Impact of training system and fruit load on seed yield, quality and economics of seed production in bell pepper (*Capsicum annuum* L)

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ABSTRACT

Effect of training system and fruit load was studied on seed yield, quality and economics of capsicum using cv Solan Bharpur in the Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during kharif season of 2018. The experiment was laid out in randomized block design (factorial) in the open field and in completely randomized design (factorial) in the laboratory. The treatment combination Tr_2FL_2 (Two-stem training with ten fruits/plant) proved superior in terms of number of seeds/fruit (187.77), 1,000-seed weight (6.21 g), germination (96.50%), speed of germination (15.95), seed vigour index-I (1,448.30), seed vigour index-II (284.77) and electrical conductivity of seeds (0.060 dS/m). However in terms of number of ripe fruits/plant (12.13), ripe fruit yield/plant (0.58 kg), seed yield/plant (10.34 g) and seed yield/hectare (306.22 kg), control treatment gave better results. Maximum B-C ratio (6.03:1) was obtained in treatment combination Tr_1FL_1 (No training and all fruits retained) followed by Tr_2FL_2 (5.23:1) which favoured all the seed quality characters. Therefore Tr_2FL_2 treatment combination can be recommended for quality seed production of bell pepper under mid-hills of Himachal Pradesh.

Keywords: Bell pepper; training system; fruit load; seed; yield; quality; economics

INTRODUCTION

Bull nose capsicum or Shimla mirch or sweet pepper or bell pepper (*Capsicum annuum* L var *grossum* Sendt) is among important vegetable crops cultivated in different regions of India. Britishers introduced it in 19th Century in Shimla, Himachal Pradesh and Nilgiri hills of Tamil Nadu (Greenleaf 1986). The Indian states like Andhra Pradesh, Himachal Pradesh, Karnataka, Maharashtra, Orissa and Tamil Nadu account for more than 75 per cent of the area and total production of bell pepper.

Capsicum is a cool season crop but it can be grown round the year using protected structures where temperature and relative humidity can be manipulated. The crop requires day temperature of 25-30°C and night temperature of 18-20°C with relative humidity of 50-60 per cent. If temperature exceeds 35°C or falls below 12°C, fruit setting is affected. Himachal Pradesh is a leading supplier of bell pepper fruits to the plains during summer and rainy seasons by using protected cultivation. The produce in off-season to the plains fetches a higher price to vegetable growers of the state.

Bell pepper is rich in vitamin A (8,493 IU), vitamin C (283 mg) and minerals like calcium (13.4 mg), magnesium (14.9 mg), phosphorus (28.3 mg) and potassium (263.7 mg) per 100 g fresh weight (Athulya and Vethamoni 2018). Capsicum also finds place in preparations like pizza stuffings and burger with growing popularity of fast food. The high market price is attributed to the heavy demand from the urban consumers.

Seed quality is very important aspect of any seed producing programme. Farmers generally lack quality seed to get higher yield. There are various techniques and methods to enhance the quality of seed in capsicum. One of the simple methods is use of

different combinations of training system and fruit load. Guo et al (1991) reported higher sweet pepper yields in 2-stem trained plants at 4.5 plants/m^2 than in 4-stem plants at 2.25 plants/m^2. Lal (2013) studied the effect of spacing and training levels on seed yield of capsicum and observed that planting density 45 cm x 30 cm in combination with two-shoot training system can be recommended for commercial seed production of bell pepper.

Nabi et al (2009) observed that retaining 1st six fruits/plant in capsicum increased seed germination, 1,000-seed weight and seedling vigour indices (both I and II). Tabasi et al (2011) studied the effect of cultivar, shrub pruning and fruit thinning on qualitative and quantitative characteristics of tomato (seed and seedling). Each tomato cultivar was fruit-thinned to three different levels (4, 5 and 6 fruits per plant). The results showed that all treatments had significant influence on 1,000-seed weight and germination but shrub pruning did not affect the germination of seeds. Lakshmi et al (2015) studied apical bud pinching and application of growth retardant maleichydrzide to enhance seed yield in fenugreek. Seed quality attributes like germination (95.40%), seedling vigour index-I (2,271), seedling vigour index-II (1,584) and field emergence (87.20%) were superior in seeds obtained from pinched plants with lower electrical conductivity (126 dS/m). Therefore apical pinching could be advocated to fenugreek in order to obtain higher seed yield with better quality. Maboko et al (2012) investigated the effect of plant population and flower and stem pruning of hydroponically grown peppers and concluded that quality can be effectively manipulated by plant population and stem pruning while flower pruning had insignificant ($p < 0.05$) effect.

MATERIAL and METHODS

The experiment was laid down on 1 May 2018 at the experimental farm of the Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh located at an altitude of 1,250 m amsl with latitude of 35.50° N and longitude of 77.80° E in the mid-hill zone of Himachal Pradesh. Bell pepper cv Solan Bharpur seedlings were transplanted in a randomized block design (factorial) comprising twelve treatment combinations replicated thrice. The seeds harvested were tested for quality parameters in laboratory using completely randomized design (factorial) with the same set of treatment combinations replicated four times.

Different combinations of training systems and fruit load (Tr_1FL_1: No training and all fruits retained, Tr_1FL_2: No training and 10 fruits retained/plant, Tr_1FL_3: No training and 12 fruits retained/plant, Tr_1FL_4: No training and 14 fruits retained/plant, Tr_2FL_1: Two-shoot training and all fruits retained, Tr_2FL_2: Two-shoot training and 10 fruits retained/plant, Tr_2FL_3: Two-shoot training and 12 fruits retained/plant, Tr_2FL_4: Two-shoot training and 14 fruits retained/plant, Tr_3FL_1: Four-shoot training and all fruits retained, Tr_3FL_2: Four-shoot training and 10 fruits retained/plant, Tr_3FL_3: Four-shoot training and 12 fruits retained/plant, Tr_4FL_4: Four-shoot training and 14 fruits retained/plant) were used in the study.

On plot basis, observations recorded were number of ripe fruits/plant, ripe fruit yield/plant (kg), seed yield/plant (g), seed yield/hectare (kg) and number of seeds/fruit determined on freshly harvested fruits from the healthy plants. Three replications were used in each case. 1,000-seed weight (g), germination (%), speed of germination, seed vigour index-I, seed vigour index-II and electrical conductivity were determined after drying the seed to moisture content of <8 per cent as per the ISTA guidelines (Anon 1985). Ultimately seed benefit-cost ratio was determined for different treatment combination @ Rs 4,000/kg. In case of laboratory experiment, 400 seeds in the form of four replications were used for each treatment (Anon 2017).

Seed yield/plot was worked out by weighing the total seed yield from all the plants in a plot. Seed yield/hectare was worked out on the basis of seed obtained per m^2 as under:

$$\text{Seed yield/ha (kg)} = \frac{\text{Seed yield/m}^2\text{ (g)} \times 10{,}000 \times 0.8}{1{,}000}$$

While calculating the seed yield per hectare, twenty per cent area was considered as depreciation for construction of channels and paths, where:

$$\text{Seed yield/m}^2\text{ (g)} = \frac{\text{Seed yield/plot}}{\text{Size of plot}}$$

Germination was calculated by using the formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used}} \times 100$$

Speed of germination was calculated as:

$$\text{Speed of germination} = \frac{\text{Sum of number of normal seedlings emerging on day 'd'}}{\text{Days after planting}}$$

Speed of germination was measured by using top of the paper method.

Seed vigour index-I and index-II were calculated as per the formulae given by Abdul-Baki and Anderson (1973) as:

$$\text{Seed vigour index-I} = \text{Germination (\%)} \times \text{Seedling length (cm)}$$

$$\text{Seed vigour index-II} = \text{Germination (\%)} \times \text{Seedling dry weight (mg)}$$

The measurement of electrical conductivity (EC) of the leachate by conductivity meter gives an accurate estimation of membrane permeability. EC was calculated using the formula:

$$\text{Actual EC of seed sample (dS/m)} = \text{EC of leachate} - \text{EC of distilled water}$$

Benefit-cost (B-C) ratio of project was calculated by using relationship:

$$\text{B-C ratio} = \frac{\text{Benefit expected from the project}}{\text{Cost of the project}} \times 100$$

Statistical analysis was done as per experimental design suggested by Panse and Sukhatme (1967).

RESULTS and DISCUSSION

Fruit and seed yield parameters

All observations pertaining to number of ripe fruits are shown in Table 1. Significantly maximum (9.90) number of ripe fruits was obtained in case of Tr_1 (No training) and minimum (8.56) in Tr_2 (Two-shoot training). The results of the present study are in line with those of Ansari (2012) in tomato and Lal (2013) in capsicum. In case of fruit load, significantly maximum number of fruits (10.32) was obtained in FL_1 (All fruits retained) while the minimum (8.27) was observed in FL_2 (10 fruits retained/plant). These findings are in conformity with those of Manjunatha et al (2007) in capsicum and Khan and Rab (2019) in okra. The interaction of two factors resulted in significantly highest number of ripe fruits/plant (12.13) obtained in Tr_1FL_1 (No training and all fruits retained) and the minimum (7.87) in case of Tr_2FL_2 (Two-shoot training and 10 fruits retained/plant). Similar finding was made by Mitra et al (2014).

Data pertaining to ripe fruit yield/plant are shown in Table 2. The mean effect of training systems showed maximum (0.52 kg) ripe fruit yield/plant in Tr_1 which was statistically at par with Tr_2. The observation is in line with the work of Shukla et al (2011). Minimum ripe fruit yield/plant (0.48 kg) was observed in Tr_3 (Four-shoot training). Non-significant differences were observed in case of fruit load. Interaction Tr_1FL_1 gave maximum fruit yield/plant (0.58 kg) being statistically at par with Tr_2FL_4 (Two-shoot training and 14 fruits retained/plant) and Tr_2FL_3 (Two-shoot training and 12 fruits retained/plant). This might be due to more number of shoots/plant and having more fruit bearing area. The interaction effect Tr_3FL_1 (Four-shoot training and all fruits) recorded minimum fruit yield/plant (0.46 kg) and was statistically at par with Tr_3FL_2, Tr_3FL_3, Tr_3FL_4, Tr_1FL_3, Tr_2FL_1, Tr_1FL_2, and Tr_3FL_2.

In case of seed yield/plant and seed yield/hectare (Tables 3, 4), Tr_1 showed maximum yield (8.78 g/plant and 260.29 kg/hectare respectively) and the results are in line with the findings of Guo et al (1991) and Hellemans (1998) in capsicum. Minimum seed yield/plant and seed yield/ha (8.24 g/plant and 244.09 kg/ha respectively) were obtained in Tr_3.

Maximum seed yield/plant and seed yield/ha (9.16 g/plant and 271.29 kg/ha respectively) were observed in FL_1 whereas minimum seed yield/plant and seed yield/ha (8.27g/plant and 244.97 kg/ha respectively) were recorded in FL_3. The observation maximum seed yield/plant and seed yield/ha observed in FL_1 is in line with the work of Kumari et al (2013) in okra. Amongst the interactions, Tr_1FL_1 showed significantly maximum seed yield/plant and seed yield/ha (10.34 g/plant and 306.22 kg/ha respectively). On the other hand, minimum seed yield/plant and seed yield/ha (7.88 g/plant and 233.42 kg/ ha respectively) observed in Tr_3FL_2 were statistically at par with Tr_2FL_1, Tr_3FL_3, Tr_1FL_2, Tr_1FL_3, Tr_2FL_3, Tr_3FL_1, Tr_1FL_4, Tr_2FL_4 and Tr_3FL_4. Maximum seed yield/plot and seed yield/ha obtained in Tr_1FL_1 are in line with the work of Mitra et al (2014) in tomato.

Table 1. Effect of training systems, fruit load and their interactions on number of ripe fruits/plant in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	12.13	8.87	9.07	9.53	9.90
Two-stem training (Tr_2)	9.23	7.87	8.27	8.87	8.56
Four-stem training (Tr_3)	9.60	8.07	8.53	9.07	8.82
Mean	10.32	8.27	8.62	9.16	

$CD_{0.05}$	
Training system (Tr)	0.48
Fruit load (FL)	0.52
Interaction effect of training system and fruit load (Tr x FL)	0.89

Table 2. Effect of training systems, fruit load and their interactions on ripe fruit yield/plant (kg) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	0.58	0.50	0.49	0.52	0.52
Two-stem training (Tr_2)	0.47	0.52	0.53	0.54	0.51
Four-stem training (Tr_3)	0.46	0.51	0.47	0.48	0.48
Mean	0.50	0.51	0.50	0.51	

$CD_{0.05}$	
Training system (Tr)	0.02
Fruit load (FL)	NS
Interaction effect of training system and fruit load (Tr x FL)	0.05

Table 3. Effect of training systems, fruit load and their interactions on seed yield/plant (g) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	10.34	8.26	8.21	8.34	8.78
Two-stem training (Tr_2)	8.40	9.16	8.52	8.58	8.67
Four-stem training (Tr_3)	8.73	7.88	8.07	8.27	8.24
Mean	9.16	8.43	8.27	8.40	

$CD_{0.05}$	
Training system (Tr)	0.45
Fruit load (FL)	0.52
Interaction effect of training system and fruit load (Tr x FL)	0.90

Significantly maximum (172.22) number of seeds/fruit (Table 5, Plates 1, 2) was observed in Tr_2, which is in line with the report of Osman and George (1984) and the minimum (159.62) was noticed in case of Tr_1. Significantly highest seed number (174.51) was found in FL_2 being in conformity with the observation of Manjunantha et al (2007) in bell pepper. Minimum seed number (158.81) was observed in FL_1 (All fruits

Table 4. Effect of training systems, fruit load and their interactions on seed yield/ha (kg) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	306.22	244.69	243.21	247.08	260.29
Two-stem training (Tr_2)	249.05	271.46	252.58	254.26	256.84
Four-stem training (Tr_3)	258.60	233.42	239.13	245.21	244.09
Mean	271.29	249.85	244.97	248.85	

$CD_{0.05}$	
Training system (Tr)	13.27
Fruit load (FL)	15.32
Interaction effect of training system and fruit load (Tr x FL)	26.54

Table 5. Effect of training systems, fruit load and their interactions on number of seeds/fruit in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	154.03	165.43	161.20	157.80	159.62
Two-stem training (Tr_2)	161.80	187.77	171.80	167.53	172.22
Four-stem training (Tr_3)	160.60	170.33	166.58	160.03	164.38
Mean	158.81	174.51	166.52	161.79	

$CD_{0.05}$	
Training system (Tr)	3.33
Fruit load (FL)	3.84
Interaction effect of training system and fruit load (Tr x FL)	6.66

Plate 1. Effect of training system and fruit load on number of seeds/fruit: no training and all fruits retained (Tr_1FL_1)

Plate 2. Effect of training system and fruit load on number of seeds/fruit: two-stem training and 10 fruits retained/plant (Tr_2FL_2)

retained) that was statistically at par with FL_4 (161.79). In case of interaction, significantly maximum number of seeds/fruit reported for treatment combination Tr_2FL_2 (187.77) might be due to large size of fruits with reduced sink load. Tr_1FL_1 resulted in minimum number of seeds/fruit (154.03) which was statistically at par with Tr_1FL_4, Tr_3FL_1 and Tr_3FL_4.

Seed quality parameters

Data pertaining to effect of training system and fruit load on 1,000-seed weight are given in Table 6. The data depict that training system Tr_2 recorded significantly highest (5.90 g) whereas Tr_1 resulted in the lowest 1,000-seed weight (5.58 g). Similar results were reported by Lal et al (2016) in capsicum. For fruit load, significantly maximum 1,000-seed weight (5.86 g) was observed in FL_2 (10 fruits retained/plant) and minimum (5.61 g) in FL_1 (Retaining all fruits/plant) that was statistically at par with FL_4 (5.68 g).

This might be due to the reason that removal of flowers from bell pepper increased the concentration of stored carbohydrates in stems making them available to developing seeds. Significantly maximum 1,000-seed weight (6.21 g) was noticed in Tr_2FL_2 and minimum (5.53 g) in Tr_1FL_1 that was statistically at par with Tr_1FL_2, Tr_1FL_3, Tr_1FL_4 and Tr_2FL_1.

Tr_2 (Two-stem training system) resulted in significantly higher germination (91.25%) that is in line with the work of Ansari (2012) in tomato and Lal (2013) in bell pepper. Tr_1 (No training) lead to minimum germination (84.18%). This might be due to more partitioning of carbohydrates to different stems. FL_2 (Ten fruits/plant) recorded maximum seed germination (92.16%) and FL_1 (All fruits) had minimum seed germination (82.16%) (Table 7).

Significantly higher germination (96.50%) noticed in Tr_2FL_2 might be due to less branches and fruits that lead to more photosynthates availability to developing fruits and seeds which can be correlated to higher seed germination. Minimum germination (81.75%) observed in Tr_1FL_1 was statistically at par with Tr_1FL_4, Tr_2FL_1 and Tr_3FL_1.

Training system Tr_2 (Two-stem) recorded significantly maximum speed of germination (12.31) while minimum (9.40) was obtained in Tr_1 (No training). This could be because of its correlation with high germination in two-stem training system. FL_2 (Ten fruits/plant) showed significantly maximum speed of germination (12.74) and FL_1 (All fruits retained/plant) resulted in minimum speed of germination (9.13). Among the interactions, treatment combination Tr_2FL_2 resulted in significantly maximum (15.95) and Tr_1FL_1 minimum speed of germination (7.72) (Table 8, Plates 3, 4).

Significantly maximum seed vigour index-I (1,066.05) was obtained in Tr_2 (Two-stem) and minimum (747.39) in Tr_1 (No training). Maximum seed vigour index-I in Tr_2 could be due to the fact that two stems/plant had less number of fruits and there was less competition among the fruits for photosynthates thereby resulting in bigger size fruits with bolder seeds. In case of fruit load, maximum seed vigour index-I (1,112.9) was recorded in FL_2 (Ten fruits/plant) and the minimum (757.05) in FL_1 (All fruits retained). Amongst interactions, Tr_2FL_2

Table 6. Effect of training systems, fruit load and their interactions on 1,000-seed weight (g) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	5.53	5.63	5.62	5.54	5.58
Two-stem training (Tr_2)	5.63	6.21	6.00	5.78	5.90
Four-stem training (Tr_3)	5.66	5.73	5.68	5.70	5.70
Mean	5.61	5.86	5.77	5.68	

$CD_{0.05}$	
Training system (Tr)	0.06
Fruit load (FL)	0.07
Interaction effect of training system and fruit load (Tr x FL)	0.12

Table 7. Effect of training systems, fruit load and their interactions on germination (%) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	81.75 (9.09)	88.00 (9.43)	85.00 (9.27)	82.00 (9.11)	84.18 (9.23)
Two-stem training (Tr_2)	82.75 (9.15)	96.50 (9.88)	94.00 (9.75)	91.75 (9.63)	91.25 (9.60)
Four-stem training (Tr_3)	82.00 (9.11)	92.00 (9.64)	92.00 (9.64)	86.75 (9.36)	88.18 (9.43)
Mean	82.16 (9.12)	92.16 (9.65)	90.33 (9.55)	86.78 (9.37)	

Figures in the parentheses represent square root transformed values

$CD_{0.05}$	
Training system (Tr)	0.04
Fruit load (FL)	0.05
Interaction effect of training system and fruit load (Tr x FL)	0.09

Table 8. Effect of training systems, fruit load and their interactions on speed of germination in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	7.72	10.75	10.03	9.16	9.40
Two-stem training (Tr_2)	9.88	15.95	12.38	11.03	12.31
Four-stem training (Tr_3)	9.80	11.52	10.01	10.36	10.42
Mean	9.13	12.74	10.81	10.18	

$CD_{0.05}$	
Training system (Tr)	0.47
Fruit load (FL)	0.55
Interaction effect of training system and fruit load (Tr x FL)	0.95

Plate 3. Effect of training system and fruit load on speed of germination: no training and all fruits retained (control- $Tr_1 FL_1$)

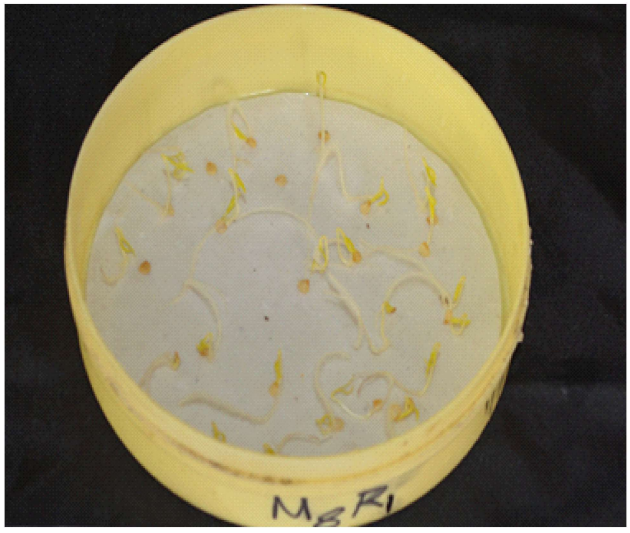

Plate 4. Effect of training system and fruit load on speed of germination: two-stem training and 10 fruits retained/ plant (Tr_2FL_2)

Table 9. Effect of training systems, fruit load and their interactions on SVI-I in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	664.56	823.42	774.20	727.37	747.39
Two-stem training (Tr_2)	846.95	1,448.30	1,021.56	947.38	1,066.05
Four-stem training (Tr_3)	759.64	1,065.14	989.06	891.97	926.45
Mean	757.05	1,112.29	928.27	855.57	

$CD_{0.05}$	
Training system (Tr)	53.54
Fruit load (FL)	61.82
Interaction effect of training system and fruit load (Tr x FL)	107.09

Table 10. Effect of training systems and fruit load and their interactions on SVI-II in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	173.13	231.98	208.40	196.39	202.48
Two-stem training (Tr_2)	199.14	284.77	253.79	237.90	243.90
Four-stem training (Tr_3)	191.52	254.51	239.39	200.72	221.54
Mean	187.93	257.09	233.86	211.67	

$CD_{0.05}$	
Training system (Tr)	3.43
Fruit load (FL)	4.54
Interaction effect of training system and fruit load (Tr x FL)	7.86

resulted in significantly maximum seed vigour index-I (1,448.30) while minimum (664.56) was observed in Tr_1FL_1 that was statistically at par with Tr_1FL_4 and Tr_3FL_1 (Table 9).

Seed vigour index-II (Table 10) was significantly maximum (243.90) in Tr_2 and minimum (202.48) in Tr_1. For fruit load, significantly maximum seed vigour index-II (257.09) was found in FL_2 (Ten fruits/plant) and minimum (187.93) in FL_1 (All fruits/plant). Interaction Tr_2FL_2 recorded significantly maximum seed vigour index-II (284.77) and minimum (173.13) was obtained in Tr_1FL_1.

Two-stem training system (Tr_2) registered significantly minimum electrical conductivity (EC) (0.090 dS/m) and in Tr_1 (No training at all), it was maximum (0.123 dS/m). This might be due to more partitioning of photosynthates in case of no training. FL_2 (Ten fruits) recorded significantly minimum EC (0.082 dS/m) that is similar to the observation of Vasudevan et al (2008) in methi and Lakshmi et al (2015) in fenugreek. Fruit load FL_1 (All fruits) had maximum EC (0.117 dS/m) being statistically at par with FL_4 and FL_3. Interaction Tr_2FL_2 had minimum EC (0.060 dS/m) of seed being statistically at par with Tr_3FL_2.

This might be due to effective translocation of phtotosythates from source to sink which is evident from high seed weight, high germination, high dry weight and more seed vigour index. The maximum EC (0.127 dS/m) observed in case of Tr_1FL_3 (No training and twelve fruits/plant) and Tr_3FL_1 was statistically at par with Tr_1FL_4, Tr_1FL_2, Tr_1FL_1 and Tr_3FL_4 (Table 11, Plates 5, 6).

Economics of seed treatment

The impact of training systems and fruit load on benefit-cost ratio in bell pepper seed production was worked out and the data are given in Table 12. It was observed that maximum B-C ratio (6.03:1) was obtained in treatment combination Tr_1FL_1 (No training and retaining all fruits) because of higher seed yield. This

Table 11. Effect of training systems, fruit load and their interaction on EC (dS/m) in bell pepper cv Solan Bharpur

Training system	Fruit load				
	All fruits (FL_1)	10 fruits/plant (FL_2)	12 fruits/plant (FL_3)	14 fruits/plant (FL_4)	Mean
No training (Tr_1)	0.120	0.121	0.127	0.126	0.123
Two-stem training (Tr_2)	0.103	0.060	0.100	0.097	0.090
Four-stem training (Tr_3)	0.127	0.067	0.110	0.120	0.106
Mean	0.117	0.082	0.112	0.114	

$CD_{0.05}$	
Training system (Tr)	0.008
Fruit load (FL)	0.009
Interaction effect of training system and fruit load (Tr x FL)	0.015

Plate 5. Effect of training system and fruit load on electrical conductivity of seeds: no training and all fruits retained (control- Tr_1FL_1)

Plate 6. Effect of training system and fruit load on electrical conductivity of seeds: two-stem training and 10 fruits retained/plant (Tr_2FL_2)

treatment combination was followed by Tr_2FL_2 (Two-stem training system and retaining ten fruits/plant) with a B-C ratio of 5.23:1 which favoured all the seed quality characters. However minimum B-C ratio (4.36:1) was observed in treatment combination Tr_3FL_2 (Four-stem training system and retaining ten fruits/plant). Hence quality seed (Tr_2FL_2) can be sold at slightly higher price as compared to control treatment (Tr_1FL_1) to get more profit along with quality seed supply.

CONCLUSION

The treatment combination Tr_2FL_2 (Two-stem training with ten fruits/plant) proved superior in terms of seed quality parameters such as number of seeds/fruit (187.77), 1,000-seed weight (6.21 g), germination (96.50%), speed of germination (15.95), seed vigour index-I (1,448.30), seed vigour index-II (284.77) and electrical conductivity of seeds (0.060 dS/m).

But in terms of ripe fruit yield/plant (0.58 kg) number of ripe fruits/plant (12.13), seed yield/plant (10.34 g) and seed yield/ha (306.22 kg), Tr_1FL_1 (No training and all fruits retained) gave better results. On comparing benefit-cost ratio of Tr_1FL_1 (best seed yield treatment combination) and Tr_2FL_2 (best seed quality treatment combination), it was found that Tr_1FL_1 (6.03:1) resulted in higher B-C ratio followed by Tr_2FL_2 (5.23:1). Therefore Tr_2FL_2 treatment combination can be recommended for quality seed production of bell pepper under mid-hills of Himachal Pradesh.

Table 12. Effect of training systems and fruit load on economics of seed production in bell pepper cv Solan Bharpur

Treatment combination	Seed yield/ha (kg)	Gross income (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B-C ratio
Tr_1FL_1	306.22	12,24,880	1,74,300	10,50,580	6.03
Tr_1FL_2	244.69	9,78,760	1,74,300	8,04,460	4.61
Tr_1FL_3	243.21	9,72,840	1,74,300	7,98,540	4.58
Tr_1FL_4	247.08	9,88,320	1,74,300	8,14,020	4.67
Tr_2FL_1	249.05	9,96,200	1,74,300	8,21,900	4.71
Tr_2FL_2	271.46	10,85,840	1,74,300	9,11,540	5.23
Tr_2FL_3	252.58	10,10,320	1,74,300	8,36,020	4.80
Tr_2FL_4	254.26	10,17,040	1,74,300	8,42,740	4.83
Tr_3FL_1	258.60	10,34,400	1,74,300	8,60,100	4.93
Tr_3FL_2	233.42	9,33,680	1,74,300	7,59,380	4.36
Tr_3FL_3	239.13	9,56,520	1,74,300	7,82,220	4.49
Tr_3FL_4	245.21	9,80,840	1,74,300	8,06,540	4.63

Sale price of bell pepper seed= Rs 4,000/kg fixed by the Seed Technology and Production Center, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh

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