

Original Research Article

Screening of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) genotypes for higher marketability and bacterial wilt resistance under mid-hill conditions of North-Western Himalayas

ABSTRACT

Bacterial wilt, caused by *Ralstonia solanacearum*, is a major soil borne disease of bell pepper in hot and humid growing areas around the world. The existing varieties of bell pepper are highly susceptible and not even a single commercial variety resistant to this disease has been developed yet and commercially available. The chemical control measures and manipulation of agronomical practices have been applied, but these are found ineffective against this disease, hence growing of resistant cultivars is the only way to overcome the yield losses. Along with resistance, varieties with early yielding ability and superior morphological characters fetch high prices in the market. Thus, an attempt was made to screen 39 genotypes of bell pepper along with four checks during summer-rainy season, 2018 and 2019. Genotypes DPCBWR-14-39, DPCBWR-14-36, DPCBWR-14-2, DPCBWR-14-35 and DPCBWR-14-29 were identified as top yielders and showed high level of resistance to bacterial wilt. Among these, DPCBWR-14-39 and DPCBWR-14-29 genotypes were earliest in flowering and picking. Besides, most of the resistant and top yielders genotypes were also green in fruit colour, pendent in fruit position, blocky in fruit shape, cordate at pedicel and sunken at blossom end. Therefore, from this study, it has been summarized that these genotypes could be utilized in hybridization programmes or could be directly released as a variety after preliminary and multi-location yield trials for commercial release.

Keywords: Bacterial wilt; *Capsicum annuum* L. var. *grossum* Sendt.; earliness; morphological traits; yield

1. INTRODUCTION

Bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.; $2n=24$) is the second most important Solanaceous vegetable after tomato. It grows well in tropical, subtropical, and sub-temperate climates all over the world. In India, this vegetable was brought by British people during 19th century and was grown first time in Shimla hills, earning it the nickname "Shimla Mirch" [1]. Besides this, it is also famous among people as sweet pepper or pepper or capsicum. Bell pepper is one of the most potential off-season vegetables of mid hill zone of Himachal Pradesh [2] and is generally grown during summer-rainy season. Being off-season vegetable, crop fetches very high prices in plains and generates cash revenues to the farmers of North-Western hills [3]. However, bell pepper yield potential and overall production are low because of low yielding cultivars and increased frequency of diseases and insect-pests in lower and mid-hill

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pockets. Among diseases, bacterial wilt is the most common soil borne disease of sweet peppers causes upto 100 per cent yield losses in hot and humid tropics, sub-tropics and sub-temperate areas at 30-35°C [4]. The pathogen involved is '*Ralstoniasolanacearum*'. The disease is called as 'Green wilt' in some regions because the infected plant's leaves remain green until the signs of wilt appear [5,6]. In low and mid hill zones of Himachal Pradesh, it is the major limiting factor in profitable cultivation of bell pepper. Initially, this disease has been reported from traditional bell pepper growing areas viz., Solan and Kullu valley but gradually, it is spreading to other districts like Bilaspur, Kangra and Hamirpur. Bacterial wilt is also an important disease in other states like Karnataka, Kerala, Odisha, Bihar, Maharashtra, Sikkim, West Bengal and Andaman and Nicobar islands [7]. The existing cultivars/varieties lack resistance to bacterial wilt due to unavailability of stable resistance source in bell pepper [8]. The chemical control measures and manipulation of agrochemical practices have been applied but none of them found effective to control this disease. Therefore, improved disease resistant varieties must be identified and developed to increase the yield potential of bell pepper. Further, earliness is a very desirable characteristic in all vegetables as the market value of early crop is generally high and produce fetches high prices in market. Early maturing strains hold extensive importance in procuring early markets [8]. The morphological characterization of bell pepper germplasm is the foremost step for beginning any improvement scheme, and it is still utilized in places where the capacity to use molecular markers to carry out in situ analysis is not yet completely developed. On the basis of phenotype or visual appearance, morphological descriptors form the base of characterization of genotypes. These are also equally important to genotypic, biochemical and molecular characterization of collected germplasm. Hence, the present study was undertaken on 43 genotypes including one susceptible, one moderately resistant and two resistant checks to measure the extent of genetic variability for bacterial wilt resistance, earliness and morphological characters in bell pepper.

2. MATERIAL AND METHODS

In the year 2003, lines resistant to bacterial wilt were brought from World Vegetable Center (WVC), Taiwan to CSKHPKV, Palampur. They were screened *in vivo* and *in vitro* for six seasons and after that two accessions viz., EC-464107 and EC-464115 resistant to bacterial wilt were selected. To introgress resistance gene into indigenous cultivars, these resistant accessions were then crossed to Kandaghat Selection and Sweet Happy-1 followed by backcross breeding [9]. The best lines were picked up in 2013 from F₂ and BC₅F₂ and subjected to repeated selfing. In 2018 and 2019, we evaluated 39 (F₇ and F₈ progenies) genotypes tolerant to bacterial wilt disease along with four checks viz., California Wonder (susceptible check), Kandaghat Selection (moderately resistant check), and EC-464107 and EC-464115 (resistant checks) as shown in figure 1 at research farm of Department of Vegetable Science and Floriculture, CSK HPKV, Palampur (HP) for bacterial wilt resistance, earliness and morphological characterization under natural sick field conditions in three replications using Randomized Complete Block Design (RCBD) at 60 × 45 cm spacing. California Wonder was planted at each tenth row for ensuring homogeneity in disease inoculum. For bacterial wilt incidence, observations were recorded at regular intervals on every plant of all replications. For confirmation of bacterial wilt, ooze test was performed on all the infected plants after 90 days of transplanting and plant survival (%) rate was calculated from the recorded data. On the basis of incidence, the genotypes were classified into four different categories viz., susceptible (>60%), susceptible (>60 %), moderately resistant (20-40%) and resistant (< 20%) [10]. Formula of plant survival (%) is as under:

$$\text{Plant survival (\%)} = \frac{\text{Number of healthy plants 90 days after transplanting}}{\text{Number of established plants}} \times 100$$

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*In 2018 and 2019, the researchers evaluated the 39 (F₇ and F₈ progenies) genotypes tolerant to bacterial wilt disease along with four checks viz., California Wonder (susceptible check), Kandaghat Selection (moderately resistant check), and EC-464107 and EC-464115 (resistant checks) (**Fig. 1**) at the research farm of the Department of Vegetable Science and Floriculture, CSK HPKV, Palampur (HP), for bacterial wilt resistance, earliness and morphological characterization under natural sick field conditions in three replications using Randomized Complete Block Design (RCBD) at 60 × 45 cm spacing.

*Please include in the Materials and Methods the following:
 - the total experimental area, block measurement, distance between plots, and number of plants per plot from which the sample plants were taken. Consider presenting the layout for the study.
 - describe the experimental site as to location, weather, and soil conditions. Explain the **sick field condition** as mentioned in this section.
 - Was the research conducted in six consecutive seasons? Kindly describe the seasons when the study was conducted.

*Verification on the number of genotypes tested. There were 43 genotypes mentioned in the Introduction but 39 in the abstract and materials and methods. Please consider the genotypes as presented in Table 1.

*Discuss the crop cultivation practices used in the research, including seedling preparation, nutrient management, water management, weed management and pest and disease management.

*Please include the statistical tools used to analyse the data and the significance level being considered.

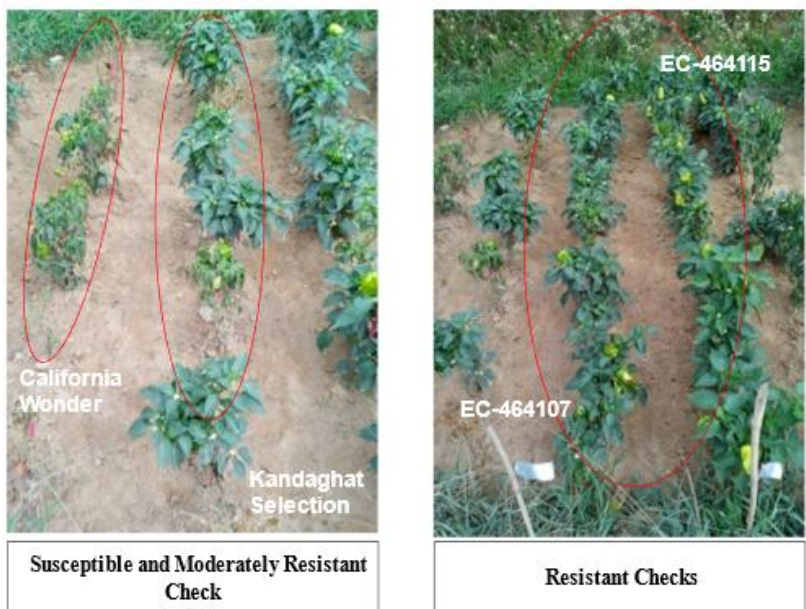


Fig. 1: Disease reaction of checks used in the study

Along with resistance, observations were also recorded on days to 50 per cent flowering, days to first harvesting, marketable fruit yield per plant and morphological traits viz., overall fruit shape (Fig. 2), fruit shape at pedicel and blossom end (Fig.3&4), and fruit position (Fig.5) on randomly preferred five plants in each replication at horticultural maturity. Morphological traits were reported in accordance with the descriptor [11]. On the basis of colour, the fruits were divided into two groups (green group; GG and yellow green group; YGG) and compared to Royal Horticultural Society (RHS) colour chart. Each descriptor's frequency distribution was determined once the genotypes were characterized.

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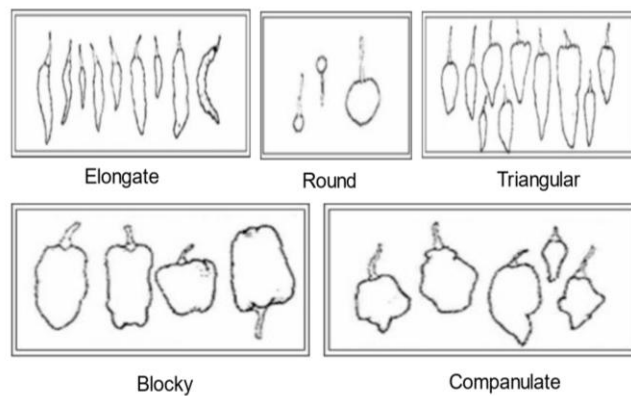


Fig. 2: Fruit shape

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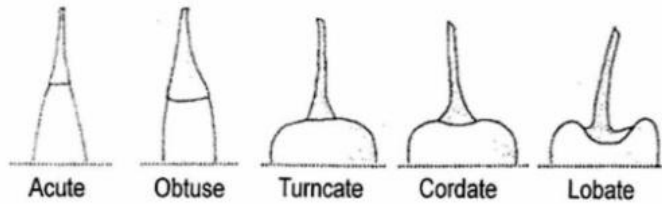


Fig.3: Fruit shape at pedicel end

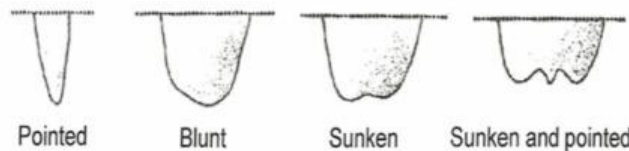


Fig.4: Fruit shape at blossom end



Fig. 5: Fruit position

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3. RESULTS

Experimental results unveiled the presence of sufficient genetic variability for all attributes among genotypes. A high resistance level was reported in genotypes along with resistant checks. The genotypes DPCBWR-14-6-1 and DPCBWR-14-7 have the maximum plant survival (99.17 % and 99.13 %, respectively) and found statistically *at par* with L-22 (97.67 %), DPCBWR-14-31 (97.67 %) and DPCBWR-14-16 (97.67 %) (Table1). All the resistant checks *viz.*, EC464107 and EC414115 gave 100 per cent plant survival and susceptible check *viz.*, California Wonder gave quite low plant survival (7.50 %). In the genotypes studied, the minimum plant survival was recorded in DPCBWR-14-14 (37.25 %). The range for this trait varied from 7.50 to 99.38 %.

Out of 39 genotypes evaluated, genotype DPCBWR-14-39 (35.05 days) recorded minimum number of days to 50 per cent flowering and was found to be statistically *at par* with genotype DPCBWR-14-32 (35.55 days) followed by DPCBWR-14-29 (37.22 days) and then DPCBWR-14-7 (38.22 days). These genotypes were also significantly superior to the check. The range for this trait varied from 35.05 to 48.55 days. Data pertaining to days to first harvesting showed that genotype DPCBWR-14-29 was the earliest (51.55 days) and was statistically *at par* with DPCBWR-14-39 (52.55 days). As many as 15 genotypes were

significantly superior to susceptible check including EC-464107, EC-464115 and Kandaghat Selection. The character ranged between 51.55 to 69.55 days. In every crop improvement programme, higher fruit yield is the fundamental objective. Perusal of result in Table 1 revealed that DPCBWR-14-39 (546.94 g) produced highest marketable fruit yield per plant escorted by genotype DPCBWR-14-36 (515.80 g) and then DPCBWR-14-2 (454.43 g). DPCBWR-14-36 was statistically *at par* with DPCBWR-14-39. Whereas, California Wonder was the lowest yielder (95.82 g). The range for this trait varied from 95.82 to 546.94 g per plant. From commercial point of view, in Table 1, marketable fruit yield per plant of different genotypes is also presented in q/ha.

Fruit colour is an important visual character because it adds aesthetic value to the produce and attracts consumers. In Indian market, green to dark green fruits are generally preferred as consumers are not much aware about coloured bell peppers. From this study, we have recorded green (GG) and yellow green (YGG) colour intensities in tested genotypes (Table 2). 27 genotypes *viz.*, DPCBWR-14-1, DPCBWR-14-2, DPCBWR-14-4, DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-13, DPCBWR-14-14, DPCBWR-14-15, DPCBWR-14-17, DPCBWR-14-22, DPCBWR-14-23, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-25, DPCBWR-14-28, DPCBWR-14-29, DPCBWR-14-30, DPCBWR-14-31, DPCBWR-14-32, DPCBWR-14-35, DPCBWR-14-38, DPCBWR-14-39, DPCBWR-14-40, L-22, L-4 along with checks (Kandaghat Selection and California Wonder) had shown green colour intensity, whereas all other genotypes produced yellow green fruits (Fig. 6). Further, the shape of the fruit is extremely important quality trait in peppers which is considered as key attribute to classify the different fruit types. Generally, blocky fruits are preferred by the consumers. All the genotypes were blocky in fruit shape (Table 2). Cordate and truncate fruit shapes at pedicel end are generally preferred, whereas lobate fruit shape is not desirable because water get accumulated at pedicel end which leads to fruit rot. Cordate fruit shape was noticed in most of the genotypes, whereas DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-6, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-28, DPCBWR-14-31, DPCBWR-14-40, and California Wonder had lobate fruit shape at pedicel end. Majority of genotypes were sunken at blossom end, while DPCBWR-14-5, DPCBWR-14-14, DPCBWR-14-23, DPCBWR-14-24, DPCBWR-14-39 and EC-464115 were sunken and pointed at blossom end. DPCBWR-14-4 was the only genotype categorized with blunt blossom end. Pendent fruit position was

noticed in most of the genotypes, whereas DPCBWR-14-6, DPCBWR-14-6-1, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-24-1, DPCBWR-14-39 and DPCBWR-14-40 had intermediate fruit position, and DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-22, DPCBWR-14-24, DPCBWR-14-35, DPCBWR-14-36, EC-464107 and EC-464115 were upright in fruit position (Table 2).

4. DISCUSSION

Above mentioned information reveals the existence of considerable scope for identifying excellent genotypes in the parent material as significant differences were existed for all the traits. Many of the characters investigated in bell pepper had previously been demonstrated to have sufficient genetic diversity by Ahmed *et al.*, Afroza *et al.* and Sharma *et al.*[12,13, 2]. Except for DPCBWR-14-14, all genotypes were determined to be resistant or moderately resistant to bacterial wilt disease. Sood and Kumar and Devi *et al.*[14, 9] found similar results for disease resistance using different material. Early flowering and early harvesting decide whether a variety will come early in the market or not and as a result help farmers to fetch high price for their produce in markets. On the basis of mean performance, genotypes DPCBWR-14-39, DPCBWR-14-32, DPCBWR-14-29 and DPCBWR-14-7 were earliest in 50 per cent flowering and genotypes *viz.*, DPCBWR-14-29 and DPCBWR-14-39 in days to first harvesting. Sood *et al.* and Afroza *et al.*[15, 13] found comparable results for these traits. DPCBWR-14-39, DPCBWR-14-36, DPCBWR-14-2, DPCBWR-14-35, and DPCBWR-14-29 (Table 1) were the top highest yielders, and these genotypes were also among top for other contributing characters *viz.*, days to 50 per cent flowering, days to first harvesting and plant survival (Table 1). Similar findings with different breeding material were also observed by Ahmed *et al.*[12].

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Table 1. Mean values of bell pepper genotypes for different traits over pooled environment

Genotypes	Source	PS (%)	BWI (%)	RC	DFP	DFP	MFYPP (g)	MFY (q/ha)
		2018-19	2018-19	2018-19	2018-19	2018-19	2018-19	2018-19
DPCBWR-14-1	CSKHPKV, Palampur	93.50	6.50	Resistant	42.55	58.55	325.55	94.40
DPCBWR-14-2	-do-	87.25	12.75	Resistant	39.88	54.55	454.43	131.78
DPCBWR-14-3	-do-	91.42	8.58	Resistant	41.88	64.55	347.91	100.89
DPCBWR-14-4	-do-	85.17	14.83	Resistant	40.55	54.55	227.98	66.11
DPCBWR-14-5	-do-	85.17	14.83	Resistant	41.55	64.72	251.86	73.03
DPCBWR-14-5-1	-do-	95.58	4.42	Resistant	44.88	59.72	245.93	71.31
DPCBWR-14-6	-do-	93.50	6.50	Resistant	41.55	54.55	412.11	119.51
DPCBWR-14-6-1	-do-	99.17	0.84	Resistant	38.55	62.55	232.05	67.29
DPCBWR-14-7	-do-	99.13	0.88	Resistant	38.22	56.96	365.88	106.10
DPCBWR-14-7-1	-do-	91.42	8.08	Resistant	40.55	56.96	237.82	68.96
DPCBWR-14-8-1	-do-	93.50	6.50	Resistant	41.55	56.96	367.75	106.64
DPCBWR-14-9	-do-	87.25	12.75	Resistant	45.88	56.96	255.18	74.00
DPCBWR-14-10	-do-	76.83	23.17	Moderately Resistant	44.88	56.96	317.24	91.99
DPCBWR-14-11	-do-	85.17	14.83	Resistant	43.55	56.96	336.87	97.69
DPCBWR-14-11(BS)	-do-	76.83	23.17	Moderately Resistant	45.55	56.96	278.82	80.85
DPCBWR-14-12	-do-	97.08	4.42	Resistant	43.55	61.55	296.80	86.07
DPCBWR-14-13	-do-	80.05	19.95	Resistant	41.55	55.55	402.52	116.73
DPCBWR-14-14	-do-	37.25	62.75	Moderately Susceptible	43.88	56.96	355.83	103.19
DPCBWR-14-15	-do-	93.50	6.50	Resistant	42.88	56.96	376.83	109.28
DPCBWR-14-16	-do-	97.67	2.33	Resistant	48.55	56.96	319.88	92.76
DPCBWR-14-17	-do-	87.25	12.75	Resistant	42.22	54.55	307.17	89.07
DPCBWR-14-20	-do-	87.25	12.75	Resistant	48.22	54.55	301.07	87.31
DPCBWR-14-22	-do-	95.58	4.42	Resistant	46.88	69.55	305.33	88.54
DPCBWR-14-23	-do-	76.83	23.17	Moderately Resistant	43.22	56.96	364.01	105.56
DPCBWR-14-24	-do-	93.50	6.50	Resistant	41.55	54.55	316.11	91.67
DPCBWR-14-24-1	-do-	95.58	4.42	Resistant	44.88	54.55	398.87	115.67
DPCBWR-14-25	-do-	62.25	37.75	Moderately Resistant	42.55	56.96	359.93	104.37
DPCBWR-14-28	-do-	95.58	4.42	Resistant	43.22	56.96	310.86	90.14
DPCBWR-14-29	-do-	93.50	6.50	Resistant	37.22	51.55	426.99	123.82
DPCBWR-14-30	-do-	89.33	10.67	Resistant	46.22	54.55	391.08	113.41
DPCBWR-14-31	-do-	97.67	2.33	Resistant	43.88	54.55	399.79	115.93
DPCBWR-14-32	-do-	95.58	4.42	Resistant	35.55	64.55	395.80	114.78
DPCBWR-14-35	-do-	85.17	14.83	Resistant	42.88	66.96	429.84	124.65
DPCBWR-14-36	-do-	87.25	12.75	Resistant	43.55	56.96	515.80	149.58

DPCBWR-14-38	-do-	65.34	34.66	Moderately Resistant	42.55	60.72	268.43	77.84
DPCBWR-14-39	-do-	93.50	6.50	Resistant	35.05	52.55	546.94	158.61
DPCBWR-14-40	-do-	93.50	6.50	Resistant	41.88	54.55	386.17	111.98
L-22	-do-	97.67	2.33	Resistant	47.55	60.72	385.18	111.70
L-4	-do-	95.58	4.42	Resistant	42.55	61.96	259.00	75.11
EC-464107	WVC, Taiwan	100.00	0.00	Resistant	42.55	54.55	344.00	99.76
EC-464115	WVC, Taiwan	100.00	0.00	Resistant	43.88	54.55	298.22	86.48
Kandaghat Selection	RRS, Kandaghat, UHF, Solan	93.50	6.50	Resistant	45.22	54.55	343.02	99.47
California Wonder	IARI, Res Stn, Katrain	7.50	92.50	Susceptible	41.88	56.96	95.82	27.78
SE(m)±		1.12			1.18	0.56	11.08	
SE(d)±		1.58			1.67	0.79	15.67	
C.V. (%)		2.22			4.79	1.68	5.67	
C.D. (P ≤ 0.05)		3.14			3.33	1.57	31.21	
Range		7.50-99.38			35.05-48.55	51.55-69.55	95.82-546.94	

*PS = Plant survival; BWI = Bacterial wilt incidence; RC = Reaction category; DFF = Days to 50 per cent flowering; DFP = Days to first harvesting, MFYPP = Marketable fruit yield per plant; MFY = Marketable fruit yield



Fig.6: Variability among genotypes of bell pepper for fruit colour

Comment [Ma10]: *Fig. 6: Fruit colour variability among bell pepper genotypes

Attractive green to dark green fruit colour, blocky fruit shape and upright/intermediate fruit position are the preferable horticultural attributes from purchaser's point of view. Appealing fruit colour, desirable fruit shape and position are the most important quality factors. Green and blocky fruits are preferred by consumers, and these observations frequently provide preconceived ideas about other quality attributes. Excluding DPCBWR-14-3, DPCBWR-14-6, DPCBWR-14-6-1, DPCBWR-14-7, DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-12, DPCBWR-14-13, DPCBWR-14-16, DPCBWR-14-20, DPCBWR-14-36, EC-464107 and EC-464115, all other genotypes had green fruit colour at immature fruit stage (Fig.5 and Table 2). All genotypes were blocky in fruit shape. The genotypes DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-22, DPCBWR-14-24, DPCBWR-14-35, DPCBWR-14-36, EC-464107 and EC-464115 showed upright fruit position while rest of them had pendent and intermediate fruit position. All the genotypes showed cordate fruit shape at pedicel end while rest of the genotypes had lobate fruit shape (DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-6, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-28, DPCBWR-14-31, DPCBWR-14-40 and California Wonder). For fetching crop during rainy season, upright fruit position is generally preferred, whereas lobate fruit shape with pendent fruit position is not desirable as stagnation of rainwater at pedicel area generally enhances rotting. Genotypes DPCBWR-14-5, DPCBWR-14-14, DPCBWR-14-23, DPCBWR-14-24, DPCBWR-14-39 and EC-464115 showed sunken and pointed blossom end fruit shape while rest of them had sunken fruit shape except DPCBWR-14-4 (blunt fruit shape at blossom end) (Table 2). Variability for visual characters in bell pepper also reported by Sood and Kumar, Sattar *et al.*, Sharma *et al.* and Ferdousi *et al.* [16-19].

Table 2. Frequency distribution of 43 genotypes of bell pepper based on morphological traits

Sr. No.	Traits	Category (Minimal Descriptors)	Total Genotypes	Genotypes
1.	Fruit colour (RHSCC)	GG(137A)	8	DPCBWR-14-2, DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-17, DPCBWR-14-23, DPCBWR-14-31, DPCBWR-14-32, DPCBWR-14-39
		GG(137B)	11	DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-14, DPCBWR-14-15, DPCBWR-14-22, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-25, DPCBWR-14-40, Kandaghat Selection, California Wonder
		GG(137C)	3	DPCBWR-14-4, DPCBWR-14-35, DPCBWR-14-38
		GG(137D)	1	DPCBWR-14-1
		GG(143A)	6	L-22, L-4, DPCBWR-14-13, DPCBWR-14-28, DPCBWR-14-29, DPCBWR-14-30
		YGG(144A)	8	DPCBWR-14-3, DPCBWR-14-6-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-12, DPCBWR-14-16, DPCBWR-14-20
		YGG(144B)	3	DPCBWR-14-6, DPCBWR-14-7, DPCBWR-14-7-1
		YGG(146A)	1	DPCBWR-14-36
		YGG (150C)	1	EC-464115
		YGG (151A)	1	EC-464107
		2.	Fruit shape	Blocky
3.	Fruit shape at pedicel end	4	27	DPCBWR-14-1, DPCBWR-14-2, DPCBWR-14-3, DPCBWR-14-4, DPCBWR-14-6-1, DPCBWR-14-7, DPCBWR-14-7-1, DPCBWR-14-12, DPCBWR-14-13, DPCBWR-14-14, DPCBWR-14-15, DPCBWR-14-16, DPCBWR-14-22, DPCBWR-14-23, DPCBWR-14-25, DPCBWR-14-29, DPCBWR-14-30, DPCBWR-14-32, DPCBWR-14-35, DPCBWR-14-36, DPCBWR-14-38, DPCBWR-14-39, L-22, L-4, EC-464107, EC-464115, Kandaghat Selection
		5	16	DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-6, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-24, DPCBWR-14-24-1, DPCBWR-14-28, DPCBWR-14-31, DPCBWR-14-40, California Wonder
4.		2	1	DPCBWR-14-4

Sr. No.	Traits	Category (Minimal Descriptors)	Total Genotypes	Genotypes
	Fruit shape at blossom end	3	36	DPCBWR-14-1, DPCBWR-14-2, DPCBWR-14-3, DPCBWR-14-5-1, DPCBWR-14-6, DPCBWR-14-6-1, DPCBWR-14-7, DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-11 (BS), DPCBWR-14-12, DPCBWR-14-13, DPCBWR-14-15, DPCBWR-14-16, DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-22, DPCBWR-14-24-1, DPCBWR-14-25, DPCBWR-14-28, DPCBWR-14-29, DPCBWR-14-30, DPCBWR-14-31, DPCBWR-14-32, DPCBWR-14-35, DPCBWR-14-36, DPCBWR-14-38, DPCBWR-14-40, L-22, L-4, EC-464107, , Kandaghat Selection, California Wonder
		4	6	DPCBWR-14-5, DPCBWR-14-14, DPCBWR-14-23, DPCBWR-14-24, DPCBWR-14-39, EC-464115
5.	Fruit position	3	27	DPCBWR-14-1, DPCBWR-14-2, DPCBWR-14-3, DPCBWR-14-4, DPCBWR-14-5, DPCBWR-14-5-1, DPCBWR-14-7, DPCBWR-14-11 (BS), DPCBWR-14-12, DPCBWR-14-13, DPCBWR-14-14, DPCBWR-14-15, DPCBWR-14-16, DPCBWR-14-17, DPCBWR-14-20, DPCBWR-14-23, DPCBWR-14-25, DPCBWR-14-28, DPCBWR-14-29, DPCBWR-14-30, DPCBWR-14-31, DPCBWR-14-32, DPCBWR-14-38, L-22, L-4, Kandaghat Selection, California Wonder
		5	7	DPCBWR-14-6, DPCBWR-14-6-1, DPCBWR-14-10, DPCBWR-14-11, DPCBWR-14-24-1, DPCBWR-14-39, DPCBWR-14-40
		7	9	DPCBWR-14-7-1, DPCBWR-14-8-1, DPCBWR-14-9, DPCBWR-14-22, DPCBWR-14-24, DPCBWR-14-35, DPCBWR-14-36, EC-464107, EC-464115

*Royal Horticultural Society Colour Charts (RHSCC): GG = green group, YGG = yellow green group
#Minimal descriptors; Fruit shapes at pedicel end: 3- truncate, 4-cordate, 5- lobate, Fruit shapes at blossom end: 2- blunt, 3- sunken, 4-sunken and pointed
Fruit positions: 3- pendent, 5- intermediate, 7-upright

5. CONCLUSION

The genotypes of bell pepper had wide variations for bacterial wilt resistance, morphological characters (fruit colour, fruit shape, fruit shape at pedicel and blossom end, and fruit position), earliness (days to 50 per cent flowering and first harvesting) and fruit yield. Except for DPCBWR-14-14, all genotypes were identified to be resistant or moderately resistant to bacterial wilt disease. Among the top five high yielding genotypes, all showed green fruit colour, pendent fruit position, blocky fruit shape, cordate fruit shape at pedicel and sunken fruit shape at blossom end with few exceptions including DPCBWR-14-36 (YGG); DPCBWR-14-39 (intermediate fruit position); DPCBWR-14-35 and DPCBWR-14-36 (upright fruit position) and DPCBWR-14-39 (sunken and pointed blossom end fruit shape). The genotypes DPCBWR-14-39 and DPCBWR-14-29 also took fewer days to 50 per cent flowering and days to first harvesting. Hence, for future hybridization programme, they can be used as better parents or released as a variety after multi-location testing because they have a high yielding ability as well as bacterial wilt resistance and advantageous morphological characteristics.

REFERENCES

1. Anuradha, Sood S. Path analysis identify indirect selection criteria for fruit yield in bacterial wilt tolerant genotypes of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.). International Journal of Chemical Studies. 2019; 7(4): 2376-2382.
2. Sharma VK, Punetha S, Sharma BB. Heterosis studies for earliness, fruit yield and yield attributing traits in bell pepper. African Journal of Agricultural Research. 2013 Aug 1; 8(29):4088-98.
3. Devi J, Sood S, Sagar V. Deciphering genetics of bell pepper for agro-morphological and quality traits through generation mean analysis. Indian Journal of Horticulture. 2019; 76(4):645-52.
4. Assefa M, Dawit W, Lencho A, Hunduma T. Assessment of wilt intensity and identification of causal fungal and bacterial pathogens on hot pepper (*Capsicum annuum* L.) in Bako Tibbe and Nonno districts of West Shewa zone, Ethiopia. International Journal of Phytopathology. 2015 May 2; 4(1):21-8.
5. Jiang G, Wei Z, Xu J, Chen H, Zhang Y, She X, Macho AP, Ding W, Liao B. Bacterial wilt in China: history, current status, and future perspectives. Frontiers in Plant Science. 2017 Sep 11; 8:1549.
6. Mamphogoro TP, Babalola OO, Aiyegoro OA. Sustainable management strategies for bacterial wilt of sweet peppers (*Capsicum annuum*) and other Solanaceous crops. Journal of Applied Microbiology. 2020 Sep 1; 129(3):496-508.
7. Anuradha, Sood S. Genetic assessment for fruit yield and horticultural traits in bacterial wilt tolerant genotypes of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.). International Journal of Current Microbiology and Applied Sciences. 2019; 8(08): 872-888. doi: <https://doi.org/10.20546/ijcmas.2019.808.101>
8. Anuradha, Sood, S, Sood, T. Over environments evaluation of bell pepper hybrids developed through modified triple test cross mating design for earliness, yield and quality under North-Western Himalayas. Vegetable Science. 2023; 50(1): 23-32.

9. Devi J, Sonia S, Vidyasagar V, Yudhvir S. Inheritance of bacterial wilt resistance and performance of horticultural traits in bell pepper (*Capsicum annuum* var. *grossum*). Indian Journal of Agricultural Sciences. 2015; 85(11):1498-503.
10. Mew TW, Ho WC. Varietal resistance to bacterial wilt in tomato. Plant Disease Reporter. 1976 Jan 1; 60(3):204-8.
11. Srivastava U, Mahajan RK, Gangopadyay KK, Singh M, Dhillon BS. Minimal descriptors of Agri-Horticultural crops. Part-II: *Veg Crops* NBPGR, New Delhi. 2001. pp 181-184.
12. Ahmed N, Singh SR, Lal S, Mir KA. Genetic variability in bell pepper (*Capsicum annum* L.) under high altitude temperate environment. Indian Journal of Plant Genetic Resources. 2012; 25(3):304-6.
13. Afroza B, Khan SH, Mushtaq F, Hussain K, Nabi A. Variability and correlation studies in sweet pepper (*Capsicum annum* L.). Progressive Horticulture. 2013; 45(1):209-13.
14. Sood S, Kumar N, Vidyasagarand SY. Heterosis of bacterial wilt (*Pseudomonas solanacearum*) resistance, yield and related traits in bell pepper (*Capsicum annum* L. var. *grossum*Sendt.). Breakthroughs in the Genetics and Breeding of Capsicum and Eggplant. 2013 Nov 1:455.
15. Sood S, Kumar N, Chandel KS, Sharma P. Determination of genetic variation for morphological and yield traits in bell pepper (*Capsicum annum* var. *grossum*). Indian Journal of Agricultural Sciences. 2011;81: 590-594.
16. Sood S, Kumar N. Morphological studies of bell pepper germplasm. International journal of vegetable science. 2011 Apr 14; 17(2):144-56.
17. Sattar MA, Islam MN, Hossain MJ, Bhuiyan MSR, Hossain MI. Characterization of sweet pepper genotypes by using morphological traits. Scientific Research. 2015; 3: 304-313.
18. Sharma V, Sood S, Sood VK, Singh Y. Morphological characterization of Bell Pepper (*Capsicum annum* L. var. *grossum*Sendt.) genotypes. Himachal Journal of Agricultural Research. 2017 Jun 1; 43(1):33-9.
19. Ferdousi J, Zakaria M, Hoque MA, Saha SR, Ivy NA, Hossain MI. Morphological Characterization of Twenty One Sweet Pepper (*Capsicum annum* L.) Genotypes Collected from Native and Alien Sources. European Journal of Biology and Biotechnology. 2021 Sep 4; 2(5):1-8.