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Effect of different growing environments on growth, yield and quality attributes of strawberry

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Abstract

Shading is one of the cooling methods for changing the microclimate and maximizing crop growth in hot and sunny regions. A study was conducted to determine the effect of the growing environment on the growth, yield and fruit quality parameters of strawberries. The experimental treatments included net house, poly shed house, UV poly shed house, and open field (control) conditions. The results revealed that the plants grown in the net house condition had maximum plant height (18.5 cm), total chlorophyll content (62.66), fruit number (17), and yield (289.16 g/plant) of strawberries. In contrast, plants grown under UV poly shed conditions recorded higher total soluble solid (7 °Brix), titratable acidity (0.46 %), ascorbic acid (39.68 mg/100g) and lower pH (3.41). Reducing sugar (7.57 mg/g) and phenol (2.44 mg/g) levels were higher in fruits grown in poly shed. Results indicated that the most suitable growing condition for yield and yield parameters of strawberries is under the net house. In contrast, UV poly and poly house conditions are favourable for producing better quality fruit.

Key words: Strawberry, shade house, growth, yield, quality

Introduction

Strawberry is one of the world's most tasty and fragrantly sweet aromatic fruits. It is a small, creeping, perennial, stoloniferous herb that belongs to the Roseaseace family. It is a important fruit and has a major natural source of bioactive compounds (Ariza *et al.*, 2016). Strawberries are to a lesser extent, a source of healthy, essential fatty acids, since its seed oil is rich in unsaturated fatty acids. The fruit also has a high content of manganese, potassium, iodine, magnesium, copper, iron, and phosphorus. In addition to these nutrient compounds, strawberries contain a number of non-nutrient elements, such as poly phenolic phyto chemicals (Giampieri *et al.*, 2012). Moreover, strawberries such as jams, juices, and jellies, are economically and commercially relevant and commonly consumed fresh or in processed forms. This is why, from an agronomic, genetic, and nutritional points of view, they are among the most studied berries.

Due to its charming red colour and high nutritional value, strawberry has a unique place among all the berry fruits (Sharma *et al.,* 2013). It is a thermo and photo sensitive crop (Sharma, 2002). Strawberry is planted in Bangladesh in the month of October-November and it starts flowering from December and its harvesting time is from January to March. Being a winter fruit crop, it has to face a lot of natural advertisement like poor soil moisture, temperature fluctuation and so on specially during flowering and fruiting (Sharma *et al.,* 2013).

Because of its high variability, climate is the most influential factor in agricultural production, so that the environment in which the crops are grown can be modified through a protected environment (Iizumi and Ramankutty, 2015). It is necessary to evaluate the conditions in which the plants are developed and take into account that environmental variables affect the quality of the fruit (Martínez *et al.,* 2017). Some of the environmental effects that have an important impact are temperature, relative humidity (Rivera *et al.*, 2017). Temperature is the principal environmental factor influencing cymes, flowers, and fruit production. Mireku (2012) indicated that increased growth temperatures led to a small leaf area, while the length of the leaf increased. Chlorophyll content of leaves and light interception by plants in screen house also increased as the growth temperature increased. Increasing environmental growth temperatures resulted in reduced fruit quality like soluble solids, sugar-acid ratio, titratable acids and pH varied among the cultivars. Kumakura and Shishido (1995) observed that the fruit weight in the glasshouse dropped as the mean temperature increased.

Several studies have been made about strawberry responses to various temperature regimes. Zang *et al.* (1997) found that strawberry cells at 30 °C grew gradually and usually did not proliferate in suspension cultures. Hellman and Travis (1998) determined that the crucial range of strawberry growth inhibition was between 35 and 40 °C and the runner output is drastically decreased by a temperature exposure of 3 days to 40 °C. The mechanisms involved in heat stress on strawberry fruit yield and quality, are minimal. Strawberry is one of the crops that respond well to the increase in soil temperature/ light reflectance produced in polyhouses. When modifying the environmental conditions, it is necessary to know its effect on the postharvest quality of the fruits. The behaviour of the temperature inside the high tunnel is of great importance, because it intervenes in the "metabolic activity, the absorption of water and nutrients, the gas exchange, the production and expenditure of carbohydrates and growth regulators" (Argandar, 2010). Additionally, an increase in temperature increases the efficiency of metabolic processes and, therefore, in crop yield. Temperature is a factor that affects the chemical composition of the fruits (Lee and Kader, 2000). It interferes in the formation of sugars, due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates and the increase in the transpiration rate (Palonen *et al.*, 2017). When the temperature is very low at night, there is a decrease in the content of anthocyanins that affects the antioxidant capacity.

Now protected agriculture has expanded to help improve agricultural productivity. To date, there is a little research available of strawberry cultivation under shade conditions. To meet the increasing demand of fruit crops, there is an urgent need to assess the cultivation and suitability of strawberry production and quality measurement within different shade houses. The experiment was thus aimed at determining the efficacy of various shade houses cultivation compared to open field on strawberry quality and yield.

Materials and methods

Plant materials and growing conditions: During November 2019 to March 2020, the experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42′37″ N (Latitude), 90°24′26″ E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The strawberry cv. Festival planted under raised bed planting system at 60 cm × 30 cm spacing under four environments, *i.e.* open field condition (control), net house, naturally ventilated polyhouse (entire roof and half the portion of four sides covered with poly sheet, the remaining half covered with 25 % shade net) and Fan pad UV polyhouse (Fully covered with UV film sheet), between November 2019 and March 2020. The experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication five plants were randomly selected for observations on fruit production, yield and physio-chemical parameters. Temperature and relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions to which the plants were grown.

Measurement of plant height (cm): Five plants in each treatment and each replication were used for plant height at harvest. Plant height was measured from the base of the plant to the top of the main plant.

Measurement of leaf chlorophyll content: Leaf chlorophyll content was measured using SPAD-502 chlorophyll meter in first fully expanded leaves (Minolta, Tokyo, Japan). Measurements were recorded from the middle of the leaf lamina of each treated and control plants.

Fruit yield and yield traits: The yield/plant (g) was recorded by adding yield of all the harvests obtained from five plants in each treatment and each replication. The weight of fruits (g) from each selected plants was taken on each date of harvest with the help of electronic top pan balance. The number of fruits/plant was recorded by counting the fruits that reached harvestable ripeness.

Moisture content: Moisture content in strawberry fruit was determined following Karathanos method modified (1999). Five fruits were pooled and their fresh weight (FW) determined for each replicate of each treatment. To assess the dry weight (DW), the fruits were then dried in an oven at 65 °C for 48. The moisture content was determined using the equation below:

Moisture content (%)=(Fresh weight-dry weight)/dry weight x100

Total soluble solids content: The TSS content of strawberry was measured by hand refractometer. A drop of strawberry juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juice of individual treatments strawberries were filtered separately, and pH was measured using digital pH meter.

Titratable acidity (TA %): For determination of TA, 5 g sample was macerated in mortar and pestle and filtered. Final volume was made to 100 mL using distilled water. Then 10 mL of stock solution was taken in conical flask and 2 drops of phenalpthelin was added. The solution was titrated with 0.1N NaOH. The reading was recorded when the titrate colour was rosy pink. The titration was done for three times.

Vitamin C determination: Oxidation Reduction Titration Method (Tee *et al.*, 1988) was used to calculate the Vitamin C content of strawberry. The single fruit was mixed and filtrated with filter paper Whatman No.1. The volume was made 100 mL with 5 % oxalic acid solution. The titration was done with dye solution 2, 6-dichlorophenol indophenol. The mean observations provided the amount of dye required to oxidize unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic acid as known sample. 5 mL solution was taken for titration each time and pink colour determined the last point of titration which remains for 10 seconds. The burette reading was recorded.

Phenolic content: The content of phenols was calculated using Singleton *et al*. (1999) method. Fresh fruits (250 mg) were homogenized with 85 % methanol. At 10 °C the extract was centrifuged at 3,000 g for 15 min and separated the supernatant. Folin and Ciocalteu's reagent (2 mL) has been added to the supernatant per 2 mL. A sodium carbonate solution was applied to each test tube (7.5 %, 2 mL) and after 30-45 min, the absorbance was read against a reagent blank at a wave length of 725 nm. To determine the concentration of total phenols in the unknown sample a standard curve was generated using gallic acid.

Reducing sugars content: Determination of reducing sugars was based on the phenol-sulphuric acid method (DuBois *et al.*, 1956). With deionized water a total of 0.2 g fresh fruit was homogenized and the extract was filtered out. 2 mL of the solution was combined with 0.4 mL of 5 % of phenol. Subsequently, the mixture was rapidly added to 2 mL of 98 % sulphuric acid. The test tubes were keept at room temperature for 10 min and positioned for colour development in a water bath at 30 °C for 20 min. Light absorption with the spectrophotometer was then measured at 540 nm. Similar to the above, blank solution (distilled water) was prepared (Ammar *et al.*, 2009). Reducing sugar content was expressed as mg g^{-1} fresh weight (FW).

Statistical analyses: The experiments used a randomized complete block design (RCBD) with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with version 9.4 of the Statistical Analysis System (SAS) (SAS Institute, Cary NC, USA). The mean value among the treatments were considered to be statistically significant when $P<0.05$. All results were presented with mean ± SE from the replicates. Graphs were drawn using the Microsoft excel.

Results

Environmental conditions: Under protected conditions temperature can be monitored and managed, and better plant growth could be expected. Different shade houses and open field condition influenced the air temperature. Data of the temperatures for each treatment was measured at 12 pm daily during the experimental period. The average monthly temperature varied from approximately 21.03 to 31.41°C as shown in Table 1.

Table 1. Monthly average air temperature (°C) at 12 hrs in different shade house and open field

Month	12 h			
	Poly shed	UV Poly shed	Net house	Open field
November, 2019	28.19	30.03	26.87	29.33
December, 2019	22.00	25.93	21.45	25.03
January, 2020	22.50	25.41	21.03	24.65
February, 2020	24.21	26.96	23.09	26.48
March, 2020	28.85	31.05	27.55	30.41

During the experimental period the relative humidity data for each treatment was measured at 12 pm daily. The average monthly relative humidity varied between 67.09 to 76.21 percent during November to April in day time (Table 2). Relative humidity was always higher in the net house during the growing season, while the relative humidity was approximately similar in both poly shed and open field condition.

Table 2. Monthly average relative humidity (%) at 12 hrs in different shade house and open field

Month	12 h			
	Poly shed	UV Poly shed	Net house	Open field
November, 2019	70.53	68.07	73.19	70.98
December, 2019	72.6	70.95	74.01	72.75
January, 2020	74.33	72.53	76.21	74.60
February, 2020	71.17	70.03	73.01	70.72
March, 2020	68.90	67.09	70.19	68.51

Plant height: Different growing conditions showed substantial variability within plant height. Regardless of the influence of different shade house treatments, plant height varied significantly. The maximum plant height (18.5 cm) was obtained in net house followed by poly house (17 cm) and the lowest height (15.5 cm) was obtained from open field condition (Fig.1A).

Chlorophyll: In this study, there were no significant differences of different growing environment in leaf chlorophyll content except net houses plants (Fig. 1B). The plants in the net house showed the highest chlorophyll content (62.73), and the lowest chlorophyll content (57.66) was shown in UV poly shed followed by Open field condition (58.33).

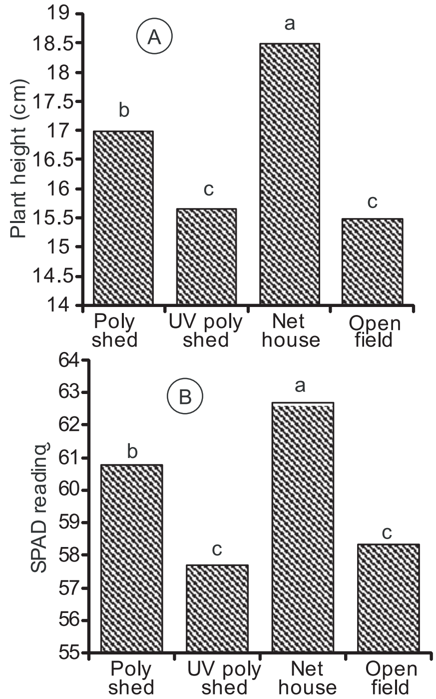

Fig.1. Average plant height (cm) (A) and leaf chlorophyll content (SPAD reading) (B) of strawberry grown under different shades and open field condition. .

Number of fruits/plant: Number of fruits/plant was significant among the shade houses (Fig. 2A). Number of fruits plant^{-1} was the highest in net house (17) and the lowest in both UV poly shed (12.33) and open field condition (12.66).

Individual fruit weight: Different growing environment showed significant variation in respect of individual fruit weight (Fig. 2B). The maximum fruit weight (17g) was recorded in net house followed by poly house (15.66 g) and minimum weight was recorded from open field condition (13.83).

Fruit yield/plant: There was a significant variation among shade houses in response to fruit yield plant^{-1}. The highest fruit yield (289.16 g) was found in net house followed by poly shed (235 g) and lowest yield (162.72 g) found from open field condition (175.16g) followed by UV poly shed (181.33) (Fig. 2C).

Moisture content: No significant change of moisture content in strawberry fruits was

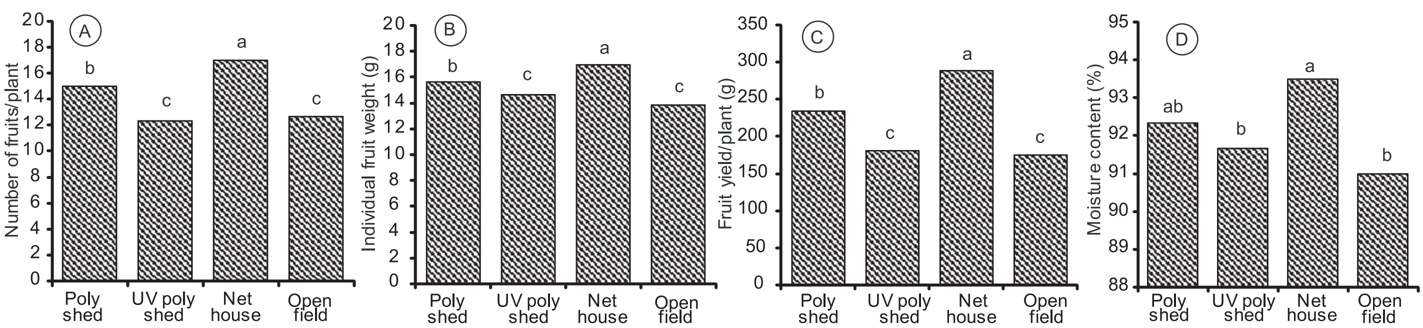

Fig. 2. Average numbers of fruit of each plant (A), individual fruit weight (g) (B), fruit yield/plant (g) (C) and moisture content (%) (D) of strawberry fruits grown under different shades and open field conditions.

found among poly shed, UV poly shed and open field conditions. The maximum moisture content in fruits (93.50 %) were found in net house followed by poly shed (92.33 %) and the minimum moisture content was found in fruits grown under open field condition (91 %) (Fig. 2D).

Ascorbic acid: The higher ascorbic acid was found in UV poly shed (39.66 mg/100 g), followed by naturally ventilated polyhouse (37.33 mg/100 g) and net house (35.45 mg/100 g) and the lowest ascorbic acid was found in the fruits grown in open field condition (33.62 mg/ 100 g) (Fig. 3A).

Total soluble solids: It was observed that there was a significant effect of growing environment on fruit TSS of strawberry (Fig. 3B). Strawberry growing in protected environment had higher TSS than fruits produced in open field condition. We found a TSS content of 7.0 ºBrix in UV poly shed, 6.5 ºBrix both in poly shed and net house and 5.5 ºBrix for strawberry grown in the open field.

Titrable acidity (TA): We found that the fruits produced in the field to be less acidic than the fruits produced in a protected environment. The higher titrable acidity was found in UV poly shed (0.46 %), followed by naturally ventilated polyhouse (0.38 %) and net house (0.36 %) and the lowest ascorbic acid was found in the fruits grown in open field condition (0.33 %) (Fig. 3C).

pH value: The lower pH was found in UV poly shed (3.4) and the higher pH was found in fruits grown in open field condition (3.57) followed by net house (3.56) and poly shed (3.52) (Fig. 3D). However, no significant differences were observed in the pH values of strawberry fruits grown in poly shed, net house and open field conditions. Determining fruit acidity at complete maturation, when acidity decreases, is possibly the explanation for the low values.

Total phenolic content: The phenolic compounds directly contributed to the antioxidant action. Shading conditions were significantly different for total phenolic content. The total phenolic content in the plants grown under poly shed was highest (2.44 mg/g FW) followed by UV poly shed (2.33 mg/g FW) and net house (2.10 mg/g FW), whereas the total phenolic content in strawberry fruits in open field was lowest (1.62 mg/g FW) (Fig. 4A).

Reducing sugar: The reducing sugar content of strawberries in shade treatments were significantly higher compared to the open field condition (Fig. 4B). The highest sugar content in the plants grown under poly shed was seen (7.74 mg/g FW), followed by UV poly shed (7.38 mg/g FW) and net house (6.68 mg/g FW), while the lowest sugar content in open field strawberry fruits (5.52 mg/g FW) was observed (Fig. 4B).

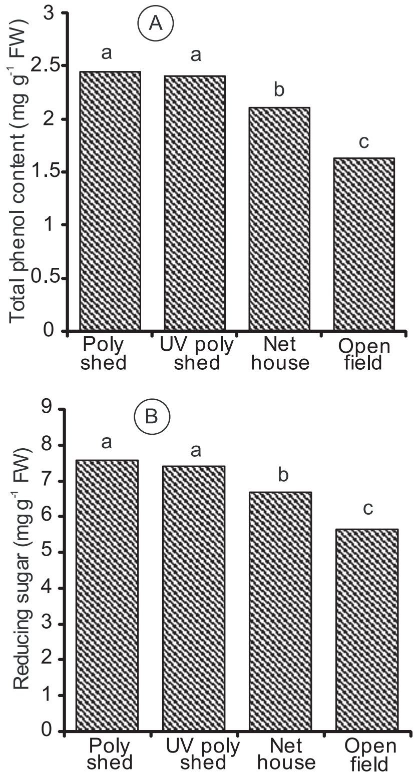

Fig. 4. Average content of total phenol (mg/g FW) (A) and reducing sugar (mg/g FW) (B) of strawberry fruits grown under different shades and open field condition.

Discussion

Temperature is primary environmental factor controlling short-day strawberry plant growth and development (Palencia *et al.*, 2013). In our experiment, it was found that air temperature in UV poly shed and open field was always more than that in other poly and net houses condition. The optimal temperatures for photosynthesis in strawberries ranges from 15 to 23°C (Hancock, 1991). Higher temperatures affect net photosynthesis more adversely than lower temperatures, leading to lower photosynthesis output above a certain temperature (Reddy *et al.*, 1999). Relative humidity increases the net energy availability for crop growth and enhances crop survival under conditions of moisture stress. Shading enhanced the fruit fresh weight, resulting in fruits with higher moisture content (Awang and Atherton, 1995). Compared to other growing conditions the relative humidity was comparatively lower in UV poly shed condition. The lower relative humidity inside the UV poly house may be due to fully covered with UV film sheet. Relative humidity retains cell turgidity that is useful in enzyme activity leading to greater yield (Reddy *et al.*, 1999). A relative humidity level of 65 to 75 % during the day was considered to be optimal

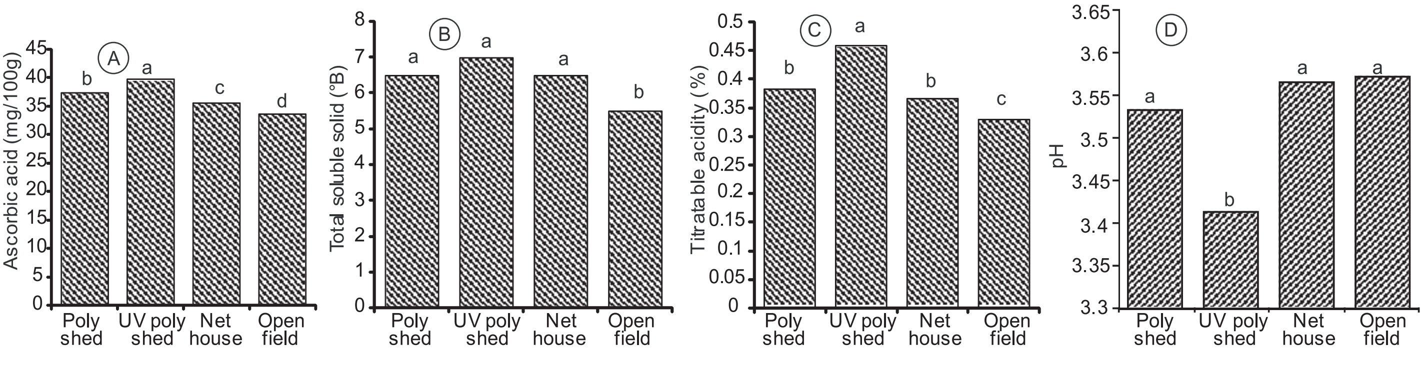

Fig. 3. Average content of ascorbic acid (mg/100g FW) (A), total soluble solid (^{0}B) (B), titratable acidity (%) (C) and pH (D) of strawberry fruits grown under different shades and open field condition.

for good growth and yield of strawberries in the greenhouse (Lieten, 2000). In our experiment, the relative humidity was at an optimum level in all the growing conditions.

In net house and naturally ventilated polyhouse, strawberry plants had higher plant height. The higher plant height may be attributed to increased photosynthesis and respiration due to the favourable micro-climatic conditions. Favourable environment and better moisture conservation resulted in better plant growth parameters (Qureshi *et al.*, 2012). This is consistent with the results of Ramesh and Arumugam (2010) on vegetables grown under a poly house and El-Aidy *et al.* (1988) in sweet pepper grown under a net house. In our experiment, open field condition and UV poly shed showed significant decrease of leaf chlorophyll content. Higher temperature are likely to play an important role in limiting growth and fruit development by reducing photosynthetic activity and increasing the rate of respiration (Darnell and Hancock, 1996). Fruit yield negatively correlated to increase in temperature (Mori 1998). Temperature above 25 °C can reduce fruit set of strawberry (Abdelrahman, 1984). In our experiment, higher temperature might have reduced strawberry flower formation and fruit yield of the plants grown in open field conditions and UV poly shed. Likewise, Ledesma and Sugiyama (2005) showed that high temperatures have a negative impact on fruit set in strawberries, decreasing pollen viability and inhibiting pollen tube growth and pollen tube elongation.

The environmental impact on fruit acidity is complex, and some studies support the presumption that organic acids are derived from stored carbohydrates in the fruit itself, although some of these acids may be translocated from the leaves and roots to the fruits (Bertin *et al.*, 2000). Thus, the higher acidity of the fruits grown in a protected environment may result from the plant's higher photosynthetic activity in this environment, and consequently from a higher accumulation of carbohydrates in the fruits. Yanagi *et al.* (1995) stated that the titratable acidity also increases with shading. High fruit quality is associated with low pH (Davies and Hobson, 1981).

Biosynthesis of ascorbic acid can be highly affected by environmental conditions, influencing the ascorbic acid content in strawberry fruits (Venter, 1977). The amount of ascorbic acid in fruit is also affected by the availability of light to the crop and to the fruits. Under shed house, the plants received proper intensity of light which could have improved the ascorbic acid content in fruits compared to open condition. Koley *et al.* (2013) investigated quality parameters of tomato under protected and open cultivation and found significant higher vitamin C in the fruit produced under protected structures at full ripe stage over the open field cultivation. Pal *et al.* (1980) found that under poly shed, the plants obtained sufficient light intensity which may have increased the amount of ascorbic acid in the fruit compared to open environment. Loures (2001) found a lower TSS content for field-grown tomatoes than tomatoes grown in a protected area. Pérez de Camacaro *et al.* (2017) reported that greater accumulation of TSS in fruit has been observed in shading conditions due to reduced sugar degradation.

In our results, there was no significant difference of phenolic content between UV poly shed and poly shed. Our results revealed that shading conditions significantly influenced total phenolic content of strawberry fruits. Koley *et al.* (2013) investigated quality parameters of tomato under protected and open cultivation and found significantly higher antioxidant activity in the fruit produced under protected structures at full ripe stage over open field cultivation. Reducing sugar content was considerably higher in fruits cultivated under shade houses. This result is similar to that of Voca *et al.* (2009) who found that fruits grown under a tunnel had usually more reducing sugar than in open field cultivated fruits. Therefore, growing strawberry under shade treatments in may be profitable for quality point of view as it increased reducing sugar.

Our results revealed that shading conditions significantly influenced growth, yield and quality of the strawberry. Fruits grown under shade houses contained higher quality than fruits grown in field conditions. Among the shade houses fruits grown under UV poly shed had substantially more total soluble solid, titrable acidity, ascorbic acid and lower pH. Fruits grown under poly shed had more reducing sugar and total phenol. However, yield and yield contributing parameters of the strawberry were higher in net house. Based on the results, we suggest that growing strawberry under net house was the most suitable growing conditions for yield and yield contributing parameters while strawberry produced in a UV poly shed and poly shed presented better quality fruits.

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References

Ammar, E.D., C.W. Tsai, A.E. Whitfield, M.G. Redinbaughand S.A. Hogenhout, 2009. Cellularand molecular aspects of rhabdovirus interactions with insect and plant hosts. *Annu. Rev. Entomol*., 54:447–468.

Abdelrahman, M.H. 1984. Growth and Productivity of Strawberry Cultivars At High Temperatures. PhD Thesis, Kans. State Univ., Manhattan.

Ariza, M.T., P. Reboredo-Rodríguez, L. Mazzoni, T.Y. Forbes-Hernández, F. Giampieri, S. Afrin, M. Gasparrini, C. Soria, E. Martínez-Ferri, M. Battino and B. Mezzetti, 2016. Strawberry achenes are an important source of bioactive compounds for human health. *Int.J.Mol. Sci.,* 17: 1103.

Argand ar, C.G. 2010. Evaluaciónagronomica de películas para invernaderoformuladas con nanopartículas de óxido de zinc. Saltillo, Cohahuila, 129.

Awang, Y.B. and J.G. Atherton, 1995. Growth and fruiting responses of strawberry plants grown on rockwool to shading and salinity. *Sci. Hort.,* 62: 25-31.

Bertin, N., N. Ghichard, C. Leonardi, J.J. Longuenesse, D. Langlois and B. Naves, 2000. Seasonal evolution the quality of fresh glasshouse tomato under Mediterranean conditions, as affected by vapour pressure deficit and plant fruit load. *Ann. Bot.,* 85: 741-750.

Darnell, R.L. and J.F. Hancock, 1996. Balancing vegetative growth with productivity in strawberry. Proc. IV North American Strawberry Conf. Orland o, Florida. pp. 144–150.

DuBois, M., K. Gilles, J. Hamilton, P. Rebers and F. Smith, 1956. Colorimetric method for determination of sugars and related substances. *Anal. Chem.,* 28: 350–356.

Davies, J.N. and G.E. Hobson, 1981. The constituents of tomato fruit - the influence of environment, nutrition, and genotype. *Crit. Rev. Food Sci. Nutr.,* 15: 205-280.

El-Aidy, F., M. El-Afry and F.Ibrahim, 1988. The influence of shade nets on the growth and yield of sweet pepper. International Symposium on Integrated Management Practice AVRDC, Taiwan

Giampieri, F., S.Tulipani, J.M. Alvarez-Suarez, J.L. Quiles, B. Mezzetti and M. Battino 2012. The strawberry: composition, nutritional quality, and impact on human health. *Nutr.,* 28: 9-19.

Hellman, E.W. and J.D. Travis, 1998. Growth inhibition of strawberry at high temperatures. *Adv. Strawberry Prod.,* 7: 36-38.

Hancock, J.F. 1991. Photosynthesis in strawberries and the potential for improvement. In: *The Strawberry into the 21st Century*. A. Dale and J.J. Luby (eds.). Timber Press, Portland , Oregon.

Iizumi, T. and N. Ramankutty, 2015. How do weather and climate influence cropping area and intensity? *Glob. Food Sec.,* 4: 46-50.

Kumakura, H. and Y. Shishido, 1995. Effects of temperature and light conditions on flower initiation and fruit development in strawberry. *Jpn.Agr. Res. Q.* 29: 241-250.

Karathanos, V.T. 1999. Determination of water content of dried fruits by drying kinetics. *J. Food Eng.*, 39: 337-344.

Koley, T. K., S.N.S. Chaurasia, S. Singh, R.B. Yadav, and P.S. Naik, 2013. Quality of tomato under protected and open cultivation: a comparison. Souvenir and abstracts, national seminar on advances in protected cultivation organized by Indian Society for Protected Cultivation. New Delhi, India, 21 March 2013, p 86.

Lee, S.K. and A.A. Kader, 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biol. Tec.,* 20: 207-220.

Ledesma, N. and N. Sugiyama, 2005. Pollen quality and performance in strawberry plants exposed to high-temperature stress. *J. Am. Soc. Hort. Sci.,* 130: 341-347.

Lieten, P. 2000. The effect of humidity on the performance of greenhouse grown strawberry. In IV International Strawberry Symposium, 567, July 2000, pp. 479-482.

Loures, J.L. 2001. Estabelecimento e avaliação do sistema de produçãodenominadoFito, emestufa e campo. Ph.D.Thesis. Universidade Federal de Viçosa, Viçosa, Brazil, pp. 109.

Mireku, P.A.T.R.I.C.K. 2012. *Influence of Temperature on the Yield and Quality of Three Strawberry Cultivars*. Doctoral dissertation, University of Ghana.

Martínez, F., J.A. Oliveira, E.O. Calvete and P. Palencia, 2017. Influence of growth medium on yield, quality indexes and SPAD values in strawberry plants. *Sci. Hort.,* 217: 17-27.

Mori, T. 1998. Effect of temperature during flower bud formation on achene number and fresh weight of strawberries. *J. Jpn. Soc. Hort. Sci.,* 67: 396-399.

Pal, D.K., M.D. Subramanyam, N.G. Divakar, C.P.A. Iyer and Y. Selvaraj, 1980. Studies on the physico-chemical composition of fruits of twelve papaya varieties. *J. Food Sci. Tech.,* 17: 254-256.

Pérez de Camacaro, M., M. Ojeda, A. Giménez, M. González and A. Hernández, 2017. Attributes of quality in strawberry fruit 'Capitola' harvested in different climate condition in Venezuela. *Bioag.*, 29: 163-174.

Palonen, P., A. Pinomaa, and T. Tommila, 2017. The influence of high tunnel on yield and berry quality in three floricane raspberry cultivars. *Sci. Hort.,* 214: 180-186.

Palencia, P., F. Martínez, J.J. Medina and J. López-Medina, 2013. Strawberry yield efficiency and its correlation with temperature and solar radiation. *Hort. Bras.,* 31: 93-99.

Qureshi, K.M., F. Hassan, Q. Hassan, U.S. Qureshi, S. Chaughati and A. Saleem, 2012. Impact of cultivation systems on growth and yield of strawberry (*Fragaria ananassa*) cv. Chandler. *Pak. J. Agr. Sci.,* 25: 129-135.

Ramesh, K.S. and T. Arumugam, 2010. Performance of vegetables under naturally ventilated polyhouse condition. *Mysore J. Agric Sci.,* 44: 770-776.

Reddy, M.T., S. Ismail and Y.N. Reddy, 1999. Shade and allelopathic effects of ber on growth, productivity and quality of radish (*Raphanus sativus* L.) under pot culture. *South Indian Hort.,* 47: 77-80.

Rivera, S.A., R. Ferreyra, P. Robledo, G. Selles, M.L. Arpaia, J. Saavedra and B.G. Defilippi, 2017. Identification of pre-harvest factors determining postharvest ripening behaviors in 'Hass' avocado under long term storage. *Sci. Hort.,* 216: 29-37.

Sharma, N.C., S.D. Sharma and R.S. Spehia, 2013. Effect of plastic mulch colour on growth, fruiting and fruit quality of Strawberry under polyhouse cultivation. *Int. J. Bio-resource Stress Manag.,* 4: 314-315.

Sharma, R.R. 2002. Growing Strawberries. International Book Distributing Co., Lucknow, India, pp. 1-99.

Singleton, V.L., R. Orthofer and R.M. Lamuela-Raventós, 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-ciocalteu reagent. *Meth. Enzymol*., 299: 152–178.

Tee, E.S., S.I. Young, S.K. Ho and S.M. Shahid, 1988. Determination of vitamin C in fresh fruits and vegetables using the dye-titration and microfluorometric methods. *Pertanika,* 11: 39-44.

Venter, F. 1977. Solar radiation and vitamin C content of tomato fruits. *Acta Hort.*, 58: 121-127.

Voca, S., L. Jakobek, J. Druzic, Z. Sindrak, N. Dobricevic, M. Seruga, and A. Kovac, 2009. Quality of strawberries produced applying two different growing systems. *CYTA J. Food.,* 7: 201-207.

Yanagi, T., E. Ueda, H. Sato, H. Hirai and Y. Oda, 1995. Effects of shading and fruit set order on fruit quality in single-truss tomato (in Japanese with English summary). *J. Jpn. Soc. Hort. Sci.,* 4: 291-297.

Zang, W., M. Seki and S. Furusaki, 1997. Effect of temperature and its shift on growth and anthocyanin production in suspension cultures of strawberry cells. *Plant Sci.,* 127: 207-214.

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