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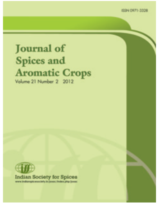

Genetic analysis for earliness under varying environments in chilli (*Capsicum annum* L.)

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Abstract

Six generations P_1 P_2 F_1 F_2 BC_1 and BC_2 of six families were developed in chilli (*Capsicum annum* L.) from 11 inbreds and were used to apply A, B, C and D scaling tests in the attributes of earliness *viz.*, days to 50.0% flowering (DTF) and days to fruit ripening (DTFR) in different environments at Jagudan (Gujarat). The experiment was conducted in *Kharif* 2007 under high fertility condition (E_1), *Kharif* 2007 under low fertility condition (E_2) and Summer 2007 under high fertility condition (E_3). For DTFR in *Kharif,* low fertility and summer grown conditions enhanced the expression of dominant/partially dominant genes. Whereas, DTF in low fertility as well as late sowing conditions depressed the expression of dominant/partially dominant genes. Detection of epistasis in a cross in one environment and not in the other emphasized the influence of environment on interaction parameters. High role of epistasis for ripening and flowering in all the three environments was observed. In general, for inheritance of days to flowering preponderance of dominance gene effects or due weightage of additive and dominance epistasis and dominance × dominance gene effects were noticed. For improvement of this trait, heterosis breeding was fruitful, where importance of non-additive gene effects with greater influence of dominance gene effects was estimated. The parents GVC–111, Junagadh Gholar, JCh–730 and JCh–725 contributed desirable genes for imparting earliness.

Keywords: *Capsicum annum*, chilli genetic analysis, environment effects, gene effects, scaling tests

In chilli (*Capsicum annum* L.), most of the reports for gene effects refer to diallel or L × T analysis. Hence, various components of digenic interactions are confounded with most of the major components, additive and non-additive, with backcross generations. Six parameters model of Hayman (1958) would give detailed account of various gene effects including all types of intra–allelic interactions with reference to particular cross combinations. Simple scaling test A B C and D of Hayman & Mather (1955) was used to test adequacy of additive-dominance model. The fruit yield of any crop variety is largely influenced by its earliness and duration of its reproductive period. For improvement of such characters, information on gene effect is prerequisite for getting efficient results in succeeding generations. Therefore, a study was carried out to assess gene effects for earliness i.e. days to 50.0% flowering and days to fruit ripening characters through generation mean analysis in six cross combinations.

Six generations *viz.*, P_1 P_2 F_1 F_2 BC_1 and BC_2 and each of following six crosses, *viz.*, JCh–712 × JCh–736, GVC–111 × Junagadh Gholar, S–49 × JCh–726, JCh–676 × JCh–659, JCh–734 × JCh–659, JCh–730 × JCh–725 involving 11 diverse parental genotypes of chilli were used in the study. Apart from these, nine developed at Centre for Research on Seed Spices, S D Agricultural University, Jagudan and two developed by Main Vegetable Research Station, Anand Agricultural University, Anand were also used for the study. The material consisted of six generations. Each of the crosses were laid during *Kharif* 2007 (E_1: under high fertility condition & E_2: under low fertility condition) and summer 2007 (E_3: under high fertility condition) in a compact family block design with three replications. Each net plot had one row for parents and F_1s, two rows for each of BC_1 and BC_2 and four rows of F_2 populations. Inter- and intra- row spacing of 90 and 60 cm was maintained with row length of 6.0 m. Extra two rows were planted on both sides of experimental blocks to eliminate border effects. The recommended package of practices was followed in nursery as well as field. RandomLy selected competitive five plants from each in P_1, P_2 and F_1 and 20 plants from F_2 and 10 plants from each of the BC_1 and BC_2 generations were tagged for recording days to 50.0% flowering and days to ripening. The means of all the six generations for different two characters of all six crosses were evaluated in E_1: *Kharif* 2007 (5th August 2007) under high fertility condition (200 kg N and 100 kg P_2O_5 ha^{-1}), E_2: *Kharif* 2007 (5th August 2007) under low fertility condition (150 kg N and 75 kg P_2O_5 ha^{-1}) and E_3: Summer 2007 (19th March 2007) under high fertility condition (200 kg N and 100 kg P_2O_5 ha^{-1}) were first subjected to simple scaling tests; A B C and D. The results of simple scaling test were further confirmed by joint scaling test (Cavalli 1952) which effectively combines the whole set of simple scaling tests and thus offers a more general convenient, adaptable and informative approach for estimating gene effects and for testing adequacy of simple additive-dominance model as well as 3-parameters model. In cases where three-parameters model did not fit to the data, gene effects were calculated with six-parameter model (Jinks & Jones 1958). The results for estimates of simple scaling tests, three parameters model and six parameters model for characters with individual cross are described in Table 2. It consists of estimating three parameters *viz.,* the mid parent (m), additive (d) and dominance (h) using weighted least squares method followed by a comparison of observed means with expected means. The comparison between observed and expected generation means were made by chi-square ($\times^2$) test assuming that the sum of square minimized in the fitting process distributed as $\times^2$. The degree of freedom is equal to the number of generations minus number of parameters estimated. The individual plant observations over three replications were used to calculate the mean of various generations.

The inheritance patterns varied with cross and character. Mean values of days to 50% flowering (DTF) and days to fruit ripening (DTFR) of F_1s are given in Table 1. DTF were found to be either intermediate or closer, at par or higher than parent to early flowering parents (desirable) indicating dominance, co-dominance or complete-dominance of genes in families III, IV and VI for early flowering. The mean values of F_1s for DTFR were less than early ripening parent with crosses II and III (Table 1) revealing influence of decreasing genes and over dominance gene effect. Cross I and cross II revealed influence of increasing genes. The estimates of gene effects for the best fit model with respect to DTF and DTFR in six crosses of chilli are given in Table 2.

Days to 50% flowering

Mean values of F_1s for DTF were either intermediate or closer, at par or higher than parent to early flowering parents (desirable) indicating dominance, co-dominance or complete-dominance of genes in crosses III, IV and VI for early flowering (Table 1). The DTF in low fertility as well as late sowing conditions were found to depress the expression of dominant/partially dominant genes. Thus, there would be a bias in the interpretation of importance of dominance unless the growing conditions were taken into consideration.

Table 1. Mean performance of parents, $F_{1'S}$, and $F_{2'S}$ for days to 50% flowering and days to fruit ripening under *Kharif*, 2007 with high fertility (E_1), low fertility (E_2) and summer 2007 under high fertility conditions (E_3)

Crosses		Environment	P_1	P_2	F_1	F_2	P_1	P_2	F_1	F_2
			Days to 50% flowering				Days to fruit ripening			
I	JCh-712 × JCh-736	E_1	65.07	67.40	64.07	66.07	157.00	146.00	149.33	143.67
		E_2	58.56	60.66	57.66	59.46	155.43	144.54	147.84	142.23
		E_3	55.97	57.97	54.57	56.83	135.33	125.67	128.33	123.67
II	GVC-111 × Junagadh Gholar	E_1	59.10	46.87	51.13	50.17	132.67	147.33	143.67	141.67
		E_2	53.19	42.18	46.38	45.15	130.01	144.39	140.79	138.83
		E_3	51.77	40.30	43.40	43.13	114.0	126.33	123.33	121.67
III	S-49 × JCh-726	E_1	60.20	62.47	61.83	61.13	133.00	141.67	137.00	137.00
		E_2	54.18	56.22	56.22	55.02	131.67	140.25	135.63	146.85
		E_3	51.77	53.73	53.17	52.60	114.33	122.00	117.67	117.67
IV	JCh-676 × JCh-659	E_1	60.77	63.21	63.20	61.23	148.33	145.33	149.00	149.00
		E_2	54.69	56.88	56.88	56.61	146.85	143.88	147.51	151.47
		E_3	52.23	54.37	54.37	52.67	127.67	125.00	128.33	127.67
V	JCh-734 × JCh-659	E_1	60.40	62.77	62.13	60.80	138.00	140.67	138.67	137.00
		E_2	54.36	56.49	55.92	55.92	136.62	139.26	137.28	134.64
		E_3	51.97	53.97	53.43	52.27	118.33	121.00	119.33	117.67
VI	JCh-730 × JCh-725	E_1	60.30	69.37	64.83	65.00	150.00	157.33	151.00	145.00
		E_2	54.27	62.43	58.35	58.50	148.50	155.76	149.49	143.55
		E_3	59.60	59.60	56.20	55.90	129.00	135.67	129.67	124.67

Table 2. Estimates of scaling tests and gene effects for developmental characters in chilli

Character	Crosses	Environment	Scaling tests				Gene effects					
			A	B	C	D	m	d	h	i	j	l
Days to 50% flowering	C_1	E_1	-1.20	0.40	3.67	2.23	66.07**	-1.97	-6.63	-	-	-
		E_2	-13.53	-5.28	-26.73*	-3.96	142.07**	5.45**	-5.12	7.92	-4.13	10.89*
		E_3	-12.33	-4.67	-23.00**	-3.00	124.50**	4.83**	-7.17	6.00	-3.83	6.00*
	C_2	E_1	2.90	0.60	-8.37	-5.93**	41.12**	6.12**	25.78**	11.87	1.15*	-15.37**
		E_2	-0.98	2.29	-0.65	-0.98	138.83**	-8.82**	5.55	-	-	-
		E_3	-	3.00	-0.33	-1.67	121.67**	-7.67*	6.50**	-	-	-
	C_3	E_1	0.57	-0.03	-1.80	-1.17	61.13**	-0.83	2.83	-	-	-
		E_2	-1.32	-3.96	-0.66	2.31	135.63**	-2.97	-4.95	-	-	-
		E_3	-0.67	-3.67	-1.00	1.67	117.67**	-2.33	-3.83	-	-	-
	C_4	E_1	-0.83	-2.60	-5.43	-1.00	59.98**	-1.22*	1.78	-	-	-
		E_2	-0.66	1.65	4.29	1.65	147.51**	0.33	-1.16	-	-	-
		E_3	-0.67	-	1.33	1.00	127.67**	1.00	-	-	-	-
	C_5	E_1	2.33	-0.63	-4.23	-2.97**	55.65**	-1.18**	14.12	5.93*	1.48	-7.63
		E_2	-2.64	-7.26	-7.92	0.99	135.63**	0.99	-2.64	143.55**	2.31**	-2.64**
		E_3	-1.67	-5.67	-7.33	-	117.67**	0.67	-0.33	-	-	-
	C_6	E_1	1.53	-1.53	0.67	0.33	65.00**	-3.00**	-0.67	-	-	-
		E_2	-4.29	-8.91**	-29.04**	-7.92	136.29**	-3.63**	15.84	-	-	-
		E_3	-3.33	-25.33	-25.33	-7.00	118.33**	-3.33**	14.00	14.00	2.33*	-2.67*

Cont......

Days to fruit ripening	C_1	E_1	-13.67	-5.33	27.00	-4.00	143.50**	5.50**	5.17	8.00	-4.17	11.00
		E_2	-13.53	-5.28	-26.73*	-3.96	142.07**	5.45**	-5.12	7.92	-4.13	10.89*
		E_3	-12.33	-4.67	-23.00**	-3.00	124.50**	4.83**	-7.17	6.00	-3.83	6.00*
	C_2	E_1	2.61	0.54	-7.53	-5.34	45.15**	6.54*	9.38	-	-	-
		E_2	-0.98	2.29	-0.65	-0.98	138.83**	-8.82**	5.55	-	-	-
		E_3	-	3.00	-0.33	-1.67	121.67**	-7.67*	6.50**	-	-	-
	C_3	E_1	-1.33	-4.00	-0.67	2.33	137.00**	-3.00	-5.00	-	-	-
		E_2	-1.32	-3.96	-0.66	2.31	135.63**	-2.97	-4.95	-	-	-
		E_3	-0.67	-3.67	-1.00	1.67	117.67**	-2.33	-3.83	-	-	-
	C_4	E_1	-0.67	1.67	4.33	1.67	149.00**	0.33	-1.17	-	-	-
		E_2	-0.66	1.65	4.29	1.65	147.51**	0.33	-1.16	-	-	-
		E_3	-0.67	-	1.33	1.00	127.67**	1.00	-	-	-	-
	C_5	E_1	-2.67	-7.33	-8.00	1.00	137.00**	1.00	-2.67	-	-	-
		E_2	-2.64	-7.26	-7.92	0.99	135.63**	0.99	-2.64	-	-	-
		E_3	-1.67	-5.67	-7.33	117.67**	0.67	-0.33	3.48	-	-	-
	C_6	E_1	-4.33	-9.00**	-29.33**	-8.00	137.67**	-3.67	16.00	16.00*	2.33**	-2.67**
		E_2	-4.29	-8.91**	-29.04**	-7.92	136.29**	3.63**	15.84	15.84	2.31**	-2.64**
		E_3	-3.33	-8.00	-25.33	-7.00	118.33**	-3.33**	14.00	14.00	2.33*	-2.67*

C_1= JCh–712 × JCh–736; C_2=GVC–111 × Junagadh Gholar; C_3=S–49 × JCh–726; C_4=JCh–676 × JCh–659; C_3=S-49 × JCh–726; C_4=JCh–676 × JCh–659; C_5=JCh–734 × JCh–659; C_6=JCh–730 × JCh–725 *,**Significant at 5 and 1% level, respectively

Detection of epistasis in a cross in one environment and not in other emphasized the influence of environment on the estimation of interaction parameters. Among the components of earliness, for DTF adequacy of additive-dominance model was detected with crosses II, IV, V and VI through significant estimates of A B C and D scaling tests. Cross II revealed the importance of all the three interactions, *viz.,* real epistasis (a × d), dominance (d × d) days to 50.0% interaction and additive epistasis (a × a). In general, for inheritance of DTF, preponderance of dominance gene effects or due weightage of additive and dominance epistasis and dominance × dominance gene effects were noticed (Table 2). The results of present study are in accordance with the findings of Shukla *et al.* (1999) who reported greater magnitude of dominance gene effects. The results are also in agreement with Anand & Subbaraman (2006), who reported importance of both and non-additive gene effects for inheritance of DTF. For improvement of this trait, heterosis breeding would be fruitful, where importance of non-additive gene effects with greater influence of dominance gene effects are estimated.

Days to fruit ripening

For DTFR, in *Kharif*, low fertility and summer grown conditions enhanced the expression of dominant/partially dominant genes. The preponderance of additive component of major gene effects was observed with crosses I and VI, of which in cross I greater magnitude of dominance epistasis was detected, whereas for cross VI, significance of additive × additive (i) in E_1, dominance × dominance (l) and additive × dominance (j) of digenic interactions in all environments revealed presence of additive gene effects. Both gene actions were at work in E_3 of cross-II preponded with dominance gene effects. For crosses I and VI, additive gene effects were detected (Table 2). The present findings are in accordance with the results reported by Patel *et al.* (2001). However, these are in contrast with Shukla *et al.* (1999) and Kamboj *et al.* (2008) who reported the major role of non-additive gene effects. Therefore, for improvement of this character, pedigree selection method would be more effective, whereas, duplicate epistasis could cause balancing effect of genes and selection would be restricted in such cases. Therefore, biparental mating or reciprocal recurrent selection is suggested.

The higher role of epistasis for DTFR and DTF was observed in all the three environments. Epistatic expression in DTFR under both fertility levels and in summer grown in high fertility level was found to be depressed. The epistasis had been expressed through influencing the phenotypic traits and it is suggested that breeder should be aware of this as a source of variation, which might influence predicted gain in selection programme.

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