Indian Journal of Agricultural Sciences **85** (12): 1540–5, December 2015/Article
https://doi.org/10.56093/ijas.v85i12.54292

Influence of growing environment on growth, yield and chemical composition of strawberry (*Fragaria* × *ananassa*) fruits under open *vs* naturally ventilated polyhouse conditions

SWAPNIL PANDEY[1], JEETENDRA SINGH[2], SANJAY KUMAR SINGH[3] and I B MOURYA[4]

College of Horticulture and Forestry, Agriculture University, Kota Campus, Jhalarapatan, Jhalawar, Rajasthan 326 023

Received: 29 July 2015; Accepted: 27 August 2015

ABSTRACT

Strawberry (*Fragaria* × *ananassa* Duch.) is grown extensively in the plastic greenhouses for higher productivity and off season production. The growing environment influences morphology, composition and quality of strawberry fruits. A study was conducted to determine the effects of growing environment on various growth, yield and fruit quality parameters of Winter Dawn strawberry under semi-arid conditions of Rajasthan. The results reveal that the fruits harvested from the open field condition had higher root volume, root weight, number of roots/plant and total chlorophyll content (2.02 mg/g), maximum leaves/plant (73.33), fruit length and fruit weight. In naturally ventilated polyhouse, strawberry plants had higher crown height, plant spread and produced higher fruit yield (242.77 g/plant) with maximum number of fruits/plant (29.00) and total anthocyanin content (45.51 mg per 100 g) in the fruits. In contrast, fruits of open field conditions have recorded higher total and reducing sugar content, vitamin C content (50.32 mg per 100 g) and maximum sensory scores (8.35 out of 10) which indicates that both types of environmental conditions are favourable for strawberry.

Key words: Anthocyanin, Green house, Growth, Poly house, Strawberry, Yield

Fruits are considered as health foods because of their nutritional content. In fruit production, the major emphasis is being given to improve the quality of produce along with higher production. Apart from genetic potential of a variety, the other components which influence productivity and quality of fruits are growing environment and agro techniques. Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most delicious, attractive, nutritious and refreshing soft fruits of the world. The plants are herbaceous in nature comprising of fibrous roots, rosette short crown attached with bunched trifoliate leaf with long petiole and the runner producing shoots. Being a surface feeder, strawberry requires optimum moisture and temperature conditions especially in the upper layer of the soil. These conditions have great influence on growth and development (yield performance) of the crop. Pre-requisites for a successful strawberry growing are climate, cultivars and soil (Albregts and Howard 1980).

[1]Research Scholar (e mail: swapnilpandey.kanchan10368@gmail.com), Department of Horticulture, PAU, Ludhiana; [2, 4]Professor (e mail: jsingh_rau2s@rediffmail.com, ibmaurya@rediffmail.com), Agriculture University, Kota; [3]Scientist (e mail: sanjayhor@rediffmail.com), ICAR-National Research Centre on Litchi, Muzaffarpur

The use of polyethylene in commercial cultivation of strawberry can play a pivotal role in minimizing winter injury, plant mortality, and increasing productivity (Pramanick *et al*. 2013). It can be cultivated in both open fields (OF) and greenhouses (GH); however its cultivation in GHs is so intensive in terms of energy consumption, investments, costs as well as whole year production. A greenhouse or heated high tunnel offers growers the ability to manipulate water, light, and heat as well as minimize/prevent diseases and insects. The fruit size becomes smaller with increase in temperature in strawberry (Draper *et al*. 1981). Open field (OF) production can be regarded as a low-input or extensive cultivation compared with GH production because the amount of energy consumption from different sources is so low and consequently extensive farming systems really result in a clear reduction in environmental impacts, especially if their lower productivity is taken into account (Nemecek *et al*. 2011). In these cases a better performance may be secured by specific treatments, depending on the cultivar and the environmental conditions, both factors being critical for adequate yield and economic viability (Lieten 1991). Greenhouse production of strawberry has the advantage of increased yield per unit area, early production when market prices are high, relatively easier pest management with reduced use of chemicals, as well as better fruit quality (Dinar 2003).

Environmental control of flowering of the cultivated strawberry has been extensively studied and under semi arid zone of Rajasthan, strawberry is grown mostly during post-monsoon season under polyhouse conditions and to some extent under open field conditions. The plant remains in cultivation during winter when temperature sometimes dips down, and if goes down to 10°C, the growth and production are badly affected. Mulching with vested attributes of temperature buffering seems promising in mitigating the ill effect of low temperature during winter. It holds special significance for cultivation of strawberry outside polyhouse conditions. Strawberry is one of the crops that respond well to the increase in soil temperature/ light reflectance produced with the use of mulches (Sonkar *et al.* 2012) and in polyhouses. There is no information available on the influence of variation in the growth conditions and management practices on the performance of strawberry for semi-arid region of Rajasthan. Keeping the knowledge gaps in view and considering the utility of such a study, the present investigation aimed to study the effect of growing environment on root growth, yield and fruit quality parameters of strawberry under semi-arid condition of Rajasthan.

MATERIALS AND METHODS

The experiment was conducted in the Protected Cultivation Unit**,** College of Horticulture and Forestry, Jhalrapatan, Jhalawar, Rajasthan during the year 2013-14. The experimental site was situated at 23°4' to 24 °52' N latitude and 75 °29' to 76 °56' E longitude in south-eastern part of Rajasthan. The average rainfall in the region is 954.7 mm, and maximum temperature range in the summer is 43-48°C and minimum to 1.0- 2.6°C.

The strawberry cv. Winter Dawn planted under raised bed planting system at 60 cm × 30 cm spacing under four environments, i.e. Control (open field) (T_0); Agro shade net (75 per cent light intensity) (T_1); Naturally ventilated polyhouse (T_2) and Fan pad system greenhouse (T_3). The experiment was laid out with 4 numbers of treatments with 5 replications. All necessary cultural practices and plant protection measures were followed uniformly for all the plots and experiments during the experimentation.Three plants were selected randomly in each replication for taking observations on growth and physico-chemical parameter of fruits.

Light measurements was carried out periodically (three times a day) during the growth stages in all environments, to monitor the actual light conditions to which the plants were grown and light intensity (Lux) in each treatment was expressed in hundred lux with the help of Lux meter. As the yield of strawberry plants is closely related to vegetative growing parameters such as crown height, petiole length, number of leaves/plant, plant weight and spread, root weight and volume and number of roots per plant, was investigated in different growing environments. The plant growth parameters like crown (aerial portion of the plant) height, petiole length (cm) of the leaves of the randomly selected plants were measured in each replication at final harvest with the help of meter scale. Total number of leaves (per plant) was counted from tagged plants in each replication after completion of harvesting period. The spread (cm) of the plants was recorded in east-west and north-south direction with the help of a meter scale. After completion of harvesting, tagged plants were uprooted and cleaned properly. They were then dried in oven at 70°C and the plant (Fresh and dry) weight (g) was recorded.

Various root parameters like fresh weight of the roots was taken by excavation of the plants and the weight was taken with the help of electronic balance. The dry weight of the roots was taken by drying the roots in oven at 70 °C till the weight was constant up to 2 days. The root volume was taken by water displacement method, root length of the plants was observed with the help of meter scale, the number of thin roots (<0.20 mm) and thick roots (> 0.20 mm) were estimated by counting the number of roots/plant. The root to shoot ratio was calculated by dividing the root weight by the shoot weight. After completion of harvesting, leaves from tagged plants were analyzed for chlorophyll estimation as per method suggested by Sadasivam and Manickam (1997).

Fruit length and width (mm) of 10 fruits from each treatment was taken with the help of digital vernier caliper and fruit length: diameter ratio of the same 10 fruits was used to record length and width. The weight of fruits (g) from each tagged plants was taken on each date of harvest with the help of electronic top pan balance and dry weight (g) of the fruit was recorded by drying the fruits in oven at 70°C till the constant weight up to 2 days. The number of fruits/plant was recorded by counting the fruits reaching harvestable maturity. The yield/plant (g) was recorded by adding yield of all the harvests obtained from selected plant.

Total soluble solids (TSS) (°Brix) were recorded with the help of hand refractometer. The titratable acidity (%) was determined by titrating the juice against standard alkali solution (0.1 N NaOH). TSS: acid ratio was calculated by dividing the value of total soluble solids content by per cent acidity. Total and reducing sugars were estimated by Lane and Eynon method (1923) as described in AOAC (1984). For estimation of juice percentage, the ripe fruits of strawberry were taken in muslin cloth and crushed. It was squeezed firmly to get juice. The juice was weighed with the help of balance and the percentage of juice was worked out on the basis of total weight of fruit taken for juice extraction. Ascorbic acid content was determined by titration with 2, 6-dichlorophenolindophenol, according to the AOAC (1984).

Estimation of total anthocyanin content was done through methods suggested by Fuleki and Francis (1968), aliquots weighing 5.0 g of the homogenized strawberry samples were dissolved in 25 ml methanolic hydrochloric acid (85:15) solution and kept for 24 hours at cool temperature (4-5°C). The flocculate was filtered off by whatman filter paper 1 and the absorbance of the resulting

clear liquid was measured at 535 nm in Spectrophotometer (Model: Systronics 118).

Total anthocyanin content was calculated using the following formula:

$$\text{Anthocyanin (mg/100g pulp)} = \frac{\text{OD (abs 535Å)} \times \text{volume of solution} \times 100}{\text{Weight of sample} \times 98.2} \times 100$$

For estimation of sensory score, a panel of five judges conducted organoleptic test of the fruits immediately after harvest. The observation were recorded on the basis of flavour, colour, taste and general appearance of fruit and rated on 10.0 scale as Excellent (9.1 to 10.0), Very Good (8.1 to 9.0), Good (6.1 to 8.0), Acceptable (5.1 to 6.0), Non-acceptable (0.0 -5.0)

The data was subjected to appropriate statistical analysis as described by Gomez and Gomez (1984) using probability values (P=0.05) to test significance of observed differences and LSD for mean separation.

RESULTS AND DISCUSSION

Meteorological variations during fruit production season, i.e. July-April (Fig 1) revealed that average light intensity (in 100 lux) was maximum in open field condition during 41st week (630) of 2013 and 15th week (650) of next year (2014). Agro shade net has least light intensity except February-April months of year 2014. The light intensity ranges from 350-400 hundred lux is found to be best for total anthocyanin production of fruits (Fig 2). Naturally ventilated polyhouses was better for anthocyanin production as it provided optimum light intensity, growing strawberry in agro shade net was not good for coloured fruits of strawberry, i.e. least synthesis of anthocyanin.

Plant growth parameters like crown height (cm), petiole length (cm), number of leaves/plant, plant spread (E-W and N-S) (cm), plant fresh weight and dry weight (g) were significantly influenced by different growing environments (Table 1).The crop grown in naturally ventilated polyhouse recorded maximum crown height (26.46 cm), whereas the

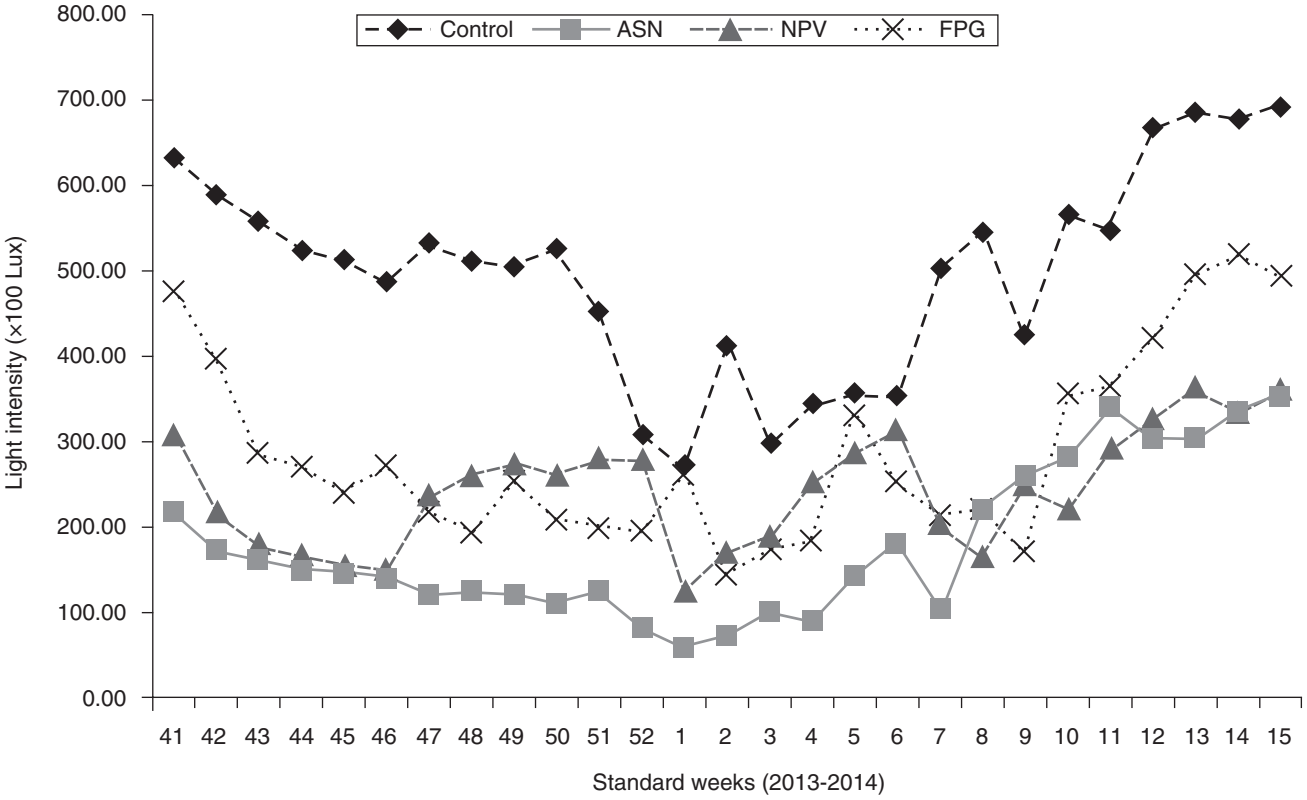

Fig 1 Variation of light intensity across the growing season (July 2013-April 2014)

Table 1 Effect of different growing environment on morphological characters of strawberry cv. Winter Dawn

Different growing environment	Crown height (cm)	Petiole length (cm)	Number of leaves/plant	Plant spread (cm)		Plant weight (g)	
				E-W	N-S	Fresh weight	Dry weight
Open field	21.11	10.82	73.33	38.50	39.33	90.03	30.88
Agro shade net	14.89	7.80	18.33	26.50	24.94	21.00	5.00
Naturally ventilated polyhouse	26.46	14.87	72.55	48.05	44.06	115.33	28.46
Fan pad system greenhouse	22.94	15.35	55.00	41.33	39.38	97.66	23.72
CD (P=0.05)	2.94	1.43	9.25	5.63	5.06	9.88	2.72
SEm±	1.01	0.49	3.18	1.94	1.75	3.40	0.93

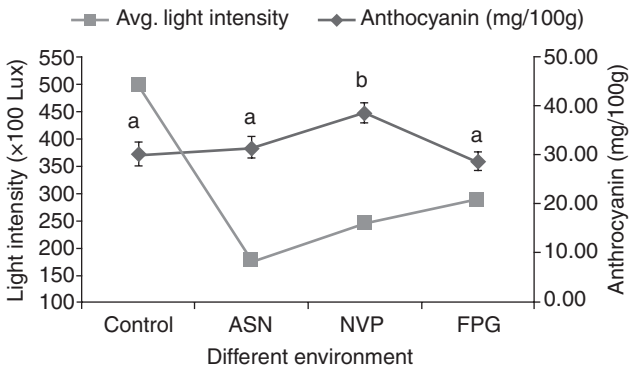

Fig 2 Variation of light intensity and total anthocyanin content across growing environment

minimum crown height (14.89 cm) recorded due to agro shade net. The maximum plant spread (E-W: 48.05 cm; N-S: 44.06 cm) was recorded in the plants grown in naturally ventilated polyhouse, whereas minimum plant spread was observed in Agro shade net. The present findings are in accordance with those as reported by Pires *et al.* (2006). These findings may be attributed to favourable environment and better moisture conservation *vis-a-vis* suppression of weeds resulted in better plant growth parameters (Qureshi *et al.* 2012). Strawberry plants grown in Fan pad system green house recorded the maximum petiole length (15.35 cm), while minimum (7.80 cm) was observed in plants grown in Agro shade net. The plants grown under open field or naturally ventilated polyhouse has highest number of leaves (73.33) per plant due to better exploration of nutrients and water (Sturm *et al.* 2003) and once it is grown under agro shade net, number of leaves/plant reduced to 18.33. The plant weight was maximum on fresh weight (115.00 g) if grown under naturally ventilated polyhouse but on dry weight basis open field conditions improved plant weight (30.88 g). Agro shade net had significantly reduced plant weight (Table 1).

Root parameters like volume, length, weight, numbers, thickness and root: shoot ratio is significantly affected to each other. The maximum fresh (18.52 g) and dry (3.96 g) weight of roots, root volume (20.00 cm^3) was observed in open field conditions while minimum root weight (1.93, 1.00 g) was in Agro shade net however the root volume (6.14 cc) was least in Fan pad system greenhouse (Table 2). Similar results have been observed by Verma *et al.* (2005). The maximum root length (21.33 cm) was recorded in plants grown in naturally ventilated polyhouse and open field conditions (20.55 cm) while minimum root length (11.33 cm) was seen when strawberry was grown in Agro shade net. The maximum number of thin (146.22) and thick (131.00) roots was recorded in open field conditions however minimum number of thin roots (30.77) and thin roots was observed in Agro shade net. The maximum root: shoot ratio (0.46) was observed in plants grown in open field conditions while minimum (0.13) was recorded in Fan pad system greenhouse (Kumar and Dey 2012).

The total chlorophyll content was maximum (2.02 mg/g) in plants grown in open field conditions, followed by 1.88 mg/g in naturally ventilated polyhouse. The minimum total chlorophyll content (1. 64 mg/g) was recorded in plants grown in Fan pad system greenhouse (Table 2). Similar result has been observed by Sheng *et al.* (2011) in pear. The increased chlorophyll content may be attributed to differential synthesis and degradation of chlorophyll in the open field conditions. More photo-oxidation of the chlorophyll and high activity of enzyme chlorophyllase in naturally ventilated conditions may be ascribed to minimum total chlorophyll content. The role of chlorophyllase in degrading chlorophyll has also been highlighted by Kuroki *et al.* (1981).

It is evident from the data that fruit length (47.72 mm), fruit width (42.59 mm), length: diameter ratio, fruit weight (on fresh weight and dry weight basis) (26.85 g, 2.08g) was recorded maximum in plants grown under open field conditions than growing environment while minimum fruit length, length: diameter ratio (1.03) was observed in Fan pad system greenhouses and least fruit width and fruit weight was found in Agro shade net conditions (Table 3). There was a significant difference in term of yield between the growing environments (Table 3). The significantly higher yield recorded in the plants grown under naturally ventilated polyhouse condition over the plants grown in the open field was associated with the production of higher number of fruits (29.00) and fruit yield (242.77 g per plant) than those in open field (Table 3) and high temperature (24–32 °C) might have reduced strawberry flower formation and fruit quality in open field conditions. Agro shade net drastically reduces fruit yields (4.66 numbers of fruits and

Table 2 Effect of different growing environment on root characters and total chlorophyll content of strawberry cv. Winter Dawn

Different growing environment	Root volume (cc)	Root length (cm)	Root weight (g)		No. of roots/plant		Root: shoot ratio	Total chlorophyll content of leaves (mg/g)
			Fresh weight	Dry weight	Thin (<0.20 mm)	Thick (>0.20 mm)		
Open field	20.00	20.55	18.52	3.96	146.22	131.00	0.35	2.02
Agro shade net	8.87	11.33	1.93	1.00	30.77	46.89	0.18	1.66
Naturally ventilated polyhouse	18.00	21.33	6.17	2.29	47.00	84.33	0.15	1.88
Fan pad system greenhouse	6.14	16.33	4.14	1.31	65.22	114.44	0.13	1.64
CD (P=0.05)	1.79	1.95	1.43	0.48	8.18	9.73	0.03	0.12
SEm±	0.62	0.67	0.49	0.16	2.82	3.35	0.009	0.01

Table 3 Effect of different growing environments on fruit yield and quality characteristics of strawberry cv. Winter Dawn

Different growing environment	Fruit length (mm)	Fruit width (mm)	Length: diameter ratio	Fruit weight (g)		No. of fruits/ plant	Fruit yield/ plant (g)
				Fresh weight	Dry weight		
Open field	47.72	37.60	1.30	26.85	2.08	25.33	218.89
Agro shade net	31.66	24.32	1.30	8.74	0.72	4.66	29.22
Naturally ventilated polyhouse	38.30	30.73	1.25	15.31	0.91	29.00	242.77
Fan pad system greenhouse	28.39	27.43	1.03	11.33	0.76	25.77	202.22
CD (P=0.05)	4.12	4.04	0.12	4.55	0.40	4.36	35.00
SEm±	1.42	1.39	0.04	1.57	0.14	1.50	12.06

Table 4 Effect of different growing environments on fruit bio-chemicals parameters of strawberry cv.Winter Dawn

Different growing environment	TSS (°B)	Titrable acidity (%)	Total sugars (%)	Reducing sugars (%)	Juice (%)	Vitamin C (mg/100g)	Total anthocyanin (mg/100g)	Sensory score
Open field	7.30	1.66	5.15	4.06	96.10	50.32	38.90	8.35
Agro shade net	6.10	1.64	3.75	2.74	91.13	50.22	35.53	7.66
Naturally ventilated polyhouse	7.20	1.45	4.69	3.58	94.90	47.55	45.51	7.64
Fan pad system greenhouse	6.63	1.90	3.51	2.52	87.89	48.31	31.74	6.90
CD (P=0.05)	NS	NS	0.50	0.44	7.62	3.84	4.76	0.59
SEm±	0.52	0.10	0.17	0.15	2.62	1.32	1.64	0.20

29.22 g/plant (Nagalakshmi *et al.* 2002). Favourable and integrated effect of moderation in hydrothermal regime that possibly enhanced the root growth for better uptake of water and nutrients might lead to better yield. Singh *et al.* (2009) also found enhanced fruiting, i.e. fruit yield increased by 27% and advanced flowering by two weeks through using plastic tunnels during night (5 pm to 9 am) in northern India.

It was observed that there was no significant effect of growing environment on fruit TSS and acidity of strawberry fruits (Table 4). Strawberry growing in open field condition was better with respect to fruit juice (96.10 %) and sensory scores (8.35). The total sugars (5.15 %), reducing sugars (4.06 %), contents of strawberry fruits produced in the open field condition had higher than fruits produced in the other protected environment (Table 4). Beckmann *et al.* (2006) explained as high sugar content in the fruits produced in the field may be due to the greater light intensity and greater photosynthetic plant activity in this crop environment. Significantly high ascorbic acid was found in open field (50.32 mg/100 g) than the fruits grown in agro shade nets and naturally ventilated polyhouse (47.55 mg/ 100 g). Ascorbic acid biosynthesis can be strongly influenced by environmental cultivation conditions, with light intensity affecting the content of ascorbic acid in strawberry fruits (Venter 1977). In this investigation, a lower ascorbic acid content of the fruits produced in a protected environment is probably caused by the lower luminosity in this environment, which may have reduced the production of sugar, a substrate that is used in the synthesis of ascorbic acid. In contrast, more light exposure and greater accumulation of photosynthates might have contributed to an increase in vitamin C content in berry (Sonkar *et al.* 2012) under open field condition. Growing strawberry in Fan pad system may not be profitable for quality point of view as it reduced total and reducing sugar, juice percentage, total anthocyanin content and sensory score. Such differential in sensory score may be due to differences in physico-chemical properties of strawberry under various degree of light reflectance (Decoteau *et al.* 1988) under various growing conditions.

The plants growing under naturally ventilated polyhouse has enhanced total anthocyanin content (45.51 mg/100 g) but recorded lowest content of vitamin C. Agro shade net might help in anthocyanin accumulation in the ripening fruits though partial shade may have increase phenylalanine ammonia lyase (PAL) and UDPGFT (Uridine-diphosphate-glucose- flavonoid-3-o transferase) regulatory enzyme activities (Cheng and Breen 1991).

The increase in soil temperature in open field condition might be responsible for increased nutrients use, metabolite mobilization, and energy and ultimately favours increased sugars. This type of finding may be due to favourable activity of enzyme sacharose, phosphate synthase in the open field conditions. Hubbard *et al.* (1991) has cited the role of sugar accumulation dependent to the enzyme saccharose phosphate synthase.

In general, the yield and other physical parameters (fruit length, width, average fruit weight) of the strawberry were higher in naturally ventilated polyhouse and in open field condition than the fruits grown in Agro shade net house or Fan pad system greenhouse. However, open field condition caused better root volume, root weight and number of roots per plant and higher total chlorophyll contents. Although Fan pad system increased total anthocyanin content but juice percentage, vitamin C

content and sensory score were highest in open field condition than in fruits produced in shaded or any other protected environment. Field-grown fruits were more palatable due to the high total and reducing sugars.

Therefore, it may be concluded that shade nets may be avoided on the protected structures during post-rainy season especially in the semi dry conditions of Rajasthan where weather remains cloudy, to improve the quality of the fruit in addition to the yield. However, more studies are required to see the effects of shade nets during other seasons.

ACKNOWLEDGMENTS

The authors are thankful to the scientists of ICAR-National Research Centre on Litchi, Muzaffarpur for rendering technical assistance in carrying out the work using standard protocol for biochemical analysis and help rendered for statistical analysis.

REFERENCES

Albregts E E and C M Howard. 1980. Accumulation of nutrients by strawberry plants and fruit grown in annual hill culture. *Journal of the American Society for Horticultural Science* **105**: 386–8.

AOAC. 1984. *Official Methods of Analysis, 14th edn. Association of Official Analytical Chemists*, Washington DC.

Beckmann, M Z, Duarte, De Paula, G R B, Gonzales-Mendes, V A, Piel, R M N. 2006. Radiação solar em ambiente protegido cultivado com tomateiro nas estações verão-outono do Rio Grande do Sul. *Ciência Rural, Santa Maria* **36**(1): 86–92.

Cheng G W and Breen P J. 1991. Activity of PAL and concentration of anthocyanins and phenolics in developing strawberry fruit. *Journal of the American Society for Horticultural Science* **116**(5): 865–9.

Decoteau D R, Kasperbauer M J, Daniles D D and Hunt P G. 1988. Plastic mulch colour effects on reflected light and tomato plant growth. *Scientia Hort.* **34**: 169–75.

Dinar M. 2003. Strawberry production in greenhouse. (*In*) *Proceedings on International Congress*. Greenhouse, Puerto Vallarta, Jalisco, Mexico.

Draper A D, Galletta G J and Swartz H J. 1981. "Tribute" and "Tristar" everbearing strawberries. *HortScience* **16**: 794–5.

Fuleki T and Francis F J. 1968. Quantitative methods for anthocyanins. 2. Determination of total anthocyanin and degradation index for cranberry juice. *Journal of Food Science* **33**: 78–83.

Hubbard, N, Pharr D and Huber S. 1991. Sucrose phosphate synthase and other sucrose metabolizing enzymes in fruits of various species. *Plant Physiology* **82**: 191–6.

Kuroki M, Shioi Y and Sasa T. 1981. Purification and properties of soluble chlorophyllase from tea leaf sprouts. *Plant and Cell Physiology* **22**: 717–25.

Lane J H and L Eynon. 1923. Determination of reducing sugars by means of Fehling solution with methylene blue as an indicator. *Journal of the Society of Chemical Industry* **42**: 32–7.

Lieten F. 1991. Greenhouse strawberry culture in peat bags. *Advances of Strawberry Production* **10**: 56–7.

Nagalakshmi S, Palanisamy D, Eswaran S and Sreenarayanan V V. 2002. Influence of plastic mulching in chilli yield and economics. *South Indian Horticulture* **50**(1/6): 262–5.

Nemecek T, Huguenin-Elie O, Dubois D, Gaillard G, Schaller B, Chervet A. 2011. Life cycle assessment of Swiss farming systems. II. Extensive and Intensive Production. *Agricultural Systems* **104**: 233–45.

Pramanick K. K, Kishore, D K, Sharma S K, Das B K, Murthy B N S. 2013. Strawberry cultivation under diverse agro-climatic conditions of India. *International Journal of Fruit Science* **13**(1-2): 36–51.

Pires, R C M, Folegatti M V, Passos F A, Arruda F B and Sakai E. 2006. Vegetative growth and yield of strawberry under irrigation and soil mulches for different cultivation environments. *Scientia Agricola (Piracicaba, Brazil)* **63**(5): 417–25.

Qureshi K M, Hassan F, Hassan, Q, Qureshi U S, Chaughati S and Saleem A. 2012. Impact of cultivation systems on growth and yield of strawberry *(Fragaria ananassa)* cv. Chandler. *Pakistan Journal of Agricultural Research* **25**(2): 129–35.

Sadasivam S and Manickam A. 1997. *Biochemical Methods,* 2nd edn. New Age International Publishers Limited, New Delhi.

Sheng, B L, Li, X G, Lin, J, Wang, Z H, Yang, Q S, Li, H and Chang, Y H. 2011. Physio-biochemical and ultra structural characteristics in leaves of Huasu pear grown in polyhouse. *Journal of Southern Agriculture* **42**(9): 1 049–53.

Singh R, Sharma R R, Kumar A and Singh D B. 2009. Package of practices for strawberry cultivation with modern techniques under north Indian plains. *Acta Horticulturae* **842**: 607–10.

Sonkar P, Ram R B and Meena M L. 2012. Effect of various mulch material and spacing on growth, yield and quality of strawberry. *HortFlora Research Spectrum* **1**(4): 323–7.

Sturm K, Koron D and Stampar F. 2003. The composition of fruit of different strawberry varieties depending on maturity stage. *Food Chemistry* **83**: 417–22.

Venter F. 1977. Solar radiation and Vitamin C content of tomato fruits. *Acta Horticulturae* **58**:121–5.

Verma M L, Sharma R K, Bhandari A R. 2005. Effect of soil water conservation practices on root growth, yield, nutrient removal and quality of pea and tomato crop. *Journal of Indian Society of Soil Science* **53**(4): 602–7.