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Full Length Research Paper

Genetic variability and character association analysis in bell pepper (*Capsicum annuum L.)*

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The present investigation on genetic variability including mean, genotypic and phenotypic variances, coefficient of variation, heritability, and genetic advance was conducted on genetically diverse twenty three genotypes of bell pepper. Significant differences were observed among the genotypes for all the traits. On the basis of mean performance, genotypes PRC-1, SSP, Kandaghat Sel. and Ranichauri Sel-1 were outperformed for fruit yield per plant, average fruit weight, number of fruits per plant and took less number of days to 50% flowering. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for fruit yield per plant and ascorbic acid content indicating that these traits had wide genetic variability and would respond better to selection. High heritability and high genetic advance were recorded for average fruit weight, fruit yield per plant, fruit diameter, number of lobes per fruit, days to first harvest, leaf area and ascorbic acid content indicating the role of additive gene action for the inheritance of these traits. At genotypic levels, the traits fruit length, fruit diameter and number of fruits per plant revealed significant positive correlation with fruit yield per plant. Number of fruits per plant exhibited the highest positive direct effect followed by average fruit weight, number of branches per plant, pedicel length and harvest duration at genotypic level.

Key words: Garden pea, GCV, PCV, heritability, correlation, path analysis

INTRODUCTION

Bell pepper (*Capsicum annuum L.*), commonly known as sweet pepper or capsicum, a low volume high value vegetable, is one of the most potential off-season vegetables of mid and high hill areas of Uttarakhand, India. At present, the productivity of bell pepper in Uttarakhand is very low (5.64 t/ha) because of the simple reason of non-availability of quality seed suitable for growing under mid and high hill regions in India. A few old varieties are still recommended for commercial cultivation, which indicates that very limited improvement work has been carried out because of narrow genetic base of the crop (Singh et al., 1993). There is a need for genetic restructuring of the bell pepper germplasm for increasing the productivity considering the preference of the consumers for typical bell shaped fruits with moderate size. For this, the first and foremost step is the evaluation of available variability in the germplasm so as to identify the potential genotypes for their use either directly as varieties or as parents in future breeding programme. Considering these stand points, a study on genetic variability and character association in bell pepper was undertaken.

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MATERIALS AND METHODS

Planting materials and raising of crop

The experiment materials comprised genetically diverse twenty three genotypes of bell pepper selected from various parts of the country. The experiment was laid out in a randomized block design with three replications during summer rainy season of 2008 at vegetable research block, GBPUA&T, Hill Campus, Ranichauri (TG), Uttarakhand. Geographic position of the experimental site lies between 30° 15' N latitude and 78° 30' E longitude under mid hill zone of Uttarakhand, India. The mean monthly minimum and maximum temperature varied between 6.0 - 16.6°C and 17.5 – 23.7°C, respectively during the cropping season. Row-to-row and plant-to-plant spacing was maintained at 60 and 45 cm, respectively. A

Table 1. Mean performance of bell pepper genotypes in relation to different horticultural traits.

Genotypes	Days to 50% flowering	Days to first harvest	Fruits length (cm)	Fruit diameter (cm)	Fruit girth (cm)	No. Of fruits per plant	Average fruit weight (g)	Pericarp thickness (mm)	No. of lobes per fruit	Pedicel length (cm)	No. of branches per plant	Plant height (cm)	Leaf area (cm^2)	No. of pickings	Harvest duration	Ascorbic acid content (mg)	Fruit yield per plant (g)
DARL-205	37.00	72.33	9.40	5.31	18.79	7.25	39.64	0.42	3.41	3.69	3.00	49.82	21.86	3.00	50.66	83.18	297.62
PRC-1	34.00	63.66	10.14	6.26	20.25	7.95	80.82	0.40	3.23	3.83	2.75	44.96	18.62	4.66	71.33	178.10	693.10
SSP	39.00	58.00	9.44	6.69	19.26	7.51	77.44	0.50	3.45	3.96	2.55	45.70	18.24	3.66	72.00	168.20	685.31
Ranichauri Sel-1	38.00	64.33	10.55	6.26	18.50	6.57	77.62	0.37	3.08	3.44	2.61	45.43	19.63	4.33	69.66	174.30	569.51
KandaghatSel-1	36.67	62.00	9.97	5.79	19.68	9.30	67.50	0.39	3.00	3.60	2.53	46.96	21.87	4.33	61.00	163.40	628.11
Solan Baharpur	38.67	67.66	10.14	5.29	18.46	8.10	61.55	0.38	3.23	4.06	3.23	50.33	32.71	4.00	55.33	151.90	499.47
Solan Pepper	37.00	77.33	9.63	5.07	18.94	7.72	37.00	0.39	3.23	4.84	2.63	63.84	17.71	3.66	45.66	163.60	287.07
HC-201	39.00	77.33	9.76	5.54	17.17	4.34	65.60	0.34	3.31	4.54	2.61	50.80	17.90	3.33	45.66	113.00	289.88
FEROZ	41.00	76.66	9.45	5.27	18.35	7.83	41.36	0.40	4.00	4.71	2.71	63.00	20.39	2.33	61.33	123.90	325.48
Sel-10-2	39.00	76.66	10.05	5.66	18.36	8.65	56.32	0.41	3.48	4.91	2.64	59.83	41.68	3.00	66.33	114.00	495.58
Sel- 12-2	40.33	75.66	9.83	5.34	17.19	4.96	46.10	0.38	3.15	5.17	2.57	54.56	25.82	3.33	47.33	112.50	226.69
Sel-613	36.33	62.00	9.78	6.02	19.67	7.50	51.60	0.36	3.15	4.47	2.76	56.63	18.61	3.33	60.00	144.00	388.44
Sel-104-1	36.00	76.00	10.72	4.98	18.62	6.21	56.78	0.39	3.81	4.63	2.99	53.46	24.88	4.00	62.00	120.70	352.43
Solan Local	39.33	74.66	9.95	4.97	19.08	7.30	47.70	0.41	3.75	4.91	2.86	52.66	17.65	3.00	63.33	144.60	348.40
SP-701	41.00	75.33	9.50	5.16	19.04	4.25	46.36	0.34	3.23	5.03	2.00	45.66	14.53	2.00	62.66	148.30	196.99
SP 633	36.67	71.33	9.60	5.37	18.69	7.58	58.52	0.37	3.07	4.00	2.46	55.58	19.72	4.00	51.66	114.50	443.14
DARL-202	39.00	75.33	9.66	4.85	18.31	3.86	62.72	0.34	3.08	4.21	2.36	54.53	18.55	3.66	47.66	133.90	244.51
Russian yellow	37.00	59.33	9.45	4.94	18.63	8.77	57.10	0.33	3.33	4.79	2.46	61.08	23.71	4.33	63.66	125.80	552.17
Yollow wonder	39.67	70.00	9.69	5.29	17.23	3.87	68.08	0.41	3.08	4.09	3.00	53.23	26.50	4.33	53.00	174.50	260.62
Solan wonder	39.67	74.00	9.16	4.76	17.32	3.83	42.65	0.38	3.00	4.03	2.63	51.76	14.95	3.33	68.00	187.80	163.96
HC-203	42.67	72.33	8.45	5.26	17.32	6.12	43.43	0.43	4.00	4.45	2.75	51.96	21.70	4.33	62.66	150.70	460.18
Sel- 3	39.67	70.00	7.53	5.15	17.10	4.84	42.61	0.36	3.58	3.71	2.58	49.88	18.21	4.66	70.00	140.50	324.96
California wonder	39.67	63.00	8.39	6.10	18.62	5.76	72.36	0.43	3.91	4.84	3.28	43.74	31.11	3.66	69.66	172.60	553.36
SE(d)	2.14	2.69	0.37	0.16	0.73	0.83	3.11	1.00	0.10	0.04	0.16	2.53	1.74	0.63	18.92	9.07	44.03
CD (P=0.05)	3.57	4.49	0.61	0.26	1.21	1.38	5.19	1.67	0.16	0.06	0.26	4.22	2.90	1.05	30.54	15.14	43.48
CV %	3.10	1.90	4.45	5.18	3.16	9.60	2.15	1.11	24.00	7.02	10.00	2.06	4.00	14.71	4.54	1.56	1.12

single non-experimental row was planted on either sides of each plot so as to minimize environmental error due to border effect. All the recommended cultural practices were followed to raise the normal crop. Data were recorded on seventeen different traits viz**.,** days to 50% flowering, days to first harvest, fruit length (cm), fruit diameter (cm), fruit girth (cm), number of fruits per plant, average fruit weight (g), fruit yield per plant (g), pericarp thickness (mm), number of lobes per fruit, pedicel length (cm), number of branches per plant, plant height (cm), leaf area (cm^2), number of pickings, harvest duration (days) and ascorbic acid content (vitamin C) (Table 1).For each observation, eight competitive plants had been chosen randomly.

Statistical analysis

The data recorded were analyzed statistically as per the

Table 2. Estimates of variance and other genetic parameters in bell paper.

Trait	Range	General mean ± SE (m)	Variance			Coefficient of variation (%)			Heritability (h^2) (%)	Genetic advance	Genetic advance (% of mean)
			(PCV)	(GCV)	(ECV)	(PCV)	(GCV)	(ECV)			
Days to 50% flowering	34.00-42.67	38.84 ± 1.51	10.10	3.18	6.92	8.18	4.59	6.77	31.50	2.06	5.30
Days to first harvest	58.00-77.33	70.31 ± 1.90	47.76	36.84	10.92	9.83	8.63	4.70	77.10	10.97	15.60
Fruit length	7.39-10.14	9.53 ± 0.27	0.78	0.56	0.22	9.31	7.88	4.95	71.70	1.31	11.85
Fruit diameter	4.76-6.69	5.45 ± 0.12	0.29	0.25	0.04	9.95	9.14	3.94	84.29	0.94	9.86
Fruit girth	17.10-20.25	18.43 ± 0.525	1.70	0.88	0.82	7.10	5.11	4.92	51.86	1.39	7.54
No. of fruits/plant	3.86-9.30	6.50 ± 0.59	9.60	8.54	1.06	29.47	24.82	15.88	70.95	2.80	43.07
Average fruit wt. (g)	37.00-80.82	56.15 ± 2.20	189.15	174.57	14.58	24.49	23.52	6.79	91.29	26.14	46.55
Pericarp thickness(cm)	0.33-0.50	0.39 ± 0.29	3.00	0.0005	0.0026	14.30	5.78	13.08	16.35	1.88	48.20
No. of lobes/fruit	3.00-4.00	3.37 ± 0.99	0.129	0.10	0.029	9.63	10.89	5.09	78.10	0.59	17.50
Pedicel length (cm)	3.4-5.17	4.34 ± 0.14	0.29	0.246	0.062	12.62	11.24	5.73	79.39	0.89	20.50
No. of branches/ plant	2.00-3.23	2.68 ± 0.12	0.11	0.067	0.043	9.66	12.38	7.74	60.88	0.41	15.29
Plant height at first picking	43.74-63.84	52.82 ± 1.79	40.07	30.41	9.66	11.98	10.44	5.88	75.88	9.89	18.72
Leaf area	14.53-41.68	22.06 ± 1.23	42.67	38.09	4.58	27.93	29.56	9.68	89.24	11.99	54.36
No. of pickings	2.00-4.66	3.66 ± 0.44	0.83	0.23	0.60	24.92	13.18	21.15	27.99	0.52	14.20
Harvest duration	45.66-72.00	64.53 ± 12.93	530.95	29.04	501.91	35.70	8.35	34.71	54.70	2.59	4.01
Ascorbic acid content (mg.)	83.18-187.80	131.65 ± 6.41	1398.05	1274.46	123.59	27.98	26.68	8.44	90.89	68.98	52.39
Fruit yield/ plant	163.96-685.31	404.30 ± 31.13	2652.11	23611.85	2908.26	40.27	38.00	13.33	89.03	298.68	73.87

model suggested by Gomez and Gomez for all the characters. The correlation between all the characters under study at genotypic and phenotypic level was estimated as per the method described by Scarle (1961). Path coefficient was obtained according to the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance revealed significant difference among the genotypes for all the traits indicating the presence of sufficient genetic variability in the germplasm and considerable scope for their improvement. Sufficient genetic variability for many of the horticultural traits studied in bell pepper and chilli had also been reported by earlier workers (Acharya et al., 2007; Vani et al., 2007; Ukkund et al., 2007).

GCV, PCV, Heritability and genetic advance

A perusal of the data revealed that the magnitude of PCV was higher than GCV for all the characters except number of lobes per fruit and leaf area. The estimates of PCV and GCV were high for fruit yield per plant, ascorbic acid content and average fruit weight, moderate for days to first harvest, plant height and low for days to 50% flowering, fruit length, fruit girth, number of lobes per fruit, number of branches, number of fruit per plant and number of pickings. Mishra et al. (2005) also reported high phenotypic and genotypic coefficient of variations, for ascorbic acid content, fruit number per plant, fruit yield per plant and fruit length, respectively. PCV was high and GCV was moderate for harvest duration, where as pericarp thickness had moderate PCV and low GCV. High values of PCV and GCV indicated the existence of substantial variability, ensuring ample scope for their improvement through selection. These results further confirmed the findings of earlier researchers for fruit yield per plant (Vani et al., 2007; Ukkund et al., 2007), for number of fruits per plant (Sreelathakumary and Rajamony, 2002; Mishra et al., 2005), for fruit length (Ibrahim et al., 2001), for average fruit weight (Sreelathakumary and Rajamony, 2002), for plant height and days to 50% flowering (Ibrahim et al., 2001) (Table 2 and 3).

Table 3. Estimates of phenotypic (P), genotypic (G) and environmental (E) correlation coefficient for different horticultural traits in bell pepper

Trait		Days to 50% flowering	Days to first harvest	Fruits length	Fruit diam eter	Fruit girth (cm)	No. of fruits / plant	Average fruit wt. (g)	Pericarp thick ness (cm)	No. of lobes/ fruits	Pedicel length (cm)	No. of branches	Plant height	Leaf Area (cm^2)	No. of Pickings	Harvest duration	Ascorbic acid (mg.)	Fruit yield/ plant
Days to 50% flowering	P		0.14	-0.32	-0.12	-0.43*	-0.25	-0.16	0.29	0.24	0.23	-0.10	-0.36	0.85**	-0.18	-0.08	0.30	-0.16
	G		0.27	-0.42*	0.65**	0.28	-0.31	-0.23	0.55**	0.36	0.29	-0.26	0.14	0.13	-0.40*	0.38	0.14	-0.14
	E		0.34	-0.29	-0.14	0.12	-0.20	-0.14	0.22	0.16	0.22	0.14	-0.01	0.56**	-0.96**	-0.73**	0.10	-0.24
Days to first harvest	P			0.11	-0.63**	-0.26	-0.34	-0.58**	-0.14	0.13	0.41*	0.09	0.39	0.53**	-0.39	-0.13	-0.44*	-0.70**
	G			0.10	-0.75**	-0.29	-0.42	-0.69**	-0.40	0.10	0.48*	-0.04	0.57**	0.53**	-0.88**	-0.58**	-0.53**	-0.84**
	E			0.14	-0.12	-0.25	-0.11	-0.05	-0.13	0.24	0.17	0.40*	0.22	0.55**	0.52**	-0.03	-0.34	-0.23
Fruit length	P				0.90**	0.13	0.25	0.19	-0.12	-0.36	-0.35	-0.11	0.15	0.24	-0.18	-0.12	-0.16	0.50**
	G				0.04	0.25	0.30	0.21	-0.28	-0.43*	-0.39	-0.16	0.19	0.24	-0.29	-0.13	-0.21	0.75**
	E				0.41*	0.51**	0.13	0.16	-0.65**	-0.15	-0.24	-0.10	0.50**	0.29	-0.10	-0.19	0.34	0.56**
Fruit diameter	P						0.31	0.63**	0.32	0.31	-0.27	0.06	-0.45*	0.71**	0.22	0.23	0.34	0.66**
	G						0.34	0.72**	0.76**	-0.02	-0.35	0.01	-0.60**	0.11	0.33	0.16	0.38	0.78**
	E						0.21	-0.36	0.10	0.17	0.73**	0.20	0.10	-0.24	0.17	-0.31	0.59**	-0.84**
Fruit girth(cm)	P						0.31	0.18	0.02	-0.09	-0.04	-0.04	-0.03	0.02	0.08	0.05	0.08	0.29
	G						0.48*	0.25	0.59**	-0.17	-0.10	-0.22	-0.17	0.05	0.02	0.18	0.11	0.42*
	E						0.08	0.04	-0.23	0.44*	0.07	0.17	0.22	-0.07	0.12	0.03	0.01	0.04
No. Of fruits/ plant	P							0.12	0.18	-0.02	-0.07	0.08	0.16	0.24	0.02	0.04	-0.13	0.62**
	G							0.10	0.21	0.09	-0.07	0.13	0.24	0.31	0.09	0.64**	-0.18	0.71**
	E							0.24	0.21	-0.10	0.18	0.08	-0.02	-0.08	-0.02	-0.14	0.06	0.42*
Average fruit wt. (g)	P								0.12	-0.12	-0.37	0.02	-0.52*	0.14	0.36	-0.03	0.37	0.65**
	G								0.23	-0.11	-0.44*	0.07	-0.61**	0.13	0.74**	-0.35	0.42*	0.68**
	E								0.12	-0.19	0.09	-0.17	-0.07	0.25	-0.03	0.18	-0.01	0.44*
Pericarp thickness (cm)	P									0.32	-0.06	0.27	-0.09	-0.08	-0.08	0.07	0.19	0.26
	G									0.67**	-0.12	0.71**	-0.55**	0.14	0.14	0.39	0.52**	0.61**
	E									0.18	-0.04	0.08	0.23	-0.05	0.05	0.04	-0.04	0.08
No. Of lobes /fruit	P										0.24	0.40*	0.03	0.31	0.01	0.07	-0.11	0.06
	G										0.33	0.46*	0.02	0.40	-0.16	0.52**	-0.11	0.08
	E										-0.09	0.27	0.07	-0.18	0.22	-0.08	-0.14	-0.05
Pedicel length (cm)	P											0.05	0.39	0.20	-0.40*	-0.27	-0.31	-0.30
	G											-0.08	0.58**	0.23	-0.56**	-0.67**	-0.35	-0.37
	E											0.42*	-0.24	-0.08	-0.35	-0.29	-0.08	0.02
No. of branches	P												-0.02	0.40*	0.12	0.12	0.05	0.03
	G												-0.12	0.59**	0.31	0.73**	0.08	0.10
	E												0.18	-0.17	-0.05	-0.01	-0.03	-0.21
Plant Height	P													0.08	-0.16	-0.12	-0.39	-0.34
	G													0.11	-0.67**	-0.96**	-0.50**	-0.41
	E													-0.05	0.34	0.14	0.21	-0.08

Table 3. Contd.

Leaf Area (cm^2)	P	0.07	0.13	-0.19	0.26	
	G	0.09	0.31	-0.19	0.27	
	E	0.11	0.20	-0.15	0.23	
No. of pickings	P		0.05	0.37	0.37	
	G		-0.08	0.73**	0.72**	
	E		0.06	0.01	0.04	
Harvest duration	P			0.03	0.12	
	G			0.05	0.38	
	E			0.06	0.12	
Ascorbic acid (mg.)	P				0.29	
	G				0.31	
	E				0.09	
Fruit yield/ plant	P					
	G					
	E					

*,** significant at p=0.05 and p=0.01, respectively.

Heritability and genetic advance

Most of the traits studied had high heritability estimates though they were moderate for fruit girth, harvest duration and number of branches and low for pericarp thickness and number of pickings. The heritability of the highest magnitude was noticed for average fruit weight (91.29%) and the lowest for pericarp thickness (16.35%). Thus, it indicated that larger proportion of phenotypic variance has been attributed to genotypic variance and reliable selection could be made for almost all the traits on the basis of phenotypic expression. High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection procedures. High heritability estimates for fruit yield per plant (Das and Choudhary, 1999; Sreelathakumary and Rajamony, 2002), average fruit weight (Das and Choudhary, 1999), num ber of fruits per plant (Sreelathakumary and Rajmony, 2002), days to 50% flowering and fruit length (Bhardwaj et al., 2007), plant height (Ibrahim et al., 2001; Bhardwaj et al., 2007) observed by earlier workers were in consonance with the present study. High heritability and high estimates of genetic advance (as per cent of mean) were observed in case of fruit yield per plant (89.03 and 73.87%), leaf area (89.24 and 54.36%), and ascorbic acid content (90.89 and 52.39%). This suggested the presence of additive gene action (Panse, 1957) and hence these characters are likely to respond better to selection. High heritability and high genetic advance have also been obtained by many workers (Bhardwaj et al., 2007) for fruit yield per plant, (Sreelathakumary and Rajamony, 2002) for average fruit weight, (Kataria et al., 1997; Sreelathakumary and Rajamony, 2002) for number of fruits per plant.

High heritability along with moderate genetic advance was observed for average fruit weight. These results are in consonance with the findings of Ibrahim et al., 2001 for fruit length and days to 50% flowering. High heritability and low genetic advance were observed for days to first harvest, fruit length, fruit diameter, number of lobes per fruit, pedicel length, number of branches per plant and plant height, which may be attributed to the non-additive gene effects and these traits can be improved through hybridization and use of hybrid vigour (Panse, 1957). Pericarp thickness (16.35

and 48.20) and number of pickings (27.99 and 14.20) showed low heritability associated with low genetic advance indicating the role of non additive genes for these traits suggesting thereby that their improvement could be achieved through heterosis breeding. Fruit yield per plant, number of fruits per plant, harvest duration, average fruit weight, plant height, number of lobes per fruit can be improved by selection, as these characters exhibited high
moderate genotypic and phenotypic coefficient of variation along with medium to high heritability and medium to high genetic advance.

Correlation coefficient of variation

A high positive significant correlation of days to 50% flowering and days to first harvest suggested that early flowering genotypes would be an appropriate selection criterion to get early marketable fruit yield (Table 4). The number of fruits per plant had positive correlation with harvest duration and fruit yield per plant at genotypic level. Similar findings were noticed by Mishra et al. (1998) and Ibrahimet al. (2001). Average fruit weight at marketable stage had significant positive relationship with number of pickings, ascorbic acid content and fruit yield per plant. Whereas, it had negative association with pedicel length and plant height at phenotypic level and fruit weight only at genotypic level. A significant positive correlation of fruit weight with pericarp thickness was also observed by Ben-Chaim and Peron (2000) and their findings are in consonance with the present findings. Fruit length had positive association with plant height and number of fruits per plant at genotypic level. Hence, on the basis of correlation studies and their coefficient of determination, the selection for harvest duration, number of fruits per plant, average fruit weight, fruit diameter, fruit girth will be effective for isolating plants with higher fruit yield in bell pepper.
Number of lobes per fruit revealed significant positive association with harvest duration and number of branches. The character pedicel length of fruit had significant positive correlation with plant height and significant negative correlation with harvest duration and number of pickings. Number of branches exhibited significant positive correlation with harvest duration and leaf area. while number of pickings showed significant positive association with ascorbic acid content and fruit yield per plant. Fruit yield per plant had significant and positive association with fruit length, fruit diameter, number of fruits per plant and number of pickings both at phenotypic and genotypic level. The results are in consonance with the findings of earlier researchers for number of fruits per plant (Ibrahim et al., 2001; Sreelathakumary and Rajamony, 2002; Bharadwaj et al., 2007), fruit weight (Mishra et al., 1998; Sreelathakumary and Rajmony, 2002; Smith and Basavaraja, 2005) and pericarp thickness (Depestre et al., 1981). The significant association fruit length, fruit diameter, number of fruits, number of pickings suggests that increase in any one of these traits may results in increase in fruit yield. These results are conformity with those reported by Smith and Basavaraja (2005) and Bharadwaj et al. (2007), who advocated that the importance should be given to number of fruits per plant, fruit weight, number of primary branches, fruit length, fruit diameter and plant height during selection during selection process because these characters contribute directly towards the yield.

Path analysis

Path analysis helps in partitioning correlation coefficients into direct and indirect effects of component characters in yield. Direct and indirect effects of all the traits on yield were computed at the genotypic level. At genotypic level, number of fruits per plant had the highest positive direct effect on yield per plant followed by average fruit weight (0.85), number of branches (0.28), pedicel length (0.20) and harvest duration (0.90), while negative direct effect was observed for days to first harvest (-0.23), plant height (-0.17), pericarp thickness (-0.09) and fruit length (-0.07). High direct
and positive effect of fruit weight (Mishra et al., 2002), number of fruit per plant (Mishra et al., 1998; Mishra et al., 2002) have also been reported by earlier workers. Average fruit weight had high positive direct effect alongwith indirect effect via days to first harvest, number of fruits per plant, number of lobes per fruit and pedicel length. The highly significant positive association of fruit diameter and number of pickings were the result of positive indirect effect of these traits via average fruit weight, number of fruits per plant and days to first harvest and also some individual direct effect of average fruit weight towards fruit yield per plant. Number of fruits per plant, besides having positive direct effect of high magnitude, had also positive indirect effects of considerable magnitude via days to first harvest, average fruit weight, number of picking and harvest duration. Similar findings have also been reported by Mishra et al. (1998, 2002). Low magnitude of residual effect genotypic (0.0271) level indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable that is. fruit yield per plant.

Conclusion

In view at the direct and indirect contributions of component traits towards fruit yield, selection on the basis of horticultural traits viz., average fruit weight and number of fruits per plant would be a paying preposition in the genotypes included in the study. Vani et al. (2007) also reported that number of fruits per plant and fruit diameter on yield per plant is the main contributors to

Table 4. Estimates of direct and indirect effect of different horticultural traits on fruit yield at phenotypic(P) and genotypic (G) levels in bell pepper.

Trait		Days to 50% flowering	Days to First harvest	Fruits length	Fruit diameter	Fruit girth (cm)	No. of fruits/ plant	Average fruit wt. (g)	Pericarp thickness (cm)	No. of lobes/ fruits	Pedicel length (cm)	No. of branches	Plant height	Leaf area (cm^2)	No. of pickings	Harvest duration	Ascorbic acid (mg.)	Correlation coefficinet with Fruit yield/ plant
Days to 50% flowering	P	-0.00	-0.03	0.01	-0.00	0.00	-0.12	-0.05	0.00	0.04	-0.00	0.01	0.00	0.01	-0.01	-0.00	0.00	-0.16
	G	0.00	-0.06	0.03	-0.02	-0.01	-0.29	-0.20	-0.05	-0.03	0.05	-0.07	-0.02	-0.04	-0.03	-0.02	0.01	-0.14
Days to first harvest	P	-0.00	**-0.21**	-0.00	-0.02	-0.00	-0.16	-0.18	-0.00	0.02	-0.00	-0.00	-0.04	0.00	-0.03	-0.00	-0.04	-0.70**
	G	0.16	**-0.23**	-0.08	0.32	-0.01	-0.36	-0.59	0.03	-0.08	0.09	-0.01	-0.09	-0.01	-0.07	-0.05	-0.06	-0.84**
Fruit length	P	0.00	-0.02	**-0.04**	0.00	-0.00	0.13	0.06	-0.00	-0.06	0.00	0.02	-0.01	0.00	-0.05	-0.00	-0.01	0.50**
	G	-0.25	-0.02	**-0.07**	-0.01	0.01	0.32	0.18	0.02	0.03	-0.08	-0.04	-0.03	-0.07	-0.02	-0.02	-0.02	0.75**
Fruit diameter	P	0.00	0.13	-0.00	**0.04**	-0.00	0.17	0.20	0.00	0.00	0.00	-0.01	0.05	0.01	0.01	-0.00	0.03	0.66**
	G	0.03	0.17	-0.03	**-0.42**	0.01	0.35	0.62	-0.07	0.01	-0.07	0.04	0.10	-0.03	0.02	0.05	0.04	0.78**
Fruit girth(cm)	P	0.00	0.05	-0.00	-0.00	**-0.01**	0.16	0.05	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
	G	-0.17	0.06	-0.02	-0.08	**0.05**	0.45	0.22	-0.05	0.01	-0.02	-0.06	0.02	-0.01	0.02	0.01	0.01	0.42*
No. of fruits/ plant	P	0.00	0.06	-0.01	0.01	-0.04	**0.53**	0.03	0.00	-0.00	0.00	-0.01	-0.01	0.03	0.00	0.00	-0.01	0.62**
	G	-0.19	0.08	-0.02	-0.05	0.02	**0.95**	0.09	-0.01	-0.08	-0.01	0.03	-0.04	-0.10	0.08	0.06	-0.02	0.71**
Average fruit wt.(g)	P	0.00	0.12	-0.00	0.02	-0.00	0.06	**0.31**	0.00	-0.02	0.00	-0.00	0.05	0.02	0.03	-0.00	0.03	0.65**
	G	-0.14	0.16	-0.01	-0.31	0.01	0.10	**0.85**	-0.02	0.09	0.09	-0.02	0.10	-0.04	0.06	-0.03	0.05	0.68**
Pericarp thickness (cm)	P	0.00	0.03	0.00	0.01	-0.00	0.09	0.04	**0.08**	0.05	0.00	-0.04	0.01	0.02	-0.00	0.00	0.01	0.26
	G	0.33	0.09	0.02	-0.32	0.03	0.20	0.20	**-0.09**	-0.05	-0.02	0.20	0.09	-0.13	0.01	0.03	0.06	0.61**
No. of lobes/fruit	P	-0.00	-0.02	0.01	0.00	0.00	0.00	-0.03	0.00	**0.16**	0.00	-0.07	-0.00	0.04	0.00	0.00	-0.01	0.06
	G	0.22	-0.02	0.03	0.09	-0.01	0.09	-0.09	-0.06	**-0.08**	0.06	0.13	-0.03	-0.13	-0.01	0.04	-0.01	0.08
Pedicel length (cm)	P	-0.00	-0.08	0.00	-0.01	-0.00	-0.00	-0.11	-0.00	-0.04	**-0.02**	-0.01	-0.04	0.02	-0.03	-0.01	-0.03	-0.30
	G	0.17	-0.11	0.03	0.15	-0.06	-0.07	-0.38	0.01	-0.02	**0.20**	-0.02	-0.09	-0.07	-0.04	-0.06	-0.04	-0.37
No. of branches	P	0.00	-0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.06	-0.00	**-0.17**	0.00	0.05	0.01	0.00	0.00	0.03
	G	-0.16	0.09	0.01	-0.06	-0.01	0.12	0.06	-0.06	-0.04	-0.01	**0.28**	0.02	-0.19	0.02	0.06	0.01	0.10
Plant height	P	0.00	-0.08	-0.00	-0.02	0.00	0.08	-0.16	-0.00	0.00	0.00	0.00	**-0.10**	0.01	-0.01	-0.00	-0.03	-0.34
	G	0.09	-0.13	-0.01	0.25	-0.01	0.23	-0.52	0.05	-0.01	0.11	-0.03	**-0.17**	-0.03	-0.05	-0.09	-0.06	-0.41
Leaf Area (cm^2)	P	-0.00	-0.11	-0.00	0.00	-0.00	0.12	0.04	0.00	0.05	-0.00	-0.07	-0.00	**0.14**	0.00	0.00	-0.01	0.26
	G	0.08	-0.01	-0.01	-0.05	0.03	0.30	0.11	-0.03	-0.03	0.04	0.16	-0.01	**-0.32**	0.07	0.02	-0.02	0.27
No. of pickings	P	0.00	0.08	0.00	0.01	-0.00	0.01	0.11	-0.00	0.00	0.00	-0.02	0.01	0.01	**0.08**	0.00	0.03	0.37
	G	-0.24	0.20	0.02	-0.14	0.01	0.08	0.63	-0.01	0.01	-0.11	0.08	0.11	-0.02	**0.08**	0.08	0.09	0.72**
Harvest duration	P	0.00	0.02	0.00	-0.00	-0.00	0.02	-0.00	0.00	0.01	0.00	-0.02	0.01	0.01	0.00	**0.04**	0.00	0.12
	G	0.01	0.13	0.01	-0.24	0.01	0.61	-0.30	-0.03	-0.04	-0.13	0.20	0.16	-0.10	-0.07	**0.09**	0.06	0.38
Ascorbic acid (mg.)	P	-0.00	0.09	0.00	0.01	-0.00	-0.07	0.11	0.00	-0.01	0.00	-0.01	0.04	-0.02	0.03	0.00	**0.10**	0.29
	G	0.08	0.12	0.01	-0.16	0.06	-0.17	0.36	-0.04	0.09	-0.07	0.02	0.08	0.06	0.06	0.04	**0.01**	0.31

*Significant at P=0.05 and ** Significant at P=0.01,Rredidual effect P=0.1266, G=0.0271; Bold values indicate direct effects.

yield in bell pepper.

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