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Significance of protected structures on growth and yield of tomato (*Solanum lycopersicum*) in semi-arid region and its influence on blight of tomato

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Abstract
Protected cultivation of vegetables is the best means of increasing the productivity and quality of tomato. The yield of tomato under protected structures can be increased by manifolds when compared to open field cultivation. An experiment was conducted to investigate the performance of tomato under different protected structures in semi-arid region of Raichur district. There were four treatments in the experiment consisting of different protective structures such as polyhouse, shadenet, sides opened shadenet and open field condition (control) which were replicated five times. Protective structures had remarkable and significant influence on plant growth and yield parameters of tomato. The tomato grown under shadenet exhibited higher plant height (246.31 cm), number of branches (74.82), rind thickness (5.69 mm), diameter of fruit (51.16 mm), chlorophyll content (72.15 per cent), number of fruits per plant (56.31) and yield per square meter (7.63 kg). Added to this, the water use efficiency and fertilizer use efficiency was more in shadenet, when compared to other structures and open condition. On contrary *Alternaria* blight severity was maximum in poly house (29.2 per cent) whereas open field condition has recorded minimum severity (21.2 per cent). The result indicates that there is a bright scope for cultivation of tomato under shadenet.

Keywords: Open field, protective structures, polyhouse, shadenet, sides opened shadenet

Introduction

Protected cultivation is a unique and specialized form of agriculture in which the microclimate surrounding the plant is controlled partially or fully, as per the requirement of the crop species grown during its growth period. The objective is to grow crops in uncongenial conditions by modifying the natural environment, prolonging the harvest period, increasing the yield, improving the quality of the crop and making the commodities available when there is no outdoor production. In India, the area under protected cultivation is presently around 25000 ha. while the greenhouse vegetable cultivation area is about 2000 ha [1]. Faced with constraints of land holdings, rapid urbanization, declining crop production, declining biodiversity, ever increasing population and growing demand for food, especially for vegetables has offered a new dimension to produce more in a limited area through protected cultivation. Protected cultivation also known as controlled environment agriculture (CEA) is highly productive, as it conserves water, soil and protects the environment[2]. The quality of the vegetable crops grown in greenhouse improves in all respects such as fruit size, TSS content, ascorbic acid content and pH [3]. The economic returns are 10 to 15 times higher under protected structures as compared to that of open-field cultivation [4]. Protected structures extend the crop span as they safeguard the crop from vagaries of weather as well [5].

The concept of growing vegetables under protected structures has been gaining popularity among Indian growers, especially those with small land holdings [6]. India being a vast country with diverse and extreme agro-climatic conditions, the protected vegetable cultivation technology can be utilized for year round and off-season production of high value, low volume vegetables, production of virus free quality seedlings, quality hybrid seed production and as a tool for disease resistance breeding programs [7]. Green house, polyhouse, shade net house and low tunnels are the different types of protected cultivation structures commonly adopted by the Indian farmers [8, 9]. The main vegetable crops produced under protected conditions in India are tomato, cucumber, muskmelon, capsicum, lettuce and cauliflower.

Tomato (*Lycopersicon esculentum Mill.*) belonging to solanaceae family is one of the most popular and nutritious vegetable crops grown all over India. Presently, tomato is grown in an area of 8.79 lakh ha with a production of 182.26 lakh ton [10]. Not much work is available on shade net cultivation of tomatoes, hence there is an urgent need to assess the cultivation and suitability of tomato under protected conditions to meet the growing demand of the vegetables. Thus, the investigation was aimed to determine the influence of different protected structures on growth and yield of tomato.

Material and Methods

The study was conducted at an experimental field of College of Agricultural Engineering, University of Agricultural Sciences, Raichur during *Kharif* 2017 and *Kharif* 2018 seasons. The experimental block was located at 16˚15' N latitude and 77˚20′ E longitude with an elevation of 407 m above mean sea level (MSL). The region falls under North-Eastern dry zone *i.e*., Zone-II in region-1 of Karnataka.

The experiment consisted of four treatments comprising closed shade net, polyhouse, sides opened shadenet and open field condition. The experiment was laid out in Factorial Randomized Block Design with five replications. Raised beds of 1 m width and 18 m length were prepared with a gap of 50 cm between two beds in all the structures and in open field. Tomato seeds of cv. Himmasona were treated with bio-fungicide, *Trichoderma viridae* and they were sown in portrays filled with cocopeat as a propagating media. One month old healthy seedlings of tomato were selected and they were transplanted in the raised beds in two rows at spacing of 60 cm between rows and 45 cm between plants within a row. Recommended dose of fertilizers (in water soluble form) were provided through drip pipes placed on the raised beds.

The rainfall data during the study was collected from the meteorological observatory, Main Agricultural Research Station, Raichur and the same is presented in Fig. 1. Meteorological observations such as light intensity, humidity and air temperature were recorded daily inside the shadenet, polyhouse, sides opened shadenet and open field at 9 am, 2 pm and 5 pm during the cropping period using Lux meter, Hygrometer and Digital Thermometer. Every fortnight, soil moisture at surface and 10 cm depth was recorded using soil moisture meter. Plant growth parameters such as plant height (cm), number of branches per plant, 50 per cent flowering (days), diameter of fruit (mm), rind thickness (mm) and chlorophyll content (%) were recorded randomly in selected five plants from each replication. Yield parameters including number of fruits per plant (kg) and total yield (kg m^{-2}) was recorded during harvest. The data was subjected to statistical analysis as per the standard procedures. The observations on *Alternaria* leaf blight was recorded by using 0-5 disease scale and the disease grades will be converted in to per cent disease index by using the formula [11]. The data of two years (2017-18 and 2018-19) and the pooled data were subjected to Fisher's method of analysis of variance (ANOVA) as applicable to randomized block design.

$$\text{Per cent disease index} = \frac{\text{Sum of all observation grades}}{\text{Total number of plants observed}} \times \frac{100}{\text{Maximum grade}}$$

Results and Discussion

Protected structures provided congenial conditions of temperature, relative humidity and sunshine which play major role in promoting the production of good quality produce. The maximum temperature range during the crop growth period in shadenet was 32.01 to 36.45 ℃ and the minimum temperature ranged from 23.95 to 27.88 ℃. On contrary, the maximum and minimum temperature range in open field (control) was 30.46 to 35.04 ℃ and 21.48 to 27.14 ℃, respectively (Fig. 2). The maximum relative humidity (RH) recorded in shadenet was in the range of 38.11 to 61.54 per cent and minimum RH recorded in shadenet was in the range of 17.83 to 38.56 per cent. In control, the maximum RH was in the range of 32.68 to 72.67 per cent and minimum RH was in the range of 15.61 to 36.33 per cent (Fig. 3). Maximum light intensity and minimum light intensity recorded in shadenet was in the range of 11056.11 to 28118.50 lux and 2856.32 to 7416.95 lux, respectively. Maximum and minimum light intensity recorded in open field was in the range of 31656.13 to 48650.00 lux and 8697.42 to 18967.00 lux, respectively (Fig.4). Observations recorded on temperature in these protected structures showed variations and this could be due to the use of different covering materials for different structures. Higher temperature during day time was due to trapping of short wave radiation in the shadenet. The air temperature in the open field condition was lower than the shadenet house throughout the crop growth period. These findings were also supported by earler workers [12], shadenet house with ventilation gaps in four sidewalls was found more suitable for better plant growth and yield of tomato than the open field condition. Air temperature is the main environmental component influencing vegetative growth, cluster development, fruit setting, fruit development, fruit ripening and fruit quality. Higher the average air temperature faster the growth. It is also believed that, the larger the variation in day-night air temperature, taller the plant and smaller the leaf size [13]. The variation in the RH with time in shadenet may be due to the increase in temperature. Higher humidity was observed inside the shadenet during morning hours and gradually decreased in the afternoon because of increase in temperature.

There was a significant difference among the treatments in the growth parameters during 2017-18, 2018-19 and the pooled data (Table 1 to 2).

During 2017-18 the plant height, number of branches, rind thickness, diameter of fruit and chlorophyll content in shadenet increased by 154.77 per cent, 94.25 per cent, 101.10 per cent, 70.52 per cent and 77.27 per cent, respectively over control. During 2018-19 the plant height, number of branches, rind thickness, diameter of fruit and chlorophyll content in shadenet increased by 153.37 per cent, 86.30 per cent, 101.34 per cent, 63.49 per cent and 72.80 per cent, respectively over control. The pooled data also exhibited similar trend (43.27%, 190.42%, 72.73%, 26.45% and 190.42% increase in plant height, number of branches, rind thickness, diameter of fruit and chlorophyll content, respectively over control). Temperature affects the vital functions of plants such as transpiration, respiration, photosynthesis, growth and flowering. When temperature falls below optimum or exceeds the optimum temperature, growth is usually retarded and yield decreases. High air humidity improves the fruit set. Plant height was highest under shade net house in both the years of study compared to open field (Fig 5). This may be due to enhanced photosynthesis and respiration due to the favorable micro-climatic conditions in the shade net house. These results are in agreement with the results of earlier worker [14].

During 2017-18, the yield per plant (kg) and yield per square meter (kg m^{-2}) increased by 46.62 per cent and 105.23 per cent, respectively in shadenet when compared to open field condition (control) (Table 3). During 2018-19, the yield per plant (kg) and yield per square meter (kg m^{-2}) increased by 43.07 per cent and 105.59 per cent, respectively in shadenet when compared to control. The pooled data also exhibited similar trend (67.92% and 50.23% increase in yield per plant (kg) and yield per square meter (kg m^{-2}), respectively over the control). In shadenet house, the shade intercepts the photosynthetic active radiation. Shade resulted in increasing water content in shaded plants which increased the ability of leaves in absorbing radiation and decreasing reflection [15]. The screens used for shading, probably redistribute the light on the canopy in a qualitative way. Further tomato produced in shadenet house had less pest population when compared to the open field. Tomato had higher yield under shadenet house due to light compensation for higher photosynthesis. Similar results were also reported in sweet pepper [16, 17], where they observed that, under shade net highest leaf area per plant was also recorded in tomato during summer and winter seasons. This might be due to leaf physiology and increased number of stomata and photosynthesis.

The severity of *Alternaria* blight was recorded in different protected cultivation structures. During 2017-18, the per cent severity of *Alternaria* blight was more in polyhouse cultivation (28.00) followed by closed shade net (24.80). The least disease severity was noticed with open field cultivation (18.40). The same trend was noticed during 2018-19 on per cent severity of *Alternaria* blight in tomato, where in more severity of the disease was noticed in polyhouse cultivation (30.40) with least severity of 24.00 was noticed in open filed cultivation. The pooled results on per cent severity of *Alternaria* blight in tomato revealed that, the maximum severity of the disease was noticed in polyhouse cultivation (29.20%) which was on par with closed shade net cultivation condition (26.00%) whereas the least severity of the disease was noticed with open field (21.20%) and sides opened shade net (23.60%) cultivation condition.

The early blight disease severity of tomato comparatively higher in the maximum and minimum temperatures (35.2 – 38.3 ^{0}C), evening RH (30-58%) and wind speed (1.2–2.2 km/hr) [18]. The abiotic factors like minimum temperature (r= 0.90) and evening RH (r= 0.77) were negatively highly correlated, while maximum temperature (r= 0.59) had negative significant impact on *Alternaria* leaf blight of tomato. Wind speed showed positive and highly significant effects (r= 0.69) on development of early blight. The partial regression between leaf blight and abiotic factors indicated that an increase in 1 ^{0}C in maximum temperature, an increase in 1 km/hr wind speed and one per cent in evening RH, increase the early blight.

Mean and maximum PDI of early blight was found significantly and positively correlated with morning and evening RH. The relation between minimum temperature and early blight was significantly negative. Maximum temperature and wind velocity of two lagged weeks accounted for 78 per cent variability of maximum severity of early blight [19].

Tomato production in open field conditions require high irrigation water compared to other protected structures. During 2017-18 and 2018-19 the water use efficiency (1316.88 kgha^{-1} cm and 1385.99 kg ha^{-1} cm, respectively) was high in shadenet when compared to open field where the water use efficiency was 671.14 kg ha^{-1} cm and 693.56 kg ha^{-1} cm (during 2017-18 and 2018-19, respectively) The results are presented in table 4. Under protected cultivation, soil water content was higher when compared to open field. Polythene covering material in shadenet, reduces the crop evapo-transpiration, causing reduction in transpiration, resulting in decreased soil water uptake in capsicum [20]. Poly house increased yield, reduced crop transpiration and thus water uptake and improved water use efficiency by 62 per cent in cucumber crop [21]. On the other hand, crops grown in open fields were subjected to direct sun-light, high temperatures and wind resulting in high crop evapo-transpiration, therefore demanding large quantity of water.

Fertilizer use efficiency of capsicum was maximum in shadenet when compared to open field conditions (Table 5). Nitrogen (0.29 kg per kg of nitrogen applied), phosphorous (0.29 kg per kg of phosphorous applied) and potassium (0.29 kg per kg of potassium applied) use efficiency was higher in shadenet during 2017-18 when compared to open field (0.14, 0.14 and 0.14 kg per kg of nitrogen, phosphorous and potassium applied, respectively). In 2018-19, similar trend of higher fertilizer use efficiency was observed in shadenet (0.35, 0.35 and 0.35 kg per kg of nitrogen, phosphorous and potassium applied, respectively) when compared to open field (0.18, 0.18 and 0.18 kg per kg of nitrogen, phosphorous and potassium applied, respectively). Modification of crop microclimate through structural and agronomic interventions improve the plant growth and yield through optimization of soil and air temperature which is critical for promoting the cultivation of tomato. The shadenet, improves the root zone temperature, which might have improved the root growth. This could have resulted in enhanced uptake of nutrients and water in the current investigation.

Table 1: Growth parameters of tomato as influenced by protected structures

Treatments	Plant height (cm)			Number of branches			Days to 50% flowering		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Closed shade net	241.6	250.96	246.31	71.97	76.42	74.82	43.84	49.25	46.16
Polyhouse	135.88	142.24	139.25	58.89	62.23	60.12	50.72	54.69	52.62
Sides opened shade net	126.51	130.45	128.62	49.77	53.94	51.63	57.58	62.41	59.31
Open field	94.83	99.05	96.73	37.05	41.02	39.25	62.37	67.12	64.68
S.Em.±	4.52	4.58	4.01	0.67	0.71	0.56	0.72	0.87	0.56
CD at 5%	13.92	14.10	14.56	2.06	2.2	2.25	2.22	2.68	2.12

Table 2: Rind thickness, diameter of fruit and chlorophyll content of tomato as influenced by protected structures

Treatments	Chlorophyll content (%)			Rind thickness (mm)			Diameter of fruit (mm)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Closed shade net	70.36	74.51	72.15	5.47	6.02	5.69	50.61	52.66	51.16
Polyhouse	62.57	66.75	64.62	4.26	4.76	4.35	41.56	43.68	42.75
Sides opened shade net	48.64	52.57	50.56	3.26	3.67	3.52	35.58	38.17	36.92
Open field	39.69	43.12	41.49	2.72	2.99	2.91	29.68	32.21	30.86
S.Em.±	1.85	1.87	1.78	0.20	0.23	0.31	2.23	2.18	2.01
CD at 5%	5.70	5.76	5.21	0.62	0.71	0.72	6.87	6.71	6.52

Table 3: Yield of tomato as influenced by different protected structures

Treatments	No. of fruits per plant			Yield (kg m^{-2})			Severity of *Alternaria* blight (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Closed shade net	55.10	57.60	56.31	7.45	7.73	7.63	24.80 (29.66)	27.20 (29.98)	26.00 (30.55)
Polyhouse	46.66	48.73	47.62	6.52	6.84	6.71	28.00 (31.90)	30.40 (27.85)	29.20 (32.66)
Sides opened shade net	40.44	42.99	41.71	5.13	5.45	5.36	21.60 (27.60)	25.60 (23.54)	23.60 (29.04)
Open field	37.58	40.26	38.85	3.63	3.76	3.78	18.40 (25.19)	24.00 (21.27)	21.20 (27.35)
S.Em.±	2.40	2.40	2.32	0.06	0.07	0.06	1.66	1.44	1.17
CD at 5%	7.38	7.41	7.31	0.19	0.22	0.19	5.12	4.43	3.59

Table 4: Water use efficiency of tomato as influenced by different structures

Treatments	Water use efficiency (kg ha^{-1} cm)	
	2017-18	2018-19
Closed shade net	1316.88	1385.99
Polyhouse	1177.21	1214.16
Sides opened shade net	925.08	932.58
Open field	671.14	693.56

Table 5: Fertilizer use efficiency of tomato as influenced by different structures

Treatments	Fertilizer use efficiency (kg yield/ kg nutrient applied)					
	N		P		K	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Closed shade net	0.29	0.35	0.29	0.35	0.29	0.35
Polyhouse	0.25	0.29	0.25	0.29	0.25	0.29
Sides opened shade net	0.20	0.25	0.20	0.25	0.20	0.25
Open field	0.14	0.18	0.14	0.18	0.14	0.18

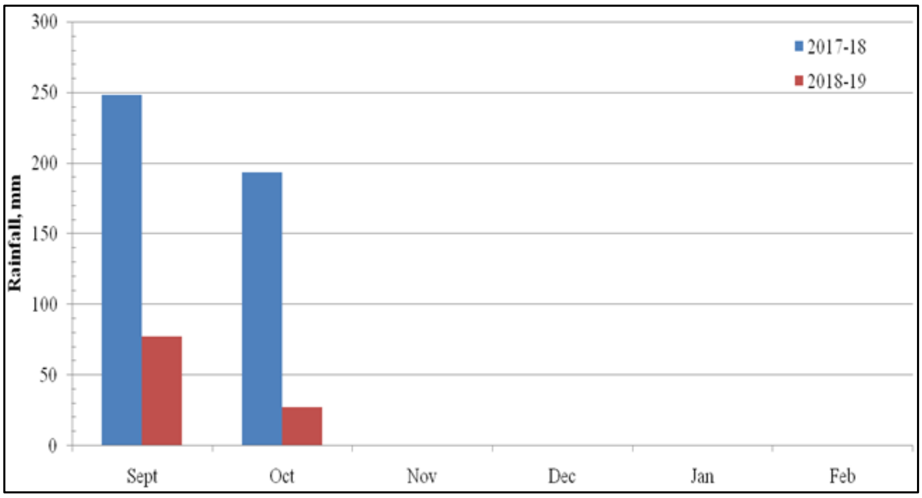

Fig 1: Rainfall recorded during the crop growth period during 2017-19

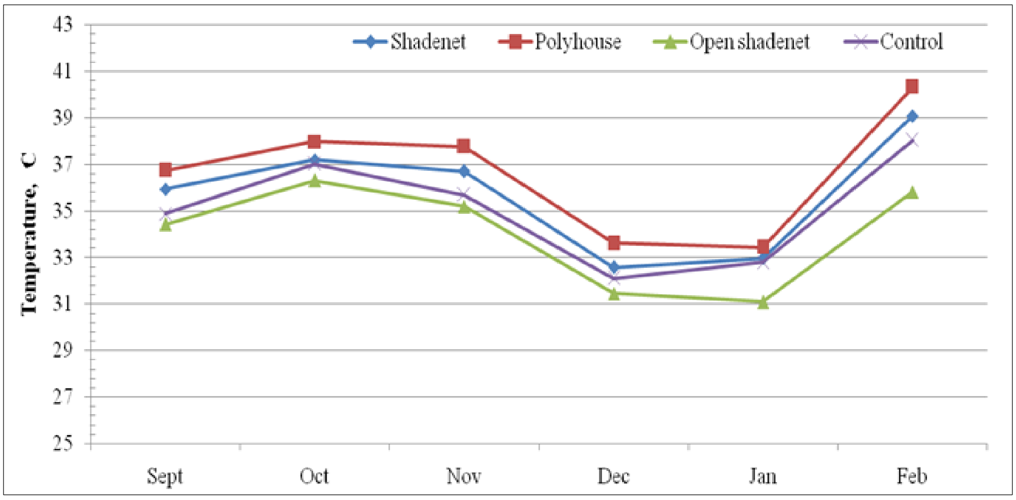

Fig 2: Temperature variation in different protected structures during 2017-19

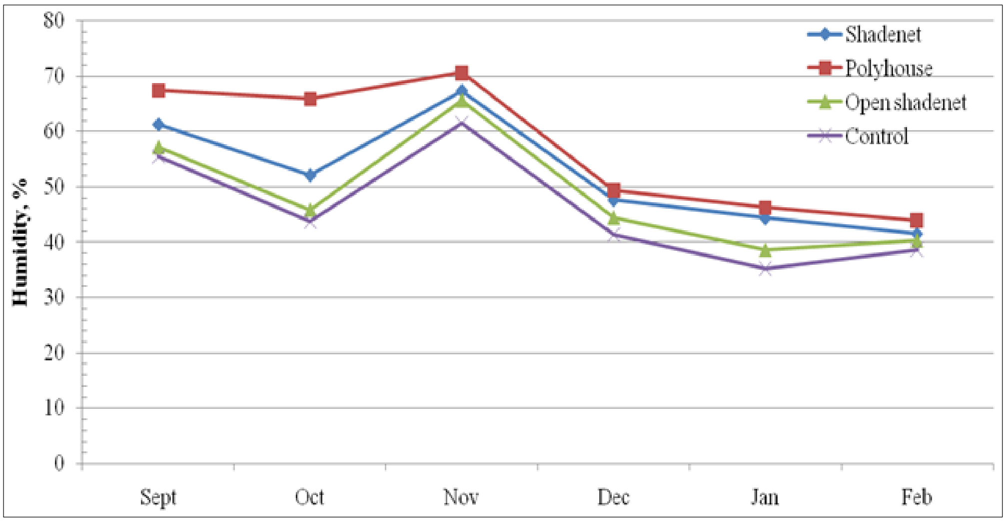

Fig 3: Humidity variation in different protected structures during 2017-19

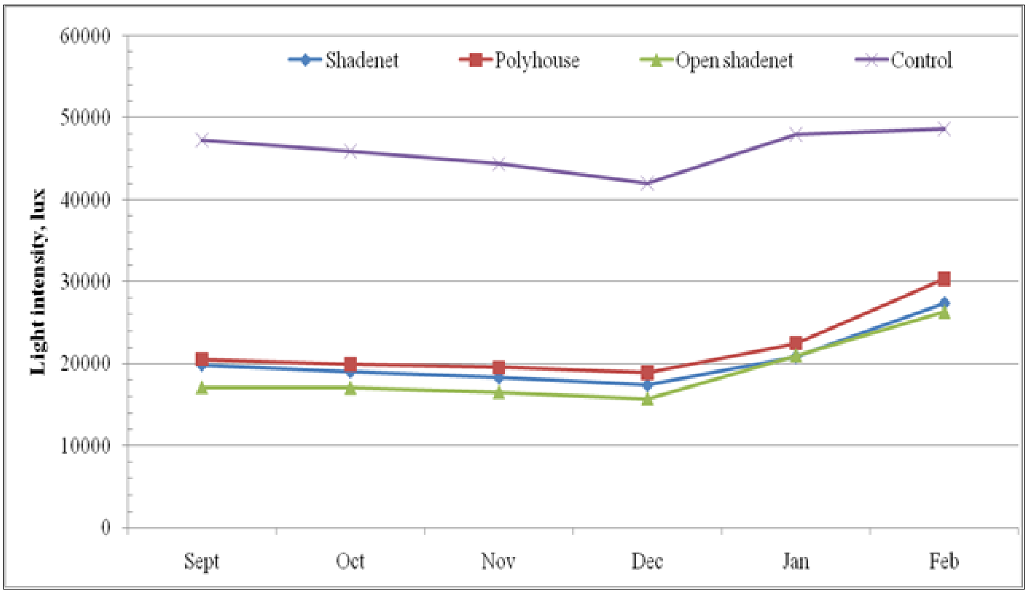

Fig 4: Light intensity variation in different protected structures during 2017-19

Conclusion

Among the protected structure, shadenet was found suitable for cultivation of tomato in semiarid region of Raichur. Hence, growing of tomato, under shadenet conditions will be more profitable irrespective of the seasons. The shade net controls the plants from frost and cold waves during winter and from solar injury due to high intensity of solar radiation during summer. This positively influenced the morphophenological and physiological events of tomato plants. Less pest and disease attack was observed in shade net houses as compared to open field in all the crops. Hence the present study is concluded that the better growth, development and yield of tomato were achieved under shade net due to optimum temperature and humidity. Therefore, if tomato is planted under shade net, it will establish well and produce higher and off- season tomato which would fetched premium price in the market.

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