Himachal Journal of Agricultural Research 43(1): 33-39 (2017)

Morphological characterization of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) genotypes

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Received: 20.06.2017; Accepted:22.07.2017

Abstract

Morphological characterization of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) germplasm is a prerequisite in any crop improvement programme. The present study was conducted in 2015 at the Vegetable Experimental Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to evaluate morphological traits of bell pepper genotypes in 43 F_5 progenies, one susceptible and two resistant checks. Characterization of genotypes was done for the plant descriptors that included fruit shape, fruit shape at pedicel attachment, blossom end fruit shape, fruit position, plant height and fruit colour. Blocky fruit shape, truncate/ cordate fruit shape at pedicel attachment, sunken blossom end fruit shape, pendent/ erect fruit position and dark green fruit colour at the time of horticultural maturity were the desirable horticultural attributes from consumer's point of view. Bell pepper germplasm contains sufficient genetic variability and can be used for crop improvement. Among the evaluated genotypes, 14 had blocky fruit shape, 12 with lobate fruit shape at pedicel attachment, 25 with sunken blossom end fruit shape, 7 with upright fruit position and 28 genotypes with plant height of 46-65 cm. Green and yellow green coloured fruits were prominent. 27, 9 and 10 progenies were categorized under green group, yellow yellow green group and yellow green green group, respectively. Characterization of bell pepper germplasm will provide valuable information for strengthening breeding programmes because it helps in selection of parents on the basis of morphological characters. P-43, P-24, P-25, P-33, P-34, P-10, P-23 were the progenies with desirable horticultural attributes and can be used for their exploitation in future breeding programme.

Key words: *Capsicum annuum* var. *grossum*, bell pepper, colour, descriptor and fruit.

Bell pepper (*Capsicum annuum* L. var. *grossum* Sendt) has high nutritive and medicinal value (Maldonado *et al.* 2002). Use of bell pepper as fresh or processed, in different culinary forms (Wang and Bosland 2006) has been on a rise. In addition, a wide variability in germplasm of bell pepper (Naik *et al.* 2014) also provides an ample scope for its improvement for horticultural traits. Accordingly the crop breeding programmes have been designed to suffice the requirements of consumers as well as bell pepper breeders/scientists. Morphological descriptors are the base for characterization of plant genotypes on the basis of external appearance. Further characterization of bell pepper varieties is required for their description under plant variety protection legislation, because varietal testing for distinctness, uniformity and stability is the basis for protection for a new plant variety under Indian law (Protection of Plant Varieties and Farmer's right Act, 2011). Proposed new varieties are compared against a set of relevant characteristics prescribed according to Shrivastava *et al.* (2001). This investigation was undertaken to study bell pepper genotypes on the basis of morphological traits to select the most promising germplasm for cultivation and use in improvement programs.

Materials and Methods

The experiment was conducted at the Vegetable Experimental Farm of the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32°6' N, 76° 3' E), India, which is 1290.8 m above sea level. The genetic material used included 46 genotypes (43 F_5 progenies, one susceptible (California Wonder) and two resistant (EC-464107 and EC-464115) checks (Table 1). These progenies had been earlier selected in the Department of Vegetable Science and Floriculture ,CSKHPKV, Palampur derived from different inter-varietal crosses. The experiment was undertaken during February-August, 2015.

Seedlings of 43 F_5 progenies alongwith resistant and susceptible checks were transplanted in a Randomized Block Design (RBD) with three replications. Each entry/progeny was accommodated as 12 plants per entry per replication with inter and intra row spacing of 60 cm and 45 cm, respectively.

Nursery sowing was done for summer-rainy season crop in raised beds. Seeds were treated with Bavistin (2 g/kg seed) to avoid fungal diseases. The field soil was a silty clay loam having a pH 5.7. Raised beds were used to facilitate drainage during the rainy season. The chemical fertilizers were applied as per the recommended package of practices (90 kg N, 75 kg $P_2O_5$and 50 kg K_2O/ha). One third dose of N and full doses of P_2O_5 and K_2O were applied at the time of field preparation. Remaining two third dose of N was top dressed in two equal splits after 30 and 45 days of transplanting. To maintain the vegetative growth and vigour of the plants, five sprays of urea (1.5%) at an

Table 1. Description of parental bell pepper lines used in the study

Sr. No.	Progeny	Pedigree	Sr. No.	Progeny	Pedigree
1	P-1	(P13 X KS)-9-8-2	24	P-24	(P14 X KS)-43-5-1
2	P-2	(P13 X KS)-12-1-1	25	P-25	(P14 X KS)-70-5-2
3	P-3	(P13 X KS)- 15-2-1	26	P-26	(P14 X KS)-52-1-1
4	P-4	(P13 X KS)-15-3-2	27	P-27	(P14 X KS)-52-2-7
5	P-5	(P13 X KS)-16-6-1	28	P-28	(P14 X KS)-70-8-1
6	P-6	(P13 X KS)-24-1-2	29	P-29	(P14 X KS)-53-3-2
7	P-7	(P13 X KS)-24-2-1	30	P-30	(P14 X KS) -76-3-1
8	P-8	(P13 X KS)-24-3-1	31	P-31	(P14 X KS)- 54-2-1
9	P-9	(P13 X KS)-24-3-8	32	P-32	(P14 X KS)-55-3-1
10	P-10	(P13 X KS)-28-4-1	33	P-33	(P14 X KS)-57-4-1
11	P-11	(P13 X KS)-28-4-9	34	P-34	(P14 X KS)-57-6-1
12	P-12	(P13 X KS)-34-1-2	35	P-35	(P14 X KS)-58-2-1
13	P-13	(P13 X KS)-38-1-4	36	P-36	(P14 X KS)-68-2-1
14	P-14	(P13 X KS)-38-2-1	37	P-37	(P14 X KS)- 70-4-1
15	P-15	(P13 X KS)-38-2-6	38	P-38	(P14 X KS)- 72-1-1
16	P-16	(P13 X KS)-38-10-2	39	P-39	(P14 X KS)- 73-1-1
17	P-17	(P13 X KS)-38-12-4	40	P-40	(P14 X KS)- 76-2-1
18	P-18	(P13 X KS)-42-1-2	41	P-41	(P14 X KS)- 45-10-1
19	P-19	(P13 X KS)-42-4-1	42	P-42	(P14 X KS)- 45-10-1
20	P-20	(P13 X KS)-83-8-2	43	P-43	(P14 X KS)- 57-2-1
21	P-21	(P13 X KS)-84-4-1	44	EC-464107	Resistant check
22	P-22	(P13 X KS)-84-2-2	45	EC-464115	Resistant check
23	P-23	(P14 X KS)-43-6-1	46	California Wonder	Susceptible check

interval of about 8-10 days during the flowering and fruiting periods were done. When plants had attained a height of 10-15 cm, they were transplanted. Soil moisture was maintained during the growing season with flood irrigation at 7 to 10 day interval.

Progenies were evaluated for the descriptors fruit shape, fruit shape at pedicel attachment, blossom end fruit shape, fruit position and plant height according to the descriptor for bell pepper (Srivastava *et al.* 2001). Fruit colour was assigned from standardized charts (Royal Horticultural Society 1804). Observations were recorded on 5 randomly chosen plants in each replication at stages of crop growth when the character under study was fully expressed. Fruit shape, fruit shape at pedicel attachment, blossom end fruit shape, fruit position and fruit colour were observed at horticultural maturity. At horticultural maturity for each variety/cultivar, fruits of 5 randomly selected plants of each genotype in each replication were harvested. Plant height was measured at the time of final harvest. The progenies were characterized and frequency distribution of each descriptor was determined.

Results and Discussion

There was considerable variation observed among genotypes for all attributes (Table 2 and 3). Fruit shape and colour are important characters that attract consumers. Fourteen progenies, susceptible

Table 2. Description of bell pepper progenies based on morphological traits

Progenies	Overall fruit shape[b]	Fruit shape at pedicel attachment	Fruit shape at blossom end	Fruit position	Average plant height	Fruit colour RHSCC[a]
P-1	1	1	3	1	3 (46.08)	GG- 143 B
P-2	2	3	3	1	3 (59.65)	YYG- 144 A
P-3	3	2	3	2	3 (49.90)	YGG- 146 A
P-4	3	1	3	1	3 (50.91)	GG- 143 B
P-5	4	2	2	1	3 (48.44)	GG- 143 B
P-6	4	4	3	1	2 (38.85)	YGG- 153 C
P-7	4	2	3	3	2 (41.85)	YGG- 145 A
P-8	2	3	3	1	3 (51.11)	YYG- 144 A
P-9	3	3	3	1	2 (41.17)	YGG- 144 C
P-10	1	3	3	1	3 (54.49)	YYG- 144 A
P-11	4	2	3	1	3 (59.69)	GG- 143 B
P-12	2	2	3	1	3 (54.23)	YGG- 146 B
P-13	2	3	2	1	2 (39.51)	GG- 143 B
P-14	2	1	3	1	2 (40.19)	GG- 143 A
P-15	4	4	2	1	3 (49.49)	GG- 143 A
P-16	2	3	3	3	2 (37.55)	YYG- 144 A
P-17	3	3	2	1	3 (48.50)	GG- 141 A
P-18	4	2	3	2	3 (53.68)	YGG- 146 B
P-19	3	4	2	2	3 (55.61)	YYG- 144 A
P-20	3	3	3	2	3 (56.33)	GG- 143 A
P-21	4	2	1	1	2 (45.73)	GG- 143 A
P-22	3	3	2	1	3 (49.45)	GG- 143 A
P-23	1	3	3	1	3 (46.16)	GG- 143 B
P-24	1	3	3	2	2 (37.94)	YYG- 144 A
P-25	1	3	3	1	3 (48.39)	GG- 143 A
P-26	3	3	2	1	2 (44.79)	YGG- 146 A
P-27	1	2	1	3	2 (42.59)	GG- 143 B
P-28	3	3	2	1	3 (48.55)	YYG- 144 A
P-29	4	2	2	1	3 (47.77)	GG- 143 A

P-29	4	2	2	1	3 (47.77)	GG- 143 A
P-30	2	4	3	1	2 (41.98)	GG- 141 A
P-31	3	4	2	2	3 (50.57)	GG- 143 A
P-32	3	4	1	2	2 (39.67)	YYG- 144 A
P-33	1	2	1	3	2 (30.67)	YGG- 146 A
P-34	1	2	2	1	2 (44.23)	YGG- 146 A
P-35	5	3	1	3	3 (51.31)	GG- 143 B
P-36	4	3	1	3	3 (58.01)	GG- 143 B
P-37	3	4	2	1	3 (55.27)	GG- 143 C
P-38	3	3	2	2	3 (51.20)	GG- 141 A
P-39	1	4	3	1	2 (42.07)	YYG- 144 A
P-40	3	4	4	2	2 (45.23)	GG- 143 A
P-41	2	3	3	1	2 (39.61)	GG- 143 A
P-42	1	4	1	1	3 (53.07)	GG- 143 A
P-43	1	3	3	2	3 (51.99)	GG- 143 A
EC-464107	1	4	3	1	3 (46.43)	YGG- 145 C
EC-464115	1	4	3	1	3 (47.30)	GG- 143 A
California Wonder	1	3	3	1	2 (30.64)	GG- 135 A

Values in parentheses are averages

[a]Royal Horticultural Society Colour charts (1804): GG= green group; YGG= yellow green group; YYG= yellow yellow green group; [b]Minimal descriptors based on Srivastava *et al.*(2001) for characters in columns.

Fruit shape: 1, blocky; 2, companulate; 3, triangular; 4, almost round; 5, elongate.
Fruit shape at pedicel attachment: 1, obtuse; 2, truncate ; 3, cordate; lobate.
Fruit shape at blossom end: 1, pointed; 2, blunt; 3, sunken; 4, sunken and pointed.
Fruit position: 1, pendent; 2, intermediate; 3, upright. Average plant height; 2 = 25-45 cm; 3 = 46-65 cm;

Table 3. Frequency distribution and example progenies of some attributes of 46 genotypes (43 F_5 progenies, one susceptible and two resistant checks)

Plant descriptor	Range of Expression	No. of Progenies	Example progenies
Fruit shape	Blocky	14	P-1, P-10, P-23, P-24, P-25, P-27, P-33, P-34, P-39, P-42, P-43, EC-464107, EC-464115 and California Wonder
	Companulate	9	P-2, P-8, P-12, P-13, P-14, P-16, P-30, P-35 and P-41
	Triangular	15	P-3, P-4, P-9, P-13, P-17, P-19, P-20, P-22, P-26, P-28, P-31, P-32, P-37, P-38 and P-40
	Almost round	11	P-5, P-6, P-7, P-11, P-15, P-16, P-18 P-19, P-21, P-29 and P-36
	Elongate	1	P-35
Fruit shape at pedicel end	Obtuse	2	P-4 and P-14
	Truncate	10	P-3, P-5, P-7, P-11, P-12, P-18, P-21, P-27, P-29 and P-34
	Cordate	20	P-2, P-8, P-9, P-10, P-13, P-16, P-17, P-20, P-22, P-23, P-24, P-25, P-26, P-28, P-35, P-36, P-38, P-41, P-43 and California Wonder
	Lobate	12	P-6, P-15, P-19, P-30, P-31, P-32, P-37, P-39, P-40, P-42, EC-464107 and EC-464115

Blossom end fruit shape	Pointed	8	P-4, P-21, P-27, P-32, P-33, P-35, P-36 and P-42
	Blunt	13	P-5, P-13, P-15, P-17, P-19, P-22, P-26, P-28, P-29, P-31, P-34, P-37 and P-38
	Sunken	25	P-1, P-2, P-3, P-6, P-7, P-8, P-9, P-10, P-11, P-12, P-14, P-16, P-18, P-20, P-23, P-24, P-25, P-27, P-30, P-39, P-41, P-43, EC-464107, EC-464115 and California Wonder
	Sunken and Pointed	1	P-40
Fruit position	Pendent	30	P-1, P-2, P-4, P-5, P-6, P-8, P-9, P-10, P-11, P-12, P-13, P-14, P-15, P-17, P-21, P-22, P-23, P-25, P-26, P-28, P-29, P-30, P-34, P-37, P-39, P-41, P-42, EC-464107, EC-464115 and California Wonder
	Intermediate	11	P-3, P-18, P-19, P-20, P-24, P-31, P-32, P-38, P-39, P-40 and P-43
	Upright	7	P-7, P-15, P-16, P-27, P-33, P-35 and P-36
Plant height	25-45 cm	17	P-6, P-7, P-9, P-14, P-16, P-21, P-24, P-26, P-27, P-30, P-32, P-33, P-34, P-39, P-40, P-41 and California Wonder
	46-65 cm	27	P-1, P-2, P-3, P-4, P-5, P-8, P-10, P-11, P-12, P-15, P-17, P-18, P-19, P-20, P-22, P-23, P-25, P-28, P-31, P-35, P-36, P-37, P-38, P-42, P-43, EC-464107 and EC-464115
Fruit colour	Green group (GG)	27	California Wonder, P-1, P-4, P-5, P-11, P-13, P-14, P-15, P-17, P-20, P-21, P-22, P-23, P-25, P-27, P-29, P-30, P-31, P-35, P-36, P-37, P-38, P-40, P-41, P-42, P-43 and EC-464115
	Yellow yellow green group (YYG)	9	P-2, P-8, P-10, P-16, P-19, P-24, P-28, P-32 and P-39
	Yellow green green group (YGG)	10	P-3, P-6, P-7, P-9, P-12, P-18, P-26, EC-464107, P-33 and P-34

check (California Wonder) and two resistant checks (EC-464107 and EC-464115) had a blocky fruit shape and 15 progenies were triangular. A few progenies possessed almost round, companulate and elongate fruit shapes. For fruit shape at pedicel end 12 progenies had lobate fruit shape including two resistant checks (EC-464107 and EC-464115) and 19 were cordate. A few progenies possessed Turncate and obtuse fruit shapes. For blossom end fruit shape, 25 progenies, susceptible check (California Wonder) and two resistant checks had a sunken blossom end fruit shape; 8 progenies had pointed blossom end.

fruit shape; 8 progenies had pointed blossom end. Sunken and pointed blossom end occurred in P-40 and 13 progenies had a blunt blossom end. Out of 43 progenies, 31 were pendent along with susceptible check and two resistant checks. A few progenies possessed intermediate and upright fruit positions. Stommel and Griesbach (2008) provided information on genetic control of fruit attributes, leaf characters and plant habit in *Capsicum*. For bell pepper, there appears to be genetic control of morphological traits and fruit colour. Fruit position was pendent in 31 progenies and in susceptible check (California Wonder). Fruit position was upright in 7 progenies while plant height of progenies ranged from 30.64 cm (California Wonder) to 59.69 cm (P-11).

Green and yellow green fruits were prominent; these are grouped as green group (GG), yellow yellow green (YYG) and yellow green group (YGG). The progenies P-1, P-4, P-5, P-11, P-13, P-14, P-15, P-20, P-21, P-22, P-23, P-25, P-27, P-29, P-31, P-35, P-36, P-37, P-40, P-41, P-42, P-43, EC-464107, EC-464115 and California Wonder were categorized under green group, whereas the progenies P-3, P-6, P-7, P-9, P-12, P-18, P-26, P-33, P-34 and EC-464107 produced yellow green fruits. Other progenies P-2, P-8, P-10, P-16, P-19, P-24, P-28, P-32 and P-39 were of yellow yellow green fruits. Attractive dark green fruit colour, blocky fruit shape and upright/intermediate fruit position are the desirable horticultural attributes from consumer's point of view. Fruit colour, shape and position are the most important quality factors on the basis of which consumer prefer green and blocky fruits, and these observations often provide preconceived idea about other quality attributes. Barring P-2, P-3, P-6, P-7, P-8, P-9, P-10, P-12, P-16, P-18, P-19, P-24, P-26, P-28, P-32, P-33, P-34, P-39, EC-464107, EC-464115, all other progenies had green to dark green fruit colour at immature fruit stage. The progenies P-1, P-10, P-18, P-23, P-24, P-25, P-27, P-33, P-34, P-39, P-42, P-43, EC-464107, EC-464115 and California Wonder had blocky fruits while rest of them had companulate, triangular and almost round fruits.P-15, P-16, P-17, P-27, P-33, P-35 and P-36 had upright fruit position while rest of them had pendent and intermediate fruit position.

Wide range of variation was found for fruit shape, fruit colour and fruit position. As per consumer's preference is concerned, blocky fruits are preferred. Besides, for fetching crop during rainy season, lobate fruit shape and pendent fruit position is not desirable as stagnation of rain water at pedicel area generally enhances rotting.

Coincidently, among the top five high yielding progenies P-39 and P-33 produced fruits of desirable shape (blocky), intermediate and upright fruit position, respectively. Bindal (2005), Valiskova (2006), Devi (2013), Devi (2014) and Muhammad *et al.* (2015) reported variability for fruit colour. Valiskova (2006) and Muhammad *et al.*(2015) also reported for fruit shape and position in bell pepper.

Uzo (1984) confirmed single gene inheritance for fruit colour in peppers. Adetula and Olakojo (2006) reported that in *C. frutescens* L. genotypes, fruit colour at maturity and fruit position were the traits that had potential for use in breeding for higher yield and improved fruit quality. For bell pepper, fruit colour and fruit position are also important morphological traits to be used to develop improved cultivars. Blocky fruit shape, lobate pedicel attachment, sunken blossom end fruit shape, pendent fruit position and dark green fruit colour at maturity are desirable horticultural attributes. Fruits of bell pepper were characterized based on morphological descriptors, which will enable breeders to select desirable lines for breeding programmes. Bell pepper germplasm contain sufficient genetic variability and can be used for further crop improvement.

Conclusion

Variability study revealed that sufficient variability existed in material which could be exploited through hybridization or selection. P-24; P-25 and P-43 were the only progenies with all desirable horticultural attributes i.e. blocky fruit shape, cordate fruit shape at pedicel attachment, sunken blossom end fruit shape and intermediate fruit position. Whereas P-33 and P-34 were the progenies with blocky fruit shape, truncate fruit shape at pedicel attachment, attachment, upright fruit position and pointed/blunt blossom end fruit shape. P-10 and P-23 were the progenies with blocky fruits, cordate fruit shape at pedicel end, sunken fruit shape at blossom end and pendent fruit position. These progenies can be used for their exploitation in future breeding programme.

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