVC 112, CCA 4759 × ACS 08 – 09 and ACGMS 1 × ACS 13 – 03 were considered as best specific cross combinations. Pre-dominance of non-additive nature of genes governing the various characters. This experiment helps to identify the genetic effects of a trait which directly applicable for the development of better hybrids with desirable traits.

Keywords: Combining ability, Capsaicinoids, Chilli, Gene action and Heterosis.

INTRODUCTION

Chilli pepper is a valuable green vegetable as well as spice crop, grown in tropical, sub-tropical regions of world and originated in Mexico. It is part of genus *Capsicum* which includes 30 species, and solanaceae family with 2n=24 chromosome number. *C. annuum* L., *C. frutescens* L., *C. chinense* Jacq, *C. pubescens* and *C. baccatum* L. are cultivated spp. of chilli (Ince *et al.*, 2010).

Wide variation can be observed in C. *annuum* L. for fruit size, shape, colour and capsaicinoids content of the fruit *etc*. Studying flower structure is very important in order to develop a breeding strategy needed for improvement of any crop. Chilli has pedicellate, bisexual and hypogynous flower with 5 anthers. Chilli is classified as often cross pollinated crop though natural cross-pollination occurs to the extent of 7 - 60 % (Aiyadurai, 1966).

Among the cultivated species, *Capsicum annuum* L. is widely cultivated in India. Genotypes having bell shaped fruits and mostly non-pungent are called as sweet pepper (or bell pepper *i.e.* commonly known as capsicum in India) and genotypes having varying levels of pungency and cylindrical shape with tapering towards the end are called as hot pepper (or commonly known as chilli in India). Chilli offers a wide range of culinary benefits due to its composition, which includes various compounds such as steam-volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, proteins, fibers, and mineral elements (Bosland and Votava 2000).

Chilli contains numerous components that contribute to its nutritional value, flavor, aroma, texture, and color. The spiciness of chilli is attributed to "capsaicinoids." Chilli fruits not only serve as a natural source of bactericides but also contain capsaicin, which has been associated with anti-cancer properties. Chilli peppers are low in sodium, free of cholesterol, and abundant in essential nutrients such as vitamin A, vitamin C, vitamin E. They are also a good source of potassium and folic acid. Interestingly, fresh green chilli peppers contain more vitamin C than citrus fruits, while fresh red chilli peppers surpass carrots in terms of vitamin A content (Gopalan *et al*., 2004).

Knowledge of various qualitative and quantitative traits and their pattern of inheritance and nature of their gene action and extent of environmental influence important to any breeder and based on this, breeding strategies for any crop is decided along with mode of pollination. The primary challenge encountered by plant breeders is the identification and pairing of distinct parents for the purpose of crossbreeding. Thus, estimating the true combining ability *i.e.* gca and sca are important for any hybrid development and hence it is advocated to get full genetic information of any variety. Nature of gene action also provide information to plan breeding strategy for improving the traits. Several mating designs

are available for assessing general combining ability (GCA) and specific combining ability (SCA), but the simplest approach with a minimal number of crosses is the line x tester mating design. In this design, a group of inbred lines or varieties is used as the pollen parents and crossed with another group of sterile lines or inbred lines/varieties serving as the female parents.

MATERIALS AND METHODS

The study was conducted at the Main Vegetable Research Station, Anand Agricultural University, Anand, during the *kharif-rabi* season of 2019-2020. The experimental materials consisted of seven lines and six testers (as shown in Table 1), and a total of 42 hybrids were developed using the line × tester mating design. Additionally, a standard hybrid check was included in the experiment. Out of seven lines of chilli, two were cytoplasmic male sterile lines and remaining were govern by genetic male sterility system. A total of fifty-six genotypes were assessed in a Randomized Complete Block Design with three replications during the *kharif-rabi* season of 2020-21. For each plot, seedlings were transplanted in a single row consisting of ten dibbles, with a spacing of 60 cm between rows and 60 cm between plants.

Five plants will be randomly selected from each experiment unit in all the replications except the border plants and those will be used for recording the observation like days to flowering initiation, plant height, primary branches per plant, fruit per plant, fruit length (cm), fruit girth (cm), fruit weight (g), Seeds per fruit, test weight (g), Green fruit yield per plant (g), Capsaicin content (mg/g) and ascorbic acid content (mg/g). Where, the character days to initiation of flowering was taken based on plot basis. The difference observed among hybrids were divided into more specific category based on their general combining ability (gca) and specific combining ability (sca), following the recommended method proposed by Kempthorne (1957).

Table 1: List of genotypes and their source.

Genotypes	Source
Lines (Females)	
CCA 4759, ACCMS 1, ACGMS 1, ACGMS 2, ACGMS 3, ACGMS 4, ACGMS 5	MVRS, AAU, Anand
Testers (Males)	
GAVC 112, ACS 08 – 09, ACS 13 – 03, ACS 13 – 24, ACS 18 – 02, ACS 18 – 08	MVRS, AAU, Anand
Standard Check Hybrid	
GAVCH-1	MVRS, AAU, Anand

RESULTS AND DISCUSSION

A comparison of variances between lines and testers showed significant difference in contribution of lines and testers towards GCA variances. For all the traits examined, the mean squares originating from the lines were greater. This result showed that contribution of lines for these characters towards gca was greater than testers. The analysis of variance conducted to assess combining ability indicated that the variance attributed to general combining ability was extremely significant for the following traits: days to flowering initiation, plant height, primary branches per plant, fruit girth, fruit weight, seeds per fruit, test weight, green fruit yield per plant, capsaicin content, and ascorbic acid content. On the other hand, the variance related to specific combining ability was highly significant for all the traits examined.

A. General Combining Ability Effects

Early flowering is a desirable trait, thus parents exhibiting significant and negative general combining ability (GCA) were considered to be effective general combiners. ACGMS 5 (-4.48) and ACS 18 – 08 (-1.11) were good general combiners and can be selected for earliness (Table 2). Positive and significant general combining ability (GCA) effects for plant height were regarded as favorable attributes in terms of general combining ability. ACCMS 1 (9.08) and ACS 13 – 03 (4.19) were found good general combiners. For primary branches per plant ACGMS 1 (0.51) and ACS 13 – 24 (0.15) were good general combiners. Parents exhibiting significant and positive general combining ability (GCA) effects were considered valuable combiners due to their ability to contribute to desirable traits such as a greater number of fruits, higher fruit weight, increased seed count per fruit, improved test weight, and ultimately higher green fruit yield per plant. ACGMS 3, ACGMS 2, ACCMS 1 and ACS 13 – 24were considered as good general combiners for these traits. Among the female parents, ACCMS 1 (0.97) and ACGMS 1 (0.78) were good general combiners and these parents possessed favourable genes for higher fruit length. Capsaicin and ascorbic acid are important biochemical present in chilli. CCA 4759 (1.46) and ACGMS 4 (0.16) were good combiners for capsaicin and ascorbic acid content, respectively due to significant and positive gene effects.

B. Specific Combining Ability Effects

The evaluation of specific combining ability (SCA) effects demonstrated that none of the hybrids consistently outperformed others across all traits. Among the 42 hybrids assessed, 11 hybrids displayed significant positive SCA effects specifically for green fruit yield per plant. The hybrid combinations ACCMS1 × GAVC 112, CCA 4759 × ACS 08-09, and ACGMS 1 × ACS 13-03 were regarded as the most favorable specific crosses, as they exhibited the highest significant positive SCA effects for green fruit yield per

plant. Among these hybrids, hybrid ACCMS 1 × GAVC 112 also had significant and desirable sca estimates for fruits per plant, fruit weight, seeds per fruit, test weight and capsaicin content. The hybrid CCA 4759 × ACS 08 – 09 also recorded significant and desirable sca estimates for the characters fruits per plant, fruit length, fruit weight, seeds per fruit, test weight and ascorbic acid content. The hybrid ACGMS 1 × ACS 13 – 03 also depicted significant and desirable sca effects for primary branches per plant, fruits per plant, fruit length, fruit girth, fruit weight, seeds per fruit, test weight and capsaicin content.

C. Gene Action

The ratio of GCA to SCA variance ($\sigma^2_{GCA}/\sigma^2_{SCA}$) were found to be lesser than unity for all the characters under study, indicating the pre-dominance of non-additive nature of genes governing the various characters. This finding is in agreement with results of Kaur *et al.* (2017); Chakrabarty *et al.* (2019) for days to initiation of flowering, plant height and seeds per fruit; for primary branches per plant, fruit girth, fruit weight, Green fruit yield per plant and capsaicin content by Aiswarya *et al.* (2019); Patel (2020); for fruit length by Galal *et al.* (2018); for fruits per plant and Ascorbic acid content by Rekha *et al.* (2016b); Rohini and Lakshmanan (2017). The additive and dominance variance were estimated for all the characters. All the characters had higher amount of dominance variance thus improvement of such characters would be done through heterosis breeding.

DISCUSSION

A comprehensive evaluation of general combining ability (GCA) effects indicated that ACGMS 2 and ACGMS 3 among the female parents, as well as ACS 13-03 and ACS 13-24 among the male parents, were identified as strong general combiners for green fruit yield per plant and one or more related traits. These parents were recognized as potential sources of favorable genes that contribute directly or indirectly to higher fruit yield through various component traits, making them valuable for breeding programs

The female parent ACCMS 1 was also good general combiner for plant height, fruits per plant, fruit length, fruit weight, seeds per fruit, test weight and capsaicin content. Similarly, female parent ACGMS 3 was also found good general combiners for fruits per pant, fruit weight, seeds per fruit, test weight, green fruit yield per plant and ascorbic acid content; while, the female parent ACGMS 2 was good general combiner for fruits per plant, fruit weight, seeds per fruit, test weight and green fruit yield per plant.

Among the female parents, good combiner for days to initiation of flowering was ACGMS 5; while, CCA 4759 was good combiner for capsaicin content.

The male parent ACS 13-03 demonstrated good combining ability for traits such as days to flowering initiation, plant height, fruits per plant, seeds per fruit, test weight, and green fruit yield per plant. On the other hand, ACS 13-24 exhibited favorable general combining ability for primary branches per plant, fruits per plant, fruit weight, seeds per fruit, test weight, and green fruit yield per plant. Additionally, ACS 18-08 showed good combining ability for traits such as days to flowering initiation, fruit girth, and ascorbic acid content.

Table 2: Analysis of variance (mean squares) and variance components for combining ability for various traits in chilli.

Sr. No.	Source of variation	Degrees of freedom (df)	Days to initiation of flowering	Plant height	Primary branches per plant	Fruits per plant	Fruit length	Fruit girth
1.	Replications	2	3.39	26.74	0.41*	424.89	3.54	0.11
2.	Hybrids	41	49.01**	176.50**	0.37**	5965.73**	6.64**	0.26**
3.	Lines	6	148.33**	416.54**	1.05**	6678.85**	9.25**	0.46**
4.	Testers`	5	23.35**	271.67**	0.21	4177.06**	2.48	0.41**
5.	Lines × Testers	30	33.42**	112.62*	0.26**	6121.28**	6.81**	0.20*
6.	Error	82	1.89	64.61	0.12	227.80	1.33	0.11
7.	σ^2_{GCA}		2.50**	11.02**	0.02**	###	###	0.01**
8.	$\sigma^2_{GCA} / \sigma^2_{SCA}$		11.26**	21.80**	0.05**	1965.14**	1.80**	0.04**
9.	$\sigma^2_{GCA} / \sigma^2_{SCA}$		0.22	0.51	0.35	###	###	0.33
10.	**Additive Variance** (σ^2_A)		9.99	44.09	0.07	###	###	0.05
11.	**Dominance Variance** (σ^2_D)		45.06	87.21	0.21	7860.57	7.21	0.14

*, ** Significant at P = 0.05 and P = 0.01 levels, respectively; ###: Indicates negative estimates of variance

Contd..

Sr. No.	Source of variation	Degrees of freedom (df)	Fruit weight	Seeds per fruit	Test weight	Green fruit yield per plant	Capsaicin content	Ascorbic acid content
1.	Replications	2	2.55**	6.35	0.01	1466.02	0.001	0.001
2.	Hybrids	41	1.58**	1240.65**	2.77**	120068.20**	1.90**	0.13**
3.	Lines	6	2.55**	1454.91**	3.43**	154420.00**	8.50**	0.21**
4.	Testers`	5	1.17**	1184.85**	3.44**	130168.90**	0.67**	0.04**
5.	Lines × Testers	30	1.45**	1207.10**	2.53**	111514.40**	0.79**	0.13**
6.	Error	82	0.21	6.86	0.02	12241.40	0.001	0.001
7.	σ^2_{GCA}		0.02**	5.37**	0.04**	1466.02**	0.18**	0.001**
8.	σ^2_{SCA}		0.42**	402.59**	0.85**	34048.62**	0.32**	0.04**
9.	$\sigma^2_{GCA} / \sigma^2_{SCA}$		0.05	0.01	0.05	0.04	0.56	0.03
10.	Additive Variance (σ^2_A)		0.08	21.49	0.17	5864.10	0.72	0.001
11.	Dominance Variance (σ^2_D)		1.67	1610.37	3.41	136194.49	1.29	0.17

*, **: Significant at P = 0.05 and P = 0.01 levels, respectively.

Pictures of High yielding Hybrids

Plate 1. ACCMS 1 × GAVC112.

Plate 2. CCA 4759 × ACS 08 – 09.

CONCLUSIONS

The best *per se* performing five hybrids for green fruit yield per plant *viz.*, ACCMS 1 × GAVC 112 (average × poor), ACGMS 3 × ACS 18 – 08 (good × average), ACGMS 3 × ACS 13 – 24 (good × good), ACGMS 2 × ACS 13 – 03 (good × good) and CCA 4759 × ACS 08 – 09 (poor × poor) also had significant positive sca effects except for ACGMS 3 × ACS 13 – 24 and high heterotic response over better parent and standard check hybrid. Hybrids with high yield not only demonstrated significant specific combining ability (SCA) effects and substantial heterosis but also exhibited impressive individual performance across most of the traits contributing to yield.

FUTURE SCOPE

Chilli is used as vegetable as well as spice crop. Pungency of chilli is due to capsaicin. Heterosis in chilli for number of fruits, length and width of fruit, fruit weight, and number of secondary branches in plant give remarkable productivity per unit area. Biochemical parameters such as capsaicin content and ascorbic acid are important for health as well as industrial purpose.

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Conflict of Interest. None.

REFERENCES

Aiswarya, C. S., Vijeth, S., Sreelathakumary, I. and Kaushik, P. (2019). Diallel analysis of chilli pepper (*Capsicum annuum* L.) genotypes for morphological and fruit biochemical traits. *Plants*, *9*(1), 1-15.

Aiyadurai, S. G. (1966). A review work of research work on spices and cashew nuts in India, Ernakulam-6, ICAR. *In Spices*, Vol. I. Edited by Purseglove, J. W., Brown, E. G., Green, C. L. and Ribbins, S. R. J. Longmat group Ltd., New York.

Bosland, P. W. and Votava, E. J. (2000). Peppers: Vegetable and Spice Capsicums. CABI Publishing, Wallingford, UK., 1-16.

Chakrabarty, S., Islam, A. K. M. A., Mian, M. A. K. and Ahamed, T. (2019). Combining ability and heterosis for yield and related traits in Chilli (*Capsicum annuum* L.). *The Open Agriculture Journal*, *13*, 34-43.

Galal, R. F., Mohamed, A. G. and Ismail, H. E. M. (2018). Combining ability for yield and fruit quality in sweet pepper (*Capsicum annuum* L.*). Plant Production Science*, *45*(3), 835-850.

Gopalan, C., RanaSastri B. V., and Balasubramanian, S. C. (2004). Nutritive Value of Indian Foods, National Institute of Nutrition, ICMR, Hyderabad.

Ince, A. G., Karaca, M. and Onus, A. N. (2010). Genetic relationships within and between *Capsicum* species. *Biochemistry Genetics*, *48*, 83-95.

Kaur, D., Jindal, S. K., Dhaliwal, M. S. and Meena, O. P. (2017). Improving fruit traits in chilli pepper through heterosis breeding. *SABRAO Journal of Breeding and Genetics*, *49*(1), 26-43.

Patel, U. (2020). Heterosis and combining ability studies in chilli (*Capsicum annuum* L.) using line × tester analysis M.Sc. (Agri.) thesis submitted to AAU, Anand.

Rekha, G. K., Naidu, L. N., Ramana, C.V., Umajyothi, K., Paratpararao, M. and Sasikala, K. (2016b). Combining ability studies for development of new hybrids in chilli over environments. *International Journal of Biological Research*, *6*(2), 195-201.

Rohini, N. and Lakshmanan, V. (2017). Heterotic expression for dry pod yield and its components in chilli (*Capsicum annuum* var. *annuum*). *The Journal of Animal and Plant Sciences*, *27*(1), 207-218.

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