



Generation mean analysis for yield and contributing traits in sweet pepper

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ABSTRACT

To study the genetics of yield and contributing traits, six generations (P_1 , P_2 , F_1 , B_1 , B_2 and F_2) of six crosses evolved by utilizing four parents (PBC-631, IHR-546, California Wonder and Yolo Wonder) were evaluated in a Randomized Block Design with three replications at the experimental farm of Department of Vegetable Science and Floriculture, CSK HPKV, Palampur. Sufficient genetic variability was generated through hybridization for all the traits studied. The presence of dominance components for yield per plant in all the crosses along with complementary type of interaction in IHR-546 x YW suggested the exploitation of heterosis breeding for improving yield per plant. Similarly, positive dominance components were recorded in most of the cross combinations for number of fruits per plant, which further indicate the importance of exploiting hybrid vigour for this trait. However, most of the crosses had negative additive component and positive additive x additive [i] gene interactions suggesting delaying the selection for improving average fruit weight. In the present study, the nature and magnitude of gene effect varied with different crosses for most of the traits. Hence, specific breeding strategy has to be adopted for a particular cross to get improvement. In some crosses, inbreds can be developed through hybridization following the pedigree method of selection. In other crosses, though high magnitude of dominance gene effects and dominance x dominance interactions were present, however, it is difficult to exploit them due to the presence of duplicate epistasis. In such cases, some form of recurrent selection like diallel selective or biparental mating can be effective.

Key words: Capsicum, genetics, contributing traits, yield.

INTRODUCTION

Among fruit vegetables, sweet pepper is a versatile crop and has a specific identity. Sweet pepper has become money spinner for the hill farmers of Himachal Pradesh, wherein ideal climatic conditions enable its off-season production (June-October), when the crop does not grow well in the adjoining plains. The decision regarding selection of suitable breeding methodology for a purposeful management of genetic variability generated through the hybridization programme would largely depend on the nicking ability and practical utility of the parents in a cross and the genetic architecture of economic traits under consideration (Sprague, 10). The present investigations were, therefore, planned to derive information on the nature and magnitude of generation means and gene effects for various yield and contributing traits in sweet pepper.

MATERIALS AND METHODS

To study the genetics of bacterial wilt resistance, six generations (P_1 , P_2 , F_1 , B_1 , B_2 and F_2) of six crosses evolved by utilizing four parents (PBC-631, IHR-546, California Wonder and Yolo Wonder) were evaluated in a Randomized Block Design three replications at

the experimental farm of Department of Vegetable Science and Floriculture, CSK HPKV, Palampur during summer-rainy season. The F_1 seed of the above crosses was produced at Palampur in the polyhouse during summer-rainy season. F_1 s were then selfed and backcrossed with both the parents (P_1 and P_2) to get F_2 , B_1 and B_2 seeds, respectively at Palampur in the polyhouse during summer-rainy season in second year. Simultaneously, crosses were also attempted in the second year to generate F_1 s to have sufficient seed for final evaluation. The data were recorded on randomly tagged 5 plants per replication in the non-segregating generations (P_1 , P_2 and F_1), 20 plants per replication in the back cross generations (B_1 and B_2) and 40 plants per replication in the segregating generation (F_2) for days to 50 per cent flowering, days to first picking, fruit length (cm), fruit diameter (cm), fruit pedicel length (cm), pericarp thickness (cm), number of fruits per plant, fruit yield per plant (kg), average fruit weight (g), number of pickings, number of branches per plant, and plant height (cm). To test the adequacy of additive-dominance model scaling tests given by Mather (7); and Hayman and Mather (3) were used. Estimation of various gene effects and test of fitness of appropriate genetic model was done following 'joint scaling test' of Cavalli (1), as described in detail by Jinks and Jones (4).

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RESULTS AND DISCUSSION

Earliness is a highly desirable attribute in capsicum in the sense that the prevailing prices in the market are invariably higher early in the season and thus brings lucrative returns to the farmers. For days to 50 per cent flowering, the non-significant estimates of A, B, C and D scaling tests along with χ^2 values in crosses, viz., PBC-631 × YW, IHR-546 × YW, YW × CW and IHR-546 × PBC-631 suggested the absence of non-allelic interactions (Table 1). Similarly, Sood *et al.* (12) have also observed epistasis for days to first flower. Further, the dominance gene effects were in desirable (negative) direction in these crosses. These findings substantiate the findings of Rodrigo da Silva *et al.* (9). In the cross PBC-631 × CW, the presence of duplicate type of epistasis along with positive dominance and additive × additive genic effects suggested that the selection for early flowering segregants should be carried out in later generations. However, in IHR-546 × CW, the dominance and additive × additive genic effects were in desirable direction coupled with presence of duplicate type of interaction suggesting the scope of hybrids as well as reciprocal recurrent selection and biparental mating followed by selection in getting desirable segregants in subsequent generations.

For days to first picking, fitting of additive dominance model was displayed in PBC-631 × CW and PBC-631 × YW. All the crosses except IHR-546 × YW and YW × CW displayed dominance gene effects in the desirable direction indicating the effectiveness of heterosis breeding in these crosses. The cross IHR-546 × PBC-631 also showed negative additive × additive genic effects along with duplicate type of gene action suggesting the scope of hybrids as well as reciprocal recurrent selection and biparental mating followed by selection in getting desirable segregants. These results also corroborate the findings of Maheshwari and Patil (6), who have also reported the importance of non-additive gene action for early yield. In IHR-546 × YW and YW × CW, the dominance × dominance interaction was in negative direction, which further indicates the importance of heterosis breeding for getting desirable segregants. The negative additive × additive gene interaction in IHR-546 × CW and YW × CW revealed the importance of simple pedigree selection.

Additive dominance model was adequate to explain the variation for fruit length in PBC-631 × YW only. Joshi (5) has also observed epistasis for fruit length. Dominance component was positive in crosses, viz., PBC-631 × YW and IHR-546 × YW indicating the usefulness of heterosis breeding. In PBC-631 × CW, IHR-546 × CW, YW × CW and IHR-

546 × PBC-631, dominance × dominance component was positive and of higher magnitude, which also suggests the importance of heterosis breeding. In the cross IHR-546 × YW, duplicate type of epistasis was present indicating to defer the selection in the later generations. Epistasis was present in all the crosses for fruit diameter. All the crosses except PBC-631 × YW had opposite signs of [h] and [l] revealed the presence of duplicate type of gene action. In such situations maximum gain could be obtained by maintaining heterozygosity through mating of selected parents in early segregating generations. In the cross PBC-631 × YW, additive gene effect was negative and additive × additive [i] in positive direction further advocating to defer selection for improving fruit diameter. However, significant Chi-square value in IHR-546 × CW indicated the presence of higher order interaction.

All the crosses showed inter-allelic interactions for pedicel length also. The crosses, viz., PBC-631 × CW, PBC-631 × YW, IHR-546 × YW and IHR-546 × PBC-631 showed pronounced dominance gene effects for this trait as evident from their significant dominance or dominance × dominance gene effects signifying the effectiveness of heterosis breeding. However, Milkova (8) has reported additive gene action for this trait. In PBC-631 × YW, additive × dominance gene effect was negative, whereas, duplicate type of interaction was present in IHR-546 × CW revealing the importance of reciprocal recurrent selection and biparental mating followed by selection. In crosses, viz., PBC-631 × CW, YW × CW and IHR-546 × PBC-631, additive gene effects were also present showing the usefulness of simple pedigree selection.

For pericarp thickness, epistasis was present only in two crosses, viz., PBC-631 × YW and IHR-546 × PBC-631. Earlier, Surya Kumari *et al.* (12) have also reported epistasis for this trait. All the crosses recorded the presence of additive gene effects in the undesirable (negative) direction suggesting to defer the selection in the later generations for getting improved pericarp thickness. In PBC-631 × YW, duplicate type of epistasis and in IHR-546 × PBC-631 negative additive × additive gene effects were observed, which also indicate the usefulness of delaying the selection to later generations. However, Sood and Kaul (11) have reported both additive as well as non-additive gene action for pericarp thickness.

High yield is the basic objective of all the crop improvement programmes. It is of immense importance to develop a genotype, which has a potential to surpass the commercial cultivar(s) otherwise it will achieve little or no success even if it

Table 1. Estimates of genetic parameters in sweet pepper genotypes.

Traits						
Days to 50 per cent flowering	m	[d]	[h]	[i]	[j]	[l]
PBC-631 × CW	28.190	1.517	8.898	3.737	-	-6.554
PBC-631 × YW	32.778	1.018	-1.92	-	-	-
IHR-546 × CW	36.340	0.737	-9.862	-4.905	-	3.873
IHR-546 × YW	31.925	-	-0.464	-	-	-
YW × CW	31.393	0.528	-1.188	-	-	-
IHR-546 × PBC-631	32.975	-0.545	-1.136	-	-	-
Days to first picking						
PBC-631 × CW	61.577	2.463	-4.796	-	-	-
PBC-631 × YW	61.523	2.456	-3.121	-	-	-
IHR-546 × CW	66.315	-	-10.261	-7.234	-3.999	-
IHR-546 × YW	59.331	-	-	-	-2.543	-5.173
YW × CW	61.830	-	-	-2.722	-	-5.566
IHR-546 × PBC-631	73.415	-2.899	-27.034	-12.291	-	9.849
Fruit length						
PBC-631 × CW	8.364	1.723	-	-	-	2.621
PBC-631 × YW	7.907	1.738	2.265	-	-	-
IHR-546 × CW	5.982	-0.210	-	0.451	-	2.039
IHR-546 × YW	6.196	-	4.640	-	-	-2.736
YW × CW	6.385	-0.218	-	-	-	1.055
IHR-546 × PBC-631	8.923	-1.828	-	-0.875	-2.407	2.718
Fruit diameter						
PBC-631 × CW	4.203	-1.990	-2.162	-	-	1.209
PBC-631 × YW	2.865	-1.719	-	1.078	-	0.282
IHR-546 × CW	4.472	-1.792	-1.229	-	0.920	0.584
IHR-546 × YW	4.172	-1.492	-1.974	-	0.765	1.409
YW × CW	6.032	-0.370	-1.167	-	-	1.725
IHR-546 × PBC-631	3.851	0.251	-3.585	-1.420	-	2.675
Pedicel length						
PBC-631 × CW	2.529	0.776	1.595	0.758	0.525	-
PBC-631 × YW	3.258	0.806	0.879	-	-0.241	-
IHR-546 × CW	1.765	-	2.305	0.747	0.253	-1.070
IHR-546 × YW	2.545	-	0.928	-	0.960	-
YW × CW	2.229	-	0.422	0.278	-	-
IHR-546 × PBC-631	2.461	-0.752	-	0.850	0.904	1.623
Pericarp thickness						
PBC-631 × CW	0.285	-0.074	0.027	-	-	-
PBC-631 × YW	0.501	-0.074	-0.474	-0.233	-	0.263
IHR-546 × CW	0.327	-0.039	-	-	-	-
IHR-546 × YW	0.315	-0.028	0.016	-	-	-
YW × CW	0.355	-0.010	-	-	-	-
IHR-546 × PBC-631	0.275	0.042	-	-0.030	-	-

Contd...

Generation Mean Analysis for Yield Traits in Sweet Pepper

Table 1 Contd...

Traits	m	[d]	[h]	[i]	[j]	[l]
Days to 50 per cent flowering						
No. of fruits per plant						
PBC-631 × CW	15.146	3.322	-	-4.588	2.145	4.739
PBC-631 × YW	12.019	3.606	-	-1.750	-	8.037
IHR-546 × CW	10.291	2.871	7.721	-	-2.303	-
IHR-546 × YW	9.903	3.233	12.701	-	-2.036	-5.564
YW × CW	6.156	-0.131	2.412	0.743	-	-
IHR-546 × PBC-631	13.513	-0.368	5.177	-	-	-
Av. fruit weight						
PBC-631 × CW	23.795	-20.390	-	9.557	15.309	-
PBC-631 × YW	27.422	-20.580	-	6.141	10.233	-4.197
IHR-546 × CW	24.066	-17.219	-	10.894	16.577	-
IHR-546 × YW	35.905	-18.145	-40.741	-	18.482	31.712
YW × CW	53.357	-	5.364	-	-	-
IHR-546 × PBC-631	12.141	2.346	8.374	3.258	-	-
Yield per plant						
PBC-631 × CW	284.837	-105.385	186.776	-	73.454	-
PBC-631 × YW	340.713	-91.005	-	-71.180	-	128.280
IHR-546 × CW	159.113	-79.047	442.084	153.210	-	-169.887
IHR-546 × YW	296.84	-63.789	27.441	-	-	132.386
YW × CW	321.192	-14.206	181.808	53.594	-	-
IHR-546 × PBC-631	82.901	25.949	423.201	124.200	-	-128.872
No. of pickings						
PBC-631 × CW	3.467	0.341	1.233	0.575	-	-
PBC-631 × YW	3.156	0.284	1.629	0.907	-	-
IHR-546 × CW	3.998	0.303	0.279	-	-	-
IHR-546 × YW	3.359	0.303	1.094	0.679	-	-
YW × CW	3.733	-	0.332	-	-	-
IHR-546 × PBC-631	4.324	-	0.299	-	-	-
Branches per plant						
PBC-631 × CW	3.699	-0.079	0.128	-	-	-
PBC-631 × YW	3.611	-	0.131	-	-	-
IHR-546 × CW	3.884	-	-	-	0.832	-
IHR-546 × YW	2.593	0.147	2.888	1.163	-	-1.547
YW × CW	3.724	-0.114	-	-	-	-
IHR-546 × PBC-631	3.732	0.113	0.356	-	-	-
Plant height						
PBC-631 × CW	57.382	8.417	11.644	-	8.071	-
PBC-631 × YW	55.802	9.749	-	-	8.552	14.041
IHR-546 × CW	48.599	-0.485	1.754	-	-	-
IHR-546 × YW	51.303	-	-	-3.182	16.371	5.279
YW × CW	47.679	-1.391	4.253	-	-	-
IHR-546 × PBC-631	56.978	-8.853	11.715	-	-	-

has excellent quality and resistance to various pests. Number of fruits per plant and average fruit weight has direct bearing on yield. For number of fruits per plant, epistasis was observed in all the crosses except IHR-546 × PBC-631. These results are in line with those of Chaim and Paran (2), Sood and Kaul (11) and dominance and non-additive gene effects were recorded in all the crosses indicating the importance of heterosis breeding for getting increased number of fruits per plant. However, duplicate type of interaction along with dominance gene effects was observed in IHR-546 × YW. The importance of both additive and dominance gene effects has been reported by Sood *et al.* (13).

Additive dominance model was adequate only in YW × CW for average fruit weight indicating the presence of epistasis in rest of the crosses. Significant negative additive gene effects [d] were observed in all the crosses except IHR-546 × PBC-631, but had positive additive × additive gene effects suggesting the scope of improving this trait through delayed selection. However, additive × dominance effects [j] were predominantly positive in all the crosses except YW × CW and IHR-546 × PBC-631. In YW × CW and IHR-546 × PBC-631, dominance gene effects were pronounced along with additive × additive gene effects in the latter cross only advocating the importance of both non-additive as well as additive gene action. These results have corroborated the findings of Sood and Kaul (11) and Surya Kumari *et al.* (14).

A significant contribution of epistasis in controlling the inheritance of yield per plant was observed in all the crosses, which was reflected from the significance of scaling tests. Epistasis for yield has also been reported by Surya Kumari *et al.* (14). The results of six parameter model for yield per plant revealed that dominance gene effects [h] were significant in all the crosses except PBC-631 × YW. However, PBC-631 × YW displayed significant dominance × dominance [l] effect of higher magnitude. Complimentary type of gene action, as evident from the positive sign of [h] and [l] components, was noticed in IHR-546 × YW suggesting to exploit heterosis in this cross. Duplicate epistasis was noticed in two crosses namely, IHR-546 × CW and IHR-546 × PBC-631, which was evident from the opposite signs of dominance and dominance × dominance interactions. In view of the presence of duplicate epistasis, the successful breeding method will be the one, which can mop up the genes to form superior gene constellations interacting in a favourable manner. Some forms of recurrent selection namely, diallel selective mating or biparental mating in early segregating generations might prove to be effective alternative approaches (Shekhawat *et al.*, 10). The predominance of non-additive gene action

has also been reported by Surya Kumari *et al.* (14), whereas Sood and Kaul (13) reported the importance of both additive as well as non-additive gene action for yield per plant.

The estimates of simple and joint scaling tests suggested the presence of non-allelic interactions for the inheritance of number of pickings in PBC-631 × CW, PBC-631 × YW and IHR-546 × YW, whereas, the other three crosses exhibited the fitness of additive-dominance model. The significant and positive additive component [d] in four crosses, viz., PBC-631 × CW, PBC-631 × YW, IHR-546 × CW and IHR-546 × YW along-with the presence of positive additive × additive gene action in these crosses except IHR-546 × CW showed the presence of increased alleles and associated pair of genes. These results advocated that the increased manifestation can be achieved through simple selection. Dominance component [h] was equally important in all the crosses except IHR-546 × PBC-631, which also revealed the effectiveness of heterosis breeding. For number of branches per plant, only IHR-546 × CW and IHR-546 × YW exhibited the presence of non-allelic interaction. Dominance component [h] was found to be significant and positive in PBC-631 × CW, PBC-631 × YW and IHR-546 × PBC-631, which reveals the effectiveness of heterosis breeding for this trait. Duplicate type of epistasis was observed in IHR-546 × YW.

The estimates of simple and joint scaling tests suggested the presence of non-allelic interactions for the inheritance of plant height in PBC-631 × CW, PBC-631 × YW and IHR-546 × YW. The dominance component [h] was significant for plant height in PBC-631 × CW, IHR-546 × CW, YW × CW and IHR-546 × PBC-631, while the cross combinations PBC-631 × YW and IHR-546 × YW exhibited the presence of additive × dominance and dominance × dominance components, which also indicate the importance of heterosis breeding. These results corroborate the findings of Joshi *et al.* (5).

Thus, specific breeding strategy has to be adopted for a particular cross to get improvement. In some crosses, inbreds can be developed through hybridization following the pedigree method of selection. In other crosses, although high magnitude of dominance gene effects and dominance × dominance interactions were present, but it is difficult to exploit them due to the presence of duplicate epistasis. Thus, some form of recurrent selection like diallel selective or biparental mating can be effective. However, presence of dominance components for yield per plant in all the crosses along with complementary type of interaction in IHR-546 × YW suggests the exploitation of heterosis breeding for improving yield per plant.

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