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Original Research Paper

Heterosis and heterobeltiosis in bell pepper (*Capsicum annuum* var. *grossum*) for growth and yield parameters

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ABSTRACT

The magnitude of heterosis over commercial check and better parent was estimated to identify best crosses for growth and yield traits in bell pepper. Experimental material included 21 F_1 hybrids developed by crossing seven diverse parents in half diallel mating design. The findings revealed that Arka Mohini X CW308 showed best heterotic cross combinations, recorded significantly higher heterosis and high *per se* value over commercial check with respect to number of primary branches, number of secondary branches, plant height, days to 50% flowering, days to first harvest, fruit length, fruit width, number of lobes per fruit, number of fruits per plant and average fruit weight. The cross Arka Mohini X CW308 also showed high heterobeltiosis for traits like fruit length, number of fruits per plant, average fruit weight and average yield per plant. Hence, this hybrid with high *per se* value and heterosis can be utilized to obtain desirable segregates for development of superior genotype for improvement of horticultural traits in bell pepper.

Keywords: Bell pepper, diallel, growth, heterosis, yield

INTRODUCTION

Heterosis breeding is known for increasing the productivity and quality of crop in the shortest possible time. The popularity of F_1 hybrids is mainly due to their uniformity, vigour, disease resistance, stress tolerance and good horticultural traits which in turn gives a stable yield (Khalil et al., 2014). *Capsicum*, being a highly polymorphic genus, both inter and intra-specific, bell pepper (*Capsicum annuum* var. *grossum*) is amenable for exploitation of heterosis. In India, bell pepper is grown in an area of 38,000 ha with the production of 563,000 MT (Anonymous, 2022). The main reason for their high price is due to non-availability of public institute bred hybrids in India. Hybrids ruling in Indian market are mainly imported from European and middle Eastern countries which increases the input cost for the farmers. Hence, there is an urgent need to strengthen the crop improvement programme in bell pepper in India for developing public institute bred varieties or hybrids capable of satisfying the needs of farmers as well as consumers.

Information on magnitude of heterosis in different cross combination is a basic requisite for identifying the crosses that exhibit high amount of exploitable heterosis (Sharma et al., 2013). There are different ways of estimation of heterosis. Heterobeltiosis is superiority of F_1 over the better parent; superiority of F_1 over the mean of two parents is mid parent heterosis; and superiority of F_1 over the mean of standard check is standard/ commercial heterosis. Superiority of F_1 over mid parent is non-practical for breeders since it does not provide any economic advantage. Therefore, the present study was carried out to estimate the magnitude of commercial heterosis and heterobeltiosis to identify the best cross combination for developing superior hybrids.

MATERIALS AND METHODS

The study was conducted at Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Hesaraghatta lake post, Bengaluru during 2019-2020. The geographical location of the experimental farm is having a latitude of 13' 7′ N and 77 ' 29′ E. Seven diverse bell pepper genotypes *viz*., Arka Mohini (AM), Arka Gaurav (AG), Arka Basant (AB), Yolo Wonder (YW), California Wonder (CW), UHFBP-4 and CW-308 were crossed in half diallel design to obtain twenty-one F_1 hybrids. Hybrids along with parents and commercial check Indra were

evaluated for growth and yield traits along with their parents in open field in randomized complete block design (RCBD) with three replications at a spacing of 60 x 30 cm during October, 2019 to March, 2020. The standard cultural practices were followed. Observations were recorded for growth and yield related traits *viz*., number of primary branches (NPB), number of secondary branches (NSB), plant height (cm) (PH), days to 50% flowering (DFF), days to first harvest (DFH), fruit length (cm) (FL), fruit width (cm) (FW), number of lobes per fruit (NLP), pericarp thickness (cm) (PT), average fruit weight (g) (AFW), number of fruits per plant (NFP), total yield per plant (g) (YP). Indostat software was used for statistical analysis.

Increase or decrease in performance of the F_1 hybrid was measured as the proportion of deviation of F_1 from better parent and standard check using following formulae.

$$\text{Heterobeltiosis} : \frac{F1\text{-}BP}{BP} \times 100$$

$$\text{Standard heterosis} : \frac{F1\text{-}C}{C} \times 100$$

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) revealed that mean sum of squares due to treatments (including parents and hybrids) were highly significant (p=0.05) for all the traits means the hybrids and the parents have an inherent genetic variability which could be useful to make selection and genetic advancement. However, MSS due to parents vs hybrids were significant (p=0.05) for all the traits except fruit width and days to 50% flowering (Table 1) indicating similar performance of parents and hybrids for traits like fruit width and days to 50% flowering and chances of exploitation of heterosis is meagre.

Hence, heterosis for all other traits were estimated. The range of mean performance of parents, range of heterosis percentage of F_1 hybrids, number of heterotic crosses and two superior crosses with their heterosis over better parent and commercial check in all characters are presented in Table 3, 4 and 5a&b, respectively. Sufficiently high magnitude of standard heterosis and heterobeltiosis in desired direction were observed for all the growth and yield related traits indicating possible commercial exploitation of heterosis. Heterosis over the better parent and commercial check of the hybrids are summarized in Table 2a & b.

Table 1 : Analysis of variance (mean sum of squares) in half diallel analysis for various characters in bell pepper

Character	Treatment	Parents vs Hybrids	Error
df	27	1	54
Growth traits			
Plant height	75.5*	78.1*	15.09
Number of primary branches	0.15*	0.85*	0.08
Number of secondary branches	0.72*	5.73*	0.086
Fruit width	0.26*	3.08^{NS}	0.104
Fruit length	4.97*	23.30*	0.88
Number of lobes/fruit	0.16*	0.82*	0.08
Pericarp thickness	0.02*	0.11*	0.002
Days to 50% flowering	96.86*	47.15^{NS}	24.55
Days to first harvest	123.59*	785.81*	18.41
Yield traits			
Number of fruits per plant	3.99*	30.46*	0.17
Average fruit weight	418.82*	2516.88*	8.78
Total yield per plant	86207.41*	948017.06*	131.65

* indicated significance of values at p= 0.05; NS: non-significant

Plant growth characters indirectly influence yielding ability of the plant. For instance, in open field cultivation of bell pepper, more the number of primary branches, number of secondary branches and plant height indicates more number of flowers and fruits leading to more yield. In this study, number of primary branches ranged from 2.90 to 3.47 in parents, whereas, in crosses, it ranged from 3 to 3.77, and crosses YW×CW (17.8) and AM×YW (16.49) showed highest heterobeltiosis and AM×YW (20.21) and AM×UHFBP4 (20.21) showed highest standard heterosis (Table 3). Similarly, number of secondary branches ranged from 5.5 to 6.63 in parents and 6.13 to 7.47 in crosses. Crosses AM×UHFBP4 (16.58) and AG×CW (13.37) showed highest heterobeltiosis and AM×UHFBP4 (20.83) and AM×YW (16.67) showed highest heterosis. Plant height is another important growth trait determining yield potential along with other growth parameters. In the present study, range of heterobeltiosis was from -17.17 to 19.72 and the top performing hybrids which recorded highest heterobeltiosis were CW X UHFBP4 (19.72) and AG X AB (12.40). Similarly range of standard heterosis was -11.29 to 26.56 and top performing hybrids were CW X UHFBP4 (19.72) and AG X AB (20.39) for plant height. The obtained results are in agreement with the studies by Praveen et al. (2017)

Table 2a : Better parent and commercial heterosis of growth and yield traits

Crosses	Number of primary branches		Number of secondary branches		Plant height		Days to first harvest		Fruit length	
	BP	CC	BP	CC	BP	CC	BP	CC	BP	CC
AM X AG	3.09**	6.38**	6.53**	10.42**	-8.51**	-9.36**	-17.86 **	-9.80 **	5.49**	6.36**
AM X AB	11.34**	14.89**	9.05**	13.02 **	-17.17 **	-11.29**	-6.25	2.94	3.62**	4.05**
AM X YW	16.49 **	20.21 **	12.56* *	16.67 **	-7.58*	-9.30**	-12.80 **	-4.25	0.32	4.38**
AM X CW	-4.12**	-1.06**	-6.53**	-3.13**	-9.52**	-5.31	-9.82 **	-0.98	3.65**	-1.32
AM X UHFBP4	8.65**	20.21 **	16.58 **	20.83 **	-15.64 **	-10.82**	-14.58 **	-6.21	9.81**	4.55**
AM X CW308	8.25**	11.70**	-2.01**	1.56**	11.99**	16.60 **	-17.56 **	-9.48 **	11.98**	6.61**
AG X AB	5.15**	8.51**	-2.54**	0.00	12.40 **	20.39 **	-11.32 **	-7.84 *	7.87**	8.76**
AG X YW	8.25**	11.70**	-2.11**	-3.12**	-2.95	-3.85	-17.58 **	-11.11 **	8.78**	13.18**
AG X CW	0.00	3.19**	13.37 **	10.42**	10.79**	15.94 **	-6.9	-11.76 **	-5.45**	-4.67**
AG X UHFBP4	0.96**	11.70**	-6.67**	-5.21**	4.21	10.16**	-8.39 *	-10.78 **	3.93**	4.79**
AG X CW308	7.22**	10.64**	1.53**	3.65**	4.40	8.70**	-8.01 *	-6.21	2.70**	3.55**
AB X YW	14.13**	11.70**	7.61**	10.42**	5.08	12.55**	-9.70 **	-2.61	-1.03	2.98**
AB X CW	10.87**	8.51**	-3.55**	-1.04**	11.72**	19.65 **	1.26	5.23	27.57 **	28.10 **
AB X UHFBP4	-2.88**	7.45**	-0.51	2.08**	0.93	8.10*	-1.89	1.96	1.52*	1.94*
AB X CW308	-5.15**	-2.13**	-7.11**	-4.69**	1.30	8.50**	-14.15 **	-10.78 **	51.23 **	51.86 **
YW X CW	17.78 **	12.77**	11.05**	9.90**	1.52	6.24	-11.82 **	-4.9	-5.96**	-2.15**
YW X UHFBP4	-6.73**	3.19**	5.13**	6.77**	0.25	5.98	-7.58 *	-0.33	43.96 **	49.79 **
YW X CW308	-7.22**	-4.26**	-4.08**	-2.08**	3.44	7.70*	-14.24 **	-7.52 *	-7.07**	-3.31**
CW X UHFBP4	-3.85**	6.38**	11.79 **	13.54 **	19.72 **	26.56 **	-9.40 **	-11.76 **	5.10**	-11.40**
CW X CW308	-1.03**	2.13**	1.02**	3.12**	-3.68	0.80	-10.90 **	-9.15 *	13.51**	2.07**
UHFBP4 X CW308	0.00	10.64**	-6.12**	-4.17**	0.75	6.51*	-11.22 **	-9.48 **	34.65 **	21.07 **
SEm±	0.16	0.16	0.24	0.24	2.20	2.20	2.44	2.44	0.53	0.53
CD @ 5%	0.46	0.46	0.70	0.70	6.25	6.25	6.90	6.90	1.51	1.51
CD@ 1%	0.61	0.61	0.93	0.93	8.32	8.32	9.18	9.18	2.02	2.02

*and**: significant at p= 0.05, p= 0.01, respectively
BP: heterosis per cent over better parent; CC: heterosis over commercial check (Indra)
AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder

Table 2b : Better parent and commercial heterosis of growth and yield traits

Crosses	Number of lopes per fruit		Pericarp thickness		Number of fruits per plant		Average fruit weight		Total yield per plant	
	BP	CC	BP	CC	BP	CC	BP	CC	BP	CC
AM X AG	5.88**	14.89**	46.72**	14.29**	8.18**	-0.83*	5.51*	5.51*	14.83 *	-2.3
AM X AB	0.00	6.38**	-12.79**	-11.90**	25.61 **	28.75 **	14.71 **	14.71 **	58.31 **	34.69 **
AM x YW	1.00**	7.45**	33.05**	8.16**	12.70 **	14.58 **	17.56 **	17.56 **	47.69 **	25.65 **
AM X CW	-1.92**	8.51**	5.24**	-18.03**	1.35**	-6.25**	0.54	0.54	1.23	-13.87
AM X UHFBP4	9.00**	15.96**	24.48**	2.04**	26.84 **	22.08 **	12.22 **	12.22 **	50.93 **	28.41 **
AM X CW308	2.00**	8.51**	4.53**	-13.61**	34.09 **	22.92 **	17.94 **	17.94 **	61.58 **	37.47 **
AG X AB	0.98**	9.57**	10.44**	11.56**	3.25**	5.83**	-15.24 **	-23.99 **	-15.22	-29.92 **
AG X YW	13.73**	23.40**	8.79**	-11.56**	-0.41	1.25**	9.76 **	4.85*	11.53	-6.05
AG X CW	4.81**	15.96**	51.54**	17.01**	14.41 **	5.83**	5.64*	-5.26*	43.96 **	19.00 *
AG X UHFBP4	15.69**	25.53**	6.64**	-12.59**	7.79**	3.75**	23.74 **	10.98 **	46.91 **	21.44 *
AG X CW308	0.98**	9.57**	36.63**	12.93**	21.76 **	9.58 **	-5.77*	-15.49 **	32.71 **	9.71
AB X YW	-4.26**	-4.26**	13.80**	14.97**	0	2.5**	-10.88 **	-14.87 **	-1.96	-17.41
AB X CW	-5.77**	4.26**	-30.64**	-29.93**	28.05 **	31.25 **	21.48 **	-6.30 *	46.43 **	20.81 *
AB X UHFBP4	15.96**	15.96**	-36.36**	-35.17**	3.66**	6.25**	19.33 **	-7.95 **	25.59 **	-12.82
AB X CW308	-4.00**	2.13**	17.17**	18.37**	40.24 **	43.75 **	45.23 **	18.64 **	97.35 **	37.00 **
YW X CW	6.73**	18.09**	28.87**	4.76**	29.51 **	31.67 **	22.98 **	17.48 **	63.07 **	37.37 **
YW X UHFBP4	15.22**	12.77**	39.42**	14.29**	-4.1**	-2.5**	-18.30 **	-21.96 **	42.32 **	19.89 *
YW X CW308	-2.00**	4.26**	23.87**	2.38**	2.87**	4.58**	14.44 **	9.32 **	15.47 **	-2.73
CW X UHFBP4	-2.88**	7.45**	8.30**	-11.22**	17.32 **	12.92 **	38.23 **	6.34 **	51.42 **	24.93 **
CW X CW308	4.81**	5.96**	7.41**	-11.22**	8.11**	0	23.12 **	0.58	36.38 **	12.52
UHFBP4 X CW308	7.00**	13.83**	33.33**	10.20**	2.16**	-1.67**	-1.17	-19.26 **	31.00 **	-9.80
SEm±	0.16	0.16	0.02	0.02	0.23	0.23	1.68	1.68	6.52	6.52
CD @ 5%	0.45	0.45	0.06	0.06	0.66	0.66	4.77	4.77	18.49	18.49
CD @ 1%	0.60	0.60	0.08	0.08	0.88	0.88	6.34	6.34	24.62	24.62

*and**: Significance at p= 0.05, p= 0.01respectively

BP: Heterosis percent over better parent. CC: heterosis over commercial check (Indra). AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder

Table 3 : Mean performance of parents

Parent	NPB	NSB	PH (cm)	DFF	DFH	FL (cm)	FW (cm)	NLF	PT (cm)	NFP	AFW (g)	YP (g)
AM	3.23	6.63	46.00	87.00	112.00	7.68	5.33	3.33	0.38	7.33	80.47	612.97
AG	3.23	6.23	49.73	73.00	96.67	8.13	5.46	3.40	0.33	6.60	72.17	595.57
AB	3.07	6.57	53.77	71.67	106.00	8.10	4.96	3.13	0.49	8.20	62.07	500.13
YW	2.90	6.33	49.27	77.00	110.00	8.39	5.20	3.06	0.39	8.13	76.87	606.90
CW	3.00	5.50	52.53	72.33	93.00	6.80	5.33	3.46	0.37	7.40	61.37	594.40
UHFBP4	3.47	6.50	53.07	75.00	99.33	6.73	5.13	3.06	0.40	7.70	61.90	481.77
CW308	3.23	6.53	52.27	72.33	104.00	7.25	5.56	3.33	0.40	7.20	65.73	496.07
Range	2.90-3.47	5.5-6.63	46-53.77	71.67-87	93-112	6.8-8.39	4.96-5.56	3.06-3.46	0.33-0.4	6.6-8.2	61.37-80.47	481.77-612.97
CD @ 5%	0.46	0.71	6.25	7.96	6.90	1.51	0.52	0.45	0.06	0.66	4.77	18.49

AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder
NPB-number of primary branches, NSB-number of secondary branches, PH- plant height, DFF-days to 50% flowering, DFH-days to first harvest, FL-fruit length, FW-fruit weight, NLF- number of lobes per fruit, PT-pericarp thickness, NFP-fruits/plant, AFW-average fruit weight, YP-total yield per plant

Table 4 : Mean performance of crosses

Crosses	NPB	NSB	PH (cm)	DFF	DFH	FL (cm)	FW (cm)	NLF	PT (cm)	NFP	AFW (g)	YP (g)
AM x AG	3.33	7.07	45.50	69.00	92.00	8.58	5.88	3.60	0.56	7.93	84.90	703.87
AM x AB	3.60	7.23	44.53	87.00	105.00	8.39	5.57	3.33	0.43	10.30	92.30	970.37
AM x YW	3.77	7.47	45.53	69.33	97.67	8.42	5.71	3.36	0.53	9.17	94.60	905.27
AM x CW	3.10	6.20	47.53	81.00	101.00	7.96	5.62	3.40	0.40	7.50	80.90	620.53
AM x UHFBP4	3.77	7.73	44.77	75.00	95.67	8.43	5.67	3.63	0.50	9.77	90.30	925.17
AM x CW308	3.50	6.50	58.53	70.00	92.33	8.60	6.28	3.40	0.42	9.83	94.90	990.43
AG x AB	3.40	6.40	60.43	70.67	94.00	8.77	5.95	3.43	0.54	8.47	61.17	504.93
AG x YW	3.50	6.20	48.27	69.00	90.67	9.13	5.64	3.86	0.43	8.10	84.37	676.90
AG x CW	3.23	7.07	58.20	75.00	90.00	7.69	5.66	3.63	0.57	8.47	76.23	857.36
AG x UHFBP4	3.50	6.07	55.30	69.00	91.00	8.45	5.67	3.93	0.42	8.30	89.30	874.97
AG x CW308	3.47	6.63	54.57	72.33	95.67	8.35	6.10	3.43	0.55	8.77	68.00	790.40
AB x YW	3.50	7.07	56.50	72.67	99.33	8.30	5.45	3.00	0.56	8.20	68.50	595.00
AB x CW	3.40	6.33	60.07	84.33	107.33	10.33	5.51	3.26	0.34	10.50	75.40	870.36
AB x UHFBP4	3.37	6.53	54.27	85.67	104.00	8.22	5.20	3.63	0.31	8.50	74.07	628.10
AB x CW308	3.07	6.10	54.47	69.00	91.00	12.25	5.73	3.20	0.58	11.50	95.47	987.03
YW x CW	3.53	7.03	53.33	69.67	97.00	7.89	5.89	3.70	0.51	10.53	94.53	989.70
YW x UHFBP4	3.23	6.83	53.20	76.33	101.67	12.08	5.70	3.53	0.56	7.80	62.80	863.77
YW x CW308	3.00	6.27	54.07	72.33	94.33	7.80	5.91	3.26	0.50	8.37	87.97	700.80
CW x UHFBP4	3.33	7.27	63.53	70.00	90.00	7.14	5.48	3.36	0.43	9.03	85.57	900.07
CW x CW308	3.20	6.60	50.60	70.67	92.67	8.23	5.81	3.63	0.43	8.00	80.93	810.64
UHFBP4 x CW308	3.47	6.13	53.47	70.67	92.33	9.76	5.80	3.56	0.54	7.86	64.97	649.87
Range	3-3.77	6.13-7.47	44.53-63.53	69-87	90-107.33	7.14-10.33	5.2-5.91	3.2-3.93	0.4-0.58	7.8-11.5	68-94.9	504.93-990.43
CD @ 5%	0.46	0.71	6.25	7.96	6.90	1.51	0.52	0.45	0.06	0.66	4.77	18.49

AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder
NPB-number of primary branches, NSB-number of secondary branches, PH- plant height, DFF-days to 50% flowering, DFH-days to first harvest, FL-fruit length, FW-fruit weight, NLF-Number of lobes per fruit, PT-pericarp thickness, NFP-fruits/plant, AFW-average fruit weight, YP-total yield per plant

Table 5a : Range of heterosis with top two parents and hybrids

Range of heterosis % over	Number of primary branches	Number of secondary branches	Plant height	Days to 50% flowering	Days to first harvest	Fruit length
BP	-7.22-17.78	-7.11-16.58	-17.17-19.72	-20.69-16.59	-17.86-1.26	-7.07-51.23
CC	-4.26-20.21	-5.21-20.83	-11.29-26.56	-11.54-8.12	-11.76-5.23	-11.40-49.79
			No. of heterotic crosses over			
BP	5	11	12	6	16	16
CC	18	13	12	11	11	16
Top two parents with their mean values	UHFBP4 (3.47) AM, AG, CW308 (3.23)	AM (6.63) AB (6.57)	AB (53.77) UHFBP4 (53.07)	AB (71.67) CW308, CW (72.33)	CW (93) AG (96.67)	YW (8.39) AG (8.13)
Top two hybrids over BP	YW x CW AM x YW	AM x UHFBP4 AG x CW	CW x UHFBP4 AG x AB	AM x AG AM x YW	AM x AG AM x CW308	AB x CW308 YW x UHFBP4
Top two hybrids over CC	AM x YW AM x UHFBP4	AM x UHFBP4 AM x YW	CW x UHFBP4 AG x AB	AM x AG AG x YW AG x UHFBP4 AB x CW308 AM x YW	AG x CW CW x UHFBP4 AG x YW	AB x CW308 YW x UHFBP4

Table 5b : Range of heterosis with top two parents and hybrids

Range of heterosis % over	Fruit weight	Number of lobes per fruit	Pericarp thickness	Number of fruits per plant	Average fruit weight	Total yield per plant
BP	1.43-12.81	-4.26-15.69	-36.36-51.54	-4.1-40.24	-18.30-45.23	-15.22-97.35
CC	-0.36-14.18	-4.26-25.53	-35.17-18.37	-6.25-43.75	-23.99-18.64	-17.41-37.37
			No. of heterotic crosses over			
BP	21	15	18	18	15	17
CC	16	20	12	16	10	11
Top two parents with their mean values	CW308 (5.56) AG (5.46)	CW (3.46) AG (3.40)	AB (0.49) UHFBP4, CW308 (0.40)	AB (8.2) YW (8.13)	AM (80.47) AG (72.17)	AM (612.97) AB (595.57)
Top two hybrids over BP	AM x CW308 YW x CW	AB x UHFBP4 AG x UHFBP4	AG x CW AM x AG	AB x CW308 AM x CW308	AB x CW308 CW x UHFBP4	AB x CW308 AM x AB
Top two hybrids over CC	AM x CW308 AG x CW308	AG x UHFBP4 AM x YW	AB x CW308 AG x CW	AB x CW308 YW x CW	AB x CW308 AM x CW308	AM x CW308 YW x CW

AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder

and Aditika (2018) who have reported positive heterosis for this trait.

Earliness is indicated by negative heterosis which leads to early access to market fetching good price. For days to 50 per cent flowering, similar performance of parents and hybrids were recorded, however, with respect to days to first harvest, heterobeltiosis ranged from -17.86 to 1.26 and the hybrids recording earliest harvest were AM x AG (-17.86) and AM x CW308 (-17.56). Similarly range of heterosis over standard parent was -11.76 to 5.23 and hybrids, AG x CW (-11.76), CW x UHFBP4 (-11.76), AG x YW (-11.11) recorded highest negative heterosis. Sharma et al. (2013) and Hegde (2016) also reported similar magnitude of heterosis.

High yield is the most desirable character and major goal of all breeding programmes. This is a complex trait influenced by other traits like number of fruits per plant, fruit weight, fruit size, yield per plant etc. For fruit length, standard heterosis ranged from -7.07 to 51.23 and the hybrids with top performance were AB x CW308 (51.23) and YW x UHFBP4 (43.96). Similarly, heterobeltiosis ranged from -11.40 to 9.79 and hybrids AB x CW308 (51.86), YW x UHFBP4 (49.79) recorded maximum value. Similar performance of parents and hybrids for fruit width was observed. For number of lobes per fruit, heterobeltiosis ranged from -4.26 to 15.96 and the maximum was showed by AB x UHFBP4 (15.96) and AG x UHFBP4 (15.69). Similarly, range of heterosis over standard

check was -4.26 to 25.53 and the hybrids AG x UHFBP4 (25.53) and AG x YW (23.40) recorded maximum value.

More pericarp thickness contributes to higher fruit weight and also post-harvest quality of fruits. For this trait, heterobeltiosis ranged from -36.36 to 51.54, the hybrids AG x CW (51.54) and AM x AG (46.72) showed maximum heterobeltiosis, whereas, heterosis over standard check ranged from -35.17 to 18.37, the hybrids, AB x CW308 (18.37) and AG x CW (17.01) showed maximum for pericarp thickness. For number of fruits per plant, heterobeltiosis ranged from -4.1 to 40.24 and the hybrids with maximum heterosis were AB x CW308 (40.24) and AM x CW308 (34.09). Similarly, heterosis over standard check ranged from -6.25 to 43.75, AB x CW308 (43.75) and YW x CW (31.67) recorded maximum for pericarp thickness. The range of heterobeltiosis for average fruit weight was -18.30 to 45.23, the hybrids AB x CW308 (45.23) and CW x UHFBP4 (38.23) recorded maximum. Range of heterosis over standard check ranged from -23.99 to 18.64 and the hybrids which showed maximum were AB x CW308 (18.64) and AM x CW308 (17.94). For YP, heterobeltiosis ranged from -15.22 to 97.35 and the hybrids AB x CW308 (97.35) and AM x AB (58.31) showed maximum. Range of heterosis over standard check ranged from -17.41 to 37.37, AMCW308 (37.47) and YW x CW (37.37) recorded maximum for yield per plant. This was in line with findings of Aditika (2018) and Nalwa (2019) in capsicum. The result indicates that maximum yield per plant in the hybrids mentioned was attributed by maximum number of fruits per plant. Present experiment showed high degree of heterosis for yield in most of crosses (Table 2). The range of mean values of hybrids were more than the parents for all the studied growth and yield characters (Table 3 and 4). Aditika (2018) also have reported increase in mean values for growth and yield traits in hybrids in capsicum.

CONCLUSION

It can be concluded that Arka Mohini x CW308 has the best heterotic cross combination and had significantly higher heterosis and high *per se* value over commercial check with respect to number of primary branches, number of secondary branches, plant height, days to 50% flowering, days to first harvest, fruit length, fruit width, number of lobes per fruit, number of fruits per plant and average fruit weight. The cross Arka Mohini x CW308 also showed high heterobeltiosis for traits such as fruit length, number of fruits per plant, fruit width and average yield per plant. Hence, this hybrid can be utilized to obtain desirable segregates for improvement of horticultural traits in bell pepper.

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