
ELSEVIER
SCIENTIA
HORTICULTURAE

Scientia Horticulturae 144 (2012) 36–41

Contents lists available at SciVerse ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

The effect of microclimate inside low tunnels on off-season production of strawberry (*Fragaria* × *ananassa* Duch.)

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ARTICLE INFO

Article history:
Received 19 October 2010
Received in revised form 13 June 2012
Accepted 14 June 2012

Keywords:
Fragaria × *ananassa*
Early cropping
Extended cropping
Yield component analysis
Quality component analysis
Planting time

ABSTRACT

A field trial was conducted at Horticultural Research Farm, ICAR Research complex for North Eastern Hill Region Umiam, Meghalaya, India to assess the influence of microclimate changes caused by low tunnels and effect of planting time on early production and extension of cropping season of strawberry. The plantings were done at day 10 in July, August, September, October, and November under low tunnels skinned with 75% and 50% shade net, UVS polythene (200 μm) and in open field. Irrespective of growing period, the rhizosphere temperature at 20 cm depth in polytunnel was higher by 2.64 °C, 2.23 °C and 1.82 °C compared to 75% shade, 50% shade and open field, respectively. During December–January when temperature fell to around 7.0 ± 2.0 °C, low tunnel of UVS polythene maintained a temperature range close to 15.0 ± 2.0 °C. Similarly during summer months, air temperature was 3.44–5.21° C and 3.6–6.2 °C lower, respectively in low tunnels of 75% and 50% shade than in the open field. Whereas, on an average 2–6% higher relative humidity was observed during the whole growing period inside different low tunnel structures compared to the open field. Strawberry was produced 30–35 days earlier than normal in low tunnels of 50% shade planted in July or August. The period of fruit availability was extended to 47 days from normal period under UVS polythene cover when planted in November. Highest yield with firm fruits, higher ascorbic acid, anthocyanin and (-carotene were obtained from the plants planted in November under UVS polythene which was on a par with the plants planted in July and August under 50% shade.

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is cultivated on the plains as well as in the hills 3000 m above sea level in a region that can be both humid and dry (Sharma, 2002). Recently, it has been introduced in northeastern region of India and received a great impetus. The normal planting time of strawberry in this part of the country is the middle of October and the fruits are ripe in February to March. The demand for fresh strawberry in the market is even high during off-season which also fetches better price than normal season. High temperature and heavy rainfall create unfavorable condition for plant establishment at early planting and similarly if it planted in late winter, and in both cases, fruiting periods coincide with high temperature and rain which causes deterioration in fruit quality.

Protected cultivation is the most efficient means to overcome climatic diversity. The cultivation of strawberry under protected structures has increased in the last decade and it is one of the best methods to extend the strawberry season (Hancock and Simpson, 1995), hence enabling programmed year round cultivation. Of the different forms of protected strawberry growing, cultivation in low tunnel is considered as the most suitable (for cultivation and economy) for the agro-climatic condition of the northeastern hills of India. Hence production of year-round fresh berries in low tunnel is one of the best options to attain early production as well as to extend cropping season in order to maximize the return.

Strawberry is one of the most suited crops for cultivation in low tunnel due to its short stature, bearing habit and root phenology (Fereira et al., 2004). Low tunnel creates a favorable microclimate for plant growth and protect them from adverse climate conditions. The modification caused by the low tunnel provided a better microclimate inside the tunnel resulting in early vigorous crop growth and better yield (Dorg, 2003; Gao et al., 2005). Fruit yield enhances and fruiting season may also be extended up to May. Besides, low tunnel protect the crop from impact of rain, cold wind and severe winter or adverse weather conditions. Keeping these into view, the present experiment was conducted to study the microclimate change using different low tunnels (skinned with 75% and 50% shade net, UVS polythene (200 μ)) at different planting time and the effect of tunnels on earliness and production of strawberry.

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http://dx.doi.org/10.1016/j.scienta.2012.06.025

Table 1
Weather parameters during the study.

Month	Relative humidity (%)	Maximum temperature (°C)	Minimum temperature (°C)	Total number of rainy days	Total rainfall (mm)	Sunshine hours
July	90.8	28	20.4	28	2854	3
August	90.1	26.89	20.23	30	4261	4.4
September	86.4	28.18	18.94	24	4015	3.6
October	85.1	26.47	15.88	24	2285	3.7
November	78.5	24.18	10.1	1	364	7.2
December	82.5	22.28	9.1	3	193	7.2
January	79.7	20.8	7.9	0	0.0	6.2
February	76.7	24.1	9.3	0	0.0	7.7
March	70.1	26.9	12.3	9	402	6.7
April	67.0	28.4	16.7	9	565	7.1

2. Material and method

2.1. Study site

The present investigation was carried out at Horticultural Research Farm of ICAR Research complex for North Eastern Hills Region Umiam, Meghalaya, India during 2007–2009. The experimental site was located at an elevation of 900 m above mean sea level at 25°40′–25°21′N latitude and 90°55′15″–91°55′16″E longitude. The climate of the site can be characterized as subtemperate with minimum and maximum temperatures ranging from 6 to 29 °C and with average annual rainfall of 2841 mm. Monthly weather parameters during the experimentation period are presented in Table 1.

2.2. Experimental design

The experiment was a split-plot design, planting time as main plot and tunnel cover as sub-plot, replicated thrice. The planting was done at day 10 in July (P1), August (P2), September (P3), October (P4), and November (P5) in low tunnels of 75% shade net (L1), 50% shade net (L2), UVS polythene 200 μ (L3) and in the open (L0). The tunnel frames were made from bamboo and size of tunnels were 5 m long and 1 m wide with central height of 0.75 m, skinned with commercial dark green shade net and ultra violet stabilized polythene sheet of 200 μ thickness. The soil was prepared thoroughly before planting and made free from weeds. Soil drenching was done with copper oxy-chloride and Furadon prior to planting. It was planted on 3.9 m long × 0.70 m wide, 15–20 cm high raised beds. Healthy runners of cultivar 'Ofra' with a medium to large crown and well-developed root system were selected, the outer leaves were stripped off and the adhering soil on the root was washed and dipped in fungicide (bavistin, 1%) for 30 min before planting. Twenty six plants per plot were planted at a spacing of 30 cm × 45 cm in a double row. All other cultural operations were followed as suggested by Singh et al. (2008).

2.3. Soil properties

The soil of the experimental site originates predominantly from the weathering of sedimentary and metamorphic quartzite rocks, conglomerate, phyllite and sand stone. The soil of the experimental site belonged to the typical paleudalf series with clay loam texture. Soil pH varied from 5.4 to 5.7 with surface soil being more acidic than subsurface. The average available nitrogen, phosphorous and potassium in the soil was 330, 17 and 120 kg ha^{-1}, respectively. The average organic matter content was 1.3%.

2.4. Soil temperature

The soil temperature was measured for14 h on each day at 20 cm depth inside the tunnel structures using soil thermometer (Venus brand) approved by India Meteorological Department (IMD).

2.5. Maximum and minimum temperature inside the tunnel structure

Air temperature around plant influences the rate of growth of plant. The air temperature in terms of minimum and maximum temperature during day was recorded in each low tunnel at 14 h on each day using standard thermometers.

2.6. Relative humidity inside the tunnel structure

The relative humidity values were calculated based on the dry bulb and wet bulb temperature measurements using hygrometric tables for atmospheric pressure of 900 mbar corresponding to altitude range of 457.2–1524 m published by the IMD.

2.7. Plant survival

Plant survival (%) was observed after one month of planting. The number of plants survived were registered in each plot and then compared with the total number of plants at planting and expressed in percentage.

2.8. Estimation of chlorophyll content of leaves

Total chlorophyll content of leaf was determined by using the calometric method suggested by Singh (1977). Chlorophyll content of the leaf was recorded at 50% flowering stage. Matured leaves were collected randomly from each replication for composite sample. Freshly harvested 1 g composite sample was taken and crushed with acetone and the materials were filtered with filter paper (Whatman 1 with pore size 1.2 μm). The optical density of the filtrates was measured using spectrophotometer at 645 nm and 663 nm wave lengths and calculated accordingly.

2.9. Days to 50% flowering

The number of days between planting date and 50% flowering was recorded.

2.10. Number of fruits per plant

The number of fruits per plant was recorded every alternate day from five randomly selected plants from each replication.

2.11. Harvesting period

The date of first harvest and last harvest were recorded in all the treatments. The normal picking period of strawberry in this region is 18th January to 15th March; hence earliness was recorded by comparing the first harvesting date of each treatment with the first harvesting date of the normal picking (18th January). Similarly delayed harvesting was recorded by comparing the last harvesting date of each treatment with the last harvesting date of the normal picking (15th March). The results were expressed in days.

2.12. Yield

The total yield of each plot was recorded and then divided by the total number of plants from each plot and expressed in g/plant.

2.13. Estimation of ascorbic acid

The ascorbic acid content was estimated titrimetrically using 2,6-di-chlorophenol indophenol dye (DCPIP) as suggested by Ranganna (1997). A sample of 10 g was blended with 4% (W/V) oxalic acid, made up to 100 ml, filtered and centrifuged at 10,600 × *g* for 10 min. An aliquat (5 ml) was filtered against standard dye solution (2,6-DCPIP) to a pink end point. The procedure was repeated with a blank solution omitting the sample. The ascorbic acid content was calculated using following formula and expressed as mg/100 g of fresh fruit:

$$\text{ascorbic acid} = \frac{\text{titer value} \times \text{dye factor} \times \text{volume make up}}{\text{aliquat} \times \text{weight or volume of sample}} \times 100$$

2.14. Estimation of β-carotene

A fresh sample of 5 g was grounded in 10–15 ml acetone along with few crystals of anhydrous sodium sulphate. After grinding the decant supernatant was collected in a beaker. The process was repeated twice and the combined supernatant was collected into a separatory funnel and 10–15 ml petroleum ether was added and mixed thoroughly. When two layers were formed, the lower layer was discarded while the upper layer was collected and the volume was made up to 100 ml with petroleum ether and finally the optical density was recorded at 452 nm using petroleum ether as blank. The β-carotene was calculated using the following formula and expressed in μg/100 g (Ranganna (1997):

$$\beta\text{-carotene}(\mu\text{g}/100\,\text{g}) = \frac{\text{optical density} \times 13.9 \times 10^4 \times 100}{\text{weight of sample} \times 560 \times 1000}$$

2.15. Estimation of anthocyanin

A sample of 10 g was blended with 10 ml of ethanol and HCL mixture (95% ethanol and 1.5 N HCl in the ratio of 85:15) and transferred to a 100 ml volumetric flask and made up to volume, stored over night and filtered through Whatman no. 1 filter paper. The optical density (OD) of filtrate was then recorded at 535 nm and total anthocyanin was calculated using formula given by Ranganna (1997) and expressed as mg/100 g fresh pulp.

$$\text{total OD}/100\,\text{g} = \frac{\text{OD} \times \text{volume make up} \times 100}{\text{weight of sample}}$$

$$\text{total anthocyanin}\,(\text{mg}/100\,\text{g}) = \frac{\text{total OD}/100\,\text{g}}{98.2}$$

3. Results and discussion

3.1. Effect on rhizosphere temperature of treatments

Strawberry is a shallow rooted crop, around 70–90% of its roots are confined in top 15–20 cm soil depth. Therefore, rhizosphere temperature was recorded to a depth of 20 cm soil during growing period from July to April and average value is presented in Fig. 1(A). It was observed that the rhizosphere temperature recorded at 20 cm depth during growing period from July to April was highest in UVS polytunnel and lowest in 75% shade net. In the low tunnel structures, trend of rhizosphere temperature was more or less the same from July to October followed by a sharp decline thereafter till February to increase again up to April. Soil temperatures ranged from 15.56 °C in January to 25.6 °C in July under open field, 15.0° C in January to 24.5 °C in July in 75% shade. Using UVS polythene cover, soil temperature was lowest (17.0 °C) in January and highest (27.67 °C) in August whereas, 50% shade recorded lowest (15.6 °C) in February and highest (25.°C) in July. Irrespective of growing period, the soil temperature in case of polytunnel was higher by 2.64 °C, 2.23 °C and 1.82 °C for 75% shade, 50% shade and open field, respectively. Low tunnel of 75% shade and 50% shade resulted in lower rhizosphere temperature for the whole growing period as compared to open field as well as for UVS polythene cover. This might be caused by higher absorption of solar radiation by polytunnel and uncovered bed during day time and corresponding insulating effect during night time compared to shade treatment covering as indicated in Fig. 1D.

3.2. Effect on microclimate changes of treatments

Microclimate changes inside low tunnels in terms of air temperature (minimum and maximum), and relative humidity was recorded from July to April. From Fig. 1B it was apparent that covering with UVS polythene caused slightly lower relative humidity in the tunnel from July to December compared to open field and shading whereas, from January to April, it was lowest under open field condition. However, from July to April 50% shade and 75% shade caused higher humidity in the tunnel than control. On an average covering resulted in 2–6% higher relative humidity than control during whole growing period.

UVS polythene cover caused the highest minimum temperature during the whole growing period whereas, from July till December lowest minimum temperature was recorded at 75% shade, thereafter till April the lowest minimum temperature was observed in the control. Within the growing period, minimum temperature ranged from 7.9 °C in January to 20.4 °C in July which, was altered by 3.1 °C, 7.1 °C and 3.6 °C higher temperature in 75% shade, UVS polythene and 50% shade, respectively. In July, 75% shade and 50% shade compared to control lowered the temperature by 0.92 °C and 1.4 °C, respectively. During December–January when temperature fell down to around 7.0 ± 2.0 °C, using UVS polythene maintained the temperature range close to 15.0 ± 2.0 °C, which was considered favorable for strawberry plant growth, development and quality improvement (Fig. 1D).

A similar pattern was observed during whole growing period for maximum temperature where UVS caused higher temperature than the other treatments while 50% shade and control caused the lowest temperatures. From July till September all treatments had similar temperature pattern, but both in open field and 50% shade were observed sharp decline in temperature till January. During summer months i.e. March–April and July–August, 75% shade lowered temperature by 3.44–5.21 °C whereas, 50% shade lowered temperature by 3.6–6.2 °C, compared to open field. During these months temperature at 75% shade ranged from 21.8 to 25.45 °C and from 22.2 to 25.1 °C at 50% shade, which was considered as the

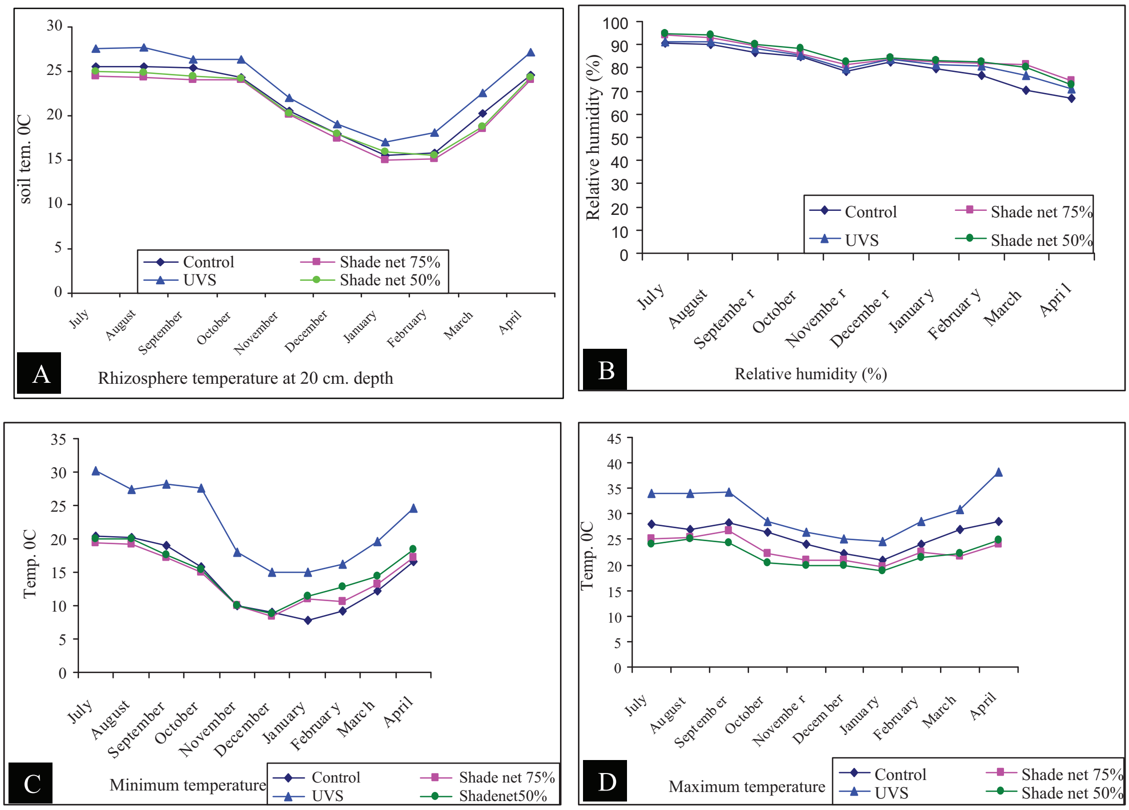

Fig. 1. (A) Rhizosphere temperature, (B) relative humidity, (C) minimum temperature and (D) maximum temperature in low tunnels.

most favorable temperature range (20–25 °C) for optimum growth and development of strawberry plants (Fig. 1C).

3.3. *Effect of treatments on crop season*

At all planting times except in November, 50% shade produced fruits 38 and 33 days earlier than normal planting time especially when planting was done in the month of July and August, respectively (Table 2). Using 50% shade during November extended the fruiting period by 35 days and in October by 10 days, however planting in July, August and September at the same treatment did not extend the period of harvesting compared to normal planting. However, the longest extension of fruit harvest (47 days) was recorded under UVS polythene tunnel after the November planting.

Planting time had a positive effect on early harvesting as well as on extension of harvesting period. This finding was in conformity with the finding of Pollard and Chundari (1988). Improving yield, quality and duration of harvesting period could optimize the economic return. Planting of strawberry at different planting time prolong the harvesting season, but sun burning and poor establishment during summer and late winter injuries were major constraints, which reduced the length of the harvesting period. Earlier production using 50% shade might be caused by reduction of excessively high temperature and strong sunlight (Cao et al., 2002). This fact was well supported by metrological data in the present study where a constant optimum temperature range of 20.0–25.1 °C was recorded during summer. However, extension of harvesting period when planted in November using UVS polythene covering was caused by a higher temperature of 7.0 ± 2.0 °C–16.0 ± 2.0 °C inside the tunnel during the cold winter. This finding was in line with the finding of Waterer (1992); who reported that the increase in air temperature in the tunnel accelerated crop development and extended the growing season. An increase in both soil and air temperature inside the UVS polythene cover and their effect on early flowering and fruiting have also been reported (Fereira et al., 2004; Gao et al., 2005).

3.4. *Effect on plant survival of treatments*

Hundred percent of the plants survived when planted in October (P4) which was significantly higher than for other planting dates, while planting in July (P1) recorded the lowest plant survival (Table 3). Among treatments 50% shade (L2) caused the highest plant survival followed by 75% shade (L1). However, it was noticed that open field planting caused the lowest plant survival of all planting date except for October (P4L0). Planting dates in low tunnel also had a significant effect on plant survival. Irrespective of cover method, planting in October showed 100% plant survival even in open field. Planting in August and September caused higher plant survival percentage in 75% shade. This might be caused by the effect of shade net in protecting the plants from scorching sun and direct impact of heavy rain. Secondly, the relative humidity and temperature using 75% shade in August and September was favorable for plant growth. Whereas, 100% plant survival for November planting and 100% mortality following July planting were recorded using UVS polythene (P1L3). This might be caused by heat shock in the tunnel during July, which was well supported by the data recorded for microclimate change in the tunnels. However, during November due to favorable soil (22.0 °C) and air temperature (26.4 °C), using UVS polythene was optimal compared to other treatments giving too, low temperature. Planting in open field caused the lowest plant survival compared to covering at all planting dates.

3.5. *Effect on chlorophyll content of treatments*

The data presented in Table 3 showed that the planting time and cover treatment had significant effect on the chlorophyll content of leaves, which was highest after October followed by November and

Table 2
Effect of low tunnel covers and planting time on the harvesting period of strawberry.

Planting time	Open field	50% Shade	75% Shade	UVS polythene
July	24 January–24 February	10 December–5 February	25 December–20 February	–
August	30 January–18 March	15 December–15 February	28 December–25 February	8 January–18 February
September	14 January–24 February	7 January–5 March	15 January–5 March	14 January–8 March
October	18 January–15 March	15 January–25 March	5 January–20 March	9 January–30 March
November	27February–20 March	20 February–25 March	15 February–30 March	10 February–2 May

July plantings. The effect of covering treatment on chlorophyll content was affected by treatment. It was found that 50% shade (L2) caused highest chlorophyll content and open condition recorded the least. There were significant interactions between planting date and covering treatment. Irrespective of the planting time, planting in open field caused the lowest content of chlorophyll of all treatments. These findings were supported by the findings of Rotundo et al. (1998) who reported that shading increased the chlorophyll content of leaves, similar result was also reported by Son et al. (2003).

3.6. *Effect of treatment on number of days to 50% flowering*

Planting in November resulted in the lowest number of days to 50% flowering followed by the October planting, while planting in July caused the highest number of days. High temperature was reported to inhibit flowering in many species (Warner and Erwin, 2002) since high temperature lowered the level of endogenous GA and its precursor (Su et al., 2001) and it was recorded that the soil and air temperatures were very high in the month of July and hence it took much more days to come to flowering compared to the November planting. For covering treatment, UVS polythene took much lesser days to 50% flowering followed by 50% shade. It was noticed that planting in the month of November using UVS polythene (P5L3) resulted in 80.3 days to start flowering, which was significantly lower than other treatment combinations. Open field planting at all planting times, however, took more days to come to 50% flowering than other covering. Besides micro-climate change, gaseous composition of the air surrounding the plant is also important because content of CO_2, O_2, N, water vapor and other trace gases influence the plant metabolism immensely which influence better plant growth and reproductive growth (Sirohi et al., 2005). This finding was in conformity with the findings of Pollard et al. (1989) who reported earlier flowering of strawberry under cover than in open field.

Table 3
Effect of low tunnel and planting time on plants survival, chlorophyll content, yield and quality attributes of strawberry.

Treatments	Plants survival (%)	Chlorophyll content (mg/100 g leaves)	Days to 50% flowering	Number of fruits/plant	Yield (g/plant)	Ascorbic acid (mg/100 g)	β-carotene content (μg/g)	Anthocyanin (mg/100 g)
Planting time								
P_1	66.10	2.33	128.50	20.18	194.65	100.85	7.80	104.01
P_2	89.23	1.93	120.50	28.44	175.60	98.03	7.76	104.54
P_3	90.37	2.01	115.75	31.38	174.00	99.98	8.36	116.44
P_4	100.00	2.35	92.82	27.69	222.98	105.29	9.10	113.86
P_5	84.72	2.33	91.37	20.29	203.06	107.98	8.77	126.44
Mean	86.08	2.19	109.79	25.60	194.06	102.43	8.36	113.06
LSD = p(0.05)	4.329	0.203	2.613	6.681	19.86	2.645	0.696	4.132
Low tunnels covering								
L_0	77.81	1.97	121.14	13.78	146.19	98.90	8.16	111.17
L_1	89.37	2.21	105.76	21.52	217.34	100.82	8.15	106.26
L_2	90.83	2.36	98.10	31.98	222.56	102.42	8.75	116.74
L_3	73.12	2.20	94.08	31.05	189.02	109.26	8.64	120.99
Mean	82.78	2.18	104.77	24.58	193.78	102.85	8.42	113.79
LSD = p(0.05)	5.757	0.187	1.61	4.302	19.52	2.758	NS	4.705
Interactions								
P_1L_0	55.81	2.14	148.01	10.17	142.84	92.30	7.32	96.40
P_1L_1	58.31	2.08	123.20	22.20	210.60	100.47	7.36	102.78
P_1L_2	84.16	2.77	114.30	28.17	230.50	109.78	8.72	113.20
P_1L_3	0.00	–	–	–	–	–	–	–
P_2L_0	73.87	1.59	134.00	15.25	104.11	92.50	7.36	97.72
P_2L_1	97.91	2.09	121.30	21.00	229.00	96.94	7.20	102.58
P_2L_2	95.46	2.06	103.70	31.75	228.30	95.18	6.80	112.54
P_2L_3	89.69	1.98	123.00	45.75	140.98	107.51	8.12	105.33
P_3L_0	81.49	2.01	127.00	8.75	101.00	98.21	8.12	115.35
P_3L_1	100.0	2.06	101.70	27.75	215.90	100.46	8.26	107.00
P_3L_2	95.00	1.99	114.30	50.50	229.00	95.18	8.46	123.00
P_3L_3	85.00	1.96	120.00	38.50	150.10	106.08	8.62	120.41
P_4 L_0	100.0	2.26	98.00	20.25	229.00	102.53	9.14	118.69
P_4 L_1	100.0	2.35	92.30	19.50	217.93	100.47	9.30	105.50
P_4 L_2	100.0	2.45	92.00	28.00	215.00	102.23	9.23	104.44
P_4 L_3	100.0	2.35	89.00	43.00	230.00	115.94	8.76	126.82
P_5 L_0	77.80	1.84	98.70	14.50	154.00	108.94	8.90	130.41
P_5 L_1	90.63	2.47	90.31	17.17	213.25	105.75	8.16	113.44
P_5 L_2	79.55	2.51	96.20	21.50	210.0	109.73	8.96	130.52
P_5 L_3	90.91	2.50	80.30	28.00	235.00	107.51	9.06	131.41
Mean	82.78	2.18	108.80	25.88	194.03	102.51	8.27	113.55
LSD = p(0.05)	12.87	0.419	3.608	9.62	26.36	6.167	0.33	7.52

3.7. Effect of treatments on fruit number

Fruit number per plant was highest at 50% shade (L1) while planting in open field (L0) produced fewest. Further plants at 50% shade in the month of July produced highest fruit number, while the lowest fruit number was recorded following the September planting in open field. Long day conditions increased the number of inflorescence of strawberry while short day decreased the number (Nishiyama et al. (2003), this might be the reason of highest number of flower per plant in the July planting compared to other planting times. Similarly, planting in the month of October and November under UVS polythene was recorded to have the highest number of flowers and fruits per plant. During winter season UVS polythene increased the temperature in average 2–6 °C higher than in open, which may have caused the increase in fruit number. Davies et al. (2002) reported similar effects of temperature on flower and fruit numbers.

3.8. Effect of treatments on fruit yield

It was found that 50% shade (L1) gave the highest yield while open field (L0) gave the lowest yield except for the October planting (P4) (Table 3). The reason of this may be that shade protects the crop from excessively high temperature and strong sunlight (Cao et al., 2002), which prevailed during the summer month and resulted in better crop development and ultimately increased the yield. Planting in November in polythene produced highest yield compared to other interactions. The increased yield in polythene cover when planting was done in the winter months, might be a temperature effect inside this tunnel which is considered to be within the effective range for strawberry cultivation. Another possible reason of higher yield using covers on low tunnels could be CO_2 enrichment stimulating growth directly and finally increasing the number of flowers and fruit set which ultimately resulted in higher yield.

3.9. Effect of treatments on biological fruit compounds

The investigation revealed that among the planting times, significantly highest ascorbic content was found following the November planting and the lowest amount was found following the August planting (Table 3). The covering treatments had effect on the content and fruit produced under UVS polythene cover had the highest content of ascorbic acid. There was a significant interaction between the October planting and polythene cover producing fruits of the highest ascorbic content, while planting in the open field in July yielded the lowest ascorbic acid content. That the content was highest in November and lowest in August might be a temperature effect (Meng et al., 2004). However, the contrasting result obtained comparing the different covering treatments might be attributed to the better plant growth in this tunnel. The content of β-carotene was not altered by covering treatment however; it was significantly influenced by the time of planting. Among planting times, October planting was recorded significantly highest while the August planting resulted in the lowest β-carotene level. It was also found that the combinations between October planting with 75% and 50% shade recorded highest β-carotene content in the fruits. This finding was in accordance with the finding of Adam et al. (2002), who reported that shading increased the carotenoid content. It was found that the anthocyanin content of fruit was significantly highest when planted in the month of November followed by September while it was lowest following the July and August planting. For cover treatment it was found that UVS polythene covering produced fruit of highest anthocyanin content, while lowest content was recorded using 75% shade. Regarding interactions, UVS polythene cover in October and November produced fruits of higher anthocyanin content than fruits harvested from open field from July and August planting. The decrease of anthocyanin after the July planting might be caused by the finding that anthocyanin decreased with increased temperature (Dela et al., 2003), however achieving the highest anthocyanin level under UVS polythene cover and the lowest using 75% shade, imply that the anthocyanin content did not exclusively depend on the temperature.

4. Conclusion

From the study it could be inferred that the modification caused by the low tunnels provided a better microclimate i.e. more appropriate temperature and relative humidity in the tunnel and more favorable rhizosphere temperature. This resulted in earlier and more vigorous crop growth and better yield than growing in the open field. Hence, production of strawberry in low tunnel was one of the best options to attain early production as well as to extend cropping season if it planted in 50% shade net in July–August and in UVS polythene tunnels in November.

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