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GENE ACTION STUDIES IN BELL PEPPER (*Capsicum annuum* L. var. grossum) FOR EARLINESS, YIELD AND YIELD CONTRIBUTING TRAITS UNDER PROTECTED CONDITIONS

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ABSTRACT
Selection of suitable breeding methodologies in bringing desirable improvement in crop plant require the complete knowledge about the nature of gene action involved in the inheritance of quantitative and qualitative traits. Gene action for earliness, fruit yield and yield attributing traits in bell pepper were studied through Line x Tester analysis by involving 16 crosses made by using 8 lines and 2 testers. A perusal of the data indicated that all the traits under study except for fruit shape index were higher in ó2 SCA as compared to ó2 GCA (average). Similarly dominant components of variance (ó2s) for most of traits were also higher than the additive components (ó2g). Further, variance ratio in F1 was found less than one for all the traits except fruit shape index (12.50), plant height (1.21) for which it was recorded higher than one. Hence, for majority of characters there was preponderance of non-additive gene action except for fruit shape index and plant height (cm) which reaffirms the importance of hybrids in bell pepper.

INTRODUCTION

Capsicum (*Capsicum annuum* L. var. grossum Sendt.) is one of the most popular and highly remunerative annual herbaceous vegetable crop of Solanaceous family. Bell pepper fruits are generally blocky, square or triangular shaped, thick fleshed, three to four lobed and non pungent which are eaten raw, cooked as vegetable or widely used in stuffings, bakings, pizza, preparation of soups and stews for imparting flavour. One medium green sweet pepper can provide up to 8% of the Recommended Daily Allowance of Vitamin A, 180% of Vitamin C, 2% of calcium and 2% of iron (Kelley and Boyhan, 2009). In addition, capsicum fruits are an excellent source of health promoting substances particularly antioxidants, ascorbic acid (vitamin C), polyphenols, carotenoids and sugars (Jadczak *et al*., 2010).

Capsicum is an important off-season vegetable of western Himalayas and offers potential for boosting economy of farmers of hilly regions. Due to numerous factors, it is not possible to obtain higher yields of good quality fruits under open conditions and, therefore, protected cultivation offers good scope for year round production in addition to quality improvement of capsicum through utilization of vertical space and precision farming in areas where vegetable production during extreme weather conditions is not possible (Spehia, 2015).

In India, capsicum (coloured or green) is one of the most important cash crops of protected conditions and all the available hybrids belong to coloured types, since no recommended hybrid is available for green capsicum, which also has good potential under protected conditions. Therefore, there is a paramount need to develop suitable hybrids, which may be utilized on commercial scale in the North Indian conditions, by improving the yield potential of available land races through hybridization and integration of genomic tools (Thakur *et al*., 2017). Selection of parents on the basis of combining ability, rather than per se performance, depends upon the complex interaction among the genes which can't be judged by the mere yield performance and the adaptation of parents (Sharma *et al*., 2016).

Therefore, direct selection for qualitative and quantitative traits is not successful due to interaction of gene with environment. The knowledge of the nature and magnitude of gene effects controlling inheritance of characters related to productivity would add in the choice of efficient breeding methods and thus accelerate the pace of its genetic improvement and also breaking the yield barriers (Pramila *et al*., 2018). Gene action studies direct the breeders to select appropriate parents for heterosis and recombination breeding, hence are important in crop improvement. Considering the importance of such information, an experiment was conducted to understand the gene effects governing various yield and related traits in capsicum.

MATERIALS AND METHODS

Experimental Location

The present investigation was undertaken at the Experimental

Research Farm of Department of Vegetable Science and Precision Farming Development Centre, Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Kharif and Rainy seasons of 2015 and 2016. The experimental site is located at an altitude of 1,270 metres above mean sea level lying between 35.5°North latitude and 77.8° East longitude. The farm area falls in the mid hill zone of Himachal Pradesh.

Experimental material and layout plan

The experimental material comprised of F1 population, developed by crossing 8 lines of capsicum with 2 testers (Table 1). Crosses were made by conventional method, hand emasculation and pollination in open field during May, 2015. The population of male parents (testers) was kept higher than female parents so that each tester could be crossed with each line (female line). The crosses were attempted as per Line x Tester design suggested by Kempthorne (1957). During the next year (2016), 16 F1 along with their 10 parents were evaluated in randomize block design with three replication under protected conditions. Row to row and plant to plant spacing of 60 cm x 45 cm was kept in a plot having size 1.8 m x 1.8 m. Mean temperature during the crop season (March-August) inside polyhouse varied from 15R" C to 40R" C, while the relative humidity varied from 53-80 per cent. The standard cultural practices were followed as per package and practices of vegetable crops to raise the capsicum crop (Anonymous, 2014)

Observations

The characters studied were: Days to 50% flowering, days to marketable maturity, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), fruit shape index, number of lobes per fruit, pericarp thickness (mm), plant height (cm) and harvest duration (days).

RESULTS AND DISCUSSION

Gene action

Estimates of genetic components of variance in F1

After the identification of suitable parents and potential crosses, the next crucial step in a breeding programme is the adoption of suitable breeding methodology for the purposeful management of generated variability which largely depends upon the type of gene action in the population for the trait under genetic improvement (Cockerham, 1961 and Sprague, 1966). Among the various mating designs developed for this purpose, the line x tester (Kempthorne, 1957) mating design is the most appropriate. It not only helps in evaluating parents and crosses for combining ability but, also provides information on the nature of gene action governing the inheritance of the traits under consideration. The nature of gene action has been inferred from the estimates of general and specific combining ability variances. The estimates of general combining ability variances, specific combining ability variances, additive variance (ó2g), dominance variance (ó2s) are presented in Tables 2 and Proportional contributions of lines, testers and their interaction to total variances are depicted in Table 3.

A perusal of the data indicated that the estimates of ó2 SCA were higher in magnitude as compared to ó2 GCA (average) in F1 generation for all the traits under study *viz*., days to 50% flowering, days to marketable maturity, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), number of lobes per fruit, pericarp thickness (mm), plant height (cm), harvest duration (days) except for fruit shape index thereby indicating the pre-dominant role of non-additive gene action in the traits under study.

The results pertaining to analysis of variance for combining ability were also confirmed from the study of additive (ó2g) and dominant (ó2s) components of variance. In all the traits studied except for fruit shape index and plant height (cm), where SCA variances were higher than GCA values and dominant components of variance (ó2s) were also higher than the additive components (ó2g), the role of non-additive gene action have been found.

Further, variance ratio in F1 was found less than one for all the traits *viz*., days to 50% flowering (0.21), days to marketable maturity (0.18), number of fruits per plant (0.94), average fruit weight (g) (0.14), fruit yield per plant (kg) (0.80), number of lobes per fruit (-0.33), pericarp thickness (mm) (0.00), harvest duration (days) (0.52) except fruit shape index (12.50), plant height (cm) (1.21) for which it was recorded higher than one. Again, it confirmed the role of non-additive gene action controlling almost all the traits in capsicum under study.

Non-additive gene action for fruit yield and yield contributing traits has also been recorded by Salazar and Vallejo (1990), Kordus (1991), Nascimento *et al*. (2004), Sood and Kaul (2006) and Kamble *et al*. (2009) for days to 50% flowering, Ahmed *et al*. (1997), Kamble *et al*. (2009) and Sood and Kumar (2011) for average fruit weight, Ahmed *et al*. (1997) for pericarp

Table 1 : Capsicum genotypes used in the hybridization along with Testers

Sr. No.	Genotype	Source
(a)	Lines	
1	EC-579997	Asian Vegetable Research Development Center, Taiwan
2	Kandaghat Sel-9	Department of Vegetable Science, UHF, Nauni, Solan (HP)
3	ACC-16	Department of Vegetable Science, UHF, Nauni, Solan (HP)
4	UHF-8	Department of Vegetable Science, UHF, Nauni, Solan (HP)
5	UHF-6	Department of Vegetable Science, UHF, Nauni, Solan (HP)
6	UHF-10	Department of Vegetable Science, UHF, Nauni, Solan (HP)
7	UHF-14	Department of Vegetable Science, UHF, Nauni, Solan (HP)
8	UHF-11	Department of Vegetable Science, UHF, Nauni, Solan (HP)
(b)	Testers	
1	Solan Bharpur	UHF, Nauni, Solan, Himachal Pradesh, India
2	California Wonder	IARI Regional Research Station, Katrain, Kullu, (HP)

Table 2 :Estimates of genetic components of variance for earliness, yield and yield contributing traits in Capsicum

Character	σ2 GCA (Average)	σ2 SCA	σ2 g	σ2 s	σ2 g/σ2 s (variance ratio)
Days to fifty percent flowering	0.88	8.36	1.77	8.36	0.21
Days to marketable maturity	1.25	14.18	2.5	14.18	0.18
Number of fruits per plant	13.35	28.26	26.7	28.26	0.94
Average fruit weight (g)	3.86	53.3	7.72	53.3	0.14
Fruit yield per plant (kg)	0.08	0.2	0.16	0.2	0.8
Fruit shape index	0.03	0	0.05	0.004	12.5
Number of lobes per fruit	-0.002	0.099	-0.003	0.009	-0.33
Pericarp Thickness (mm)	0	0.24	0	0.24	0
Plant height (cm)	26.1	43.14	52.2	43.14	1.21
Harvest duration (Days)	1.5	5.75	3	5.75	0.52

Table 3: Proportional contribution of lines, testers and their interactions to sum of squares of crosses

% contribution of Character (s)	Lines	Testers	Line X Testers
Days to fifty per cent flowering	72.09	1.04	26.87
Days to marketable maturity	68.85	1.97	29.17
Number of fruits per plant	85.11	0.97	13.9
Average fruit weight (g)	72.77	0.1	27.11
Fruit yield per plant (kg)	84.92	0.52	14.56
Fruit shape index	96.13	0.95	2.95
Number of lobes per fruit	60.38	1.41	38.23
Pericarp Thickness (mm)	43.08	8.2	48.72
Plant height (cm)	85.77	1.73	12.49
Harvest Duration (Days)	81.01	0.01	18.98

thickness, and Sood and Kumar (2011) for days to marktable maturity, harvest duration, fruit yield per plant, Number of fruits per plant and average fruit weight suggesting that heterosis breeding will be a better option for their improvement than other breeding approaches. While for plant height, additive gene action is responsible which is similar to the findings of Khereba *et al*. (1995) and Sood and Kaul (2006). For number of lobes per fruit, additive gene action was reported by Mehta (1998) and Sousa and Maluf (2000) which was opposite to the above findings for number of lobes. Non-additive gene action for fruit yield has also been reported by Salazar and Vallejo (1990), Kordus (1991), Szwadiak and Kordus (1991), Mulge and Anand (1997) and Sood and Kumar (2010). The preponderance of non-additive gene action in the inheritance of all the traits studied clearly suggested exploitation of heterosis breeding for the improvement of these traits and the presence of sufficient hybrid vigour in different cross combinations. Alternatively, selection in the later generations can prove to be an important tool for improvement of these traits.

Proportional Contribution Of Lines, Testers And Their Interactions (%)

Proportional contribution of lines, testers and their interactions related to F1 has been presented in the table 3. Contribution of lines for different traits ranged from 43.08 (pericarp thickness) to 96.13 (fruit shape index) per cent. The contribution of lines was found higher than the individual contribution of testers and lines x testers interactions for fruit shape index (96.13%), plant height (85.77%), number of fruits per plant (85.11%), fruit yield per plant (84.92%), harvest duration (81.01%), average fruit weight (72.77%), days to fifty percent flowering (72.09), days to marketable maturity (68.85), number of lobes per fruit (60.38). The range of the proportional contribution of testers varied from 0.01 (harvest duration) to 8.20 (pericarp thickness) per cent. The contribution of testers was found very low as compared to individual contribution of lines and lines x Testers interactions. The proportional contribution of lines x tester interactions ranged from 12.49% (plant height) to 48.72% (pericarp thickness) per cent. The contribution of lines x testers was found higher than the individual contribution of lines and testers interactions for pericarp thickness (48.72%).

Proportional contribution of lines was found higher than the individual contribution of testers and lines x testers interactions for days to 50% flowering, days to marketable maturity, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), fruit shape index, number of lobes per fruit, plant height, harvest duration. The proportional contribution of lines x tester interactions was found higher than the individual contribution of lines and testers interactions for pericarp thickness. Present studies revealed that the contribution of lines was the highest followed by individual contribution of line x tester interaction and then testers. The present study is similar to the findings of Bilashini (2014) for number of fruits per plant, fruit yield per plant and harvest duration but are opposite for other characters. This may be due to the difference in the experimental material used for the study.

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