



Productivity, Quality and Economics of Sweet Pepper (*Capsicum annum*) Cultivars under Modified Net House Conditions in Arid Regions

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Abstract: An experiment conducted during Rabi 2019-20 at the College of Agriculture, Jodhpur (Rajasthan), aimed to identify superior cultivars of sweet pepper (*Capsicum annum* L. Grossum Sendt.) with regards to yield, quality, and economic viability. The study included 20 sweet pepper cultivars and employed a randomized block design with three replications. Among the cultivars, 'Pusa Deepti' exhibited the tallest plant height (77.4 cm), highest number of leaves per plant (75.4), and greatest number of branches per plant (23.1) at 120 days after transplanting (DAT). Additionally, 'Pusa Deepti' also produced the longest fruits (9.73 cm) and highest number of fruits per plant (19.5), while 'Orobelle' displayed the widest fruit diameter (6.01 cm). The cultivar 'Indra' achieved 50% flowering in shortest duration of 68.0 days, while recording the maximum fruit weight (75.1 g), fruit yield plant⁻¹ (1.34 kg), and fruit yield 1000 m⁻² (4.88 tonnes). Conversely, 'Orobelle' exhibited the longest crop duration (221 days). In terms of quality attributes, 'Arka Gaurav' showcased the highest ascorbic acid content (169 mg 100 g⁻¹) and total soluble solids content (7.5%), whereas 'Indra' displayed the longest shelf-life (8.6 days). Furthermore, 'Indra' demonstrated the highest net returns (Rs. 104666) and benefit-to-cost ratio (2.51) per 1000 m⁻² area. The study underscores the importance of selecting appropriate cultivars of sweet pepper such as 'Indra' and 'Pusa Deepti' in western Rajasthan to avoid potential losses in sweet pepper cultivation with low yielding unsuitable cultivars.

Key words: Sweet pepper, productivity, quality, modified net house, arid region.

Sweet pepper (*Capsicum annum* L. Grossum Sendt.) is an important cool-season fruit vegetable of the *Solanaceae* family. Due to its moderate spiciness and delightful flavour profile, it serves as the primary ingredient in stuffing, pizza, and burger recipes. Moreover, it may be eaten raw, cooked and sliced in the form of *salad*. Sweet pepper is a valuable source of vitamins A and C, containing 870 IU 100g⁻¹ and 175 mg 100g⁻¹ respectively. In addition to these vitamins, it offers essential nutritional components such as protein (1.2 g 100 g⁻¹), calcium (11 mg 100 g⁻¹), thiamine (0.06 mg 100 g⁻¹), and riboflavin (0.03 mg 100 g⁻¹) (Bose *et al.*, 2003). In India, sweet pepper

cultivation covers around 24,000 ha area and 326,000 mt production with productivity of around 13.58 mt ha⁻¹.

For optimum growth, sweet pepper requires 24-30°C of day temperature and 18-21°C of night temperature (Bose *et al.*, 2003). For this reason, it is difficult to grow sweet pepper hybrids in open field conditions in arid regions. Hence, protected cultivation of high-value crops like sweet pepper has emerged as an important technology for ensuring higher productivity, improved quality, and lucrative returns (Khade, 2011).

Sweet pepper is one of the highly remunerative vegetables due to its stable prices year-round owing to its high demand from the urban dwellers. However, due to low productivity, supply is inadequate, which is attributed to the lack of high-yielding adaptable varieties and hybrids. Besides, in tropical and subtropical regions of the country, it is difficult to get higher yields and quality fruits under open field conditions. As sweet pepper is a high-value-low volume crop, its exploitation on a commercial scale under protected structures like greenhouses, shade nets, insect-proof net-house and poly-houses, etc. can improve productivity and returns to growers in water-scarce and harsh climatic conditions like western Rajasthan.

Considering the nutritional and economic importance of sweet pepper, there is a need to grow sweet pepper under protected structures like insect-proof net house and shade-nets in arid regions. However, there is limited information available on cultivating adaptable sweet pepper varieties under protected conditions in the arid regions of western Rajasthan. Additionally, with numerous sweet pepper cultivars on the market, it is crucial to screen them for suitability in arid climates. Hence, this study aimed to evaluate the performance of various sweet pepper cultivars under modified net houses, focusing on growth, yield, quality, and economic factors in the arid regions of western Rajasthan.

Materials and Methods

The experiment was carried out in the modified net house during rabi 2019-20 at the College of Agriculture, Jodhpur. The experimental site is located at an altitude of 231 m amsl and positioned between 26°15''

to 26°45'' North latitude and 73°00'' to 73°29'' East longitude. This region falls under agro-climatic zone Ia, (Arid Western Plains Zone) of Rajasthan. During the experimental period, the average daily maximum and minimum temperature ranged between 15°C to 36.3°C and 5.4°C to 27.2°C, respectively. The modified net-house utilized for the experiment was covered with 50% white nylon UV-stabilized insect-proof mononet of 40 mesh. An additional shade net was employed primarily during the hot summer months from February to June. It was used sparingly during winter and whenever sunlight intensity increased notably between 11:00 am to 3:00 pm. The UV-stabilized 40 mesh nylon net was provided on all sides of the net house. The drip irrigation system was employed to supply the required quantity of water and fertilizers for fertigation. The experiment comprised 20 cultivars of sweet pepper (Table 1) raised in randomized block design with three replications in a modified net-house. Among the selected cultivars five viz., Arka Basant, Arka Gaurav, Orobelle, 738 and Eugene were of yellow coloured fruit type, nine (Arka Mohini, Yolo Wonder, California Wonder, Kandaghat Selection, Royal Wonder, Solan Bharpur, Bomby, 739 and Wendy) of red coloured fruit type and six (Pusa Deepti, Ganga, SV1865PB, Indra, Lucky and Anne) were green coloured fruit type.

The soil of the experimental field was loamy sand in texture, slightly alkaline in reaction (pH 8.2), low in organic carbon (0.13%) and available N (174 kg ha⁻¹) and medium in available P₂O₅ (22.2 kg ha⁻¹) and available K₂O (325 kg ha⁻¹). Raised beds of 29.0 m length × 0.90 m width × 0.15 m height were prepared with 40 cm walking space between the beds. The 35-day-old seedlings were transplanted on raised beds in paired row systems at a spacing of 45 cm × 45 cm plant-to-row spacing, respectively. The recommended dose of N, P₂O₅, and K₂O (150:50:50 kg ha⁻¹) was applied in the form of urea, DAP, and sulphate of potash and NPK (19:19:19). Half dose N and a full dose of P and K were applied as basal and the remaining quantity of N was applied through fertigation after 30 days after transplanting (DAT). An NPK (19:19:19) water-soluble fertilizer (2 g L⁻¹ of water) was applied at the time of fruit development and one week thereafter through fertigation and the fertigation was ceased 15

days before final harvest. Need-based plant protection measures were adopted against crop pests and diseases.

Observations on growth parameters like plant height, number of leaves per plant, and number of branches per plant were recorded at 120 DAT from five randomly selected plants from each plot. From the same plants, the number of days to 50% flowering and crop duration were recorded from the date of transplanting onwards. The fruit length, fruit diameter, and fresh weight of fruit were measured from five randomly selected fruits of each cultivar. The cumulative total of fruits harvested from the five tagged plants was averaged to obtain the number of fruits per plant. Similarly, the cumulative total weight of fruits from each plant and the net area of each cultivar were recorded as fruit yield per plant and fruit yield in ton per 1000 m². Among the quality parameters, ascorbic acid was estimated as per AOAC (1990) and total soluble solids (TSS) were recorded with a digital refractometer. For recording the shelf-life harvested fresh fruits were kept at ambient room temperature and the number of days taken for 15% weight loss was recorded as shelf life. Economic analysis of different sweet pepper genotypes grown under a modified net house was worked out taking into account the depreciation cost of the structure and the life of UV-stabilized plastic film. The net returns and B:C ratio were calculated with prevailing

market rates of the produce and cost of inputs used.

The experimental data were statistically analysed as per ANOVA technique as described by Panse and Sukhatme (1985). The least significant differences (LSD) were worked out for comparison of treatment means wherever the variance ratio (F-test) was found significant at a 5% level of significance. Tukey's HSD test was carried out for multiple comparisons among the means of different cultivars for different parameters.

Results and Discussion

Growth parameters

The sweet pepper cultivars differed significantly in terms of plant height, the number of leaves per plant, and number of branches per plant at 120 DAT under modified net house condition (Fig. 1). The highest plant height (77.4 cm), the maximum number of leaves per plant (75.4) and maximum number of branches per plant (23.1) were recorded with cultivar 'Pusa Deepti' which was found statistically at par with the cultivar 'Indra', 'Orobelle', '738', 'Bomby' and '739' whereas, the shortest plant height (59.2 cm), the minimum number of leaves per plant (65.8) and minimum number of branches per plant (20.6) were recorded in cultivar 'Yolo wonder'. These results are in close conformity with the findings of Manoj and Venugopal (2018) and Megharaja (2000) on sweet pepper. The differential response of the

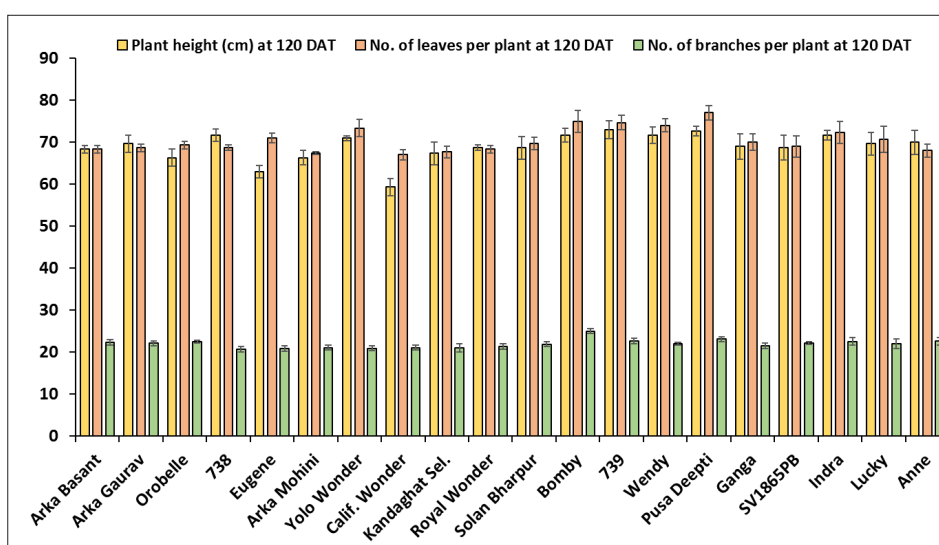


Fig. 1. Plant height, number of leaves per plant, and number of branches per plant (mean \pm standard error) at 120 DAT of different cultivars of sweet pepper under modified net house condition.

Table 1. Growth parameters, phenology, yield attributes and fruit yield of different sweet pepper cultivars under modified net house cultivation

Cultivars	Days taken to 50% flowering	Crop duration (Days)	Fruit length (cm)	Fruit diameter (cm)	Fresh weight of fruit (g)	No. of fruits plant ⁻¹	Fruit yield plant ⁻¹ (kg)	Fruit yield (ton per 1000 m ²)
Arka Basant	72.7 ^{abcd}	203 ^{cde}	7.23 ^b	3.92 ^{fghi}	40.8 ⁱ	11.3 ^{d-h}	0.46 ^h	1.84 ^h
Arka Gaurav	70.1 ^{cd}	201 ^{de}	8.82 ^{ab}	4.67 ^{b-h}	62.0 ^{bcde}	8.8 ^h	0.54 ^{fgh}	2.29 ^{fgh}
Orobelle	69.0 ^{cd}	221 ^a	7.77 ^b	6.01 ^a	71.9 ^{ab}	13.4 ^{cdef}	0.96 ^b	3.77 ^b
738	75.3 ^{ab}	213 ^{abcd}	7.83 ^b	5.37 ^{abcd}	66.8 ^{abcd}	10.2 ^{gh}	0.68 ^{c-g}	3.03 ^{b-g}
Eugene	75.7 ^{ab}	217 ^{abc}	7.18 ^b	4.53 ^{c-i}	57.1 ^{defg}	10.1 ^{gh}	0.57 ^{efgh}	2.43 ^{efgh}
Arka Mohini	73.0 ^{abcd}	197 ^e	7.69 ^b	4.47 ^{d-i}	50.4 ^{fghi}	11.6 ^{d-h}	0.58 ^{d-h}	2.48 ^{d-h}
Yolo Wonder	75.7 ^{ab}	208 ^{a-e}	8.13 ^{ab}	3.79 ^{ghi}	51.8 ^{efgh}	10.7 ^{d-h}	0.55 ^{efgh}	2.32 ^{fgh}
California Wonder	72.0 ^{abcd}	207 ^{a-e}	8.42 ^{ab}	4.70 ^{b-g}	68.5 ^{abc}	11.6 ^{d-h}	0.79 ^{bcd}	3.34 ^{b-f}
Kandaghat Selection	72.3 ^{abcd}	205 ^{bcde}	7.31 ^b	4.11 ^{e-i}	43.1 ^{hi}	13.8 ^{cd}	0.59 ^{d-h}	2.52 ^{d-h}
Royal Wonder	75.7 ^{ab}	198 ^e	7.69 ^b	4.21 ^{e-i}	49.7 ^{ghi}	10.1 ^{gh}	0.50 ^{gh}	2.11 ^{gh}
Solan Bharpur	76.3 ^a	201 ^{de}	7.54 ^b	3.67 ^{hi}	44.8 ^{hi}	10.3 ^{fgh}	0.46 ^h	1.75 ^h
Bomby	74.1 ^{abc}	219 ^{ab}	8.35 ^{ab}	5.67 ^{ab}	70.7 ^{abc}	10.6 ^{efgh}	0.75 ^{b-f}	3.21 ^{b-f}
739	74.2 ^{abc}	219 ^{ab}	8.38 ^{ab}	4.35 ^{d-i}	53.2 ^{efgh}	11.3 ^{d-h}	0.60 ^{d-h}	2.58 ^{c-h}
Wendy	76.0 ^a	215 ^{abcd}	8.11 ^{ab}	4.62 ^{c-h}	60.1 ^{c-g}	15.6 ^{bc}	0.94 ^b	3.55 ^{bcd}
Pusa Deepti	70.7 ^{bcd}	213 ^{abcd}	9.73 ^a	3.53 ⁱ	44.4 ^{hi}	19.5 ^a	0.86 ^{bc}	3.66 ^{bc}
Ganga	73.3 ^{abc}	197 ^e	7.62 ^b	4.57 ^{c-h}	60.9 ^{cdef}	12.7 ^{c-g}	0.76 ^{bcde}	3.25 ^{b-f}
SV1865PB	70.7 ^{bcd}	205 ^{bcde}	8.45 ^{ab}	4.91 ^{b-f}	56.9 ^{defg}	10.1 ^{gh}	0.57 ^{efgh}	2.38 ^{fgh}
Indra	68.0 ^d	220 ^a	9.61 ^a	5.53 ^{abc}	75.1 ^a	18.0 ^{ab}	1.34 ^a	4.88 ^a
Lucky	73.7 ^{abc}	217 ^{abc}	8.17 ^{ab}	4.22 ^{e-i}	53.1 ^{efgh}	13.6 ^{cde}	0.72 ^{cdef}	3.11 ^{b-g}
Anne	72.7 ^{abcd}	217 ^{abc}	7.31 ^b	5.01 ^{a-e}	61.1 ^{b-f}	13.5 ^{cde}	0.82 ^{bc}	3.52 ^{bcde}
SEm(±)	0.96	2.72	0.23	0.13	2.04	0.59	0.04	2.03
LSD (p=0.05)	5.16	14.6	1.76	10.02	10.9	3.16	0.22	10.9

The means superscripted with different letters in columns are statistically different at *p=0.05 as per Tukey's HSD test.

cultivars in terms of growth parameters may be due to differences in the genetic makeup of the cultivars. Moreover, under a modified net house the congenial environmental conditions provided for higher photosynthesis, respiration, nutrient uptake, translocation, reproduction, which resulted in better plant growth.

Crop phenology

Significant differences were recorded among the sweet pepper cultivars in terms of days to 50% flowering and crop duration (Table 1). The shortest duration to 50% flower appearance were recorded in 'Indra' (68.0 days) succeeded by 'Orobelle' (69.0 days), 'Arka Gaurav' (70.1 days), 'Pusa Deepti' (70.7 days) and 'SV1865PB' (70.7 days), significantly preceding rest of the cultivars. Maximum duration to 50% flowering were recorded in 'Solan Bharpur' (76.3 days). Longest crop duration was recorded in 'Orobelle' (221 days) which was closely followed by

'Indra' (220 days) while the minimum crop duration was observed in 'Ganga' (197 days). The significant differences among cultivars for flowering and crop duration could be attributed to their genetic constitution as well as the prevailing environmental conditions inside the net house. These results are contrary to the earlier findings on sweet pepper by Singh *et al.* (2011) who experimented in comparatively cooler agro-climatic conditions of Uttarakhand where favorable photo-thermal regimes could not have created significant differences in crop phonological stages.

Yield attributes

Sweet pepper cultivars exhibited significant differences in terms of fruit length, fruit diameter, fresh weight of fruit, and number of fruits per plant under modified net house condition (Table 1). Maximum average length of fruit was recorded in 'Pusa Deepti' (9.73

cm) which was closely followed by 'Indra' (9.61 cm). This indicates a marked advantage in length for these two varieties, suggesting potential suitability for markets that prefer longer peppers. In terms of fruit diameter, 'Orobelle' led with the largest diameter at 6.01 cm, closely followed by 'Bomby' at 5.67 cm and 'Indra' at 5.53 cm. The larger diameter of these cultivars could suggest a robustness in fruit development, appealing to certain consumer preferences for bulkier fruits.

Maximum fruit weight was recorded in 'Indra' (75.1 g) which was statistically at par with that of 'Orobelle' (71.9 g), 'California Wonder' (68.5 g) and 'Bombay' (70.7 g). These cultivars demonstrate a higher biomass accumulation, which might be attributed to their greater diameters and efficient photosynthetic capacities under net house conditions. In contrast, the minimum fruit length, fruit diameter, and fruit weight was observed in 'Eugene' (7.18 cm), 'Pusa Deepti' (3.53 cm) and 'Arka Basant' (40.8 g), respectively which could be due to their smaller size and possibly less efficient nutrient uptake or assimilation. These results are in agreement with the earlier findings of Jakhar *et al.* (2017) and Gill (2018) on sweet pepper. These results suggest that while some cultivars like 'Pusa Deepti' and 'Indra' are optimized for higher yield in terms of number of fruits, others might focus on size or weight of fruits, presenting a trade-off between these attributes. Among the cultivars, the significantly maximum (19.5) and minimum (8.8) number of fruits per plant was recorded in 'Pusa Deepti' and 'Arka Gaurav', respectively. These results follow the trends of Jakhar *et al.* (2017) in sweet pepper. The significant differences in fruits per plant have been due to sufficient accumulation of photosynthates in the favourable micro-climatic conditions in the net house.

Fruit yield

Significant differences were noticed among the sweet pepper cultivars for fruit yield per plant and fruit yield per 1000m² (Table 1). The highest fruit yield per plant and fruit yield per 1000m² were observed in cultivar 'Indra' (1.34 kg and 48.84 q, respectively) whereas, the minimum was observed in 'Solan Bharpur' (0.46kg and 17.56 q, respectively). Further, 'Orobelle' (37.70 q), 'Pusa Deepti' (36.62 q),

'Wendy' (35.56 q), 'Anne' (35.22 q), 'California Wonder' (33.48 q), 'Ganga' (32.52 q), 'Lucky' (31.19 q) and 'Bomby' (32.07 q) were found statistically at par to each other in terms of fruit yield per 1000m². These results are supported by the findings of Jakhar *et al.* (2017) and Samanta and Hazra (2019) in sweet pepper. The higher fruit yield observed in these cultivars was mainly on account of their inherent ability to produce earliest in days to 50% flower appearance, higher fruit volume, more number of fruits per plant, and higher fresh weight of fruit which are the main component traits contributed towards higher fruit yield.

Quality parameters

Different cultivars grown under modified net house conditions had significant differences in quality parameters like ascorbic acid, TSS, and shelf life (Table 2). The significantly maximum ascorbic acid (169 mg 100 g⁻¹) and TSS (7.5%) content were recorded in 'Arka Gaurav'

Table 2. Quality parameters of different sweet pepper cultivars under modified net house cultivation

Cultivars	Ascorbic acid (mg 100 g ⁻¹)	TSS (%)	Shelf life (Days)
Arka Basant	142 ^{bc}	6.3 ^b	5.4 ^{ghij}
Arka Gaurav	169 ^a	7.5 ^a	5.6 ^{ij}
Orobelle	162 ^a	4.7 ^{def}	7.8 ^{abc}
738	156 ^{ab}	7.3 ^a	6.7 ^{cdef}
Eugene	154 ^{ab}	4.7 ^{def}	6.1 ^{fghi}
Arka Mohini	131 ^{cde}	5.3 ^{cd}	5.7 ^{ij}
Yolo Wonder	117 ^{ef}	5.3 ^{cd}	5.9 ^{fghi}
California Wonder	157 ^{ab}	5.0 ^{cde}	7.6 ^{abcd}
Kandaghat Selection	142 ^{bc}	4.2 ^{efg}	5.5 ^{ghij}
Royal Wonder	96 ^g	3.7 ^g	5.0 ^{ij}
Solan Bharpur	123 ^{def}	3.8 ^{fg}	5.2 ^{hij}
Bomby	142 ^{bc}	4.8 ^{cde}	8.2 ^{ab}
739	125 ^{def}	4.5 ^{defg}	6.5 ^{defg}
Wendy	110 ^{fg}	5.2 ^{cd}	7.3 ^{bcde}
Pusa Deepti	109 ^{fg}	4.7 ^{def}	4.7 ⁱ
Ganga	109 ^{fg}	5.3 ^{cd}	6.2 ^{efgh}
SV1865PB	112 ^{fg}	4.5 ^{defg}	7.5 ^{abcd}
Indra	137 ^{cd}	5.2 ^{cd}	8.6 ^a
Lucky	120 ^{ef}	5.7 ^{bc}	6.3 ^{efgh}
Anne	116 ^{ef}	5.2 ^{cd}	6.0 ^{fghi}
SEm(±)	3.14	0.171	0.21
LSD (p=0.05)	16.9	0.915	1.17

The means superscripted with different letters in columns are statistically different at *p=0.05 as per Tukey's HSD test.

Table 3. Economics of cultivation of different sweet pepper cultivars

Genotype	Variable cost due to seed (Rs.1000 m ⁻²)	Total cost (Rs.1000 m ⁻²)	*Net returns (Rs.1000 m ⁻²)	B:C ratio
Arka Basant	1182	33613	21720	0.65
Arka Gaurav	1182	33613	35276	1.05
Orobelle	10962	43393	69718	1.61
738	5925	38356	52533	1.37
Eugene	5925	38356	34533	0.90
Arka Mohini	1182	33613	40831	1.21
Yolo Wonder	293	32724	36832	1.13
California Wonder	444	32875	67569	2.06
Kandaghat Selection	231	32662	43116	1.32
Royal Wonder	1067	33498	29835	0.89
Solan Bharpur	2311	34742	17925	0.52
Bomby	9599	42030	54192	1.29
739	5925	38356	39200	1.02
Wendy	5925	38356	68311	1.78
Pusa Deepti	1182	33613	76187	2.27
Ganga	948	33379	64177	1.92
SV1865PB	7821	40252	31304	0.78
Indra	9303	41734	104666	2.51
Lucky	5925	38356	55200	1.44
Anne	5925	38356	66311	1.73

*Sale rate of fruit @ Rs. 30 kg⁻¹

whereas, the minimum ascorbic acid (96 mg 100 g⁻¹) and TSS (3.7%) content were recorded in 'Royal wonder'. The results are supported by the work of Swamy *et al.* (2014) and Jakhar *et al.* (2017) in sweet pepper. Generally, high ascorbic acid and TSS content increases the nutritional value and improves the flavour of sweet pepper. Therefore, sweet pepper cultivars possessing high ascorbic acid and TSS content are highly preferred by consumers. The maximum shelf life of fruit was observed in cultivar 'Indra' (8.6 days) whereas, 'Pusa Deepti' (4.7 days) depicted minimum shelf life. Increased shelf life is directly related to the bigger size of fruits having thicker pericarp. The cultivar 'Indra' recorded a higher shelf life which is because of the thicker pericarp which prevented moisture loss and shrinkage. Similar results were reported by Manoj and Venugopal (2018) in sweet pepper.

Economics

The data (Table 3) indicated significant differences in fruit yield of sweet pepper cultivars resulted in a huge difference in net

returns and B:C ratio. The differences in net returns are due to fruit yield on the output side and due to the variable cost of seed on the input side which varied from 0.71-25.3% of total cost in different cultivars. The highest net returns and B:C ratio were recorded in cultivar 'Indra' (Rs.104666 per 1000 m² and 2.51, respectively) followed by 'Pusa Deepti' (76187 per 1000 m² and 2.27, respectively) while, the lowest net returns and B:C ratio were fetched in 'Solan Bharpur' (17925 per 1000m² and 0.52, respectively). It could be ascribed to the higher fruit yield of 'Indra' and 'Pusa Deepti'. These results are supported by the work of Jakhar *et al.* (2017) in sweet pepper.

Conclusion

Hence, among the sweet pepper cultivars, 'Indra' cultivated under a modified net house recorded the highest fruit yield, earliest flowering, maximum shelf life, highest net returns, and B:C ratio. Therefore, the protected cultivation of sweet pepper genotype 'Indra' can be economically remunerative for small and marginal farmers in western Rajasthan.

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