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Combining ability analysis for seed yield and component traits in diallel crosses of red sweet pepper (*Capsicum annuum* L. var. *grossum* Sendt)

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Abstract
The present study was aimed to estimate the combining ability of red sweet pepper genotypes for seed yield and its component traits so that the desirable genotypes and crosses can be utilized in future programmes. A field experiment was conducted during early summer, 2017 in Randomized Block Design with three replications under greenhouse with natural ventilation at research farm, department of Seed Science & Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan. Six parents and their fifteen F_1 hybrids along with the standard check (Bomby) were evaluated using half-diallel mating design excluding reciprocals for seed yield traits in sweet pepper. The observations were recorded on number of seeds per fruit, seed weight per fruit, seed yield per plant, thousand seed weight and per cent seed recovery. Significant variations were noticed among all the genotypes for all the characters under study.

The genotypes RSPUHF-2, RSPUHF-3 and RSPUHF-4 were good general combiners for number of seeds per fruit, seed weight per fruit, seed yield per plant and thousand seed weight. Amongst crosses RSPUHF-3 x RSPUHF-2 and RSPUHF-4 x RSPUHF-2 were found to be the best specific combinations for number of seeds per fruit, seed weight per fruit and thousand seed weight. However, the cross RSPUHF-7 x RSPUHF-4 was found to be best for seed yield per plant. The parents are identified on the basis of significant gca effects whereas, on the basis of significant sca effects and *per se* performance for seed yield per plant and some of its important components the crosses may be identified for release after multi location testing as it has found to be the most promising for exploitation of heterosis.

Keywords: Crosses, general combining ability, genotypes, greenhouse, half-diallel, red sweet pepper, specific combining ability

Introduction

Sweet pepper (*Capsicum annuum* L. var. *grossum*) is an excellent source of health promoting substances particularly antioxidants, ascorbic acid (vitamin C), polyphenols, caretenoids and sugars (Jadczak *et al*. 2010). Recently, with the change in the food habits of people around major cities in the country the scope for growing of many vegetables and their varieties which are generally consumed as raw and are very good source of nutrition has emerged. Sweet pepper is one such crop having different color variants like red, yellow and orange and these vegetables require special growing environments to express their nutritional properties especially protected cultivation of these crops is becoming common (Farooq *et al.* 2015) [4]. Hence, there is a need to exploit the germplasm, identify suitable combining parents and develop superior crosses.

Combining ability describes the breeding value of parental genotypes to produce hybrids. Combining ability studies further provides reliable information on selection of parents to be involved in developing hybrids and crosses having desirable seed yield attributes (Ahmed *et al*. 2009) [1]. Significant gca indicates the role of additive gene action while, significant sca corroborates to non-additive gene action (Biswas *et al.* 2005) [3]. Therefore, an attempt was made to identify suitable genotypes and their cross combinations from different parents for commercial exploitation as a F_1 variety of sweet pepper to be grown under protected condition.

Material and Methods

The experimental materials for this study consisted of six diverse red pepper lines *viz*., RSPUHF-1, RSPUHF-2, RPUHF-3, RSPUHF-4, RSPUHF-5 and RSPUHF-7 and their fifteen cross combinations. The crossing was attempted in half-diallel fashion excluding reciprocals during April, 2017 under greenhouse with natural ventilation.

All the parents and their 15 F_1 cross combinations were further planted during *kharif*, with three replications using RBD design at the experimental farm of Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan (HP) 2018 for their evaluation and generation of data Each plot consisted of size 2.0 m x 1.0 m with spacing of 70 cm x 40 cm. The observations were recorded on ten randomly selected plants for several characters *viz.*, number of seeds per fruit, seed weight per fruit, seed yield per plant, thousand seed weight and percent seed recovery. The data was subjected to analysis for general and specific combining ability as method given by Griffing (1956) [5].

Results and Discussion

Both gca and sca effects were found to be highly significant for all the characters studied and are presented in the given table 1 & 2:

Estimates of general combining ability of parents

Estimates of gca effect of the parents along with their mean values are presented in Table 2. Number of seeds per fruit is an important trait which is directly related to final seed yield in parents. Since, parents are the inbred lines which are used as varieties so more numbers of seeds are desirable. Two lines RSPUHF-3 and RSPUHF-4 were found to be good combiners for number of seeds per fruit. For seed weight per fruit and per cent seed recovery, RSPUHF-3 and RSPUHF-5 showed significant and positive values. RSPUHF-2 and RSPUHF-4 exhibited highly significant positive desirable gca values and thus considered as good general combiners for seed yield per plant. General combining ability for thousand seed weight revealed significant and positive effects by lines RSPUHF-3 and RSPUHF-7 showing superiority of gca. Similar results are in agreement with the findings of Navhale *et al.* (2014) [11], Kumari *et al.* (2014) [9], Spaldon *et al.* (2015) [15], Rekha *et al.* (2007) and Khalil *et al.* (2014) [7].

Table 1: Estimates of general combining ability of parents for different traits in sweet pepper

Parents/ Crosses	Number of seeds per fruit	Seed weight per fruit (g)	Seed yield per plant (g)	Thousand seed weight (g)	Per cent seed recovery
RSPUHF-5	-2.19*	0.004*	-1.59*	0.13*	-0.003
RSPUHF-7	0.78*	0.006*	-0.019*	-0.001	0.026*
RSPUHF-3	3.56*	0.027*	-1.49*	0.14*	0.051*
RSPUHF-4	1.57*	-0.022*	0.85*	-0.11*	-0.034*
RSPUHF-1	-1.65*	-0.009*	0.079	-0.1*	-0.014*
RSPUHF-2	-0.47	-0.006*	2.17*	-0.05*	-0.026*
S.E(gi)	0.26	0.002	0.28	0.01	0.003
S.E. (gi-gj)	0.41	0.002	0.45	0.016	0.004
CD (gi)	0.52	0.004	0.56	0.02	0.006
CD (gi-gj)	0.82	0.004	0.90	0.03	0.012

Estimates of specific combining ability of crosses

In case of hybrids pertaining to all the seed characters significant negative specific combining ability is desirable because F_1s are not to be reproduced hence less seeds per fruit are desirable in order to make it more acceptable to the consumers.

Crosses *viz.*, RSPUHF-3 x RSPUHF-2, RSPUHF-4 x RSPUHF-2, RSPUHF-5 x RSPUHF-2, RSPUHF-5 x RSPUHF-4 and RSPUHF-4 x RSPUHF-1 were good specific combiners for number of seeds per fruit due to their significant negative sca effects. Amongst the fifteen hybrids, eight crosses *viz.*, RSPUHF-3 x RSPUHF-2, RSPUHF-5 x RSPUHF-3, RSPUHF-4 x RSPUHF-2, RSPUHF-5 x RSPUHF-2, RSPUHF-3 x RSPUHF-4, RSPUHF-3 x RSPUHF-1, RSPUHF-4 x RSPUHF-1 and RSPUHF-1 x RSPUHF-2 were found to be good specific combiners for seed weight per fruit. For seed yield per plant the crosses exhibiting significant negative sca effects are RSPUHF-7 x RSPUHF-2, RSPUHF-7 x RSPUHF-4 and RSPUHF-7 x RSPUHF-1. Cross combinations *viz.*, RSPUHF-3 x RSPUHF-4, RSPUHF-5 x RSPUHF-4, RSPUHF-5 x RSPUHF-3, RSPUHF-4 x RSPUHF-2 and RSPUHF-3 x RSPUHF-1 were found to be with good specific combining ability for thousand seed weight. Significant and negative sca values were showed by eight hybrids *viz.*, RSPUHF-3 x RSPUHF-2, RSPUHF-5 x RSPUHF-3, RSPUHF-5 x RSPUHF-2, RSPUHF-4 x RSPUHF-2, RSPUHF-4 x RSPUHF-2, RSPUHF-3 x RSPUHF-4, RSPUHF-3 x RSPUHF-1and RSPUHF-4 x RSPUHF-1 for percent seed recovery. The results obtained in the present study are in conformity with Kumari *et al.* (2014) [9], Nascimento *et al.* (2004) and Khalil *et al.* (2014) [7].

Estimates of components of variation revealed that both additive and non-additive gene effects were important for most of the traits studied (Table 3). But, the magnitude of non-additive components was more than additive components for most of the traits indicating preponderance of dominance effects in expression of these traits. The perusal of data presented also indicated that estimates of σ^2s were higher in magnitude as compared to σ^2g for all the traits. The closer the predictability ratio to one, the greater the prediction of gca alone, whereas a ratio with value less than one, show sca action (Baker, 1978) [2]. This ratio was found less than one for all the traits *viz.*, number of seeds per fruit (0.06), seed weight per fruit (0.05), seed yield per fruit (0.04), thousand seed weight (0.08) and per cent seed recovery (0.08). It further confirmed the predominant role of non-additive gene action in the expression of these traits. Non-additive

Table 2: Estimates of specific combining ability of crosses for different traits in sweet pepper

Parents/Crosses	Number of seeds per fruit	Seed weight per fruit (g)	Seed yield per plant (g)	Thousand seed weight (g)	Per cent seed recovery
RSPUHF-5 x RSPUHF-7	-0.78	0.006*	-0.019	-0.001	0.026*
RSPUHF-5 x RSPUHF-3	-0.81	-0.035*	1.13	-0.29*	-0.071*
RSPUHF-5 x RSPUHF-4	-3.15*	0.016*	2.8*	-0.032*	0.014*
RSPUHF-5 x RSPUHF-1	2.4*	0.033*	2.66*	0.13*	0.031*
RSPUHF-5 x RSPUHF-2	-3.46*	-0.026*	1.51	-0.2	-0.068*

RSPUHF-5 x RSPUHF-7	3.56*	0.027*	-1.49	0.14*	0.051*
RSPUHF-7 x RSPUHF-3	1.86*	0.036*	-3.7*	0.12*	0.072*
RSPUHF-7 x RSPUHF-4	3.73*	0.04*	-1.25	0.33*	0.076*
RSPUHF-7 x RSPUHF-1	7.23*	0.051*	-3.58*	0.35*	0.111*
RSPUHF-7 x RSPUHF-2	-0.78	0.006*	-0.019	-0.001	0.026*
RSPUHF-3 x RSPUHF-4	1.56*	-0.022*	0.85	-1.11*	-0.034*
RSPUHF-3 x RSPUHF-1	4.4*	-0.019*	-4.36*	-0.07*	-0.023*
RSPUHF-3 x RSPUHF-2	-6.44*	-0.041*	0.21	0.21*	-0.074*
RSPUHF-4 x RSPUHF-1	-1.65*	-0.009*	0.079	-0.1	-0.014*
RSPUHF-4 x RSPUHF-2	-4.23*	-0.027*	1.76*	-0.11*	-0.044*
RSPUHF-1 x RSPUHF-2	-0.49	-0.006*	2.17*	-0.05	-0.026*
S.E(ij)	0.72	0.004	0.77	0.03	0.007
S.E. (sij-skl)	1	0.006	1.06	0.04	0.01
CD (sij)	1.45	0.01	1.55	0.06	0.01
CD (sij-skl)	2.01	0.01	2.13	0.08	0.02

Gene action has also been represented by Sood and Kumar (2011) [13], Sood and Kumar (2010) [14] and Kordus (1991) [8] in a set of pepper crosses for all the traits. The preponderance of non-additive gene action clearly suggests exploitation of heterosis breeding for the improvement of these traits and presence of sufficient hybrid vigour in these cross-combinations.

Further table 4 clearly depicts three best performing parents being good general combiners and best hybrids being good specific combiners for different traits with good *per se* performance.

Table 3: Estimates of genetic components of variance for different traits in sweet pepper

Character	**⌐^{2} gca**	**⌐^{2} sca**	**⌐^{2} g**	**⌐^{2} s**	**⌐^{2}g/⌐^{2}s (variance ratio)**	**Predictability ratio (2⌐^{2}g/2⌐^{2}g+⌐^{2}s)**
Number of seeds per fruit	562.806	1069.798	60.34	989.735	0.06	0.11
Seed weight per fruit (g)	0.031	0.068	3.5	0.065	0.05	0.10
Seed yield per plant (g)	266.124	669.703	21.68	577.042	0.04	0.07
Thousand seed weight (g)	1.650	2.496	0.19	2.372	0.08	0.15
Per cent seed recovery	0.108	0.167	0.0125	0.159	0.08	0.15

Additive and non-additive components were found significant for the investigated traits, but in F_1 crosses, the investigated traits were controlled by non-additive gene action. Parents RSPUHF-3, RSPUHF-4 and RSPUHF-7 were good general combiners for most of the traits which can be used in future breeding programme of sweet pepper. The cross combinations RSPUHF-3 x RSPUHF-2, RSPUHF-4 x RSPUHF-2 and RSPUHF-5 x RSPUHF-2 were found to be superior for all the traits studied and may be commercially exploited as potential F_1 varieties.

Table 4: Three best crosses showing significant sca effects, *per se* performance and standard heterosis for different traits under study

Characters	**Crosses**	**Mean value**	**sca effect**	**Standard heterosis**
Number of seeds per fruit	RSP UHF-4 x RSP UHF-2	174.00	-4.23*	-6.95*
	RSP UHF-3 x RSP UHF-2	175.00	-6.44*	-6.42*
	RSP UHF-5 x RSP UHF-2	175.67	-3.46*	-6.06*
Seed weight per fruit (g)	RSP UHF-4 x RSP UHF-2	1.20	-0.041*	-7.44*
	RSP UHF-3 x RSP UHF-2	1.21	-0.052*	-6.67*
	RSP UHF-5 x RSP UHF-2	1.22	-0.027*	-5.90*
Seed yield per plant (g)	RSP UHF-7 x RSP UHF-4	33.20	-3.35*	-21.62*
	RSP UHF-7 x RSP UHF-1	33.35	-1.83*	-21.27*
	RSP UHF-7 x RSP UHF-2	33.62	-3.56*	-20.64*
Thousand seed weight (g)	RSP UHF-4 x RSP UHF-2	6.54	-0.21*	-9.42*
	RSP UHF-3 x RSP UHF-2	6.62	0.22*	-8.26*
	RSP UHF-5 x RSP UHF-2	6.63	-0.08*	-8.13*
Per cent seed recovery	RSP UHF-3 x RSP UHF-2	0.51	-0.076*	-17.17*
	RSP UHF-4 x RSP UHF-2	0.55	-0.053*	-12.00*
	RSP UHF-3 x RSP UHF-4	0.56	-0.024*	-9.42*

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