DOI : 10.5958/0974-0112.2015.00095.X

Indian J. Hort. 72(4), December 2015: 518-522

Growth, quality and pest infestation in tomato under protected cultivation in semi-arid region of Punjab

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ABSTRACT

Studies on tomato plant growth, pest infestation, yield and quality were carried out for two consecutive years (2010-2012) under different poly-houses (PHs) and shade net-houses (SNHs). The replicates of SNH structures were covered separately by 35%, 50% and 75% green shade nets. Vigorous tomato plant growth was achieved under PHs and 35% SNHs with more stem diameters ranging from 0.9 ± 0.2 to 1.2 ± 0.1 cm with normal leaf area. Whereas, proliferated or tender plant growth with less stem diameters (0.6 ± 0.1 to 0.7 ± 0.2 cm), leaf specific weight and more leaf area were found under 50 and 75% SNHs. Comparatively, more chlorophyll '*a*' and '*b*' (Chl_a and Chl_b) levels and less carotenoid contents were recorded under 50 and 75% SNHs. Compared to open field, the colour values of tomato fruits indicated more redness under PHs and SNHs (in 35%) and also significantly more weight, fruit size, yield and good quality were achieved. Aphid and whiteflies were able to enter the SNHs, but not caused any serious infestation. Thus, PHs and SNHs (35%) were found fairly useful to create favourable microclimate for tomato plant growth and higher yield and also for minimization of pest infestation.

Key words: Poly-house, pest infestation, protected cultivation, shade-net, tomato.

INTRODUCTION

Tomato (*Lycopersicom esculemum* Mill.) is grown in regions where temperature ranges from 20-32°C. In terms of production, India ranks second in position after China with 11% of total production of the world. Hundreds of tomato cultivars are being used with different shape and size, hybrid or genetically modified. Tomato production is sensitive to temperature and availability of sunlight. Optimal temperature for flowering and fruiting ranges from 23-27°C. Temperature lower than 15°C or higher than 35°C is detrimental for fruit setting. In terms of requirement of sunlight intensity, tomato can be best grown under 25-35 klx light intensity. Low levels of light intensity greatly influence the plant growth, fruit yield and quality of the produce. Several pesticides are being used injudiciously for pest and disease management in tomato fields. Tomato can't be grown in open field in semi-arid region of Punjab due to prolonged fog and frost during Dec.-Jan and sunscald during March-May months due to increased light intensity and temperature. Protected cultivation may be useful for tomato as well as other vegetable production under such climatic fluctuations.

Therefore, present efforts were carried out to evaluate the influences of different PHs and SNHs in terms of light, temperature and relative humidity requirements on tomato plant growth, yield, quality and pest and disease infestation in semi-arid region of Punjab.

MATERIALS AND METHODS

Experiments were carried at CIPHET, Abohar Campus, Punjab at latitude 30.15°N, longitude 74.18° E, 390 m above the sea level with around 200-500 mm annual rainfall. Comparative studies were carried out on insect pest infestation and quality of produce under different PHs and SNHs for two consecutive years (2010-2012). Two dome shaped low tunnel PHs of 15 × 4 × 2.5 m were constructed. Similarly, nine gable-shaped SNH structures of three heights (2.5, 3.0 and 3.5 m) and 6 m × 4 m length and width were constructed. All the three replicates of same height were covered separately by 35, 50 and 75% green shadenets. Tomato seedlings (F_1 hybrid tomato- Naveen) indeterminate were transplanted inside the PHs and SNHs, on raised beds at 100 cm row to row and 40 cm plant to plant distance during last week of October. Daily minimum and maximum relative humidity, temperature and light intensities inside the PHs and SNHs open field were recorded using standard methods. Leaf and fruit temperature were measured by infra-red thermometer (IR-9802). Biochemical analyses were carried out by general standard analytical methods. The surface colour values of the fruits were determined by Hunter L, a, b

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values and yellowness index (Yi) were determined using Hunter Lab Miniscan XE plus colorimeter (Model No. 45/0-L, Hunter lab, USA). 'L' denotes the lightness or darkness, 'a' green or redness and 'b', blue or yellowness of the samples. Yellowness index is a derived parameter from L, a, b and was noted directly from the digital colorimeter.

The drip irrigation system was used for irrigation as per recommended doses and water soluble fertilizers applied through ventury and irrigation was done as per requirement. Crop sanitation, weeding and plant protection measures were followed uniformly throughout the crop periods. Visual growth differentiation among all the protected and open field plants was recorded after 15 days of transplantation. Although, during harsh winter months (Dec.-Jan.) plants in the open field were also protected by low tunnel polythene covering during night hours to protect from continuous fog and frost in this region. Data were analyzed by randomized block design (RBD) and analysis of variance (ANOVA) for each treatment and significance was defined as ($p \leq 0.05$). SAS statistical software was used for all analysis (Statistical Analysis Software Inc., 1990).

RESULTS AND DISCUSSION

Leaf and fruit temperature were found lower (up to 2-3°C) inside the PHs and SNHs than that of the open field during day time. Vigorous tomato plant growth was achieved under PHs and SNHs (35%). Stem diameters were recorded after 120 days of transplantation, *i.e.* in fully grown stage of the plants. Significantly more stem diameter ranging from 0.9 ± 0.2 to 1.2 ± 0.1 cm was observed in plants under PHs and 35% SNHs. Whereas, proliferated plant growth was recorded under 50 and 75% SNHs and diameter of the stems ranged from 0.6 ± 0.1 to 0.7 ± 0.2 cm only. Thus as compared to open field (0.9 ± 0.3 cm) and PHs and SNHs plants, significantly less diameter of the tomato stems were observed under 50 and 75% SNHs (Table 1). Another adverse effect of light deficiency under 50 and 75% shade net conditions was recorded, which exhibited significantly more leaf area with thin leaves. While in case of PHs, 35% SNHs and open field plants no significant variations were observed in leaf area and thickness. Likewise, specific leaf weight (SLW) was recorded having uniform circular (2 cm dia) leaf samples. Under PHs and 35% SNHs, it ranged from 135.0 ± 13.0 to 142.0 ± 10.3 mg unit^{-1} area, while there were no significant variations among these treatments (Table 1). But less SLW under 50 and 75% SNHs was observed. Dıaz-Perez (1) reported decreased stem diameter and increased leaf area of bell pepper under increased shadings with thinner leaves and low SLW. It was also observed that a 40% shade level in tomato reduced SLW by 24% compared with unshaded plants (Bertin and Gary, 4).

Chlorophyll a, b and total carotenoids contents were analyzed to observe stress of sunlight deficiency on tomato plants under different protected structures. Significantly ($p \leq 0.05$) more chlorophyll *a* (Chl_a)

Table 1. Tomato plant growth attributes and chlorophyll and carotenoid contents (µg g^{-1} FW) under different protected structure and open field conditions (2010-12).

Treatment	Stem dia. (cm)	SLW (mg)	Chl_a	Chl_b	Total leaf carotenoids
PH-1	1.1 ± 0.3	138.6 ± 11.5	36.0 ± 6.3	14.0 ± 2.0	344.0 ± 20.3
PH-2	0.9 ± 0.2	142.0 ± 10.3	35.8 ± 4.6	14.2 ± 3.5	346.5 ± 19.8
SNH-1	1.2 ± 0.1	138.0 ± 10.4	39.7 ± 5.6	15.4 ± 4.1	322.7 ± 21.6
SNH-2	1.0 ± 0.1	141.0 ± 14.6	39.8 ± 6.5	16.3 ± 3.5	335.1 ± 19.5
SNH-3	1.0 ± 0.3	135.0 ± 13.0	38.3 ± 7.2	15.6 ± 3.6	335.3 ± 20.6
SNH-4	0.7 ± 0.2	109.0 ± 12.4	59.3 ± 6.6	19.9 ± 2.8	276.6 ± 16.5
SNH-5	0.6 ± 0.2	104.0 ± 9.3	60.1 ± 4.6	21.0 ± 4.2	290.7 ± 14.6
SNH-6	0.7 ± 0.1	100.0 ± 9.6	59.3 ± 5.6	21.8 ± 3.3	284.9 ± 16.3
SNH-7	0.6 ± 0.1	95.1 ± 10.2	68.3 ± 7.2	26.1 ± 5.6	227.2 ± 14.6
SNH-8	0.6 ± 0.2	91.0 ± 11.2	71.9 ± 6.6	28.5 ± 4.5	225.4 ± 17.8
SNH-9	0.7 ± 0.2	92.0 ± 12.6	76.6 ± 5.6	27.7 ± 2.6	216.5 ± 13.5
Open field	0.9 ± 0.3	141.6 ± 12.6	35.5 ± 5.3	12.4 ± 3.8	353.8 ± 16.4
CD at 5%	0.2	14.6	9.6	4.3	17.6

PH-1 to -2 are poly-houses; SNH-1 to -3 are shade-net houses of 35% shade nets with 2.5, 3.0 and 3.5 m heights, while SNH-4 to -6 are shade-net houses of 50% shade nets with 2.5, 3.0 and 3.5 m heights and SNH-7 to -9 are shade-net houses of 75% shade nets with 2.5, 3.0 and 3.5 m heights, respectively of each shade net-house.

contents were found under 50 and 75% shaded conditions. Chl_a contents ranged from 38.3 ± 7.2 to 76.6 ± 5.6 µg g^{-1} in leaves under the SNHs and this range was significantly more than the Chl_a contents in PHs, 35% SNHs and open field tomato plants, which was only 35.1 ± 6.6 to 36.0 ± 6.3 µg g^{-1} leaf (Table 1). Similarly, $chlorophyll_b$ (Chl_b) contents were also found significantly ($p \leq 0.05$) more under 50 and 75% shade net conditions, *viz.* under this reduced sunlight condition Chl_b content ranged from 15.6 ± 3.6 to 28.5 ± 4.5 µg g^{-1} leaf, while in other protected and open field plants Chl_b content was recorded 13.0 ± 5.3 to 14.2 ± 3.5 µg g^{-1} leaf (Table 1). Whereas, total carotenoid contents indicated some adaptability in tomato plants under shade stress. Ilic *et al*. (7) reported that the shade-grown tomato plant leaves generally have higher total chlorophyll and carotenoids content than do in control leaves.

On an average, lowest plant height (52 cm) was found in open field plants after 60 days and this trend continued up to harvesting and it was only 150 cm after 150 days of transplantation (Fig. 1). On the other hand, greatest plant height with less stem diameter and more leaf area were observed under 50 and 75% SNHs. Initiation of such type of plant growth differences under SNHs was observable after 60 days of transplantation and plant height ranged from 80-90 cm. While plant height was found up to 75 cm with comparatively more stem diameter under PHs. Overall up to harvesting, highest plants (265 to 340 cm) with more leaf area and lowest stem diameter were observed under 50 and 75% SNHs. Though as compared to the plants of open field, more plant

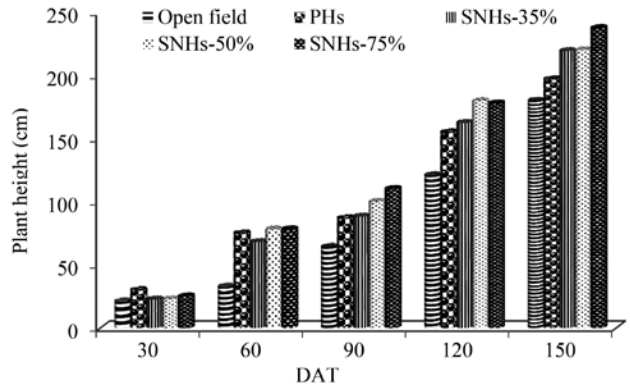

Fig. 1. Tomato plant height (cm) under different protected structures and open field

height (197 cm) was also observed under PHs, but there was healthy and vigorous plant growth with more stem diameter (Fig. 1). As well several reports indicated increased tomato plant height and leaf area with reduced stem diameter and dry weight of stem and leaves under shade net conditions (Zaki *et al*., 10; Sibomana *et al*., 9). Likewise, FAO (6) established lowest limit of 8.4 MJ m^{-2} day^{-1} solar radiations below which horticultural crops cannot survive, defined as trophic limit.

Size, colour and pest and disease incidences were significantly influenced under greenhouses. 'L' has denoted for lightness of the fruits and it showed no significant variations in lightness of the tomato fruits in open field as well as inside produce at the same maturity stage, while, significantly more redness 'a' was observed in PHs and 35% SNHs as compared to

Table 2. Colour, sphericity and insect pest incidence in tomato under different structures (2010-12).

Treatment	Colour			Sphericity	Insect pest incidence	
	L*	a*	b*		aphid	whitefly
PH-1	31.9 ± 1.6	33.1 ± 2.0	16.8 ± 1.6	0.99 ± 0.04	0.0 ± 0.0	0.0 ± 0.0
PH-2	31.6 ± 2.0	33.6 ± 1.6	16.7 ± 2.0	0.98 ± 0.06	0.0 ± 0.0	0.0 ± 0.0
SNH-1	32.1 ± 1.4	32.3 ± 4.1	17.1 ± 1.4	0.99 ± 0.01	18.6 ± 6.2	21.6 ± 5.6
SNH-2	32.4 ± 1.5	34.9 ± 1.5	17.4 ± 1.6	0.96 ± 0.05	20.3 ± 5.6	18.3 ± 4.2
SNH-3	32.1 ± 1.7	33.8 ± 3.1	16.8 ± 1.6	0.96 ± 0.01	16.0 ± 4.5	22.4 ± 4.6
SNH-4	33.9 ± 1.3	30.2 ± 1.1	17.6 ± 2.1	0.96 ± 0.01	8.6 ± 2.8	3.0 ± 1.2
SNH-5	32.4 ± 2.5	30.7 ± 5.7	16.6 ± 0.4	0.97 ± 0.01	6.6 ± 2.4	3.0 ± 1.1
SNH-6	32.6 ± 1.8	29.8 ± 2.6	16.9 ± 2.5	0.99 ± 0.01	8.2 ± 3.1	6.0 ± 1.6
SNH-7	33.5 ± 1.9	30.1 ± 3.8	17.1 ± 1.2	0.97 ± 0.02	0.0 ± 0.0	0.0 ± 0.0
SNH-8	32.9 ± 2.3	30.5 ± 5.5	16.8 ± 0.6	0.98 ± 0.01	0.0 ± 0.0	0.0 ± 0.0
SNH-9	33.1 ± 2.5	28.2 ± 3.1	16.8 ± 1.6	0.97 ± 0.02	0.0 ± 0.0	0.0 ± 0.0
Open field	30.0 ± 4.3	30.2 ± 4.6	22.8 ± 2.9	0.97 ± 0.01	58.2 ± 7.6	46.6 ± 8.6
CD at 5%	NS	2.1	1.6	NS	7.6	8.3

open field (Table 2). The 'a*' values under protected houses ranged from 32.3 ± 4.1 to 34.9 ± 1.5. But in 50 and 75% SNHs it ranged from 28.2 ± 3.1 to 30.7 ± 5.7 only. Within these two upper and lower ranges no significant variations were found (Table 2). Comparatively, more yellowness (b*) was recorded in open field produce, while in protected conditions early and red ripening was observed. These values ranged from 16.0 ± 0.6 to 17.6 ± 2.1 in protected tomato produce, while b* value in open field produce was found 22.8 ± 2.9 (Table 2).

Score counts of aphid and whiteflies were recorded in five apical leaves of tomato plants under different treatments and control. No aphids were found inside PHs. In the same way, aphid infestation was also not found in 75% shade net houses. Whereas, compared to open field, significantly ($p \leq 0.05$) less aphid counts were recorded inside 35% SNHs. Although, among the protected houses considerable number (8.2 ± 3.1 to 20.3 ± 5.6) of aphids were recorded in 35 and 50% SNHs, yet no infestation was found and almost similar pattern of whiteflies was also recorded in protected houses. Significantly ($p \leq 0.05$) more whitefly counts (46.6 ± 8.6) were recorded in open field conditions (Table 2). Therefore, aphids and whiteflies were able to enter in SNHs, but no pest infestation was found. Whence it has been experienced that the shade nets permit passage of aphids and whiteflies, but those may not be causative for severe infestation. Ben-Yakir *et al*. (2, 3) also found that coloured shading nets impede insect invasion and decrease the incidences of insect-transmitted viral diseases in vegetable crops and photo-selective net screens can reduce insect pests and diseases in agricultural crops. Studies on vision behaviour of insect vectors (virus) opened the way to the introduction of efficient tools to protect open field as well as protected cultivation from the spread of virus pandemics (Loebenstein and Lacoq, 8). Total soluble solids (°Brix) in all the tomato produce ranged from 5.7 ± 1.2 to 6.3 ± 1.1°Brix. There were no significant variations in TSS of the fruits among all the treatments and open field (Table 3). Similarly, there were also not significant differences in percent acidity and ascorbic acid mg g^{-1} fruit. Percent acidity ranged from 0.62 ± 0.1 to 0.71 ± 0.1% in all the produce, while ascorbic acid content ranged from 0.36 ± 0.04 to 0.42 ± 0.06 mg g^{-1} fruit in all the treatments and open field (Table 3). No significant variations were found in lycopene contents among the PHs and SNHs produce, which ranged from 92.0 ± 6.6 to 97.0 ± 7.6 µg g^{-1} tomato. But it was significantly more than the open field (78.0 ± 6.6 µg g^{-1}) produce (Table 3). Findings of Zoran *et al*. (11) also revealed increased lycopene contents under different coloured shade nets as compared to open field.

Fruit weight in PHs and 35% SNHs ranged from 95.6 ± 22.4 to 108.6 ± 33.0 g $fruit^{-1}$, those were significantly more than the 50 and 75% shade net produce, *i.e.* smaller fruits were found under 50 and 75% SNHs with less fruit weight, ranged from 31.7 ± 7.4 to 41.9 ± 4.7 g $fruit^{-1}$. Thus, as compared to fruit weight in open field (82.6 ± 6.5 g) and under 50 and 75% shade net, significantly ($p \leq 0.05$) more fruit weight was achieved in PHs and 35% SNHs and no significant variations were found among former treatments. Likewise, pattern was recorded in total yield, *viz.* significantly more tomato yield $plant^{-1}$ was

Table 3. Quality and yield of tomato under different protected structures and open field (2010-12).

Treatment	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/ g^{-1})	Lycopene (µg g^{-1})	Fruit wt. (g)	Yield (kg per plant)
PH-1	6.3 ± 1.1	0.67 ± 0.1	0.39 ± 0.04	95.0 ± 5.6	102.4 ± 27.0	6.8 ± 1.1
PH-2	5.8 ± 1.8	0.65 ± 0.3	0.42 ± 0.06	97.0± 7.6	108.6 ± 33.0	6.2 ± 1.3
SNH-1	5.7 ± 1.2	0.64 ± 0.3	0.36 ± 0.04	96.0 ± 5.3	100.3 ± 25.5	7.8 ± 1.8
SNH-2	6.0 ± 1.5	0.70 ± 0.2	0.41 ± 0.05	97.0 ± 6.6	95.6 ± 22.4	8.8 ± 2.2
SNH-3	6.1 ± 1.3	0.67 ± 0.1	0.36 ± 0.05	96.0 ± 7.0	105.1 ± 28.0	6.5 ± 1.5
SNH-4	6.0 ± 2.0	0.64 ± 0.2	0.37 ± 0.04	93.0 ± 7.0	32.0 ± 8.2	1.5 ± 0.2
SNH-5	5.7 ± 1.8	0.65 ± 0.1	0.38 ± 0.05	92.0 ± 6.6	38.3 ± 7.0	1.8 ± 0.3
SNH-6	5.8 ± 1.4	0.67 ± 0.1	0.37 ± 0.06	95.0 ± 5.3	31.7 ± 7.4	1.4 ± 0.3
SNH-7	5.9 ± 1.4	0.68 ± 0.2	0.36 ± 0.05	94.0 ± 4.4	40.0 ± 6.2	1.0 ± 0.2
SNH-8	5.9 ± 2.0	0.71 ± 0.2	0.37 ± 0.05	93.0 ± 6.3	35.7 ± 5.8	1.3 ± 0.2
SNH-9	5.7 ± 1.8	0.67 ± 0.1	0.40 ± 0.05	94.0 ± 7.3	41.9 ± 4.7	1.0 ± 0.3
Open field	5.7 ± 1.7	0.62 ± 0.1	0.37 ± 0.06	78.0 ± 6.6	82.6 ± 6.5	5.4 ± 0.9
CD at 5%	NS	NS	NS	9.6	21.3	1.6

recorded under PHs and 35% SNHs (Table 3). Yield under these greenhouses ranged from 6.2 ± 1.3 to 8.8 ± 2.2 kg p^{-1}, whereas it was only 1.0 ± 0.2 to 1.8 ± 0.3 kg p^{-1} under 50 and 75% shadenet conditions. Thus, lowest tomato yield was found in 50 and 75% SNHs (Table 3). Therefore, tomato yield and quality can be improved using PHs and 35% SNHs. Finally, 35% SNHs were found quite useful for highest tomato yield and quality in this semi-arid region. Abdel-Mawgoud (1) used 30% shadenet for tomato cultivation and found increased yield and quality of the tomato.

Conclusively, tomato cultivation under PHs and 35% SNHs were found fairly useful in terms of higher marketable yield, enhancement of flowering and fruiting period and protection against the insect pests, fog, frost and sun-scald in late crop season, *i.e.*, during April-May months. Although, PHs were also found useful for better plant growth and yield but those could be relevant for shorter duration, *viz.* after mid of March, when temperature started rising crop destruction may occur. Overall findings revealed that the PHs and 35% SNHs can be used for tomato production in this semi-arid region.

ACKNOWLEDGEMENTS

This work was financially supported by All India Co-ordinated Research Project on Application of Plastics in Agriculture-ICAR (AICRP on APA-ICAR), CIPHET, Ludhiana is greatly acknowledged. Authors are thankful to Dr R.K. Gupta, Director, CIPHET for facilitating the experiments at Abohar, Punjab.

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Received : June, 2015; Revised : October, 2015; Accepted : November, 2015