The Pharma Innovation Journal 2020; 9(3): 425-430

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2020; 9(3): 425-430

www.thepharmajournal.com
Received: 16-01-2020
Accepted: 20-02-2020

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Special horticultural practices for vegetable crops under protected cultivation

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Abstract
The concept of modern horticultural technologies has widened the horizon of vegetable industry in India. Now-a-days, it is not only a question of providing enough vegetables for a balanced diet, but also to produce quality vegetables throughout the year. The present per capita availability of vegetable in India is only 210 g against the requirement of 300 g/capita/day (Saravaiya *et al*.). The crops grown in open conditions are often exposed to varying levels of temperature, humidity, wind flow etc., which ultimately influence the productivity as well as quality of a crop extensively. Further, with globalization of markets and global climate change, protected cultivation along with special horticultural practices emerged as the single most important technology for ensuring high productivity, improved quality and lucrative return.

Keywords: Globalization, protected cultivation, special horticultural practices

1. Introduction

1.1 What is protected cultivation?

Protected cultivation can be defined as a cropping technique where in the micro environment surrounding the plant body is controlled partially/fully as per plant need during their period of growth to maximize the yield and resource saving.

1.2 They are different type of protected structure

- Poly house
- Glass house
- Net house
- Plastic low tunnel

1.3 Why protected cultivation?

In the changing scenario of increasing population, decreasing cultivable land / water resources, increasing urbanization / industrialization there is need to produce more from available resources.

Further, with globalization of markets and global climate change, greenhouse cultivation of high value crops has emerged as the only top most important technology for ensuring high productivity, improved quality, lucrative return and continue supply.

2. Some of special horticultural practices are below

2.1 Training

Allowing plant to grow over different structures and grooming/ trimming them in respect to give them the specific shape and structure. So that they can bear the heavy load of the fruits and produce quality harvest.

2.1.1 Objective of training

- Remove excess growth.
- Force plants to give desired/ certain shape.
- Minimize direct contact with the soil.
- Maximum use of resources.
- Easy intercultural operation.

Table 1: Show the method of training

Crops	Method of training
Tomato	Single stem training, Two stem training, Three stem training
Capsicum	Two leader system, Four leader system
Cucumber	V- system, Umbrella system, Single stem training

Table 2: Major greenhouse vegetable production areas of the world (> 500 ha only)

Country	ha ('000)	Country	ha ('000)
China	81.0	Brazil	1.0
Spain	70.4	USA	0.7
South Korea	47.0	New Zealand	0.7
Japan	36.0	India	0.7
Turkey	33.5	Lebanon	1.1
Italy	25.0	Serbia	1.0
Morocco	16.5	Libya	1.0
Poland	5.2	Bulgaria	1.1
Hungary	5.4	Canada	1.2
Algeria	5.0	Egypt	1.2
Greece	5.0	Romania	1.3
Netherlands	4.6	Tunisia	1.3
Columbia	1.2	Australia	1.3
Mexico	4.3	Germany	1.4
Israel	4.0	Russia	1.4
Iran	4.0	Belgium	1.6
Palestine	3.3	Jordan	2.0
Syria	3.1	Chile	2.1
Ukraine	2.7	Argentina	2.2
Ecuador	2.7	Portugal	1.5

***Source*:** Hickman (2011) [13]

Table 3: Major vegetables grown in greenhouses across the world (Yield ha^{-1} in tones)

Country	Tomato	Capsicum / pepper	Cucumber	Lettuce
China	In China the area under plastic greenhouse vegetable cultivation is 2.5 million hectares, out of which 90% area is under vegetable cultivation (Chang *et al.*, (2011) [7]. Among vegetables tomato, cucumber, peppers and eggplant are the major vegetables being grown under plastic greenhouse cultivation system.			
USA	484	100	-	-
Netherlands	460	262	690	NA
Canada	463	258	530	336
United kingdom	413	248	480	36
Finland	337	138	396	126
Russia	300	100	-	-
Mexico	153	NA	-	-
Syria	141	NA	-	
Spain	150	70	95	25
Israel	NA	100	-	-
Turkey	106	104	105	NA
Nicaragua	NA	49	-	-

***Source*:** Hickman (2011) [13], Chang *et al.* (2011) [7]

2.1.2 Single stem system

2.1.2.1 Tomato

Kumar and Patel (2016) [16] conducted experiment on effect of spacing and supportive training on quality parameter in tomato under protected cultivation at NAU, Navsari. They cited that significantly maximum fruit volume (146.45 cm^3), pericarp thickness (8.30 mm), equatorial diameter (6.18 cm), polar diameter (6.68 cm), dry matter content (5.23 g), fruit texture (4.22 kg cm^{-2}), total soluble solids (4.07 ^{o}Brix), vitamin A (1109.44 IU), lycopene content (2.60 mg) and shelf life (20.65 days) observed into single stem training system.

Patel *et al.* (2016) [16] tested response of tomato (*Solanum lycopersicum* L.) to varying levels of spacing and training under protected cultivation. They observed that the significantly maximum plant height at 90 and 120 DAP (163.11 and 216.69 cm, respectively), leaf area (857.09 cm^2), minimum days to first flowering (28.22 days), number of flowers per cluster (8.78), number of fruits per cluster (6.19), number of fruits per plant (31.83), fruit weight (92.86 g), yield per plant (2.71 kg) and yield per m^2 (6.76 kg) in tomato were obtained in single stem training system.

Yadav *et al.* (2017) [35] studied the effect of spacing and training on vegetative growth characteristics and yield of tomato (*Solanum lycopersicum* L.) grown in playhouse at Rajasthan. They took three level of training likewise, single stem, two stem and three stem training system and they found that significantly higher fruit weight (96.91 g), fruit diameter (11.67 cm), volume of fruits (100.52 g cm^{-3}) and total yield per plant (7 t ha^{-1}) into single stem training system.

2.1.2.2 Cucumber

Dhillon *et al.* (2017) [10] conducted experiment on influence of training on vegetative growth characteristics and yield of polyhouse grown cucumber (*Cucumis sativus* L.). They reported that significantly minimum days to fifty percent flowering (23.67), maximum harvesting duration (56 days) and fruit weight (136.23 g) noted into single stem training system.

Mardhina *et al.* (2017) [17] tested the effects of pruning on growth and yield of cucumber (*Cucumis sativus*) cv. Mercy at Indonesia. They reported that among the different treatment single main stem pruning gave better result for fruit weight (g) as compared to other.

2.1.3 Two stem system

Tomato

Khoshkam *et al.* (2014) [15] studied the impact of different plant training systems on quantitative and qualitative parameters of greenhouse tomato cultivars. They took three levels of training system likewise, one stem, two stem and four stem training system. They found that significantly maximum fruit length (34.8 cm), diameter (36.3 cm), total soluble solid (2.8 ^{0}Brix), vitamin C (85.3), acidity (0.79%) and yield (137.5) reported into two stem training systems.

2.1.4 Three stem system

Tomato

Goda *et al.* (2014) [12] conducted experiment on effect of shoot pruning on growth, yield and fruit quality of husk tomato *(Physalis pubescens* L.). They took different treatments likewise, control, three, six and nine shoots. They found that significantly maximum plant height (158.00 and 163.33 cm), stem diameter (2.30 and 2.33 cm), leaf area (9.74 and 9.52 cm^2), total chlorophyll (4.65 and 4.68 mg 100 g^{-1} F.W), average fruit weight (5.24 and 5.79 g), fruit size (4.77 and 5.33 cm^3), fruit diameter (2.06 and 1.98 cm), vitamin C (23.1 and 22.7 mg 100 g^{-1} F.W), total sugar (9.92 and 10.25 g 100 g^{-1} d. w.), total carbohydrate (3.65 and 3.93 m 100 g^{-1} F. W.) and dry matter (18.1 and 17.9%) observed into three shoot system.

2.1.5 Four stem system

Capsicum

Ahirwar and Hedau (2015) [1] studied the effect of shoot pruning on growth, yield and quality attribute for a winter capsicum (*Capsicum annum* L.) crops in protected condition. They noted that significant highest polar and radial diameter (100.94 and 111.84 mm) cited in fourth leader system.

Shetty and Manohar (2008) [28] found that the minimum days to first flowering (27.81 and 25.25 DAT), fifty percent

flowering (34.18 and 32.63 DAT), maximum number of flower per plant (34.34 and 39.41), fruit set (52.37 and 63.51), yield per plant (1.97 and 2.39 kg), yield per plot (19.70 and 23.90 kg) and yield per hectare (118.20 and 143.40 tonnes) in both season of capsicum were noted in pruning to four branches per plant + NAA 10 ppm as compared to other treatments.

Singh and Hedau (2015) [30] conducted the experiment on effect of pruning levels on yield and quality of winter capsicum in hills protected condition at Almora (Uttarankhand). They reported that fourth leader gave statistical significant result for number of fruit plant^{-1} (93), polar diameter of fruit (100.94mm) and fruit yield plant^{-1} (10.58 kg).

Thakur *et al.* (2018) [33] conducted the experiment on effect of training level on growth and yield of capsicum (*Capsicum annuum* L.) hybrid buffalo under natural ventilated polyhouse at Samastipur, Bihar. They observed that significantly maximum number of leaves per plant at 30, 60, 90 and 120 DAP (50.01, 85.37, 111.60 and 119.61, respectively), maximum number of leaves at 30, 60, 90 and 120 DAP (50.01, 85.37, 111.60 and 119.61, respectively), maximum number of flowers per plant at 60, 90, 120, 150 and 180 DAP (10.19, 11.41, 9.44, 7.54 and 3.62, respectively), leaf area (99.95 dm^2), number of fruits per plant (20.31), fruits yield per plant (3.20 kg), B:C ratio (6.21) and yield (95.01 t ha^{-1}) in capsicum were noted with four shoot system of training than two & three shoot system. While, significant higher fruit weight (175.91 g) was found into two shoot system of training than the rest treatments.

2.2 Plant growth regulators

- The growth regulators can be used to increase fruit set at high and low temperature.
- The flower dipping in PCPA (Parachloro- Phenoxy acetic acid) 30 ppm at fully open stage, to increase the fruit set at low and high temperature.
- The application of cycocel (500 ppm) on the plants to increase flower bud stimulation and increase fruit set.

Table 4: Effects of the Common Name Dose (mg l-1)

Common Name	Dose (mg l^{-1})	Effects
Ethephon	200-500 as whole plant spray	Flowering induction, better rooting and fruit setting
2,4-D	2-5 as seed treatment or whole plant spray	Increase fruit set, earliness and parthenocarpy
IBA	50-100 as foliage spray	Increase fruit set
IAA	50-100 as foliage spray	For good fruit size and yield

2.2.1 Tomato

Ali *et al.* (2012) [3] studied the effect of plant growth regulators on growth and yield of tomato (*Solanum lycopersicum* L.) varieties and they took three replications by using three plant growth regulators (G_1=NAA, G_2=GA_3 and G_3=IAA) and three tomato varieties (V_1=BARI Tomato 3, V_2=BARI Tomato 7 and V_3=BARI Tomato 9). The results of experiment showed that GA_3 produced highest number of branches per plant (12.37), number of flowers per plant (91.51) and yield (126.6 t ha^{-1}). In case of tomato variety, highest number of branches per plant (11.81), number of flowers per plant (91.66) and yield (99.74 t ha^{-1}) were recorded in BARI Tomato 7.

Bokade *et al.* (2006) [6] carried out an experiment on effects of GA_3, NAA and 4-CPA at 25 and 50 ppm on the growth and yield of tomato cv. Dhanshree. They reported that significantly maximum plant height (74.21 and 75.33 cm) was found into GA_3 at 25 and 50 ppm, respectively.

Choudhary *et al.* (2006) conducted experiment on growth and yield of summer tomato as influenced by plant growth regulators namely 4-clorophenoxy acetic acid (20 ppm), gibberelic acid (20 ppm), 4-clorophenoxy acetic acid + gibberelic acid (20 ppm). They observed that significantly maximum number of fruits per plant (36.54), single fruit weight (74.01 g), lycopene content (2.45 mg 100 g^{-1}), ascorbic acid (10.49 mg 100 g^{-1}), vitamin A (320 IU 100 g^{-1}) and yield (28.4 t ha^{-1}) noted into application of 4-CPA and GA_3 in combination.

Gelmesa *et al.* (2010) [11] carried out a experiment on effects of different concentrations and combinations of the plant growth regulators (PGRs) likewise, 2,4-D and GA_3 spray on fruit setting and earliness of tomato varieties. The experiment consisted of four levels of GA_3 (0, 10, 15 and 20 ppm) and three levels of 2,4-D (0, 5 and 10 ppm). The study indicated that application GA_3 extended flowering and maturity time and increased number of fruit per cluster, fruit set percentage and marketable fruit.

Pandita *et al.* (1976) [18] studied the significant difference in fruit set percentage after 20 days of spraying due to PCPA (50 ppm) and NAA (10 ppm) at flower initiation stage. PCPA recorded maximum number of fruits (19.5) followed by NAA (17.0) in tomato, which was significantly higher than the control (3.9).

Patel *et al.* (2006) [19] tested the influence of plant growth regulators on growth, yield and quality of tomato cv. Marutham and brinjal cv. Surati Ravaiya. They found that foliar sprays of 2, 4-D at 6 ppm and 4 ppm gave the significantly maximum fruit yield of tomato (69.80 t ha^{-1}) and brinjal (64.35t ha^{-1}), respectively and different quality parameters like TSS (5.56 and 5.06 ^{O}Brix) and acidity (0.60 and 0.29%) were found higher with foliar spray of 2 ppm 2, 4-D in tomato and brinjal, respectively. In tomato, ascorbic acid was found maximum (22.46 mg 100 g^{-1}) with 8 ppm 2, 4-D while in brinjal it was maximum (16.46 mg 100 g^{-1}) with 100 ppm NAA.

Ram *et al.* (2014) [24] carried out a field experiment to assess the growth, flowering, fruiting yield and quality traits of tomato cv. Kashi Vishesh (H-86). The experiment was laid out in randomized block design with three replications for tomato crop consisted of 10 treatments namely, control, GA_3 @ 20 ppm, GA_3 @ 40 ppm, GA_3 @ 60 ppm, NAA @ 10 ppm, NAA @ 20 ppm, NAA @ 30 ppm, 2, 4-D @ 10 ppm, 2, 4-D @ 15 ppm and 2, 4-D @ 20 ppm. They found that GA_3 significantly increase plant height (40.97 cm), number of branches (12.22), number flowers per plant (104.55), number of clusters per plant(21.87), number of fruits per clusters (12.13), number of fruits per plant (42.70), average fruit length (4.16 cm), average fruit diameter (6.07 cm), average fruit weight (43.93 g), fruit yield per plant (1.87 kg), fruit yield per plot (16.87 kg), fruit yield per hectare (694.44 q) and total soluble solids (5.18 ^{0}Brix).

Singh and Lal (2001) [31] conducted an experiment to

determine the effect of plant bio-regulators on the growth and yield of tomato cv. Pant T-3. The bio-regulator treatments comprised CIPA (10 and 20 ppm), NAA (20 and 40 ppm), 2,4-D (5 and 10 ppm), Alar (50 and 100 ppm), GA_3 (5 and 10 ppm), ethephon (50 and 100 ppm), PPP (5 and 10 ppm) and control. All the plant bio-regulators decreased plant height compared to the control. The number of branches per plant increased with 10 ppm GA_3. All the bio regulators decreased the number of days to fruit maturity except the control. The maximum and minimum number of fruits per plant was recorded in 5 ppm GA_3 and 10 ppm 2,4-D, respectively. The minimum number of days to fruit maturity were found in 10 ppm 2,4-D.

Verma *et al.* (2014) [34] studied the effect of NAA (15, 30, 45 ppm), 2,4-D (5, 10, 15 ppm) and GA_3 (20, 30, 40 ppm) on growth, quality and yield of tomato cv. Kashi Vishesh. They found significantly maximum number of fruits per plant (43.49), percentage of fruit set (64.83) and number of flowers per plant with GA_3 at 40 ppm.

2.2.2 Capsicum / Bell paper

Bharti *et al.* (2017) [5] carried out an experiment on growth, yield and economics of bell pepper (*Capsicum annuum* L.) under the influence of PGR in protected culture at NAU, Navsari. They found that the significant highest number of fruits per plant (26.0), average fruit weight (185.0 g), fruits yield per plant (3.0 kg), marketable yield per m^2 (10.75 kg), total yield per m^2 (11.44 kg), gross return (343200 Rs. ha^{-1}), net realization (188849 Rs. ha^{-1}) and BCR (1.22) were came out in 20 ppm NAA as compare to rest of the treatments under experiment. Das *et al*. (2015) [9] evaluated the influence of plant growth regulators namely GA_3 at 100 ppm, 4-CPA and Litosen on yield contributing characters and yield of bell pepper (*Capsicum annuum* L.). They noted that 4-CPA of 2000 ppm had more potential to enhanced flowering by four days earlier and it also increased number of flowers per plant (5%), number of fruits per plant (35%), fruit setting (26.02%), days to last picking and fruit yield per ha (39%) in Lamuyo.

2.3 Pollination

In the greenhouse, wind is not strong enough to shake the flowers sufficiently to transfer the pollen. The optimum temperature for pollination is within the range 21 to 27° C. Optimum relative humidity is 70 percent. Above 80 percent relative humidity, pollen grains are not dispersed well.

2.3.1 Different methods are used for effective pollination and good quality yield.

- Hand pollination
- Battery operated vibrator
- Air blowers
- Bumble bees

2.3.2 Tomato

Al-Attal *et al.* (2003) [2] tested influence of pollination technique on greenhouse tomato production at Jordan. They observed that significantly the maximum average yield per plant (5132.20 g), average fruit weight (100.3 g), firmness (3015.80 kg cm^{-2}), average fruit specific gravity (1.03 g cm^{-3}) and average fruit set (99.1%) in tomato were cited in bumbles bee pollination whereas, PGB and vibration treatment followed by them.

Yankit *et al.* (2018) [36] studied the effect of bumble bee pollination on quality and yield of tomato (*Solanum lycopersicuum* Mill.) grown under protected condition at Nauni, Solan. They reported that significantly maximum number of fruit per cluster (6.76 ± 0.18), number of fruits per plant (75.80 ± 0.78), fruit length (5.16 ± 0.49 cm), fruit breadth (5.75 ± 0.32 cm), fruit weight (93.87 ± 1.07 g), fruit yield (12.7 ± 0.12 kg m^{-2}), healthy fruits (90.33 ± 4.5%), number of seed per fruit (102.95 ± 1.52) and 100 seed weight (6.32 ± 0.36 g) found into bumble bee pollination as compare to control.

2.3.4 Bitter gourd

Rahile *et al*. (2016) studied the effect of honey bee pollination on growth and yield of bitter gourd. They found that the minimum flower drop (7.65%) and the maximum fruit set (92.35%), fruit weight (24.78±1.85 g), fruit length (6.31±0.19 cm), diameter (3.27±0.13 cm) and yield $acre^{-1}$ (4500 kg) in bitter gourd were noted in treatment of pollination by *Apis cerana* as compare to natural pollination.

2.3.5 Cole crops

Rouf *et al*. (2016) [26] conducted experiment on effect of honey bee pollination and curd scooping on seed yield of cauliflower. They noted that the significantly maximum seed per siliqua (11.08), 1000 seed weight (3.57g) and seed yield (455.88 kg ha^{-1}) in cauliflower seed production were obtained by using bee pollination inside the net.

Shushil *et al*. (2013) [29] studied the enhancing seed production of three brassica vegetables by honey bee pollination in North-western Himalayas of India. They observed that significantly maximum pod per panicle (55.10, 45.80 and 45.60), seed per pod (16.70, 19.10 and 17.15,), 100 seed weight (3.36, 1.11 and 4.19) and seed yield (620.50, 212.85 and 187.00 kg ha^{-1}) in broccoli *var.* Pusa Samridhi, chinese cabbage *var*. open type and knol-khol *var*. White Vinnea, respectively were found in planned honey bees pollination as compared to natural pollination.

2.3.6 Capsicum

Putra *et al*. (2014) [21] observed that the significantly maximum fruit production per plant (22 ± 3.5 kg $plant^{-1}$), average fruit weight (12.55 ± 4.17 g) and fruit size (25.16 ± 9.99 cm) were reported in treatment of *Apis cerana* compare to other treatment in *Capsicum annum*. L.

2.3.7 Cucumber

Kauffeld *et al.* (1975) [14] observed that honey bee pollination has significantly increased the average weight and quality of cucumbers both in open and plots caged with honey bees.

Rai *et al.* (2008) [28] studied the effect of *Apis mellifera* pollination on the yield attributing characters and yield of cucumber (*Cucumis sativus* L.). They cited that the significantly higher number of fruit per plant (75.75), average fruit weight (147.35 g) and yield (236.25 q ha^{-1}) in cucumber under poly house with bee hive as compare to without bee hive and open field condition.

2.4 Mulching

Mulching is done to cover the soil around plants with a protective material, which may be organic or synthetic.

2.4.1 Basic properties of mulch film

- Air proof so as not to permit any moisture vapor to escape.
- Thermal proof for preservation of temperature and

prevention of evaporation.
- Durable at least for one crop season.

2.4.2 Types of mulch film
A wide range of plastic films based on different types of polymers have all been evaluated for mulching at various periods in the 1960s. LDPE, HDPE and flexible PVC have all been used and although there were some technical performance differences between them, they were of minor nature. Owing to its greater permeability to long wave radiation which can increase the temperature around plants during the night times, polyethylene is preferred. Today the vast majority of plastic mulch is based on LLDPE because it is more economic in use.

2.4.3 Benefits of mulching
- It reduces evaporation of water from the soil.
- Prevents compaction of the soil surface.
- It prevents the leaching of fertilizer.
- It suppresses the weed growth.

2.4.4 Tomato
Singh *et al.* (2017) [32] studied the influence of mulching on growth and yield of tomato (*Solanum lycopersicum* L.) under protected environment. They found that the significantly maximum number of node per plant (39.5), plant height (245.8 cm), fruits per plant (40.4), fruit weight (60.2 g), yield per m^2 (10.9 kg m^{-2}), harvest duration (85.6), minimum cost of cultivation (70.2 Rs. m^{-2}), maximum gross return (211.4 Rs. m^{-2}) and maximum net return (147.6 Rs. m^{-2}) in tomato were found in double shaded plastic mulch than others coloured plastic mulch use in the experiment.

2.4.5 Cucumber
Aniekwe *et al.* (2015) [4] conducted experiment on effects of different mulching materials and plant densities on the environment, growth and yield of cucumber at Ebony State University, Abakaliki. They found that significantly maximum number of vines (5.2), vine length (129.7 cm) in cucumber found into transparent plastic mulch.
Rolaniya *et al.* (2018) [25] studied the effect of irrigation levels and mulch on growth and yield of cucumber under poly house condition at Rajasthan. They revealed that the significantly maximum number of branches per vine at 60 DAT (1.71), length of vine at 60, 90 DAT and harvest stage (3.72, 3.84, 3.97 m), number of leaves per vine at 60 and 90 DAT (22.55 and 27.32), leaf area per plant at 60 and 90 DAT (391.19 and 405.75 cm^2), minimum days to first flowering (35.24), days to first fruiting (41.71) and days to first harvest (44.11), maximum fruit length (13.16 cm), fruit girth (3.55 cm), fruit weight (110.83 g), number of fruit per vine (11.91), fruit yield per vine (1.37 kg) and fruit yield (561.31 q ha^{-1}) in cucumber found in black polythene mulch as compare to straw mulch and control.

3. Conclusion
- Various horticultural practices likes as training, pruning, pollination, PGRs and mulching in protected cultivation found significant for achieving higher yield of various vegetable crops.
- In tomato, single stem training results better vegetative and reproductive character of plant. While, in case of capsicum four leader system found higher yield and its attributes.
- In capsicum, four shoot pruning system with NAA @ 10 ppm had significantly improve the yield characters.
- In case of PGRs, NAA @ 20 ppm significantly improve the marketable yield.
- In case of pollination, bumble bee found best for fruit set and higher yield under poly house conditions.
- Use of black and double shaded as well as transparent polythene mulch gave higher yield with good quality fruits.

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