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AS Jadhav
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

RD Pawar
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

SS Dhumal
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

VK Garande
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

AS Bagade
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

SA Sarvade
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

US Shinde
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

Corresponding Author:
AS Jadhav
Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, MPKV, Kolhapur, Maharashtra, India

Effect of different training systems on growth and yield of greenhouse cucumber

AS Jadhav, RD Pawar, SS Dhumal, VK Garande, AS Bagade, SA Sarvade and US Shinde

Abstract
An investigation to study the effect of different training systems on growth and yield of cucumber under naturally ventilated polyhouse was conducted during summer season, 2018 at the Instructional-cum-Research Farm of Horticulture Section, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur. The experiment was laid out in Completely Randomized Design with three replications of eight treatments (training systems) *viz*., overhead trellis, trellis with three wire, single stem staking, nylon netting, hanger system, 'V' system, trellis with two wire and untrained control. The spacing adopted was 60 cm × 60 cm. The single stem staking treatment was found as the best training system in cucumber which recorded significant increase in number of fruits per vine (19.47), individual fruit weight (133.67 g), maximum vine length (446.53 cm at final harvest), harvest duration (38.67 days), fruit yield per vine (2.183 kg) and per 100 m^2 (611.246 kg) with a minimum internodal length (4.27 cm), while training on nylon netting recorded significantly longer (17.47 cm) fruits. The incidence of white fly and leaf miner was less in single stem staking while the lowest incidence of aphids was recorded in overhead trellis.

Keywords: Cucumber, training, staking, polyhouse

Introduction
Cucumber (*Cucumis sativus* L.) is one of the most important and very ancient old-world vegetables of family Cucurbitaceae popular throughout the world for its crisp texture and taste. It is a primary source of vitamins and minerals for human body but its calorific and nutritional value is very low. Fruits are good for people suffering from constipation, jaundice, allied diseases and indigestion (Kumar *et al.*, 2017) [11]. Cucumber is a truly versatile vegetable. Tender fruits before maturity are used as salad, pickles as well as cooked vegetable. Cucumber fruit extracts are used in health and beauty products including perfumes, lotions, soaps and shampoo. Indigenous practices create medical concentrations from the roots, leaves, stems and seeds. Cucumber is available almost throughout year from different areas with mild climates *viz.*, hills, river beds, *etc.* The cucumber has emerged as a large export-oriented delicacy (Arya, 2002) [4].
In greenhouse vegetable production, profits are greatly dependent on the quantity and quality of the yield (Premalatha *et al*., 2006, Ahirwar and Hedau, 2015) [13, 1]. Manipulation of canopy architecture through training, pruning and proper spatial arrangements has been identified as important factors of crop management to maximise marketable yields from greenhouse crops (Premalatha *et al*., 2006, Kumar *et al.*, 2014, Spehia *et al*., 2014, Lal *et al*., 2016, Rajalingam *et al.*, 2017) [13, 10, 16, 12, 14] including cucumber (Kapuriya *et al*., 2017) [9]. It facilitates interculture, more light interception for enhanced growth and create more food reserves, maintain proper air circulation around plants necessary for healthy growth, production of early and higher marketable yields per unit area with superior quality, and also reduces pest and disease complex affecting plants as well as fruits in vegetable crops *viz.*, capsicum, tomato, gourds, cucumber, *etc.*
Cucumber, an herbaceous trailing annual is capable of spreading in all directions. Training methods vary with different growth habits of cucumber cultivars and for different plant densities (Kapuriya *et al*., 2017) [9]. Keeping these points in view, the present investigation was therefore carried out to study the effect of different training systems on growth, yield, yield attributing parameters, and pest and disease incidence in parthenocarpic cucumber.

Material and Methods
The present investigation was conducted during *Summer* season, 2018 under naturally

ventilated polyhouse condition at the Instructional-cum-Research Farm of Horticulture Section, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur situated at $16^0$41' North latitude, $74^0$16' East longitude with an altitude of 548 meter above MSL and comes under *sub-montane* zone of Maharashtra state with an average annual rainfall of 1057 mm. The experiment was laid out in Completely Randomized Design with three repetitions of eight treatments *i.e.* training systems with individual gross plot size of 3.6 m x 2.4 m. The 15 days old healthy seedlings of cucumber were raised in plastic pro-trays using soilless media. Seedlings were transplanted on thoroughly prepared and sterilized raised beds of 0.9 m width and 0.3 m height at spacing of 60 cm x 60 cm. The raised beds were sterilized by standard procedure using formaldehyde. Vermicompost spot application @ 5 t/ha was done during bed preparation. The RDF of N, P_2O_5 and K_2O @ 120:60:160 kg/ha was applied 50% as a basal dose through soil application of urea, single super phosphate and murate of potash at planting and 50% through fertigation three weeks after transplanting @ 2 g/m^2 thrice a week through water soluble fertilizers.

Plants were trained according to different treatments *viz.*, T_1-Overhead trellies (plants trained on overhead trellies 2 m above ground level), T_2-Trellies with three wire (plants trained on three horizontal wires placed 2, 4 and 6 feet above the ground level, respectively), T_3-Single stem staking (plants trained on single vertical wire above 2 m from ground level), T_4-Nylon netting (plants trained on nylon netting up to 2 m from ground level), T_5-Hanger system (plants hanged on wire above 2 m from ground level), T_6-'V' system (plants were pinched and trained on two lateral shoots in 'V' shape and supported with jute thread), T_7-Trellies with two wire (plants were trained on two horizontal wires placed 2 and 4 feet above the ground level, respectively), and T_8-Untrained control (natural ground trailing). The necessary cultural practices and standard plant protection measures were also adopted from time to time to ensure good and healthy crop stand.

Results and Discussion

The growth and flowering performance of cucumber under different training systems under naturally ventilated polyhouse condition is recorded and presented in table 1.

A significant variation in vine length was recorded at different growth stages. Maximum vine length of 271.63, 347.96 and 446.53 cm was recorded in the plants trained with single stem staking at 30, 45 days and at final harvest, respectively which was statistically at par with the treatment plants trained on nylon netting at 30, 45 and at final harvest (262.77, 341.26 and 435.17 cm, respectively) and plant trained on three wire trellies at 30 days and at final harvest (249.27 and 407.19 cm, respectively). Untrained ground trailing vine recorded the minimum length at 45 days and at final harvest.

The results of present findings are in accordance with results reported by Kumar *et al.* (2014) [10], Dhillon *et al.* (2017) [5], Kapuriya *et al.* (2017) [9] and Shirahmadi *et al.* (2017) [15] who recorded the maximum vine length in single stem staking training system of cucumber. The increase in vine length by single stem staking might be due to the restriction of flow of nutrients to the axillary branches which in turn lead to the flow towards the apical tissues thereby increasing the vine length significantly.

Appearance of first female flower was found to be non-significantly influenced by different training systems recording minimum days (23.53) in the single stem staking treatment and maximum (25.20 days) in the treatment of plants trained on two wire trellies.

Table 1: Vegetative growth parameters of cucumber as influenced by different training systems

Treatment	Vine length (cm)			Appearance of first female flower (Days)	Nodal position of first female flower	Internodal length (cm)
	30 DAT	45 DAT	At final harvest			
T_1	231.93	319.06	428.87	24.40	5.27	5.30
T_2	249.27	311.83	407.19	24.70	5.47	5.33
T_3	271.63	347.96	446.53	23.53	5.33	4.27
T_4	262.77	341.26	435.17	24.73	5.50	4.40
T_5	240.10	286.83	392.17	24.07	5.40	5.30
T_6	192.90	282.33	366.00	24.20	4.87	5.37
T_7	146.70	228.70	356.70	25.20	6.27	5.07
T_8	174.67	210.80	307.60	24.00	5.77	4.73
SEm±	7.66	9.41	14.09	-	-	0.24
CD@5%	22.97	28.21	42.26	NS	NS	0.72

(T_1- Overhead trellies, T_2-Trellies with three wire, T_3-Single stem staking, T_4-Nylon netting, T_5-Hanger system, T_6-'V' system, T_7-Trellies with two wire and T_8-Untrained control)

Different training systems showed the non-significant influence on nodal position of first female flower. Plants trained with 'V' system produced first female flower at lower node (4.87) whereas plant trained with trellies with two wires produced first female flower at higher (6.27) node than plants trained with other training systems.

Plants having shorter internodal length as well as more number of nodes are desired for getting higher yield. Internodal length of cucumber vine was significantly influenced by the different training systems in which plants trained with single stem staking (T_3) produced shorter internodal length (4.27 cm) which was statistically at par with the plants trained with nylon netting (4.40 cm) and untrained control (4.73 cm) while maximum internodal length (5.37 cm) was recorded in 'V' system (T_6).

The reason for minimum internodal length of single stemmed plants was probably due to the better exposure of the plant to light, enhanced synthesis of photosynthates and more assimilation of carbohydrates that determines the height and number of nodes per plant. The results of the present investigation are in conformity with the results of Dhillon *et al.* (2017) [5], Rajalingam *et al.* (2017) [14] who reported minimum internodal length in plants trained to single stem and maximum internodal length in control (no training).

Table 2: Flowering and fruit parameters of cucumber as influenced by different training systems

Treatment	Days to 50% flowering	Days to first picking	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit yield (kg/plant)	Fruit yield (kg/ 100m^2)	Harvest duration (days)
T_1	28.10	33.33	13.57	100.67	15.10	1.483	407.196	37.93
T_2	29.50	33.13	15.07	118.00	16.33	1.898	530.125	38.47
T_3	27.17	31.43	19.47	133.67	16.57	2.183	611.246	38.67
T_4	27.47	32.00	18.57	109.00	17.47	2.056	573.888	38.53
T_5	28.33	32.87	17.40	115.00	15.33	1.928	541.708	37.33
T_6	29.00	33.10	15.33	98.67	15.30	1.632	446.118	36.40
T_7	29.83	33.90	13.47	95.00	15.63	1.369	377.170	35.93
T_8	30.37	32.60	11.73	110.00	14.87	1.345	375.182	30.53
SEm±	-	-	0.77	5.25	0.53	0.08	20.52	1.07
CD @5%	NS	NS	2.31	15.74	1.60	0.26	61.54	3.21

(T_1- Overhead trellies, T_2-Trellies with three wire, T_3-Single stem staking, T_4-Nylon netting, T_5-Hanger system, T_6-'V' system, T_7-Trellies with two wire and T_8-Untrained control)

Days to 50% flowering were non-significantly influenced by different training systems with plants trained on single stem stakes recording minimum (27.17) and untrained control the maximum (30.17) days for 50% flowering.

Days recorded to first picking were non-significantly influenced by different training systems but the plant trained on single stem staking recorded least days (31.43) to first picking. Maximum days for first picking were recorded in plants trained on trellies with two wire (33.90) system. Early appearance of flowers at lower nodes coupled with exposure of fruits to sunlight and aeration could be the reason for early picking on plants trained to single stem. Kumar *et al.* (2014) [10], Dhillon *et al.* (2017) [5] and Rajalingam *et al.* (2017) [14] recorded similar results in cucumber with earlier first harvest of fruits in plants trained to single stem system.

Different training systems had significant influence on number of fruits per plant. Maximum number of fruits per plant were produced by plants trained on single stem (19.47) which was statistically at par with plants trained with nylon netting (18.57) and hanger system (17.40) while minimum number of fruits (11.73) were recorded in untrained control. The results are in conformity with Kalyanrao *et al.* (2012) [8], Ekwu *et al.* (2012) [6] in single stem vertical staking and Shirahmadi *et al.* (2017) [15] who recorded the highest number of fruits of cucumber in high wire system.

Average fruit weight was significantly influenced by training systems with maximum fruit weight (133.67g) observed in plants trained on single stem staking which was followed by and statistically on par with plant trained on trellies with three wires (118.0 g), whereas, minimum fruit weight was observed in plants trained on trellies with two wires (95.00 g). However, untrained control treatment recorded the average fruit weight of 110 g. The results of present study are in accordance with Hochmuth *et al.* (1996) [7], Kumar *et al.* (2014) [10], Dhillon *et al.* (2017) [5] and Rajalingam *et al.* (2017) [14] in cucumber, Alsadon *et al.* (2013) [2] in capsicum and Yadav *et al.* (2017) [17] in tomato who recorded significant increase in fruit weight with single stem vertical training method over the rest of the treatments. Highest fruit weight from single stem plants might probably be due to the better exposure of the plants to light, enhanced synthesis of photosynthates and more assimilation of carbohydrates.

Maximum fruit length was recorded in plants trained on nylon netting (17.47 cm) which was statistically at par with plants trained on trellies with three wires (16.33 cm) and single stem staking (16.57 cm) while the minimum fruit length was observed in untrained control (14.87 cm). The results of present findings are in conformity with the earlier workers who recorded the increase in fruit length in varying training treatments over the untrained control system as recorded by Hochmuth *et al.* (1996) [7], Ekwu *et al.* (2012) [6], Kumar *et al.* (2014) [10] and Rajalingam *et al.* (2017) [14] in cucumber and Alsadon *et al.* (2013) [2] in Capsicum.

A significant influence of training systems on yield per vine was recorded with all training treatments over the untrained control. Significantly higher fruit yield (2.183 kg) per plant was recorded in single stem staking which was statistically at par with plants trained on nylon netting (2.056 kg) and hanger system (1.928 kg). The minimum fruit yield (1.345 kg) per plant was recorded in untrained control.

Yield per plant is one of the most important factors which attributes to the yield per unit area. Improvement in quality and increase in yield will ultimately decide the practical utility of adopting different training systems. Hochmuth *et al.* (1996) [7], Ekwu *et al.* (2012) [6], Kumar *et al.* (2014) [10] and Rajalingam *et al.* (2017) [14] in cucumber and Kalyanrao *et al.* (2012) [8] in bottle gourd recorded the similar results of higher yield per plant in single stem training system over the rest other systems and ground trailing. This might be the result of probability of adequate air movement around the plants, better exposure of the plants to light and absorbance, enhanced synthesis of photosynthates and more assimilation of carbohydrates as reported by Rajalingam *et al.* (2017) [14].

Fruit yield per 100 m^2 polyhouse area also had a significant influence of training systems. Training the plants on single stem staking recorded significantly higher fruit yield (611.100 kg 100 m^{-2}) which was statistically at par with plant trained on nylon netting (573.888 kg 100 m^{-2}). Minimum fruit yield (375.182 kg 100 m^{-2}) recorded in untrained control.

The higher yield from the plants trained on single stem staking may be attributed to its better performance in yield per plant which ultimately resulted in increased yield per 100 m^2. The results for yields per unit area with maximum yields in single stem training system are in accordance with Kalyanrao *et al.* (2012) [8] and Rajalingam *et al.* (2017) [14] who observed that drape system of training in cucumber produced significantly maximum fruit yield per m^2 whereas the control registered the lowest values for all these characters.

All the training systems recorded a significant extension of harvest duration over ground trailing under naturally ventilated polyhouse condition with maximum harvest duration of 38.67 days in plant trained on single stem which was statistically similar with rest training systems except untrained control.

The results of present study were in accordance with Dhillon *et al.* (2017) [5] and Premalata *et al.* (2006) who recorded the maximum harvest duration in single stem training method in

cucumber. This extension of harvest period might be due to early appearance of pistilate flowers at lower nodes coupled with exposure of fruits to sunlight and aeration which could be the reasons for early pickings and longer harvest duration in plants trained to single stem. Similar results were also reported by in cucumber.

The data pertaining to the infestation of aphids, white fly and jassids as affected by training systems in cucumber is presented in Table 3.

Significant differences were noticed for the incidence of aphids per plant among all training systems of cucumber under naturally ventilated polyhouse condition. The least (1.93) incidence of aphids per plant was observed in plants trained on overhead trellies. Highest survival population (2.83) of aphids per plant was observed in plant trained with 'V' system which also recorded the significantly highest incidence of white fly per plant (2.82) over the rest of the training treatments. The lowest infestation of white fly per plant was observed in plants trained on single stem staking and on hanger system (1.87). The significantly lowest (10.40%) infestation of leaf miner was observed in single stem staking which was statistically significant over rest of the treatments under study with the highest (17.56%) infestation in the untrained control. Thus, among all the treatments, single stem staking (T_3) and Nylon netting (T_4) has shown lowest population of sucking pest as well as leaf miner infestation.

There was no any disease incidence observed in different training systems of cucumber under naturally ventilated polyhouse condition.

Table 3: Pest incidence in cucumber as influenced by different training systems

Treatment	Mean Survival population of pests per plant		Leaf miner (% infestation)
	Aphids	White fly	
T_1 (Overhead trellies)	3.24 (1.93)*	4.70 (2.28)*	7.46 (15.85)**
T_2 (Trellies with three wire)	5.00 (2.34)	3.67 (2.04)	5.10 (13.05)
T_3 (Single stem staking)	3.67 (2.04)	3.01 (1.87)	3.26 (10.40)
T_4 (Nylon netting)	3.70 (2.05)	3.62 (2.03)	4.93 (12.81)
T_5 (Hanger system)	3.86 (2.09)	3.02 (1.87)	5.76 (13.89)
T_6 ('V' system)	7.53 (2.83)	7.44 (2.82)	6.62 (15.03)
T_7 (Trellies with two wire)	3.99 (2.12)	4.28 (2.18)	7.38 (15.76)
T_8 (Untrained control)	4.07 (2.14)	4.66 (2.27)	9.1 (17.56)
SEm±	0.06	0.05	0.30
CD @ 5%	0.20	0.16	0.91

*Figures in parenthesis are transformed values $\sqrt{X + 0.5}$ for sucking pests

**Figures in parenthesis are arcsine transformed value for leaf miner

Conclusion

From the present investigation, it was concluded that training systems for cucumber under naturally ventilated polyhouse conditions significantly influenced growth, yield, and yield-attributing character. Plants trained on single stem staking were found superior in plant height, internodal length, number of fruits per plant, fruit weight, fruit yield per plant, fruit yield kg/100 m^2, and harvest duration, while plants trained on nylon netting recorded maximum fruit length. The training systems did not exhibit significant influence on the appearance of the first female flower, the nodal position of the first female flower, the days for 50% flowering, and days for first picking. The incidence of pest attack was lower in plants trained on single stem staking and plants trained to the V' system; however, untrained control treatments recorded a higher pest incidence.

It concluded that the single-stem staking system was the most effective training method for cucumber grown in polyhouse because it produced the highest yield and yield attributing characters.

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