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Genetic Analysis for Green Fruit Yield and its Components in Chilli (*Capsicum annuum* var. *longum* (D.C.) Sendt.)

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Six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of six crosses, namely ACS 97-1 x Punjab Guchhadar, ACS 98-9 x SG-5, SG-5 x Punjab Guchhadar, Arka Lohit x SG-5, ACG 77 x S 49 and Jwala x DPS 120 were evaluated for green fruit yield and its four important component characters. The data of six generations were subjected to scaling tests to detect epistasis and to estimate genetic parameters m, d, h, i, j and l. Non-additive gene effect was found to be more important in the inheritance of number of fruits per plant and fruit length as well as weight. Preponderance of additive gene effect was observed for inheritance of fruit girth and green fruit yield. Duplicate, Complementry and/or both types of epistatic gene actions were evidenced for all above characters. The heterosis breeding as well as development of inbreds with due selection pressure to component characters is suggested.

Key words : Chilli,Complementry, Duplicate, Epistasis, Gene effects, Generation mean analysis
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Chilli (*Capsicum annuum* var. *longum* (D.C.) Sendt.) is an important spice cum vegetable commercial crop. Though India stands first in chilli cultivation with around 45 per cent of the world hectarage, its productivity is quite low. The main cause for that is use of open pollinated varieties with regional preference. Improvement over local cultivars and development of superior inbreds are urgent needs for research in this crop, particularly for green (tender) fruit harvest. As green fruit yield is the out come of multiplicative interactions of component characters, improvement of this traits is essential. Basic requirement in adoption of suitable breeding methods is a sound understanding of genetic behaviour of various component characters. Most of the reports for gene effects in chilli are restricted with diallel or line x tester based gca/sca analysis, hence various components of gene effects due to digenic interactions are confounded with major gene effects (Additive: Dominance or Non additive). With back cross generations, six parameter model of Hayman (1958) would also estimates various inter allelic interactions. Therefore, present study was undertaken to study the inheritance of green fruit yield and its component characters using six generations of six crosses involving nine inbreds.

Materials and Methods

The experimental material consisted of parents P_1 and P_2, F_1, F_2, BC_1 and BC_2 generations of six crosses viz., ACS 97-1 x Punjab Guchhadar, ACS

98-9 x SG-5, SG-5 x Punjab Guchhadar, Arka Lohit x SG-5, ACG 77 x S 49 and Jwala x DPS 120. The parental genotypes are improved varieties/cultivars of different states/regions. The experiment was laid out in compact family block design with three replications during the year 2007- 08 at Main Vegetable Research Station, Anand Agricultural University, Anand. The different generations were represented as single row for each P_1, P_2 and F_1, two rows for each BC_1 and BC_2 and four rows for F_2 and total 12 plants were accommodated in each row at 60 cm inter and intra row spacing.

Randomly selected five plants from each row of P_1, P_2 and F_1; 10 plants from $BC_1$and BC_2 and 20 plants from F_2 of each replication were tagged for recording observations for green fruit yield and its four important component characters *viz*., number of fruits per plants, fruit length, fruit girth and fruit weight. The analysis of variance for compact family block design performed cross wise for all the characters as per standard procedure (Panse and Sukhatme, 1969). The mean values of various generations were subjected to simple scaling tests A, B, C and D (Hayman and Mather, 1959) to test the adequacy of additive dominance model. In case of significance of any of the scaling test, data were then subjected to the estimation of various genetic components with six parameter model m, d, h, i, j and l (Hayman, 1958). More precise estimate of various parameters were than obtained by applying weighted joint scaling test (Cavalli, 1952) . In the event of non significant estimates of simple scaling test and joint scaling test, i.e. adequacy of additive

dominance model, the three parameter model (Cavalli, 1952), which is based on least square estimates (weighted analysis) was used to estimate main effects m, d and h. The individual plant data over 3 replications were pooled to calculate the mean value of various generations.

Results and Discussion

The estimates of gene effects and interactions for the best fit model with respect to different characters in six crosses of chilli are given in Table 1. The inheritance pattern varied with cross and character. The mean comparison of various

Table 1. Mean values of green fruit yield and its components in chilli

Cross	Generations								
	P_1	P_2	F_1	F_2	BC_1	BC_2	S.Em.	C.D. (0.05)	C.V. %
Number of fruits per plant									
ACS 97-1 X Punjab Guchhadar	218.47	397.67	379.20	404.22	316.17	308.93	23.36	73.66	11.99
ACS 98-9 X SG-5	309.16	94.93	336.00	227.98	315.80	174.43	27.95	88.14	19.92
SG-5 X Punjab Guchhadar	84.00	379.93	206.60	247.98	192.00	273.03	17.51	55.23	13.15
Arka Lohit X SG-5	314.20	75.60	272.80	312.58	367.17	374.63	42.11	132.79	25.49
ACG77XS49	171.93	174.27	254.13	282.63	239.37	259.23	17.36	54.74	13.06
Jwala X DPS 120	305.33	206.07	398.13	284.82	353.87	246.90	23.65	74.57	13.69
Fruit length (cm)									
ACS 97-1 X Punjab Guchhadar	9.22	6.55	8.98	7.91	8.52	8.66	0.31	0.98	6.50
ACS 98-9 X SG-5	7.99	8.37	9.51	8.91	8.73	9.25	0.36	NS	7.07
SG-5 X Punjab Guchhadar	8.59	6.90	9.26	8.05	8.73	8.12	0.40	1.25	8.32
Arka Lohit X SG-5	6.93	8.01	8.98	7.49	7.55	8.39	0.30	0.96	6.65
ACG77XS49	8.87	9.90	9.04	9.20	7.77	8.77	0.60	NS	11.66
Jwala X DPS 120	9.67	6.83	9.52	9.15	9.77	8.75	0.39	1.24	7.59
Fruit girth (cm)									
ACS 97-1 X Punjab Guchhadar	2.65	3.15	2.91	2.86	2.84	3.23	0.05	0.17	3.15
ACS 98-9 X SG-5	2.52	4.62	3.08	2.99	2.75	3.66	0.12	0.39	6.53
SG-5 X Punjab Guchhadar	4.45	3.33	4.13	3.70	4.23	3.44	0.11	0.34	4.79
Arka Lohit X SG-5	2.77	4.86	3.07	2.90	2.96	3.10	0.10	0.32	5.35
ACG77XS49	3.30	3.43	3.27	3.33	3.18	3.44	0.08	NS	3.93
Jwala X DPS 120	2.50	3.39	3.03	2.98	2.81	3.25	0.05	0.16	2.98
Fruit weight (g)									
ACS 97-1 X Punjab Guchhadar	1.46	1.56	1.93	1.49	1.65	2.16	0.05	0.17	5.35
ACS 98-9 X SG-5	1.17	4.24	2.52	2.10	1.70	2.89	0.07	0.22	4.86
SG-5 X Punjab Guchhadar	4.04	1.53	3.61	2.57	3.26	2.50	0.18	0.58	10.90
Arka Lohit X SG-5	1.63	4.40	2.17	1.72	1.89	2.37	0.14	0.44	10.22
ACG77XS49	2.32	2.82	2.49	2.29	2.25	2.57	0.18	NS	12.36
Jwala X DPS 120	1.34	2.34	1.83	1.95	1.80	2.27	0.09	0.28	8.13
Green fruit yield per plant (Kg)									
ACS 97-1 X Punjab Guchhadar	0.31	0.64	0.87	0.60	0.54	0.66	0.05	0.15	13.75
ACS 98-9 X SG-5	0.34	0.42	0.86	0.48	0.54	0.49	0.06	0.18	18.97
SG-5 X Punjab Guchhadar	0.32	0.56	0.75	0.63	0.64	0.65	0.07	0.21	19.41
Arka Lohit X SG-5	0.51	0.34	0.58	0.54	0.72	0.89	0.09	0.27	24.89
ACG77XS49	0.33	0.42	0.59	0.66	0.56	0.66	0.05	0.15	15.35
Jwala X DPS 120	0.43	0.42	0.73	0.58	0.64	0.57	0.04	0.12	11.63

generations suggested involvement of additive, co-dominance and over dominance as well as digenic interactions for the inheritance of number of fruits per plant and fruit length. For fruit girth, in general additivity of genes and partial dominance were evidenced. Additivity of genes as well as intra and inter allelic interactions were detected for the trait fruit weight. Whereas, for green fruit yield over dominance and digenic inter actions were evidenced with comparison of mean values of different generations.

The significance of estimates of simple scaling tests for all the crosses suggested inadequacy of additive dominance model for the inheritance of number of fruits per plant, which was supported by significance of χ^2 values of joint scaling test except the crosses ACS 98-9 x SG-5 and Jwala x DPS 120, for these crosses only major gene effects additive and dominance were found significant, which indicated more reliability of joint scaling test to test the adequacy of additive dominance model. Whereas, for cross ACG 77 x S 49 both the approaches indicated presence of digenic interactions but none of the component of gene effects was found significant suggesting presence of higher order interactions and/or linkages. For the cross ACS 97-1 x Punjab Guchhadar and Arka Lohit x SG-5 all the components of non-additive gene effects were significant, whereas for cross SG-5 x Punjab Guchhadar additive and real epistatic (j) gene effects were significant, positive and negative estimates of various gene effects revealed duplicate gene action for the cross ACS 97-1 x Punjab Guchhadar and Arka Lohit x SG-5. The results were in accordance with findings of Singh and Singh (1978), Singh and Rai (1986), Bhagyalakshmi *et al*. (1991), Jadhav and Dhumal (1994), Ahmed *et al*. (1999), Jagadeesha and Wali (2005) and Srivastava *et al.* (2005).

Table 2. Estimates of scaling tests and gene effects for green fruit yield and its components in chilli

Cross	Scaling tests				χ_{2} (3 d.f.)	Gene effects						Types of Epistasis
	A	B	C	D		m	d	h	i	J	l	
Number of fruits per pant												
ACS 97-1 X Punjab Guchhadar	34.67	-159.00**	242.33	183.33**	13.61**	404.21**	7.23	-295.53*	-366.70**	96.83*	491.00**	C & D
ACS 98-9 X SG-5	-19.53	-82.07*	-164.20*	-31.10	7.71	227.96**	138.37**	196.56**	62.60	31.27	39.00	C
SG-5 X Punjab Guchhadar	93.40**	-40.46	114.80	30.93	11.43**	247.98**	-81.03**	-87.23	-61.87	66.93*	8.93	C & D
Arka Lohit X SG-5	147.33	400.87**	314.93**	-116.63*	45.74**	312.58**	-7.47	311.16**	233.26*	-126.77**	-781.47**	C & D
ACG77XS49	52.67	90.07*	276.06**	66.67	16.05**	282.63**	-19.87	-52.29	-133.33	-18.70	9.40	C & D
Jwala X DPS 120	4.27	-110.47*	-168.39	-31.13	6.52	284.82**	106.97**	204.70*	62.27	57.33	43.87	C
Fruit length (cm)												
ACS 97-1 X Punjab Guchhadar	-1.16	1.78**	-2.09*	-1.36	40.48**	7.91**	-0.13	3.81**	2.72**	-1.47**	-3.34**	C & D
ACS 98-9 X SG-5	-0.04	0.62	0.24	-0.17	1.25	8.22**	-0.27	1.40**	-	-	-	-
SG-5 X Punjab Guchhadar	-0.39	0.19	-1.71	-0.76	3.51	7.62**	0.82**	1.35**	-	-	-	-
Arka Lohit X SG-5	-0.80	-0.22	-2.96	-0.97**	14.08**	7.48**	-0.83**	3.45**	1.94**	-0.29	-0.92	C
ACG77XS49	-2.35**	-1.39*	-0.05	1.84**	25.82**	9.20**	-0.99**	-4.03**	-3.69**	-0.48	7.43**	C & D
Jwala X DPS 120	0.35	1.18**	1.03	-0.25	4.42	9.15**	1.00**	1.77	0.49	-0.42	-2.02	D
Fruit girth (cm)												
ACS 97-1 X Punjab Guchhadar	0.13	0.39**	-0.18	-0.35**	19.54**	2.86**	-0.38**	0.71**	0.70*	-0.13	-1.21**	C & D
ACS 98-9 X SG-5	-0.10	-0.38*	-1.33**	-0.42**	34.44**	2.99**	-0.91**	0.34	0.84*	0.14	-0.35	C & D
SG-5 X Punjab Guchhadar	-0.13	-0.59**	-1.21**	-0.25	19.18**	3.70**	0.79**	0.73*	0.49	0.23	0.22	C
Arka Lohit X SG-5	0.08	-1.72**	-2.18**	-0.27**	221.91**	2.90**	-0.14*	-0.20	0.54**	0.91**	1.09**	D
ACG77XS49	-0.19	0.19	0.05	0.03	5.72	3.35**	-0.12**	-0.09	-	-	-	-
Jwala X DPS 120	0.10	0.08	-0.01	-0.09	1.69	2.95**	-0.45**	0.09	-	-	-	-
Fruit weight (g)												
ACS 97-1 X Punjab Guchhadar	-0.10	0.83*	-0.89**	-0.82**	62.07**	1.49**	-0.51	2.05**	1.63**	-0.47**	-2.37**	C & D
ACS 98-9 X SG-5	-0.29	-1.21**	-2.26**	-0.38*	37.83**	2.10**	-1.19**	0.46	0.76**	0.46**	0.73	C
SG-5 X Punjab Guchhadar	-1.12*	-0.13	-2.51**	-0.63*	21.22**	2.57**	0.76**	2.08**	1.26*	-0.50*	-0.01	C & D
Arka Lohit X SG-5	-0.03	-1.82**	-3.49**	-0.82**	142.26**	1.72**	0.48**	0.80**	1.64**	0.90**	0.21	C & D
ACG77XS49	-0.31	0.17	-0.83	-0.17	3.88	2.48**	-0.28**	-0.14	-	-	-	-
Jwala X DPS 120	0.44**	0.37	0.45	-0.18	7.49	1.94**	-0.47**	0.35	0.36	0.03	-1.17*	C & D
Green fruit yield per plant (Kg)												
ACS 97-1 X Punjab Guchhadar	-1.00	-0.18	-0.33	-0.02	2.05	0.46**	-0.15**	0.32**	-	-	-	-
ACS 98-9 X SG-5	0.12	0.30**	-0.58**	0.08	12.09**	0.48**	0.05	0.64**	0.15	0.09	0.26	C
SG-5 X Punjab Guchhadar	0.20	0.00	0.15	-0.03	2.15	0.45**	-0.11**	0.37**	-	-	-	-
Arka Lohit X SG-5	0.34	0.85**	0.12	-0.53**	36.41**	0.54**	-0.17	1.22**	1.06**	-0.25**	-2.24**	C & D
ACG77XS49	0.19	0.32**	0.70**	0.09	9.87**	0.66**	-0.11	0.02	-0.18	-0.06	-0.31	-
Jwala X DPS 120	0.13	-0.01	0.01	-0.05	1.05	0.44**	0.03	0.30**	-	-	-	-

, * Significant at 5 and 1 per cent levels respectively.

For fruit length at least one estimate of simple scaling tests was significant for all the crosses except ACS 98-9 x SG- 5 and SG-5 x Punjab Guchhadar suggesting influence of digenic interactions, the significant χ^2 values of joint scaling test for these crosses also confirm the same prediction. However, with cross Jwala x DPS 120, though B scaling test was significant but χ^2 value was non significant and which was reflected by significance of only additive gene effect. For cross ACS 97-1 x Punjab Guchhadar all the components of non additive gene effect were significant, whereas for cross SG-5 x Punjab Guchhadar additive, dominance and pseudo additive gene effects had significant estimates. The estimates of all types of gene effects except true epistatic were significant with cross ACG 77 x S 49. For the crosses ACS 98-

9 x SG-5 and SG-5 x Punjab Guchhadar only dominance and additive as well as dominance gene effects were significant, respectively. The positive and negative estimates of various gene effects revealed the duplicate as well as complementry epistatic gene actions for the crosses ACS 97-1 x Punjab Guchhadar, Arka Lohit x SG-5 and ACG 77 x S 49. The results are in conformity with reports of Bhagyalakshmi *et al*. (1991), Jadhav and Dhumal (1994), Ahmed *et al*. (1999), Saritha *et al*. (2005), Srivastava *et al*. (2005) and Venkataramana *et al*. (2005).

The estimates of simple scaling tests a well as χ^2 values for joint scaling tests were significant for all the crosses except cross ACG 77 x S 49 and Jwala x DPS 120 for average fruit girth, which indicated also presence of interallelic interactions. Whereas for this both crosses only additive gene effect was significant. The cross ACS 98-9 x SG-5 had significant fixable gene effects (additive as well as pseudo additive), for the cross ACS 97-1 x Punjab Guchhadar all the component of gene effects except real epistatic were significant and for cross Arka Lohit x SG-5 additive as well as all types of digenic interactions were significant. For the cross SG-5 x Punjab Guchhadar, though additive-dominance model was inadequate, only major gene effects were significant. Duplicate as well as complementry epistatic gene actions were depicted with the crosses ACS 97-1 x Punjab Guchhadar, Arka Lohit x SG-5 and ACG 77 x S 49. The results are in agreement with reports of Gopalkrishnan *et al*.

(1987), Bhagyalakshmi *et al*. (1991) and Jadhav and Dhumal (1994).

For fruit weight, the estimates of simple scaling tests as well as χ^2 values of joint scaling test were significant for all the crosses except the cross ACG 77 x S 49 and Jwala x DPS 120 revealing presence of interallelic interactions in addition to major gene effects. Whereas, for the cross Jwala x DPS 120 only A scaling test was significant, and for it additive and pseudo dominance gene effects were important. For the crosses SG-5 x Punjab Guchhadar and Arka Lohit x SG-5 all the components of gene effects except dominance epistatic were significant and for the cross ACS 97-1 x Punjab Guchhadar all the components of non-additive gene effects were significant. Additive, pseudo additive as well as real epistatic gene effects were significant for the cross ACS 98-9 x SG-5, whereas for the cross ACG 77 x S 49 only additive gene effect was significant. Duplicate, complementry and/or both types of interallelic interactions were detected with various crosses. The results confirm the findings of Gopalkrishnan *et al*. (1987), Bhagyalakshmi *et al*. (1991), Ahmed *et al*. (1999) and Jagadeesha and Wali (2005).

The significant estimates of simple scaling tests and χ^2 values for the crosses ACS 98-9 x SG-5, Arka Lohit x SG- 5 and ACG 77 x S 49 suggested the presence of digenic interactions in addition to major gene effects for inheritance of green fruit yield. However, for the cross ACG 77 x S 49, none of the components of gene effects were significant. The cross ACS 98- 9 x SG-5 had significant dominant gene effect, but for the cross Arka Lohit x SG-5 all the components of non-additive gene effects were significant. Among the crosses, which showed adequacy of additive-dominance model, importance of additive as well as dominance gene effects was detected for the crosses ACS 97-1 x Punjab Guchhadar and SG-5 x Punjab Guchhadar, whereas the cross Jwala x DPS 120, only the dominance gene effect was important. The magnitudes of estimates of various gene effects for the cross Arka Lohit x SG-5 revealed duplicate as well as complementry digenic interactions. The results are in agreement with reports of Singh and Rai (1986), Bhagyalakshmi *et al*. (1991), Ahmed *et al*. (1997), Patel *et al*. (2004), Jagadeesha and Wali (2005), Saritha *et al*. (2005) and Venkataramana *et al*. (2005).

The green fruit yield is the out come of the interplay of various yield contributing component characters and in general preponderance of intra and interallelic inter action with marginal influence of additive gene effect was evidenced for green fruit yield and most of the component characters under study. The heterosis breeding as well as development of inbred or pure line variety through pedigree selection in promising crosses, which registered importance of additive gene effect would be effective for crop improvement.

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