



Research Article

Heterosis for green fruit yield and its components in chilli (*Capsicum annuum* var. *longicum* (D.G) Sendt) over environments

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(Received: 12 Aug 2010; Accepted: 28 Sep 2010)

Abstract:

Heterosis for green fruits and related characters in chilli was studied in line \times tester fashion involving five GMS lines and 10 testers. The hybrids differed significantly for all the characters, as evident from their highly significant mean square values. Mean squares due to hybrids \times environments were significant for all the characters except average fruit weight, which indicated more sensitivity of hybrids to environments. The hybrids ACMS 8 \times IPS -2005 -15, ACMS 5 \times IPS -2005 -15, ACMS 6 \times ACS -2004 -03, ACMS 4 \times IPS -2005 -15, ACMS 6 \times IPS -2005 -15 and ACMS 8 \times ACS -2004 -03 exhibited higher magnitude of heterobeltiosis and standard heterosis for green fruit yield per plant and number of fruits per plant. In general the hybrids, which depicted higher magnitude of heterotic effects also exerted greater amount of heterotic effects for various growth attributes and yield related traits; therefore, heterotic effects for green fruit yield could be because of direct and indirect effects of various yield contributing characters. Hence, to obtain maximum advantage of heterotic effects for green fruit yield, desired level of heterosis of each component character should be determined to identify superior hybrids in respect to yield, yield contributing characters and quality parameters. A cross ACMS 8 \times IPS -2005 -15 was consistent across the environments and so, it can be used for commercial exploitation after its critical evaluation.

Key Words: Chilli, heterobeltiosis, standard heterosis, over environments

Introduction

Chilli (*Capsicum annuum* L.) belongs to genus capsicum, under solenaceae family. It is believed to have originated from South America. It is usually grown as annual crop in temperate areas, although ecologically it is a perennial shrub in tropical areas, and it can be grown for a few years as a perennial crop in greenhouses. The hot chillies are classified in two major pungent group as *C. annuum* var. *longum* (D.C.) Sendt. and non pungent chilli as *C. annuum* var. *grossum* (D.C.) Sendt. Globally *C. annuum* is important as a vegetable crop for its uses as salads and pickles, and dry ripe red powder used as cooking ingredients and colourant in various recipes including fast food, and it has special uses for cosmetic products. India is the largest producer of chillies in the world. In India, the major chilli growing states are Andhra Pradesh, Karnataka, Maharashtra, Orissa, Tamil Nadu and West Bengal. The low productivity is mainly due to uses of pure lines as varieties for cultivation, and very less area of hybrids (2.4%). The main constraint for exploitation of hybrid vigour in chilli is costly hybrid seeds. This problem can be solved by the use of male sterile lines for hybrid seed production in chilli (Patel *et al.*, 2001). Though, Chilli has been classified under self pollinated crops, some reports suggest geographical differences in the degree of out crossing, and which has been reported to be as high as 66.40 per cent

(Singh *et al.*, 1994). Patel *et al.* (2001) reported that with natural out crossing the average fruit set with male sterile plants was an average of 32.79 per cent, which was about 118.60 per cent higher than per cent fruit set on gms lines with hand pollination (14.44 %). In India, although most of the area under chilli cultivation is occupied by open pollinated varieties, in the recent past cultivation of hybrids has increased gradually. In heterosis breeding, identification of cross combinations for yield is the first step followed by minimization of cost of hybrid seed production through uses of male sterility mechanism and manipulation of plant geometry and cultural practices for increased production of hybrid seeds.

Material and Methods

The experimental material comprised five GMS lines (ACMS 2, ACMS 4, ACMS 5, ACMS 6 and ACMS 8), 10 testers (GVC 101, GVC 111, ACS -2001 - 01, ACS -2001 - 02, ACS -2001 - 04, ACS -2004 - 02, ACS -2004 - 03, ACS -2004 - 05, IPS -2005 -15 and RHRC Pendent) (Table 1), and their 50 F₁s which were grown in a randomized complete block design, replicated thrice in *kharif* 2006-07 in two environments, early (E₁) and normal sown (E₂) and *kharif* 2007-08 in normal (E₃) environment. The 25 day old healthy seedlings were transplanted in the field on 26th July, 2006 (E₁), 19th September, 2006 (E₂) and 25th August, 2007. The

genotypes were randomized separately among the parents as well as hybrids in each replication. Each experimental unit was represented by a single row accommodating 10 plants with 60 x 60 cm inter and intra row spacing. However, experimental units of gms lines were planted with two seedlings at every dibble and sterile plants were removed immediately after emergence of crown flowers. Non experimental extra two rows were also planted on both sides of experimental blocks to eliminate border effects. The recommended package of practices including plant protection measures obligatory to raise good crop were followed both in nursery as well as in field. All the observations related to fruit yield and related characters except phenological trait, days to flower initiation were recorded on five randomly selected plants in each experimental unit, while days to flower initiation was recorded on population basis. The data were analysed for individual and pooled analysis as suggested by Panse and Sukhatme (1978) and Tai (1971), respectively. The Heterobeltiosis was worked out according to formula suggested by Fonseca and Patterson (1968) and the standard heterosis was estimated against standard check variety GVC 101 and GVC 111 which showed desirable higher or better value of characters.

Results and Discussion

Pooled analysis of variance for experimental design (Table 2) revealed that the mean squares due to genotypes, parents and its sub divisions (lines, testers and lines *vs* testers) were found significant for all the characters indicating presence of sufficient amount of variability in the material. The pooled analysis of variance revealed that the hybrids differed significantly from parents for all the characters except average fruit length, indicating the existence of heterosis. Parents \times environments interactions variance were significant for all the characters except number of secondary branches per plant, number of fruits per plant and average fruit. Mean squares due to hybrids \times environments were significant for all the characters except average fruit weight, which indicated that hybrids behaved differently in different environments and strongly influenced by the environments i.e. more sensitivity of hybrids to environments.

The mean values for different characters under the three diverse environments (Table 3) revealed that the green fruit yield per plant and the yield contributing characters except average fruit girth and average fruit weight were found higher in desired direction with the hybrids as compared to parents and so possibility of presence of considerable heterosis in the studied population. In respect of *per se*

performance of parents, among the gms lines, lines ACMS 8, ACMS 6 and ACMS 4 and among the males, inbreds RHRC Pendent and ACS -2004 -05 were found to be superior for green fruit yield per plant and for most of the yield contributing and quality characters. Among the hybrids, hybrids ACMS 8 \times IPS -2005 -15, ACMS 5 \times IPS -2005 -15, ACMS 4 \times IPS -2005 -15 had high *per se* performance for green fruit yield per plant and other important yield contributing characters.

Mackey (1976) described genetic principles of expression of heterosis superior to the better parent, which may result from one or two of the following situations: (i) the accumulated action of favourable dominant or semi-dominant genes dispersed amongst two parents i.e. dominance; (ii) the complementary interaction of additive dominant on recessive genes at different loci i.e. non-allelic interaction or epistasis; (iii) favourable interaction between two alleles at the same locus i.e. intra locus or inter allelic interactions referred to as over dominance. It will be possible to recover homozygous lines as good as heterotic hybrids if either or both of the first two situations are the cause of heterosis, although the case with which such lines can be recovered will depend on linkage relationship of the genes involved and the ability to identify the recombinants as and when they arise. This will be particularly difficult with close linkage and when heterosis is expressed by a slight improvement in each of main yield components. If the heterosis is due to inter allelic interactions of dominant types, it is not possible to fix such heterosis in homozygous condition in subsequent generations. The superiority of hybrids, particularly over better parent, is more useful in determining the feasibility of commercial exploitation of heterosis and also identifying the parental combinations capable of producing the highest level of transgressive segregants. Investigation on degree of heterosis is, however, important as it may be of value in deciding the directions of future breeding programme. Kaladee (1988) pointed out that overdominance or heterosis of hybrids was due to the heterozygosity in self pollinated crops.

The range of heterosis, number of desirable significant heterotic crosses and best heterotic crosses over better parent and standard variety for 15 traits are presented in Table 4. Heterotic effects in negative direction are desirable for days to flower initiation. Hybrids ACMS 5 \times IPS -2005 -15 (-21.57%) and ACMS 2 \times GVC 101 (-14.29%) exhibited significant and the highest negative heterobeltiosis (HB) and standard heterosis (SH), respectively for days to flower initiation. A cross ACMS 8 \times IPS - 2005 - 15

exhibited maximum significant SH for green fruit yield per plant (448.55%), number of fruits per plant (277.69%) and average fruit girth (38.42%) and HB for green fruit yield per plant (197.55%). Similar findings were also reported by Gandhi *et al.* (2000), Patel (2002), Bhalala *et al.* (2004) and Patel *et al.* (2004) for both heterobeltiosis and standard heterosis, while Kumar and Lal (2001), Mamedov and Pyshanaja (2001), Singh and Hundal (2001), Nayaki and Natrajan (2002), Patel (2004) for heterobeltiosis and Meshram and Mukewar (1986), and Shah (2004) for standard heterosis who observed high heterotic effects in positive direction.

For plant height, total 29 and 49 crosses registered significant and desirable positive HB and SH, respectively and hybrid ACMS 6 × RHRC Pendent depicted the highest HB and SH. Similarly, cross ACMS 8 × ACS -2001 -01 exhibited maximum HB (21.53%) and SH (5.67%) for average fruit length. Cross combination ACMS 5 × IPS - 2005 - 15 exerted highest heterosis for number of secondary branches per plant, plant width and capsaicin content over better parent. The cross ACMS 6 × ACS -2004 - 03 manifested maximum SH for moisture content and chlorophyll content whereas ACMS 8 × GVC 101 depicted the highest for plant width and capsaicin content. The F₁s ACMS 6 × ACS -2001 - 02 and ACMS 2 × ACS -2004 - 05 had the highest SH for fruit shape index and average fruit weight, respectively and these hybrids also depicted the maximum HB for ascorbic acid content and moisture content, respectively.

In the pooled analysis, for green fruit yield per plant 36 hybrids exhibited significant and positive heterobeltiosis and 48 for standard heterosis. A large number of hybrids expressed greater amount of heterotic effects in desired direction for green fruit yield per plant, plant height, number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, chlorophyll content and ascorbic acid content.

The estimates and magnitude of various heterotic effects varied with cross combinations and characters. Inconsistent performance of most of the hybrids across the environments for various characters suggested that parental contributions for cross combinations and different characters were susceptible to environmental fluctuation. It is also due to the contribution to the heterosis of the characters changed in different environments due to character x environment interaction. A comparative performance of the most five heterotic crosses for green fruit yield, yield components and quality

parameters in each environment is presented in Table 5. The result revealed that crosses ACMS 8 × IPS - 2005 -15, ACMS 5 × IPS -2005 -15, ACMS 6 × ACS -2004 -03, ACMS 4 × IPS -2005 -15 and ACMS 6 × IPS -2005 -15 exhibited above 150 per cent heterobeltiosis in pooled over the environments, of which cross ACMS 8 × IPS -2005 -15 was consistent across the environments, whereas rest of the crosses were consistent in atleast two environments. For standard heterosis, the crosses ACMS 8 × IPS -2005 -15, ACMS 5 × IPS -2005 -15 and ACMS 8 × ACS -2004 -03 depicted high heterotic effects in each individual environment and over the environments as well. The crosses which had larger estimates of HB and SH for green fruit yield, also exerted significant positive heterotic effects for number of fruits per plant and number of primary branches per plant among the yield contributing characters and for chlorophyll content and ascorbic acid content among the fruit quality attributes. Therefore, heterotic effects for green fruit yield were because of direct effect of number of fruits per plant and could be out come of interaction effects of other yield attribute, like average fruit length and average fruit weight. Among developmental characters, early flowering, plant height, number of primary branches and number of secondary branches might have contributed indirectly for heterotic effects of green fruit yield. According to Grafius (1959), who had suggested that there could be no separate gene system for yield *per se* as yield is an end product of the multiplicative interactions between its various component characters. Therefore, green fruit yield per plant could be a result of combinational heterosis. However, positive and negative estimates of heterosis for rest of the characters could have checked each other for exerting heterotic effects. Hence, to obtain maximum advantage of heterotic effects for green fruit yield, desired level of heterosis of each component characters should be determined to identify superior hybrids in respect to yield and quality parameters.

Among parents involved in different cross combinations, the GMS lines ACMS 8, ACMS 5, ACMS 4 and ACMS 6 and pollen parents IPS -2005 -15, ACS -2004 -03, RHRC Pendent and GVC 111 yielded the best heterotic hybrids. The existence or availability of genetic variability and nature of gene effects impose the selection of breeding methodology. Several hybrids exhibited significant and desirable heterobeltiosis and standard heterosis for various traits studied including green fruit yield in different environments, which suggest the potentiality of hybrids and scope for heterosis breeding. The availability of a stable GMS lines, possibility of use of GMS lines and efficient large



scale hybrid seed production technique would facilitate for commercial exploitation of hybrids.

A perusal of *per se* performance, heterotic effects and sca effects of hybrids revealed that hybrid ACMS 8 x IPS -2005 -15 ranked first for all the approaches, and found promising for commercial exploitation after its critical evaluation. The hybrid seed production work can be made easy with male sterile lines by encasing the advantage of natural out crossing, leading to reduction in the cost of hybrid seeds. Gill and Gill (1995) also advocated for the use of natural open pollination for economical viable hybrid seed production in chilli. The cytoplasmic genetic male sterility is unstable in fluctuating environments, and hence cannot be relied upon to produce F₁ hybrid seeds (Greenleaf, 1986), and in tropical region it would be more unstable, and difficult to exploit for hybrid seed production. Therefore, hybrid seed production is largely restricted to genetic male sterility only. The uses of genetic male sterility, controlled by a single monogenic recessive gene can greatly help in making F₁ hybrid seeds as tedious and costly hand emasculation of individual flower bud can be avoided.

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Table 1. Brief description of the parental genotypes used in experiments.

Name of Parent	Origin	Parentage/ Pedigree	Flowering /Maturity	Plant growth habit	Foliage colour and leaf size	Bearing habit	Fruit length	Fruit size & shape
ACMS 2	AAU, Anand	Selection from Baloch MS ₂ -5-1- 4-1	Early	SDT, tall, erect and bushy	Green, narrow and medium long	Pendant solitary	Medium long	Medium thick, smooth and pointed
ACMS 4	AAU, Anand	Selection from Baloch MS ₂ -1-1- 3-3-1	Late	SDT, medium tall, erect and bushy	Green, narrow and medium long	Pendant solitary	Long	Thick, fleshy and smooth
ACMS 5	AAU, Anand	Selection from Baloch MS ₂ -1- 1-1-1-1	Mid-late	NDT, tall, erect and bushy	Green, narrow and medium long	Pendant solitary	Long	Thick and smooth
ACMS 6	AAU, Anand	Selection from Baloch MS ₂ -5- 1-1-1-2	Late	NDT, tall, erect and bushy	Green, narrow and medium long	Pendant solitary	Long	Thick, wrinkled and pointed
ACMS 8	AAU, Anand	Selection from Baloch MS ₂ -5- 1-4-1-1	Early	SDT, medium tall, semi-erect and open	Green, narrow and long	Pendant solitary	Medium long	Thick, wrinkled and pointed
GVC-101*	AAU, Anand	Selection from S- 49 progeny	Early	SDT, medium tall, erect and open	Green, medium long and broad	Pendant solitary	Short	Thick, compact and wrinkled
GVC-111*	AAU, Anand	Selection from Jwala progeny	Early	NDT, medium tall, erect and bushy	Green, large and broad	Pendant solitary	Short	Thick, medium fleshy and smooth
ACS- 2001-01	AAU, Anand	Selection from S- 49x AC1 progeny	Early	SDT, medium tall, compact and erect	Green and medium long	Pendant solitary	Long	Thick, smooth, and pointed
ACS- 2001- 02	AAU, Anand	Selection from S-49x AC1 progeny	Early	Medium tall, scattered and open	Green and medium long	Pendant solitary	Long	Thick, smooth with luster and pointed
ACS- 2001- 04	AAU, Anand	Selection from Pb. Guchhedar x AC1 progeny	Early	SDT, medium tall, erect, and bushy	Green and long	Pendant solitary	Medium long	Thick and slight wrinkled
ACS- 2004- 02	AAU, Anand	Selection from Jwala x ACS- 92-1 progeny	Mid-late	SDT, medium tall, semi-erect and open	Green, medium long and broad	Pendant solitary	Long	Thick, compact, smooth and pointed
ACS- 2004- 03	AAU, Anand	Selection from S-49 x RHRC - 50-1progeny	Early	Medium tall and compact	Green, long and broad	Pendant solitary	Medium long	Medium thick and smooth
ACS- 2004- 05	AAU, Anand	Selection from NS-101 progeny	Early	Medium tall and compact	Green and medium long	Pendant solitary	Medium long	Thick and smooth
IPS- 2005- 15	AAU, Anand	Selection from ACS 98-8 x RHRC -16-5 progeny	Late	Medium tall and semi- erect	Green and long	Pendant solitary	Medium long	Medium thick and smooth
RHRC Pendent	Rahuri	-	Late	SDT, medium tall, open and bushy	Green, broad and medium long	Pendant cluster	Short	Thick, compact, slightly rough and pointed

Table 2: Analysis of variance over environment for different characters in Chili

Source of variation	d.f. ⁺	Days to flower initiation	Plant height (cm)	No. of primary branches /plant	No. of secondary branches / plant	Plant width (cm)	Number of fruits / plant	Average fruit length (cm)	Average fruit girth (cm)
Environments	2	2140.31 **	314.45 **	0.02	5.01 **	748.63 **	93945.63 **	1.45 **	0.71 **
Genotypes	64	154.63 **	1793.41 **	1.74 **	3.34 **	1123.66 **	82288.72 **	11.01 **	2.70 **
Parents (p)	14	156.09 **	1260.56 **	1.03 **	4.54 **	835.06 **	80483.71 **	17.81 **	3.92 **
Lines (l)	4	197.41 **	1303.68 **	1.13 **	4.23 **	442.71 **	1900.22 **	17.68 **	2.36 **
Testers (t)	9	149.53 **	608.06 **	0.86 **	4.87 **	765.78 **	113112.01 **	17.22 **	4.96 **
Lines vs Testers	1	49.84 **	6960.52 **	2.25 **	2.89 **	3028.00 **	101162.97 **	23.59 **	0.76 **
Hybrids	49	122.96 **	1236.74 **	1.88 **	2.45 **	1224.17 **	55917.65 **	9.29 **	2.39 **
Parents vs hybrids	1	1686.25 **	36530.08 **	4.88 **	30.03 **	239.36 **	1399741.44 **	0.38	0.79 **
Genotype × environments	128	13.10 **	74.18 **	0.05 **	0.26 **	49.29 **	695.25 **	2.10 **	0.31 **
Parents × environments	28	15.77 **	28.88 *	0.05 **	0.13	41.51 **	509.05	0.93 **	0.14 **
Lines × environments	8	28.24 **	38.64 *	0.06 **	0.11	34.68	539.19	0.38 *	0.05
Testers × environments	18	11.12 **	26.73	0.03 *	0.12	48.53 **	517.74	1.27 **	0.17 **
Hybrids × environments	98	12.44 **	87.29 **	0.06 **	0.30 **	52.49 **	656.75 *	2.47 **	0.37 **
Error	384	1.29	18.48	0.02	0.15	18.94	497.45	0.17	0.04

Source of variation	d.f.	Fruit shape index	Average fruit weight (g)	Green fruit yield (g) / plant	Moisture content (%)	Chlorophyll content (µg/g)	Capsaicin content (µg/g)	Ascorbic acid content (µg/g)
Environments	2	0.52 **	2.79 **	2833036.49	463.09 **	160.14 **	0.52 **	52.20 **
Genotypes	64	2.69 **	4.63 **	1256616.90 **	67.10 **	205.68 **	0.24 **	3842.98 **
Parents (p)	14	3.69 **	5.16 **	767643.89 **	110.54 **	103.34 **	0.35 **	4001.88 **
Lines (l)	4	4.11 **	2.42 **	87068.79 **	113.88 **	103.10 **	0.15 **	2300.44 **
Testers (t)	9	3.58 **	3.37 **	1125917.63 **	119.43 **	108.63 **	0.45 **	5097.68 **
Lines vs Testers	1	2.96 **	32.24 **	265480.58 **	17.20 *	56.59 **	0.26 **	945.47 **
Hybrids	49	2.46 **	4.22 **	1054681.38 **	53.73 **	184.95 **	0.21 **	3612.76 **
Parents vs hybrids	1	0.37 **	17.19 **	17997079.70 **	115.22 **	2654.34 **	0.31 **	12898.97 **
Genotype × environments	128	0.35 **	0.05	21547.03 **	12.03 **	10.29 **	0.001 **	22.08 **
Parents × environments	28	0.16 **	0.06	16171.96	8.74 **	4.93 **	0.002 **	18.13 **
Lines × environments	8	0.06	0.03	17955.78	6.45	2.55 *	0.001	6.79
Testers × environments	18	0.21 **	0.08	15973.64	10.39 **	6.29 **	0.003 **	23.89 **
Hybrids × environments	98	0.41 **	0.04	20083.33 **	12.89 **	11.68 **	0.001 **	18.79 **
Error	384	0.03	0.08	12297.91	4.04	1.15	0.001	7.51

*, **, significant at 5 % and 1 % level of probability, respectively. + d.f. indicates Degree of Freedom



Table 3: Mean performance of parents and hybrids for various characters in Chilli (Pooled over environments)

Genotypes	Days to flower initiation	Plant height (cm)	No. of pri. branches / plant	No. of sec. branches / plant	Plant width (cm)	No. of fruits /plant	Av. fruit length (cm)	Av. fruit girth (cm)
Lines								
ACMS 2	42.33	87.13	2.38	6.29	67.95	91.94	9.82	3.58
ACMS 4	52.89	62.89	2.47	5.02	57.41	117.88	9.84	3.17
ACMS 5	43.78	82.65	2.90	4.49	56.1	118.18	7.76	3.94
ACMS 6	40.89	70.92	1.91	4.89	52.81	101.88	11.72	3.18
ACMS 8	45.00	59.56	2.52	5.43	67.81	128.36	9.97	4.36
Testers								
GVC 101	38.89	51.38	1.93	5.44	52.11	96.17	9.84	3.38
GVC 111	46.00	57.49	1.91	5.83	54.61	113.38	11.47	3.27
ACS -2001 - 01	43.78	73.78	2.41	5.38	53.18	124.20	8.06	4.21
ACS -2001 - 02	46.89	57.73	1.81	6.29	41.76	142.71	8.81	4.91
ACS -2001 - 04	45.22	49.29	2.30	4.79	37.56	152.02	7.96	2.80
ACS -2004 - 02	44.78	50.85	2.01	5.73	70.85	114.24	10.58	3.42
ACS -2004 - 03	38.33	61.47	2.24	5.41	50.90	146.67	9.30	3.95
ACS -2004 - 05	37.22	62.78	2.49	6.29	41.52	158.98	8.59	4.04
IPS -2005 -15	48.78	62.77	1.81	3.95	51.11	166.56	7.82	4.98
RHRC Pendent	47.00	46.43	2.69	6.23	50.10	482.26	6.92	3.11
Hybrids								
ACMS 2 x GVC 101	33.33	82.71	2.63	6.34	74.41	128.08	8.38	3.59
ACMS 2 x GVC 111	39.44	85.85	2.65	6.42	60.74	144.46	10.75	3.37
ACMS 2 x ACS -2001 - 01	42.78	91.40	2.91	6.500	60.64	133.95	8.67	3.09
ACMS 2 x ACS -2001 - 02	47.22	64.90	1.64	4.99	44.77	162.8	9.50	4.22
ACMS 2 x ACS -2001 - 04	46.44	99.07	2.36	5.74	52.92	196.38	8.80	3.27
ACMS 2 x ACS -2004 - 02	38.00	73.33	2.26	6.39	55.78	141.07	10.09	4.06
ACMS 2 x ACS -2004 - 03	36.33	91.77	2.68	5.54	46.46	191.25	9.12	4.4
ACMS 2 x ACS -2004 - 05	33.89	91.02	2.61	6.37	33.15	206.47	9.12	3.53
ACMS 2 x IPS - 2005 - 15	39.33	101.66	2.73	6.18	71.64	203.29	11.02	3.87
ACMS 2 x RHRC Pendent	41.89	84.24	2.72	5.23	47.41	272.62	8.77	3.89
ACMS 4 x GVC 101	41.89	80.13	2.43	5.91	46.32	190.36	10.38	3.33
ACMS 4 x GVC 111	42.11	68.40	2.56	6.42	49.46	272.11	10.07	3.37
ACMS 4 x ACS -2001 - 01	43.89	84.13	2.06	6.09	48.2	182.00	9.00	3.86
ACMS 4 x ACS -2001 - 02	45.11	82.91	3.02	6.62	62.61	205.31	8.96	4.19
ACMS 4 x ACS -2001 - 04	42.78	94.93	2.6	6.41	36.02	248.79	9.91	3.07
ACMS 4 x ACS -2004 - 02	43.11	77.91	3.02	6.27	67.74	190.88	8.39	4.31
ACMS 4 x ACS -2004 - 03	40.11	74.08	3.01	5.47	61.57	287.79	11.66	2.89
ACMS 4 x ACS -2004 - 05	35.33	85.01	1.77	5.28	51.91	299.82	9.17	3.33
ACMS 4 x IPS - 2005 - 15	46.67	92.91	2.81	6.40	54.29	393.38	7.90	3.77
ACMS 4 x RHRC Pendent	42.78	83.38	2.51	6.04	61.85	309.78	6.78	3.20
ACMS 5 x GVC 101	38.11	73.12	1.78	4.68	64.99	199.01	8.74	2.87
ACMS 5 x GVC 111	41.56	78.57	3.19	6.48	64.09	292.8	9.77	3.16
ACMS 5 x ACS -2001 - 01	42.78	86.55	2.32	5.66	56.81	197.63	8.65	4.11
ACMS 5 x ACS -2001 - 02	40.44	68.65	2.98	5.67	58.37	221.48	9.25	4.61
ACMS 5 x ACS -2001 - 04	45.44	79.80	2.44	6.13	50.32	287.76	9.35	3.91
ACMS 5 x ACS -2004 - 02	39.00	68.34	2.45	5.64	72.04	235.93	9.13	3.54
ACMS 5 x ACS -2004 - 03	34.00	95.90	3.00	6.78	50.66	306.92	10.3	3.89
ACMS 5 x ACS -2004 - 05	41.56	71.55	3.11	6.61	47.55	331.68	7.92	3.94
ACMS 5 x IPS - 2005 - 15	34.33	81.64	2.66	6.09	71.72	419.95	7.66	3.77
ACMS 5 x RHRC Pendent	40.89	70.21	1.77	5.26	61.80	342.06	8.37	3.54
ACMS 6 x GVC 101	35.44	81.72	2.95	6.38	51.42	210.40	10.39	3.53
ACMS 6 x GVC 111	36.78	83.28	2.69	6.62	34.27	293.07	8.11	3.46
ACMS 6 x ACS -2001 - 01	39.56	76.85	1.73	6.29	42.80	218.90	9.40	4.33
ACMS 6 x ACS -2001 - 02	40.00	72.55	1.73	5.70	38.42	231.98	9.66	2.39
ACMS 6 x ACS -2001 - 04	35.22	86.73	2.48	5.63	34.91	273.49	9.01	3.04
ACMS 6 x ACS -2004 - 02	39.89	81.04	2.23	5.94	68.69	233.95	10.59	3.31



Table 3 contd..

Genotypes	Days to flower initiation	Plant height (cm)	No. of pri. branches / plant	No. of sec. branches / plant	Plant width (cm)	No. of fruits /plant	Av. fruit length (cm)	Av. fruit girth (cm)
ACMS 6 x ACS -2004 - 03	38.89	78.96	2.55	5.83	62.02	328.09	9.9	3.64
ACMS 6 x ACS -2004 - 05	38.00	82.69	2.18	5.90	38.75	370.26	8.86	3.72
ACMS 6 x IPS - 2005 - 15	34.67	94.09	2.52	5.51	62.32	419.10	8.66	4.26
ACMS 6 x RHRC Pendent	36.11	120.81	1.79	5.26	60.92	343.34	9.32	2.99
ACMS 8 x GVC 101	39.11	77.56	2.37	5.82	81.90	228.88	9.38	3.51
ACMS 8 x GVC 111	35.56	69.14	1.53	5.08	67.54	347.37	10.49	3.69
ACMS 8 x ACS -2001 - 01	43.56	68.77	2.44	5.68	61.32	245.03	12.12	4.49
ACMS 8 x ACS -2001 - 02	44.00	90.36	1.79	5.22	40.87	266.86	9.50	4.44
ACMS 8 x ACS -2001 - 04	43.33	79.94	2.73	6.21	54.90	313.35	8.79	3.34
ACMS 8 x ACS -2004 - 02	42.44	94.38	3.05	6.58	54.57	288.18	9.31	3.74
ACMS 8 x ACS -2004 - 03	38.11	62.10	2.57	6.48	56.36	346.66	9.89	2.79
ACMS 8 x ACS -2004 - 05	37.22	66.32	1.71	5.42	36.48	366.90	9.11	4.06
ACMS 8 x IPS - 2005 - 15	40.78	52.16	2.48	6.53	66.56	428.23	8.86	4.68
ACMS 8 x RHRC Pendent	45.22	77.96	3.20	6.70	60.63	373.18	7.63	3.94
Mean								
Parent mean	44.12	62.47	2.25	5.43	53.72	150.36	9.23	3.75
Line mean	44.98	72.63	2.44	5.22	60.42	111.65	9.82	3.65
Tester mean	43.69	57.40	2.16	5.53	50.37	169.72	8.94	3.81
Hybrid mean	40.09	81.23	2.47	5.97	55.24	266.46	9.29	3.67
General mean	41.02	76.90	2.42	5.84	54.89	239.67	9.28	3.69
S. Ed. ±	1.71	4.06	0.11	0.24	3.31	18.32	0.68	0.26
CV%	2.77	5.59	5.46	6.57	7.93	9.24	4.5	5.33

Table 3 Contd....

Genotypes	Fruit shape index	Av. fruit weight (g)	Green fruit yield / plant(g)	Moisture content (%)	Chlorophyll content (µg/100g)	Capsaicin content (µg/g)	Ascorbic acid content (µg/g)
Lines							
ACMS 2	2.75	5.28	486.80	75.25	19.31	1.26	124.92
ACMS 4	3.11	4.78	566.32	79.21	17.28	1.50	138.11
ACMS 5	1.97	4.33	512.93	83.89	16.8	1.21	124.31
ACMS 6	3.69	5.12	523.62	80.13	24.48	1.46	142.60
ACMS 8	2.29	5.70	732.8	83.62	22.78	1.46	163.40
Testers							
GVC 101	2.93	3.91	376.43	82.26	17.52	1.14	88.46
GVC 111	3.51	3.49	397.49	85.41	19.80	1.52	117.59
ACS -2001 - 01	1.92	4.53	566.18	77.18	18.97	1.19	145.25
ACS -2001 - 02	1.80	4.66	665.34	84.90	14.34	0.87	144.52
ACS -2001 - 04	2.88	5.26	799.29	76.28	16.98	1.09	166.17
ACS -2004 - 02	3.11	3.71	425.18	82.68	24.02	1.46	131.66
ACS -2004 - 03	2.37	3.69	544.5	84.02	24.09	1.62	112.85
ACS -2004 - 05	2.16	3.78	602.87	77.17	20.98	1.35	126.91
IPS -2005 -15	1.57	3.68	613.24	84.09	15.25	1.25	165.36
RHRC Pendent	2.24	3.31	1595.12	77.77	15.61	1.33	131.78
Hybrids							
ACMS 2 x GVC 101	2.34	3.76	482.84	82.59	17.33	1.37	132.87
ACMS 2 x GVC 111	3.20	4.25	617.61	84.51	25.12	1.28	144.75
ACMS 2 x ACS -2001 - 01	2.84	4.80	644.14	82.06	17.83	1.50	155.16
ACMS 2 x ACS -2001 - 02	2.25	4.62	753.66	80.89	27.61	1.26	144.56
ACMS 2 x ACS -2001 - 04	2.70	4.39	863.04	79.37	21.07	1.36	156.68
ACMS 2 x ACS -2004 - 02	2.50	3.60	509.6	82.70	29.97	1.22	137.90
ACMS 2 x ACS -2004 - 03	2.12	3.87	742.44	81.96	29.53	1.65	133.80
ACMS 2 x ACS -2004 - 05	2.59	5.23	1079.37	82.6	30.36	1.32	143.92



Table 3 contd...

Genotypes	Fruit shape index	Av. fruit weight (g)	Green fruit yield / plant(g)	Moisture content (%)	Chlorophyll content (µg/100g)	Capsaicin content (µg/g)	Ascorbic acid content (µg/g)
ACMS 2 x IPS - 2005 - 15	2.84	4.03	822.34	83.86	18.57	1.48	92.18
ACMS 2 x RHRC Pendent	2.27	4.01	1094.51	81.27	16.24	1.25	125.42
ACMS 4 x GVC 101	3.14	4.15	792.27	81.16	29.58	1.35	134.24
ACMS 4 x GVC 111	3.01	3.48	944.66	84.16	17.65	1.38	154.60
ACMS 4 x ACS -2001 - 01	2.36	3.86	704.92	77.3	29.09	1.58	165.07
ACMS 4 x ACS -2001 - 02	2.17	3.73	767.36	83.18	21.14	1.28	154.02
ACMS 4 x ACS -2001 - 04	3.27	4.75	1186.29	84.75	16.28	1.38	170.46
ACMS 4 x ACS -2004 - 02	2.01	4.19	800.38	85.4	26.36	1.35	136.32
ACMS 4 x ACS -2004 - 03	4.05	4.40	1272.31	74.39	29.48	1.22	136.05
ACMS 4 x ACS -2004 - 05	2.76	3.34	1001.23	79.27	22.64	1.62	140.16
ACMS 4 x IPS - 2005 - 15	2.13	4.09	1612.34	82.84	23.64	1.47	124.30
ACMS 4 x RHRC Pendent	2.12	3.31	1023.94	83.21	21.33	1.30	122.19
ACMS 5 x GVC 101	3.08	3.64	725.99	74.51	23.82	1.13	134.95
ACMS 5 x GVC 111	3.13	3.84	1128.28	81.36	22.24	1.26	143.06
ACMS 5 x ACS -2001 - 01	2.11	3.35	663.34	80.77	22.84	1.35	156.17
ACMS 5 x ACS -2001 - 02	2.02	4.83	1072.41	84.1	20.69	1.08	149.88
ACMS 5 x ACS -2001 - 04	2.38	4.02	1159.36	81.72	18.66	1.29	154.39
ACMS 5 x ACS -2004 - 02	2.59	4.07	963.16	83.43	21.89	1.67	136.67
ACMS 5 x ACS -2004 - 03	2.67	3.79	1167.51	79.54	22.85	1.38	138.64
ACMS 5 x ACS -2004 - 05	2.03	3.64	1209.29	83.48	27.43	1.35	137.76
ACMS 5 x IPS - 2005 - 15	2.08	3.87	1630.44	80.94	23.15	1.66	90.76
ACMS 5 x RHRC Pendent	2.39	2.96	1015.66	81.83	21.38	1.35	126.03
ACMS 6 x GVC 101	2.94	2.5	525.44	80.66	29.31	1.04	143.19
ACMS 6 x GVC 111	2.35	4.36	1276.57	80.4	28.62	1.35	171.84
ACMS 6 x ACS -2001 - 01	2.19	5.19	1139.03	80.97	19.75	1.39	173.19
ACMS 6 x ACS -2001 - 02	4.23	2.69	623.05	79.41	27.32	1.13	175.10
ACMS 6 x ACS -2001 - 04	2.98	4.29	1179.67	82.01	25.72	1.6	187.05
ACMS 6 x ACS -2004 - 02	3.23	4.55	1067.49	85.19	29.31	1.33	134.75
ACMS 6 x ACS -2004 - 03	2.72	4.39	1443.01	85.73	32.01	1.27	144.57
ACMS 6 x ACS -2004 - 05	2.4	2.59	961.15	83.3	19.44	1.35	144.19
ACMS 6 x IPS - 2005 - 15	2.04	3.65	1533.86	80.33	22.11	1.21	166.07
ACMS 6 x RHRC Pendent	3.12	3.23	1113.37	82.61	28.82	1.34	119.35
ACMS 8 x GVC 101	2.68	4.6	1059.85	85.24	30.13	1.69	172.71
ACMS 8 x GVC 111	2.86	2.83	986.86	83.98	31.94	1.37	165.60
ACMS 8 x ACS -2001 - 01	2.71	3.56	876.6	84.29	21.79	1.36	157.41
ACMS 8 x ACS -2001 - 02	2.14	2.83	758.55	79.1	29.45	1.35	147.78
ACMS 8 x ACS -2001 - 04	2.63	4.76	1496.2	81.32	20.16	1.46	159.39
ACMS 8 x ACS -2004 - 02	2.48	4.52	1304.4	80.56	19.15	1.25	124.13
ACMS 8 x ACS -2004 - 03	3.60	4.54	1580.00	83.94	27.97	1.67	131.69
ACMS 8 x ACS -2004 - 05	2.26	2.92	1072.77	83.86	21.97	1.34	165.52
ACMS 8 x IPS - 2005 - 15	1.89	5.09	2180.44	82.89	25.03	1.40	180.45
ACMS 8 x RHRC Pendent	1.97	4.14	1546.32	83.95	27.76	1.43	166.56
Mean							
Parent mean	2.55	4.35	627.21	80.92	19.21	1.31	134.93
Line mean	2.76	5.04	564.49	80.42	20.13	1.38	138.67
Tester mean	2.45	4.00	658.56	81.18	18.76	1.28	133.06
Hybrid mean	2.61	3.94	1043.51	81.98	24.27	1.37	146.07
General mean	2.6	4.04	947.44	81.73	23.1	1.36	143.50
S. Ed. ±	0.28	0.13	89.08	1.63	1.51	0.02	2.21
CV%	7.14	7.08	11.62	2.46	4.63	1.93	1.91



Table 4: Range of heterosis, number of superior hybrids over environments and significant hybrids in desired direction with three best heterotic hybrids over BP and SH for 15 characters in Chilli.

Character Studied	Heterosis over	Range of heterosis (%)		Best heterotic hybrids	No. of hybrids in desirable direction
Days to flower initiation	HB*	-21.57	11.64	ACMS 5 × IPS - 2005 - 15	29
	SH	-14.29	21.43	ACMS 2 × GVC 101	13
Plant height (cm)	HB	-25.52	70.36	ACMS 6×RHRC Pendent	29
	SH	-9.27	110.16	ACMS 6 × RHRC Pendent	49
Number of primary branches per plant	HB	-39.06	53.11	ACMS 6 × GVC 101	21
	SH	-20.36	66.21	ACMS 8 × RHRC Pendent	40
Number of secondary branches per plant	HB	-27.37	35.59	ACMS 5×IPS - 2005 - 15	23
	SH	-19.81	23.21	ACMS 8 × ACS -2004 - 02	22
Plant width (cm)	HB	-51.21	27.84	ACMS 5 × IPS - 2005 - 15	11
	SH	-39.29	49.97	ACMS 8 × GVC 101	23
No. fruits per plant	HB	-43.47	170.62	ACMS 8 ×GVC 111	43
	SH	12.97	277.69	ACMS 8 ×IPS - 2005 - 15	48
Average fruit length (cm)	HB	-31.06	21.53	ACMS 8 × ACS -2001 – 01	9
	SH	-40.86	5.67	ACMS 8 × ACS -2001 – 01	1
Average fruit girth (cm)	HB	-51.38	26.28	ACMS 4 ×ACS -2004 – 02	5
	SH	-29.34	38.42	ACMS 8 × IPS - 2005 – 15	27
Fruit shape index	HB	-44.54	51.71	ACMS 8 ×ACS -2004 – 03	5
	SH	-46.01	20.65	ACMS 6 × ACS -2001 – 02	2
Average fruit weight (g)	HB	-51.19	3.60	ACMS 5 ×ACS -2001 – 02	0
	SH	-36.04	33.93	ACMS 2 × ACS -2004 – 05	19
Green fruit yield per plant (g)	HB	-36.33	197.55	ACMS 8 × IPS - 2005 – 15	32
	SH	21.47	448.55	ACMS 8 × IPS - 2005 – 15	48
Moisture content (%)	HB	-11.46	7.03	ACMS 2 ×ACS -2004 – 05	10
	SH	-12.90	0.37	ACMS 6 ×ACS -2004 – 03	0
Chlorophyll content (µg/g)	HB	-20.60	68.81	ACMS 4 × GVC 101	35
	SH	-17.98	61.69	ACMS 6 × ACS -2004 – 03	38
Capsaicin content (µg/g)	HB	-28.58	32.48	ACMS 5 × IPS - 2005 – 15	14
	SH	-31.66	10.94	ACMS 8 × GVC 101	8
Ascorbic acid content (µg/g)	HB	-45.11	21.1	ACMS 6 × ACS -2001 – 02	34
	SH	-22.82	59.07	ACMS 6 × ACS -2001 – 04	47

* HB and SH indicates heterobeltiosis and Standard Heterosis, respectively

Table 5: Manifestation of heterobeltiosis (HB) and standard heterosis (SH) for other characters in five top ranking crosses for green fruit yield per plant in individual as well as pooled over the environments

Crosses	Characters									
	Green fruit yield per plant (g)	Green fruit yield (g)	Days to flower initiation	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant width (cm)	Number of fruits per plant	Average fruit length (cm)	
HB										
ACMS 8 × IPS - 2005 - 15	2180.44	197.55 **	-9.38 **	-16.90 **	-1.37	30.50 **	-1.84	157.10	-11.16 **	
ACMS 5 × IPS - 2005 - 15	1630.44	165.87 **	-21.57 **	-15.05 **	-8.24 **	35.59 **	27.84 **	152.13	-2.10	
ACMS 6 × ACS - 2004 - 03	1443.01	165.02 **	1.45	11.34 **	13.52 **	7.76 *	17.42 **	123.70 **	-15.50 **	
ACMS 4 × IPS - 2005 - 15	1612.34	162.92 **	-4.33 **	47.73 **	14.10 **	27.43 **	-5.45	136.18 **	-19.69 **	
ACMS 6 × IPS - 2005 - 15	1533.86	150.13 **	-15.22 **	32.67 **	31.88 **	12.80 **	17.99 **	151.62 **	-26.05 **	
SH										
ACMS 8 × IPS - 2005 - 15	2180.44	448.55 **	4.86 **	-9.27 *	28.89 **	21.73 **	21.88 **	277.69 **	-22.76 **	
ACMS 5 × IPS - 2005 - 15	1630.44	310.19 **	-11.71 **	42.02 **	38.06 **	4.34	31.34 **	270.39 **	-33.24 **	
ACMS 4 × IPS - 2005 - 15	1612.34	305.63 **	20.00 **	61.62 **	46.08	9.71 **	-0.59	246.96 **	-31.11 **	
ACMS 8 × ACS - 2004 - 03	1580.00	297.50 **	-2.00	8.02 *	33.45 **	14.88 **	3.20	205.75 **	-13.73 **	
ACMS 8 × RHRC Pendent	1546.32	289.02 **	16.29 **	35.62 **	66.21 **	20.83 **	11.02 **	229.14 **	-33.44 **	
Characters										
Crosses	Characters									
	Green fruit yield per plant (g)	Green fruit yield (g)	Average fruit girth (cm)	Fruit shape index	Average fruit weight (g)	Moisture content (%)	Chlorophyll content (µg/g)	Capsaicin content (µg/g)	Ascorbic acid content (µg/g)	
HB										
ACMS 8 × IPS - 2005 - 15	2180.44	197.55 **	-6.13 **	-17.31 **	-10.67 **	-1.42	9.90 **	-3.96 **	9.13 **	
ACMS 5 × IPS - 2005 - 15	1630.44	165.87 **	-24.25 **	5.53	-10.45 **	-375 **	37.75 **	32.48 **	-45.11 **	
ACMS 6 × ACS - 2004 - 03	1443.01	165.02 **	-7.76 **	-26.22 **	-14.17 **	2.03	30.73 **	-21.72 **	1.38	
ACMS 4 × IPS - 2005 - 15	1612.34	162.92 **	-24.38 **	-31.45 **	-14.47 **	-1.49	36.80 **	-2.00 *	-24.83 **	
ACMS 6 × IPS - 2005 - 15	1533.86	150.13 **	-14.52 **	-44.54 **	-28.75 **	-4.48 **	-9.69 **	-16.84 **	0.43	
SH										
ACMS 8 × IPS - 2005 - 15	2180.44	448.55 **	38.42 **	-46.01 **	30.23 **	-2.95 **	26.46 **	-8.10 **	53.46 **	
ACMS 5 × IPS - 2005 - 15	1630.44	310.19 **	11.71 **	-40.75 **	-0.85	-5.24 **	16.94 **	8.90 **	-22.82 **	
ACMS 4 × IPS - 2005 - 15	1612.34	305.63 **	11.51 **	-39.27 **	4.58	-3.02 **	19.40 **	-3.65 **	5.71 **	
ACMS 8 × ACS - 2004 - 03	1580.00	297.50 **	-17.30 **	2.47	16.18 **	-1.73	41.30 **	9.70 **	11.99 **	
ACMS 8 × RHRC Pendent	1546.32	289.02 **	16.64 **	-43.92 **	5.89	-1.71	40.22 **	-6.35 **	41.64 **	

**, * , significant at 5 % and 1 % level of probability, respectively