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Research Note

Estimation of heterosis for seed yield and its component traits in red sweet pepper (*Capsicum annuum* L. var *grossum* Sendt*)* grown under protected condition

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Abstract
The objectives focuses on estimation of the magnitude of heterosis for seed yield and its component traits taking an example of six diverse lines (Pure and Stable) of sweet pepper (red color) which were attempted in half-diallel fashion excluding reciprocals during *Kharif* 2017 and evaluated with a cultivar Bombay grown in a greenhouse with natural ventilation. The analysis of variance showed significant differences among parents and crosses for all traits studied. On the basis of heterosis studies, RSPUHF-3 × RSPUHF-2 and RSPUHF-4 × RSPUHF-2 were identified highly significant cross combinations over better parent and standard check for the number of seeds per fruit, seed weight per fruit, thousand seed weight and per cent seed recovery, whereas; the crosses RSPUHF-7 × RSPUHF-1 and RSPUHF-7 × RSPUHF-4 exhibited a higher standard heterosis for seed yield per plant. This study showed a desirable heterosis over better parent and standard check for seed yield and contributing traits and can further directly be identified as a superior F_1s after their validation over different seasons for growing under protected environments or may be utilized in future breeding programmes to obtain desirable segregants for the development of trait specific superior genotypes.

Key words
Half-diallel, heterobeltiosis, plastic greenhouse, red sweet pepper, standard heterosis

Sweet pepper (*Capsicum annuum* L. var *grossum)* is a fruit vegetable well known for its high content in bioactive compounds and strong antioxidant property (Jadczak *et al.* 2010). It is one of the most popular vegetable worldwide due to its combination of colour, flavour and nutritional value (Blanco-Rios *et al.* 2013). Under the Indian conditions red, orange and yellow colour cultivars are preferably grown commercially which were highly influenced by the environment. All peppers are excellent sources of vitamins C, K, carotenoids, and flavonoids (Bosland, 1996). This have got a good potential as a greenhouse crop since quality of fruits is superior as compared to open field cultivation which fetches high prices in the market (Farooq *et al.* 2015). Since, different colour variants especially red, yellow, orange and purple are grown commercially in the greenhouses. So, there is a need to develop new varieties for growing in the northern Himalayas.

Developing high yielding varieties/hybrids in sweet pepper by heterosis breeding is the best option. It offers much scope for the development of hybrids among genetically diverse genotypes, which can further be utilized for commercial cultivation (Singh, 1999). It has been widely used in agriculture to increase yield and to broaden adaptability of hybrid varieties in improving the number of crop species (Meyer *et al.* 2004). Hence, it is pertinent to employ heterosis breeding to develop suitable hybrids of sweet pepper having good adaptability, combined with high yield and better seed quality. Therefore, this experimental study was conducted to estimate the heterosis for seed yield and its component traits to develop red varieties of pepper.

The experiment was carried out under greenhouse conditions with natural ventilation at Research Farm, Department of Seed Science and Technology, Dr Y S

Parmar University of Horticulture and Forestry, Nauni, Solan in a Randomized Complete Block Design with three replications. The experimental material consisted of six diverse genotypes of red sweet peppers *viz.,* RSPUHF-1, RSPUHF-2, RSPUHF-3, RSPUHF-4, RSPUHF-5 and RSPUHF-7 which were crossed in half-diallel fashion excluding reciprocals to obtain fifteen cross combinations. The fifteen hybrids along with parents and a standard check (Bombay) were evaluated during *Kharif*, 2018. Each plot consisted of size 2.0 × 1.0 m with spacing of 70 cm × 40 cm. The data recorded were subjected to statistical analysis using MS-Excel, OPSTAT and SPSS 16.0 packages as per the design of the experiment. The observations were recorded on the seed and yield related traits *viz.,* the number of seeds per fruit, seed weight per fruit (g), seed yield per plant (g), thousand seed weight (g) and per cent seed recovery. The standard cultural practices followed for raising a healthy crop of bell pepper under protected condition as mentioned in the "Package of Practices of Vegetable Crops", published by the Directorate of Extension Education, Dr Y S Parmar UHF, Nauni, Solan (YSP UHF, 2016).

The analysis of variance for all the traits under study showed significant differences among parents and crosses **(Table 1)** Panse and Sukhatme (1967). The mean performance of six parents and their fifteen F1s along with the % heterobeltiosis and increase or decrease over the check (Bombay) have been presented in **Table 2 and 3.** The results obtained for different traits are described as under:

The number of seeds per fruit is an important trait in parents as well as hybrids. Since, inbred lines which are used as varieties, more number of seeds per fruit are desirable. Whereas, in hybrid combinations less number of seeds is considered better, as, F_1 hybrids are not reproduced. As a result of which negative heterosis is desirable for this trait. The magnitude of heterosis for the number of seeds per fruit ranged from -5.09 to 10.00. However, a significant negative heterobeltiosis was observed in two hybrids RSPUHF-3 × RSPUHF-2 (-2.42 %) and RSPUHF-4 × RSPUHF-2 (-5.09 %). Twelve crosses recorded superiority over check variety and exhibited significant negative standard heterosis in RSPUHF-4 × RSPUHF-2 (-6.95 %), RSPUHF-3 × RSPUHF-2 (-6.42 %), RSPUHF-5 × RSPUHF-2 (-6.06 %), RSPUHF-4 × RSPUHF-1 (-5.53 %), RSPUHF-5 × RSPUHF-4 (-4.81 %), RSPUHF-1 × RSPUHF-2 (-3.74 %), RSPUHF-5 × RSPUHF- 1 (-3.57 %), RSPUHF-7 × RSPUHF-2 (-2.85 %), RSPUHF-3 × RSPUHF-4 (-2.85 %), RSPUHF-5 × RSPUHF-3 (-2.50 %), RSPUHF-7 × RSPUHF-3 (-2.32 %), RSPUHF-5 × RSPUHF-7 (-1.96 %) and RSPUHF-3 × RSPUHF-1 (-1.25 %). This indicates that these hybrids had less number of seeds and could be adopted for commercial cultivation as these varieties are consumed as raw and less seeds/ fruit are considered desirable. There is scanty information available in literature on heterosis for this trait; however, some of the studies have reported positive heterosis for these traits as desirable attributes which are similar with the findings of Reddy *et al.* (2008), Spaldon *et al*. (2015), Navhale *et al*. (2014), Kumari *et al*. (2014), Hasanuzzaman *et al.* (2012) and Rekha *et al*. (2016). Since, genotypes are also subjected for seed production hence positive *gca* effects are considered useful.

Table 1. Analysis of variance for various traits in sweet pepper

Source	Mean sum of squares			
	Replications	Genotypes	Errors	Total
Df	**2**	**20**	**40**	**62**
Character				
Number of seeds per fruit	659.937	1632.603*	80.063	2372.603
Seed weight per fruit (g)	0.006	0.099*	0.003	0.107
Seed yield per plant (g)	345.550	935.862*	92.661	1374.074
Thousand seed weight (g)	0.503	4.147*	0.124	4.774
Per cent seed recovery	0.002	0.275*	0.008	0.285

***P≤0.05**

Seed weight per fruit is also a desirable trait in bell pepper and has direct contribution to yield. In the present study, the highest standard heterosis for seed weight was recorded for RSPUHF-4 × RSPUHF-2 (-7.44 %), RSPUHF-3 × RSPUHF-2 (-6.67 %), RSPUHF-5 × RSPUHF-2 (-5.90 %), RSPUHF-4 × RSPUHF-1 (-5.38 %), RSPUHF-1 × RSPUHF-2 (-4.10 %), RSPUHF-5 × RSPUHF-4 (-3.85 %), RSPUHF-5 × RSPUHF-1 (-3.33 %), RSPUHF-5 × RSPUHF-3 (-2.31 %) and RSPUHF-3 × RSPUHF-4 (-2.05 %). Whereas, in F_1s RSPUHF-4 × RSPUHF-2 (-8.84 %), RSPUHF-3 × RSPUHF-2 (-6.91 %), RSPUHF-5 × RSPUHF-2 (-6.14 %), RSPUHF-5 × RSPUHF-1 (-1.05 %) and RSPUHF-7 × RSPUHF-3 (-1.03 %) showed a significant heterobeltiosis for this trait. This study are in line with earlier researcher's *viz.*, (Rekha *et al*. 2016), (Khalil *et al*. 2014) and (Kumari *et al.* 2014).

Higher seed yield per plant amongst genotype is the basic objective of all the crop improvement program and it is of relevance to the farmers from economic view

point in a crop like sweet pepper. But, in case of hybrids, seed yield per plant should be less in these crops to make it more acceptable to the consumers. Since, none of the hybrids depicted negative value for this trait. No hybrid combination was found to be significant over the better parent, however, eleven F_1 hybrids *viz.,* RSPUHF-7 × RSPUHF-4 (-21.62 %), RSPUHF-7 × RSPUHF-1 (-21.27 %), RSPUHF-7 × RSPUHF-2 (-20.64 %), RSPUHF-3 × RSPUHF-1 (-16.96 %), RSPUHF-5 × RSPUHF-7 (-16.81 %), RSPUHF-7 × RSPUHF-3 (-15.67 %), RSPUHF-5 × RSPUHF-3 (-13.64 %), RSPUHF-5 × RSPUHF-1 (-10.27 %), RSPUHF-3 × RSPUHF-4 (-10.20 %), RSPUHF-5 × RSPUHF-4 (-7.64 %) and RSPUHF-1 × RSPUHF-2 (-7.10 %) recorded a significant negative heterosis over standard check variety. This indicates that these hybrids can further be validated over different environments for possessing less number of seeds per plant. And will have a better consumer preference over those having positive heterosis for seed yield. These findings are also in line with Rekha *et al.* (2016), Nascimento *et al.* (2014), Ravindra *et al*. (2012) and Kumari *et al.* (2014) for seed yield per plant.

Table 2. Mean performance of parents and hybrids (F_1) in sweet pepper for different traits

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	175.67	1.27	33.94	7.05	0.64
RSPUHF-7	173.33	1.25	26.40	6.69	0.67
RSPUHF-3	179.33	1.29	36.21	7.20	0.62
RSPUHF-4	186.67	1.32	43.27	7.31	0.67
RSPUHF-1	171.00	1.23	29.74	6.84	0.63
RSPUHF-2	183.33	1.30	39.52	7.25	0.61
Hybrids (F_1)					
RSPUHF-5 × RSPUHF-7	183.33	1.30	35.24	6.94	0.70
RSPUHF-5 × RSPUHF-3	182.33	1.27	36.58	6.83	0.65
RSPUHF-5 × RSPUHF-4	178.00	1.25	39.12	6.66	0.63
RSPUHF-5 ×RSPUHF-1	180.33	1.26	38.01	6.72	0.66
RSPUHF-5 × RSPUHF-2	175.67	1.22	40.03	6.63	0.57
RSPUHF-7 × RSPUHF-3	182.67	1.28	35.72	6.89	0.68
RSPUHF-7 × RSPUHF-4	187.33	1.33	33.20	7.28	0.75
RSPUHF-7 × RSPUHF-1	186.00	1.32	33.35	7.17	0.74
RSPUHF-7 × RSPUHF-2	190.67	1.34	33.62	7.34	0.78
RSPUHF-3 × RSPUHF-4	181.67	1.27	38.04	6.75	0.56
RSPUHF-3 × RSPUHF-1	184.67	1.31	35.18	7.05	0.60
RSPUHF-3 × RSPUHF-2	175.00	1.21	40.22	6.62	0.51
RSPUHF-4 × RSPUHF-1	176.67	1.23	39.93	6.64	0.59
RSPUHF-4 × RSPUHF-2	174.00	1.20	39.93	6.54	0.55
RSPUHF-1 × RSPUHF-2	180.00	1.25	39.35	6.69	0.62
Standard check (Bombay)	187.00	1.30	42.36	7.22	0.62
SE(m)±	**1.14**	**0.01**	**1.33**	**0.05**	**0.01**
CD $_{(0.05)}$	**2.28**	**0.01**	**2.66**	**0.09**	**0.03**
CV (%)	**0.63**	**0.79**	**3.62**	**0.72**	**1.56**

Thousand seed weight is an important parameter which decide the boldness of the seed and has a direct impact on the yield. Higher thousand seed weight means bolder seeds and hence more will be the seed vigour. For this trait the parents should have high thousand seed weight. But, in case of F_1 hybrids the seed having lowered thousand seed weight is desirable. In the present studies, the magnitude of heterosis in crosses ranged from -9.79 to 9.66 over the better parent. Highest standard heterosis was recorded for RSPUHF-4 × RSPUHF-2 (-9.42 %), RSPUHF-3 × RSPUHF-2 (-8.26 %), RSPUHF-5 × RSPUHF-2 (-8.13 %), RSPUHF-4 × RSPUHF-1 (-7.99 %), RSPUHF-5 × RSPUHF-4 (-7.76 %), RSPUHF-1 × RSPUHF-2 (-7.34 %), RSPUHF-5 × RSPUHF-1 (-6.88 %), RSPUHF-3 × RSPUHF-4 (-6.46 %), RSPUHF-5 × RSPUHF-3 (-5.36 %), RSPUHF-7 × RSPUHF-3 (-4.52 %), RSPUHF-5 × RSPUHF-7 (-3.88 %) and RSPUHF-3 × RSPUHF-1 (-2.31 %) and for heterobeltiosis it was RSPUHF-4 × RSPUHF-2 (-9.79 %), RSPUHF-3 × RSPUHF-2 (-8.01 %), RSPUHF-3 × RSPUHF-4 (-6.20 %), RSPUHF-5 × RSPUHF-2 (-5.87 %), RSPUHF-5 × RSPUHF-4 (-5.49 %), RSPUHF-5 × RSPUHF-3 (-3.03 %), RSPUHF-4 × RSPUHF-1 (-2.83 %) and RSPUHF-5 × RSPUHF-1 (-1.66 %). Significant positive heterosis

was reported by Kumari *et al.* (2014), Nascimento *et al.* (2014) and Khalil *et al*. (2014).

In the seed production programme, per cent seed recovery of parents is considered important criteria to decide the parents with better seed potential whereas, the index of per cent seed recovery in case of hybrids should be low and negative heterosis should be considered desirable while computing heterosis over better parent and standard variety. Normally, per cent seed recovery ranges around 1% is considered ideal in varieties or inbreds and lower than 1% may be considered for hybrids. However, negative heterosis is considered better in case of hybrids. The hybrids RSPUHF-3 × RSPUHF-2 (-15.70 %), RSPUHF-4 × RSPUHF-2 (-10.43 %), RSPUHF-3 × RSPUHF-4 (-9.60 %), RSPUHF-5 × RSPUHF-2 (-6.48 %), RSPUHF-4 × RSPUHF-1 (-6.11 %) and RSPUHF-3 × RSPUHF-1

Table 3. Estimates of per cent heterosis over better parent and standard check for hybrids in sweet pepper

Crosses	Number of seeds per fruit	Seed weight per fruit (g)	Seed yield per plant (g)	Thousand seed weight (g)	Per cent seed recovery
	BP SC	BP SC	BP SC	BP SC	BP SC
RSPUHF-5 × **RSPUHF-7**	5.77* -1.96*	2.62* 0.26	33.51* -16.81*	3.69* -3.88*	10.90* 13.68*
RSPUHF-5 × **RSPUHF-3**	3.80* -2.50*	-1.80 -2.31*	7.80 -13.64*	-3.03* -5.36*	5.02* 5.23*
RSPUHF-5 × **RSPUHF-4**	1.33* -4.81*	-5.30 -3.85*	15.29* -7.64*	-5.49* -7.76*	-0.74 1.74
RSPUHF-5 × **RSPUHF-1**	5.46* -3.57*	-1.05* -3.33*	27.80* -10.27*	-1.66* -6.88*	4.92* 6.91*
RSPUHF-5 × **RSPUHF-2**	0.00 -6.06*	-6.14* -5.90*	17.96* -5.50	-5.87* -8.13*	-6.48* -8.12*
RSPUHF-7 × **RSPUHF-3**	5.38* -2.32*	-1.03* -1.54	35.34* -15.67*	2.99* -4.52*	9.12* 9.34*
RSPUHF-7 × **RSPUHF-4**	8.08* 0.18	0.76* 2.31*	25.79* -21.62*	8.76* 0.83	12.63* 21.62*
RSPUHF-7 × **RSPUHF-1**	8.77* -0.53	5.33* 1.28	26.35* -21.27*	7.12* -0.69	17.24* 19.46*
RSPUHF-7 × **RSPUHF-2**	10.00* 1.96*	3.07* 3.33*	27.36* -20.64*	9.66* 1.66*	28.15* 25.91*
RSPUHF-3 × **RSPUHF-4**	1.30* -2.85*	-3.54 -2.05*	5.03 -10.20*	-6.20* -6.46*	-9.60* -9.42*
RSPUHF-3 × **RSPUHF-1**	7.99* -1.25*	1.55 1.03	18.27* -16.96*	3.17* -2.31*	-2.63* -2.43
RSPUHF-3 × **RSPUHF-2**	-2.42* -6.42*	-6.91* -6.67*	11.06* -5.05	-8.01* -8.26*	-15.70* -17.17*
RSPUHF-4 × **RSPUHF-1**	3.31* -5.53*	-6.82 -5.38*	34.26* -5.73	-2.83* -7.99*	-6.11* -4.33*
RSPUHF-4 × **RSPUHF-2**	-5.09* -6.95*	-8.84* -7.44*	1.03 -5.74	-9.79* -9.42*	-10.43* -12.00*
RSPUHF-1 × **RSPUHF-2**	5.26* -3.74*	-4.35 -4.10*	32.31* -7.10*	-2.15 -7.34*	2.24 0.45
SE(m)±	1.14	0.01	1.33	0.05	0.01
$CD_{(0.05)}$	2.28	0.01	2.66	0.09	0.03

*P≤0.05 BP- Better Parent, SC-Standard Check

(-2.63 %) revealed maximum heterosis over the better parent whereas, RSPUHF-3 × RSPUHF-2 (-17.17 %), RSPUHF-4 × RSPUHF-2 (-12.00 %), RSPUHF-3 × RSPUHF-4 (-9.42 %), RSPUHF-5 × RSPUHF-2 (-8.12 %) and RSPUHF-4 × RSPUHF-1 (-4.33 %) recorded a maximum standard heterosis for this trait. Similar observations have been recorded by Rekha *et al.* (2016), Kumari *et al*. (2014) and Nascimento *et al.* (2014). There is scanty information available in literature on heterosis for this trait.

The present study revealed that the promising crosses based on heterosis for the number of seeds per fruit, seed weight per fruit, thousand seed weight and percent seed recovery are RSPUHF-3 × RSPUHF-2, RSPUHF-4 × RSPUHF-2 and RSPUHF-5 × RSPUHF-2.

On the basis of heterosis studies, it is concluded that the two cross combinations *viz.,* RSPUHF-7 × RSPUHF-4 and RSPUHF-7 × RSPUHF-1 exhibited maximum heterosis over better parent as well as over standard check for seed yield per plant. Therefore, the best performing crosses could be further evaluated and tested for their feasibility for commercial cultivation after their multi location testing and further identified for release.

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REFERENCES

Blanco-Rios, A.K. Medina-Juarez, L.A. González-Aguilar, G.A. and Gamez-Meza, N. 2013. Antioxidant activity of the phenolic and oily fractions of different sweet bell peppers. *Journal of the Mexican Chemical Society*., **57**: 137-143. [Cross Ref]

Bosland, P.W. 1996. Capsicums: Innovative uses of an ancient crop. In: Janick, J. (ed.). Progress in new crops. ASHS Press, Arlington, VA, 479-487.

Farooq, M. Ramzan, A. Chattha, M.R. Qasim, U. Nawab, N.N. and Hidyatullah, N.N. 2015. Studies on the performance of sweet pepper (*Capsicum annuum* L.) hybrids under plastic tunnel. *Science, Technology and Development*., **34**: 155-157. [Cross Ref]

Hasanuzzaman, M. Hakim, A.M. Fersdous, J. Islam, M.M. and Rahman, L. 2012. Combining ability and heritability analysis for yield and yield contributing characters in chilli (*Capsicum annuum*) landraces. *Plant Omics Journal*., **5**: 337-344.

Jadczak, D. Grzeszuczuk, M. and Kosecka, D. 2010. Quality characteristics and content of mineral compounds in fruits of some cultivars of sweet pepper (*Capsicum annuum* L.). *Elemental Journal*., 509-515.

Khalil, R.M. and Hatem, K.M. 2014. Study on combining ability and heterosis of yield and its components in pepper (*Capsicum annum* L.). *Alexandria Journal of Agricultural Research.,* **59**: 61-71.

Kumari, S. 2014. Genetic divergence and combining ability studies for exploitation of heterosis in paprika (*Capsicum annuum* L.). *International Journal of Agricultural Science and Research.,* **4**: 59-66.

Meyer, R.C. Torjek, O. Becher, M. and Altmann, T. 2004. Heterosis of biomass production in Arabidopsis. Establishment during early development. *Plant Physiology*., **134**: 1813-1823. [Cross Ref]

Nascimento, F.N. Rego, R.E. Nascimento, F.M. Bruckner, H.C. Finger, L.F. and Rego, M.M. 2014. Combining ability for yield and fruit quality in the pepper (*Capsicum annuum* L.*). Genetics and Molecular Research.,* **13**: 3237-3249. [Cross Ref]

Navhale, C.V. Dalvi, V.V. Wakode, M.M. Sawant, V.A. and Dhekale, J.S. 2014. Combining ability analysis in chilli (*Capsicum annum* L.). *Electronic Journal of Plant Breeding.,* **5**: 340-344.

Panse, V.G. and Sukhatma, P.V. 1967. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi. 381p.

Kumar, R. Srivastava, K. Somappa, J. Kumar, S. and Singh, R.K. 2012. Heterosis for yield and yield components in tomato (*Lycopersicon esculentum* Mill). *Electronic Journal of Plant Breeding*., **3**: 800-805.

Reddy, M.G. Kumar, H.D.M. and Salimath, P.M. 2008. Heterosis Studies in Chilli (*Capsicum annuum* L.). *Karnataka Journal of Agriculture Science*., **21**: 570-571.

Rekha, K.G. Naidu, N.L. Ramana, V.C. Umajyothi, K. Paratpararao, M. and Sasikala, K. 2016. Heterosis studies for yield and yield attributing characters (*Capsicum annuum* L.) over environments. *Plant Archives.,* **16**: 243-251.

Singh, B.D. 1999. Plant Breeding Principles and Methods. Kalyani Publishers, New Delhi, pp. 185.

Sharma, V.K. Punetha, S. and Sharma, B.B. 2013. Heterosis studies for earliness, fruit yield and yield attributing traits in bell pepper. *African Journal of Agricultural Research*., **8**: 4088-4098.

Spaldon, S. Hussain, S. Jabeen, N. and Lay, N. 2015. Heterosis studies for earliness, fruit yield and yield attributing traits in chilli (*Capsicum annuum* L.). *The Bioscan*., **10**: 813-818.

YSP, UHF 2016. Package of practices for vegetable crops. Directorate of Extension Education, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni Solan H.P. pp. 13-16.