EFFECT OF DIFFERENT GROWING CONDITIONS ON GROWTH, YIELD AND QUALITY ATTRIBUTES OF STRAWBERRY

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CERTIFICATE

This is to certify that thesis entitled, "EFFECT OF DIFFERENT GROWING CONDITIONS ON GROWTH, YIELD AND QUALITY ATTRIBUTES OF STRAWBERRY" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE (MS) in HORTICULTURE****, embodies the result of a piece of bonafide research work carried out by* ***MD. SAKIF ZAMAN, Registration no. 13-05476*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

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DEDICATED TO
MY
BELOVED PARENTS

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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. An Experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to investigate the effect of different growing environments on growth, yield and quality attributes of strawberry during November-2019 to March-2020. The experiment was laid out in Randomized Complete Block Design (RCBD) with four environmental treatments *i.e.* Poly shed house, UV poly shed house, net house and open field condition with four replications for each treatment. Experimental result revealed that the plants produced in the net house condition had the maximum plant height (18.50 cm), total chlorophyll content (62.66), fruit number (17.25), and yield (289.16 g/plant) of strawberries. In contrast, plants grown under UV poly shade conditions recorded higher total soluble solids (7 °Brix), titratable acidity (0.46%), ascorbic acid (39.33 mg/100g) and lower pH (3.40). Reducing sugar (7.74 mg/g) and phenol (2.44 mg/g) levels were higher in fruits grown in poly shade. Results indicated that the most suitable growing condition for yield and yield parameters of strawberries was under the net house. In contrast, UV poly and poly house conditions were favorable for producing better quality fruit.

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ABBREVIATIONS

Elaborations	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization of the United Nations	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.), belonging to the family Rosaceae, is one of the most delicious fruits of the world. It is an excellent source of antioxidant, vitamin C and manganese together with a very good source of dietary fiber, iodine, copper, potassium, biotin, phosphorus, magnesium, vitamin B_6, omega-3 fatty acids and sugar having a delicate flavor (Saridas *et al*., 2021). The fruits are eaten fresh as it is tasty and nutritious or may be used in making ice-cream, jam and other processed products.

The strawberries are native to North America and its cultivation was started in Europe in early 18^{th} century (Bhatti *et al*., 2021). It is a fruit of temperate regions but it can be grown even in tropical as well as in subtropical regions. The area of strawberry cultivation in the sub-continent is increasing rapidly (Paul *et al.,* 2017). It can be grown in a wide range of soil but sandy to sandy loam soil is most suitable with a pH range of 4.6-6.5 (Milosevic *et al*., 2009).

The main season of strawberry cultivation in Bangladesh is October to April (Ahmed and Uddin, 2012). Strawberries are usually planted in the field between October to November (Lizalo and Demirsoy, 2020). 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 of the crop (Swapnil *et al*., 2016).

Since ancient times, agriculture is an outdoor or open field production of crops. Hence, open field production is climate and weather dependent (Singh and Singh, 2017). In fact, growth and development of crops under a particular set of climate parameters define geographical location, productivity and production period of different crops (Gornall *et al*., 2010). The magnitude of impact of climate and weather on agricultural productivity and quality of produce is appreciated by farmers and the scientific community, including horticulturists (Nosipho and Mpandeli, 2021).

There are ecological optima for obtaining production potential of each of the crops (Raza *et al*., 2019). Deviation from these conditions results in yield losses partially and sometimes totally. However, near optimal climatic conditions could be created by controlling the climate with the help of greenhouse using different protected structures/methods/devices and such cultivation under controlled environment conditions is termed as protected cultivation (Tuzel *et al*., 2017)." Protected cultivation means some level of control over plant microclimate to alleviate one or more abiotic stresses for optimum plant growth which can be achieved in greenhouses, poly house, net house, poly- tunnels, cold frames, etc (Jena *et al*., 2020).

Usually under open field conditions, plants experience short cropping season but under protected conditions, the environmental factors are controlled or altered to a desirable extent to provide large growing period of the crop (Ngoune and Shelton, 2020). In protected conditions, the production and availability of crop can be taken successfully all the year round for many crops, because protected production technology is a specialized form of cultivation of fruits where environmental and edaphic conditions are adjusted as per the crops requirements (Negi *et al*., 2013).

The protected structures are designed as per the climatic require of the crops so that optimum growth and yield could be obtained (Nordey *et al*., 2017). Higher than normal temperatures, controlled humidity, or additional artificial induced light levels under protection encourage the crops to grow before and after their natural growing season and extend their overall lifespan, thus maximizing yields and improving quality (Rabbi *et al*., 2019). Thus, strawberry can be cultivated in different growing environment's to meet the increasing demand for strawberries throughout the year and also meeting the nutritional security for people living in urban and peri-urban areas. Therefore by considering the above situations, the research work was carried out with the following objectives:-

- To evaluate the effect of different growing conditions on growth and yield of strawberry.
- To evaluate the effect of different growing conditions on fruit quality of strawberry.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to investigate the effect of different growing environment's on the growth, yield and quality of strawberry under protective condition, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of different growing environmental condition

Choudhury *et al*. (2022) conducted a study to find a protective approach to papaya cultivation to mitigate the environmental factors to obtain a quality yield. This production system consists of three treatments, including net house, poly shed house, UV poly shed house, and open field conditions (control). The results revealed that plants grown in the net house had significantly higher leaf number (30), fruit number (68), and fruit yield (56.28 kg/plant) than the control grown plant. Papaya cultured in the net house also showed significantly higher accumulation of chlorophyll, ascorbic acid, total phenol, reducing sugar, and β-carotene than those grown in other environments. In terms of peel color, papaya grown in the net house had the highest a* value (redness), whereas that grown in the open field had the lowest. Thus, the study demonstrated that papaya can be cultivated successfully in a net house with increased yield and phytochemical content. The findings provide a fundamental production strategy for quality papaya production in Bangladesh.

Islam *et al*. (2020). conducted an experiment at the experimental field of Horticulture Department, Sylhet Agricultural University, Bangladesh during winter season of 2013-2014 to evaluate growth and yield of sweet pepper varieties under net protected condition. Considering the effect of net protection system, maximum values for parameters *viz*. early flowering, fruit length (10.58 cm), fruit diameter (6.29 cm), number of fruits/ plant (16.14), fruit yield/plant (0.94 kg) and per hectare (26.86 t/ha) were recorded under fine net protection system. Under fine net covering plants produced better quality fruit than open field condition. The earliest flowering (60.67 days), the highest

number of fruits per plant (19.18) and the maximum fruit yield (35.71 t/ha) were observed in BARI Mistimorich-1grown under fine net system followed by California Wonder grown under coarse net protected system. Benefit cost ratio (BCR) for fine net (5.28) and coarse net (6.75) protected system were much higher than that of open field (1.64) condition indicating bright future for sweet pepper cultivation under net protected system.

Chien and Chang (2019) conducted experiments to evaluate the comprehensive response of commercial cultivation of the white-fleshed pitaya (*Hylocereus undatus* 'VN White') under net house in Taiwan, during the natural reproductive period (from June to Sept. 2016) with fruits grown within net houses (either 16 or 24 mesh insect-proof netting, without fruit bagging) or in an open field (the control, without netting, with fruit bagging). The effects of netting on microclimate, phenological period, flowering (floral bud emergence) of current and noncurrent cladodes (shoots) (2- to 3-year-old), fruit quality, market acceptability, pests and diseases control, and level of sunburn were investigated. Indoor solar radiation in the 16 and 24 mesh net houses were 78.12% and 75.03%, respectively, and the sunlight intensities [photosynthetic photon flux density (*PPFD*), $\mu mol \cdot m^{-2} \cdot s^{-1}$] were 76.03% and 73.00%, respectively, that of control. The maximum daily temperature for the 16 and 24 mesh net houses was greater than that of the control. However, there were no significant differences in daily average temperature, minimum temperature, or relative humidity (RH). The first flowering cycle (12 June 2016) and last flowering cycle (11 Sept. 2016) in both net houses were the same as those in the control. The accumulative flowering of current cladodes was unaffected by net covering, but that of noncurrent-year cladodes in both net houses was lower than that in the control. Although the L* and C* values of fruit color in the 16 and 24 mesh net houses were lower than those in the control, the fruits still had commercial value. The average fruit weight of the 16 mesh net house was significantly greater than that of the control. Average total soluble solid (TSS) content, TSS content at the fruit center, and titratable acidity were unaffected. In addition, the 16 mesh net house blocked some large pests without exacerbating disease or sunburn.

Basu *et al*. (2019) reported that among environmental factors, light intensity, temperature and relative humidity influence crop growth and development. Solar radiation consists of different wave-lengths of light, in which the visible portion is useful for crop growth; ultra-violet and infrared radiations are not beneficial for crop growth, as they change molecular levels which lead to cellular disorganization. Temperature is the major regulator of development processes. Higher temperatures have more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates above a certain temperature

Kaur and Kaur (2019) studied the impact of various growing environments on growth and yield of strawberry cultivar Chandler. Different cultivation systems were adapted to find out the best possible cultivation system among them. The result of the study revealed that the vegetative growth was found significant higher in the crop grown in plastic crates while the fruit yield was maximum in the crop grown under low poly tunnels.

Nagamani *et al.* (2019).In cucumber also, along with the variation in fruit length, maximum flesh thickness and highest fruit diameter, average fruit weight, higher fruit yield per vine, fruit yield per meter square and fruit yield per hectare, different hybrids outperformed under shade house than in open conditions.

Tayade *et al.* (2019) reported that the soil moisture content (SMC) was retained under the polyethylene plastic mulch. The silver plastic films have lower soil moisture content than the transparent film. Moisture Content was observed at 45 days after planting in plots covered with black plastic film as compared to the silver plots and clear or transparent mulched plot. But, soil moisture content at 45 days after planting was not black plastic mulch treatment in case flowering crop. This means that black plastic reduced soil water evaporation and thus, helps retain soil water. Moisture content was higher in transparent plastic mulch and lower in black plastic mulch in shade net. The maximum moisture content was observed 23.2 % in transparent plastic mulch in shade net. The minimum moisture content was observed 16.6 % in black plastic mulch in shade net.

Mochizuki *et al*. (2018) recorded the effect of low solar radiation and temperature on the strawberry. Strawberry cultivar Mouikko plants grown under different combinations of heating (25º C and no heating) and shading (55% shading and no shading). It was found that at low solar radiation and low temperature, emergence of malformed fruit may be affected by lower level of assimilation products caused by decreased leaf area.

Beniwal *et al.* (2017) conducted an experiment for propagation of strawberry mother plant and runner production under protected conditions viz., Greenhouse, Naturally ventilated polyhouse, Shadenet house (50%) and Open field conditions. The initiation of runner was early (29.5 days) and the number of strawberry runners per plant was maximum (10.19) under Shadenet house. Diameter and height of runner crown increased significantly with time and was maximum under Naturally ventilated polyhouse. Other growth parameters like plant height, spread of the runner plant and number of leaves per runner were better under Naturally ventilated polyhouse.

Fan *et al*. (2017) observed the effect of production systems on strawberry quality. It was reported that the production systems had positive effect on improving crop quality. In this observation, strawberry was planted under three production systems: matted row system (MRS), plastic mulch (PM) and plastic mulch with row covers (PMRC). Various variables were taken into account before analysing the result. It was found that PMRC advanced the fruit maturity and enhanced fruit weight compared to the MRS production system. Soluble solids content, titratable acidity and firmness of strawberry fruits from PMRC were significantly increased at all harvests.

Thenmozhi and Kottiswaran (2017) conducted experiments (Field No. NA5) in naturally ventilated polyhouse and open field conditions at PFDC farm, TNAU, Coimbatore to study the effect of drip fertigations in Capsicum crop under polyhouse and open field conditions, two fertigation levels, viz. 100 and 80% of recommended N and K fertigation through drip irrigation and replicated thrice. In polyhouse, the higher yield was obtained in the treatment of 25 micron thickness with 100 per cent RDF.

Gaurav *et al.* (2016) found that the ornamental plant Dracaena fragrans grown under white and red nets exhibited maximum height as compared to green and black coloured

shade nets. Favorable environment and better moisture conservation resulted in better plant growth parameters.

Pandey *et al.* (2015) studied the influence of weather parameters on the growth and yield of the strawberry (*Fragaria x ananassa Duch*.) in the open and naturally ventilated polyhouse. They observed that fruits grown in the open field conditions had higher number of roots per plant, root weight, root volume and total chlorophyll content, leaves per plant, fruit length and weight. In the controlled conditions, plant had higher growth, crown height and plant spread. Other factors are somewhat similar in the open and controlled conditions.

Abdrabbo *et al*. (2013) while studying on potato under shade house revealed that the plants under white net produced the highest vegetative characteristics (number of leaves and fresh and dry weight) and tuber yield/plant, followed by yellow net, while black net produced the lowest vegetative characters. The plants under black net gave the highest plant height followed by blue shade net.

Koley *et al.* (2013) found significantly higher vitamin C in the tomato fruit produced under protected structures.

Rajasekar *et al.* (2013) conducted at the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India to screen ten vegetables for cultivation under shade net house (33 per cent shade) and open field for year round production of vegetables. The influence of environmental variables temperature, relative humidity and light intensity were studied. Relative humidity was always higher under shade net house than in open field during both seasons. Light intensity in the shade net house was lower than in the open field. Mean weekly temperature during summer and winter were higher under open field conditions than in the shade net house. Lower temperature caused plant height, number of branches, internodal length, average fruit weight and yield per plant to be higher in the shade net house than in the open field. Hence shade house conditions will be more profitable than open field.

Thapa *et al*. (2013) studied the assessment of producing quality sprouting broccoli (Brassica oleracea var. italica) under cover and open condition situation and reported that

plants grown in polyhouse gave the highest production in all the four genotypes as compared to the plants grown in open field. Marketable curd yield of 'Early you' were highest in polyhouse condition.

Andhale (2012) studied the influence of colour shadenet and physiological parameter in capsicum and indicated that, micrometeorological parameters *viz*., absorbed photosyn thetically active radiation, rate of photosynthesis, stomatal conductance, light use efficiency and growth parameters *viz*., plant height, number of branches, number of leaves, leaf area, and dry matter per plant significantly increased under green + white coloured shadenet house than black, red and blue coloured shadenet house.

Hallmann (2012) found that the combined amount of the identified phenolic acids was 36% higher than the flavonoid concentration in conventionally grown, open-field tomatoes.

Kumar and Ahad (2012) studied the growth, yield and fruit quality under the protected cultivation at an altitude of 1600 m in South Kashmir and to identify the suitable strawberry cultivars for that region. Eight strawberry cultivars were grown for two consecutive years (2008-09 and 2009-10) under protected structures. Among the cultivars grown, Chandler performed the best with maximum plant spread (27.43 cm), maximum number of runners (8.54) and flowered for maximum number of days (56.79). Chandler also produced the maximum number of flowers per plant (27.23) and set maximum berries (86.01%). Tioga cultivar produced first flower in 97 days after planting and recorded maximum yield per plot (2.26 kg), berry weight (12.24 g) and berry size (5.10 cm). Cultivar Catskill showed maximum for all the biochemical characters. From the result, it was concluded that Chandler, Catskill and Tioga performed well under protected cultivation in the Kashmir valley.

Milenkovic *et al*. (2012 a) revealed that capsicum plants grown under 50 per cent shade achieved similar fruit yield in comparison with the yield obtained under 40 per cent. Total and marketable yield increased with 40 per cent shading level and then decreased with 50 per cent shade. Significantly higher vitamin C content was observed in

greenhouse pepper integrated with red shade netting technologies (188.4 mg/100g) than in greenhouse pepper without colour shade nets (151.4 mg/100g).

Ramana Rao *et al*. (2012) evaluated the performance of capsicum crop (Swarna variety) in open field and under covered cultivation. Under covered cultivation, black colour shade net having 50% shade factor was used in the study. Same crop cultural practices in the open field and under covered cultivation were adopted for comparison. Drip irrigation system was adopted in both the cases and irrigation system parameters such as frequency of irrigation and wetting pattern were collected. Other parameters such as soil temperature, duration of the crop, morphological parameters of the crop and yield were monitored. The study revealed that under shade net the crop yield was increased by 80 per cent over open field cultivation along with water saving of about 40 per cent in covered cultivation. Duration of the crop was also extended by 40 more days under covered cultivation. Sun scalding affect was found absent under covered cultivation whereas, majority of the fruits were damaged due to sun scalding in open field.

Singh *et al*. (2012) conducted a field trial 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.

Ilic *et al.* (2011) observed that red and pearl shade nets significantly increased the total yield (43.5 % and 49.5 %) which was associated with both higher productivity for number of fruits produced per plant and larger fruits. Pepper plants grown under black colour nets with 40 per cent shade had higher yield (10.5 %) than plants grown without nets.

Kumar *et al.* (2011) worked out on the influence of growth conditions on yield and quality of two strawberry varieties named Ofra and Chandler in the hills of Sikkim. At an altitude of 1400 m, field experiment was conducted in five consecutive years (2005-09) to identify the best suited environmental conditions for the strawberry in that region. Both the varieties were grown under open field conditions, plastic tunnel and low cost polythene. Chandler showed the maximum number of flower trusses per plant under the open conditions (13) closely followed by plastic tunnel (12.7). Ofra produced under the plastic tunnel observed highest fruit weight (26.2 g), fruit length (5.5 cm) and fruit diameter (3.9 cm). Maximum number of runners per plant was observed in Ofra (12.3) in open conditions. Chandler was observed best in the terms of the quality when grown under plastic tunnel conditions.

Nami *et al.* (2011) reported that the lower TSS (total soluble solids) and pH of Cabernet-Sauvignon grapes were in high temperature than in the low temperature. Higher total acidity and berry weight was recorded under low temperatures than in the high temperature.

Zoran *et al.* (2011) evaluated the influence of different colour shadenet (photoselective) on the plant development yield and quality of bell pepper (*Capsicum annuum* L.) grown under four different colored shadenet (pearl, red, blue and black) with different relative shading (40 and 50%). They revealed that, use of color-shade nets improve the

productivity by moderating climatic extremes. The total fruit yield (t/ha) under colour shadenet were higher by 113 to 131 percent relative to the open field.

Ganiger (2010) reported that high fruit length of chilli under poly house might be due to translocation of more photosynthates from source to sink and also favorable microclimate throughout the crop growth period. The less interference of weather conditions like wind velocity and rainfall during cop growth and development might be the reason for increased harvesting span, increased flower production and fruit set. The moderate temperature (21.45˚C -27.71˚C) with higher relative humidity (88.50%) prevailing inside the poly house might have helped in cells multiplication and cellular elongation, results in better vegetative growth improving yield attributes.

Goren *et al.* (2010) in a study conducted on two red coloured capsicum cultivars, observed that capsicum grown under pearl and yellow shade nets significantly maintained better fruit quality even after 15 days of storage at 7°C, compared to the traditional black or red shade net of equivalent shading capacity (35 %). Red shade net significantly reduced fruit weight loss compared to the other shade nets but other quality parameters such as firmness, elasticity and sugar level have not been affected by the coloured shade nets.

Panigrahi *et al.* (2010) conducted an experiment with green house and open field condition on capsicum annum cv. California Wonder. The germination percentage (52.47%) growth characters, like plant height, number of primary branches, number of leaves, number of fruits per plant, length of fruits and girth of fruits found significantly better under green house as compared to open field condition (37.32%). Under protected environment the yield was two times more (5.18 kg/m2) as compared to open field condition (2.46 kg/m^2).

Takeda *et al*. (2010) worked on the methods for altering the flowering time in strawberry. In this study, plants were grown under blue or red-coloured photo-selective shade net. This shade net over the plants affected the light signals which were necessary for flower bud initiation and hence delaying flower initiation until plants were transplanted in the

open field conditions. It is very important to notice that the coloured nets did not affect runner production.

Basu and Singh. (2009) studied hybrid seed production of brinjal under net house condition and reported that higher seed yield with better seed quality can be obtained under net house condition as compared to open field condition.

Dhatt and Kaler (2009) studied the effect of Shade net and growing media on nursery raising of cauliflower in subtropical area. Among the three shade treatments, agro Shade net (green colour 6 mesh size, 25 % reduction of sunlight), monofilament insect net (white colour 26 mesh size, 10 % reduction of sunlight) and open field, the monofilament insect net showed the best results for cauliflower germination, seedling length, number of true leaves, dry matter, field establishment of transplant, plant height, days to harvesting and yield.

Fallik *et al.* (2009) conducted an experiment and found that crops grown under various colored (photo-selective) shade nets (Chromatinets) were found to improve their fruit yield and fruit quality. The pepper grown in an arid region under red and yellow shade nets, had a significant higher yield compared with black nets of the same shading factors, without reducing fruit size. The results suggest the advantage of growing pepper under light-dispersive photo-selective shade nets, rather than the traditional black nets for improving productivity, quality and probably also, shelf-life.

Kurubetta and Patil (2009) revealed that the earliest flower initiation (33.00 days), least time taken for first harvesting (86.00 days) and highest per cent fruit set (49.81) were recorded under naturally ventilated polyhouse. The quality parameters like fruit weight (160.00 g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) were also significantly maximum under naturally ventilated polyhouse.

Lamont and Edward (2009) reported that high tunnels are unheated passive- solar greenhouse structures used to extend the growing season and protect high-value horticultural crops, especially when temperature fall drastically during the fall and winter. A high tunnel fruit growing system provides a competitive edge in the market, the single layer of 6 mil greenhouse – grade polythene material that covers the structure provide

stable microclimate conditions, which prevents fluctuations of the temperature. Temperature under high tunnels are high enough to extend the growing season, improve the fruit quality, and protect strawberry flowers from early frost damage under protected conditions high tunnel about 2 to 3 weeks of early production of strawberry has been reported then open field conditions.in addition, the, microclimate of the high tunnel accelerated the ripening process of strawberries by 2 weeks, compared with that under open field conditions. Temperature under the high tunnels is usually higher then open field conditions which might enhance the nutritional value of strawberries.

Medany *et al.* (2009) conducted an experiment and reported that, black net greenhouse gave significantly the highest early yield, while white net greenhouse gave significantly the highest plant height, number of leaves per plant, leaf area index and total yield of sweet pepper compared to other greenhouse.

Voca *et al.* (2009) conducted a survey on the quality of the strawberry fruits cultivars Clergy and Asia grown under plastic tunnel and open field conditions. Result from the open field conditions stated that the cultivar Clergy possessed more antioxidant compounds in its fruits when compared with the fruits of the cultivar Asia. Data analysed from the high tunnel showed that the both cultivars had good properties such as higher total acids content and total soluble solids. Cultivation systems can have a greater influence on the chemical composition of the fruits of the strawberry.

Farhad *et al.* (2008) found that Different growing conditions had significant influences on length of fruit, no of fruit plants, fruits yield per plant, total fruit yield .plants which are grown under poly house recorded maximum number of fruits per plant (110) length of fruit 11.70 cm, yield of fruit per plant (604.08 g) and total fruit yield (29.54 t per ha) and these were 37.90% more respectively, compared to open field chilli crops. Reduction in number of fruits per plant under open conditions might be due to poor fruit set under high temperature and low humidity. High temperature might have caused dehydration in cells causing permanent injury or stress to the plant and cessation of growth.

Ambad *et al.* (2007) studied the growing conditions of strawberry under the low tunnels with mulch cover. Maximum plant spread (31.01 cm) and earliest 50% flowering (57

days) was observed in the low tunnel condition with mulch. Similarly, fruit weight (10.19 g), average fruit size (3.43 cm) and fruit per plant (19.28) were considerably better under the low tunnel with mulch cover. The cultivar Chandler was proved best in the production (11.78 t/ha) and it was also proved superior in yield and biometric characters.

Gent (2007) reported that there was high total chlorophyll content in the leaves of tomato cultivated under the black and blue coloured shade nets as compared to the tomato plants cultivated in the open conditions.

Elad *et al.* (2007) tested the effect of coloured shade nets with different shade intensities and qualities of irradiation transmittance on field pepper. They reported that, yield was higher under nets than in the open, nevertheless the yield from plants grown under the 10 per cent shade black net was not higher than that of the plants under the 25 per cent black net, despite the significantly lower levels of disease at the higher shade intensity. B quality pepper field was significantly higher in the plots covered by 25 per cent shade. Thus, growing sweet pepper under shade nets results in increased yield.

Pandey *et al*. (2007) studied performance of capsicum varieties under greenhouse and open field condition. They concluded that different capsicum varieties gave higher yield under greenhouse condition as compared to open field condition.

Voca *et al.* (2007) reported that the cultivation systems can have a greater influence on the chemical composition of the fruits of the strawberry.

Jessica and James (2006) observed that the titratable acidity and pH were slightly higher in exposed treatment (control) than the shade net in the Pinot Noir vineyard, while shaded and exposed treatments had similar proportions of seed, skin, and pulp, also total soluble solid (TSS) at harvesting time.

Kadir *et al*. (2006) examined the effect of high tunnels on the growth, yield and quality of the strawberry. Plants were covered with black polythene mulch. Microclimate of the high tunnels advanced the fruit production of strawberry five weeks earlier as compared to the plants grown in the open field conditions. Average minimum and maximum temperature under the high tunnels were 5º C and 12º C warmer as compared to the open field crop. Fruits grown under high tunnels were larger in size with higher soluble solids

concentrations (SSC) inside the high tunnels. Results indicated that strawberries were of higher quality and of larger size. High tunnels suppressed runner growth, but enhanced development of branch-crown.

Luthria *et al.* (2006) reported that the large range could be explained by variable conditions such as cultivar, environmental conditions, and location, maturity, as well as storage conditions and duration. It was found that total phenolic and individual phenolic acid concentrations of tomato fruit at harvest increased by 20% when cultivated under a UV-transmitting (clear) covering, compared with UV-blocking covering.

Pires *et al.* (2006) recorded the vegetative growth and yield of strawberry under different environmental conditions. Two experiments were carried out, one in protected cultivation and one in open field conditions. It was found that protected cultivation enhanced the vegetative growth, compared through plant height, horizontal dimension of the plant, leaf area index and total fruit yield.

Swagatika *et al.* (2006) observed that the cauliflower sown on september month and grown under shadenet recorded the highest values for plant height, number of leaves, girth and curd yield.

Gindaba and Wand (2005) reported that the shade nets reduced the fruit growth in 'Royal Gala' apple. In the 'Fuji' apple, increased fruit growth. Contrary to this, covering the 'Mondial Gala' apple orchard with nets, did not affect fruit size. Heavy shading during early stages of fruit growth reduced apple fruit growth rate and induced fruit drop, and it was closely related to decreases in photosynthesis.

Naik (2005) reported that, among the three growing conditions namely, medium cost polyhouse, low cost polyhouse and net house. The medium cost polyhouse observed higher yield. The favourable environmental conditions prevailing in medium cost polyhouse might have helped in better growth of roots and shoots which directly helped in better vegetative growth and finally improving the yield attributing parameters *viz*., number of fruits per plant (10.29), fruit weight per plant (1.02 kg), pericarp thickness at blossom end (1.23 cm), fruit length (8.49 cm) and fruit breadth (7.24 cm) and these finally led to highest total yield of 37.77 t per ha.

Prohens *et al.* (2005) reported that mostly, non-hybrid varieties are used for open field cultivation, while protected production relies on F1 hybrids and parthenocarpic varieties, which have been developed and selected under greenhouse conditions and have the ability to bear high load of fruits under suboptimal conditions for fruit set. Suboptimal conditions for fruit set and high yield of brinjal under greenhouse resulted clean and quality produce that could be sent to fresh vegetable markets, whereas open field produce was destined to the processing industry. Greenhouse cultivation has been better in terms of the economic return per plant as compared to open field conditions due to off season cultivation of the vegetables.

Shahak *et al.* (2004) showed that the fruit size and fruit set of apple cv. 'Red Delicious', 'Smoothee Golden Delicious' and 'Hermosa' Peach increased with all nets (blue, red, yellow, grey and pearl of 30% shading and a white 12%) especially the red/white shade net than compared with the control (no-net).

Singh *et al.* (2004) found that, out of seven capsicum hybrids, the hybrid bharat had significantly higher marketable yield (1.118 kg plant^{-1}) and total yield (1.176 kg plant^{-1}) as compared to other hybrids (0.468-0.910 kg plant^{-1}) marketable and (0.511-0.930 kg plant^{-1}) total yield under protected cultivation. Fruits were more uniform, larger in size, and mature one month earlier to conventional cultivation.

Ganesan (2003) conducted a study to compare naturally ventilated greenhouse and open field conditions for their effect on yield (2145.21g fruits/plant) and quality of fruits of tomato and they were found that greenhouse with ventilation gaps in four side walls had significantly higher total sugar, reducing sugar, protein and nitrogen content. The lycopene content and chlorophyll content was not much affected compared to open field conditions.

Takte *et al*. (2003) reported that, plastic films and shade nets were used for protection of valuable crops against excess sunlight, cold, frost, wind and insect/birds. Further, they added that ventilation played an important role in crop production under controlled conditions. Which was provided naturally or mechanically to create optimum condition for crop growth.

Spayd *et al.* (2002) concluded that the TSS (total soluble solid) and colour of *Vitis vinifera* cv. Merlot berries were higher in control than under shade but titatable acidity, pH and berry mass was higher in the net shade than in control (sunlight).

Ban *et al.* (2000) reported that the anthocyanin content in berries of Kyoho grapes were higher than in the control than shading treatment (covered with aluminum film) and no effect on the resveratrol levels in grape berry skin was observed.

Jeevansab (2000) reported that highest and significant fresh fruit yield (30.5 t/ha) was obtained under poly house followed by open condition (12 t/ha). Similarly capsicum fruits obtained from poly house had a higher ascorbic acid and total soluble solids (TSS) compared to fruits of open field.

Megharaja (2000) reported that Capsicum fruits grown under greenhouse condition were recorded significantly higher TSS and total chlorophyll content (3.24% and 17.54 mg/100 g) as compared to fruits from open condition (1.44 % and 11.36 mg / 100 g respectively).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University Horticulture farm, Dhaka to investigate the Effect of different growing environment's on growth, yield and quality attributes of strawberry. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from November-2019 to March-2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.2 Growing conditions

Strawberry seedling were raised in beds at 60 cm × 30 cm spacing under four protected cultivation systems, namely open field condition (Control), net house (60 mesh), poly shed house (naturally ventilated poly house, entire roof and half the portion of four sides covered with poly sheet, the remaining half covered with 25 % shed net), and UV poly shed house (Fan pad UV poly house, fully covered with UV film sheet). Temperature and relative humidity were recorded during the growing period in all environment to monitor the actual environment conditions in which the plant were grown. During the experiment, all essential cultural practices and plant protection measures were followed across all the plots (Plate 1). Growth, yield and physiochemical parameters were measured on randomly selected plants in each replication.

3.3 Planting materials

In this experiment strawberry cv. Festival was used as planting material.

3.4 Experimental treatment

There was a single factor in this experiment namely different growing conditions as mentioned below:

i. Poly shed
ii. UV poly shed.
iii. Net house and
iv. Open field condition.

Plate 1: Different shade houses for crop growth

3.5 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with single factor and six replications. Total 24 unit plots were used in for the experiment with 4 treatments.

3.6 Application of manure fertilizer

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of strawberry.

Table 1. Dose and fertilizer application method of strawberry in field

Fertilizers and manures	Doses/ha
Cow dung	30 ton
Urea	250 kg
TSP	200 kg
MOP	220 kg
Gypsum	150 kg

Source: KRISHI PROJUKTI HATBOI (Handbook on Agro-Technology), 9th edition Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh.

The total amount of Cow dung, TSP, Gypsum and half of MOP was applied as basal dose at the time of land preparation. On the other hand the total amount of urea and half of MOP was applied at three equal installments at 15, 25 and 35 days after transplanting. Cowdung@ 10 t ha^{-1} was applied during final plot preparation. Chemical fertilizers were not used in this experiment.

3.7 Intercultural operations

3.7.1 Weeding

Weeding is an important intercultural operation for successful production of strawberry for both commercial and research level. Weeds of different types were removed and collected from the field manually as and when necessary. The collected weeds were piled in bunds or in case of certain weeds, taken home to feed animals.

3.7.2 Irrigation

Light over-head irrigation was provided with a watering cane to the plots immediately after transplanting and it was continued for a week for rapid and well establishment of the planted seedlings. Irrigation was also applied as and when necessary.

3.7.3 Disease and pest management

Diseases and pests is a major limiting factor to strawberry production. Experimental strawberry plants were treated with Malathion 250 EC and Cupravit 50 WP to prevent unwanted disease problems @0.5 ml/L and 2 g/L. On the other hand, leaf feeder is one of the important pests during growing stage. Leaf feeder was controlled by Pyrithrum @ 1.5 ml/L. Those fungicides and pesticide were sprayed two times, first at vegetative growing stage and next to early flowering stage to manage pests and diseases.

3.8 Harvesting

Harvesting of fruits was done after the fruits reached at maturity stage. Mature fruits were harvested when fruits turned to red in color with waxy layer on surface of fruits. The optimum time to harvest strawberries is the early morning when the fruits are cool. If picked later in the day, the berries will need to be cooled to remove the field heat and maintain their quality. Fruit should be uniformly coloured and be harvested complete with a stalk conjoined with the berry. Fruits were harvested from last week of January 2020 to last week of February 2020.

3.9 Data collection

The data were recorded on different growth and yield component traits and quality traits on all the plants in each treatment and each replication.

i. 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.

ii. SPAD value

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.

iii. 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 (Plate 2). 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.

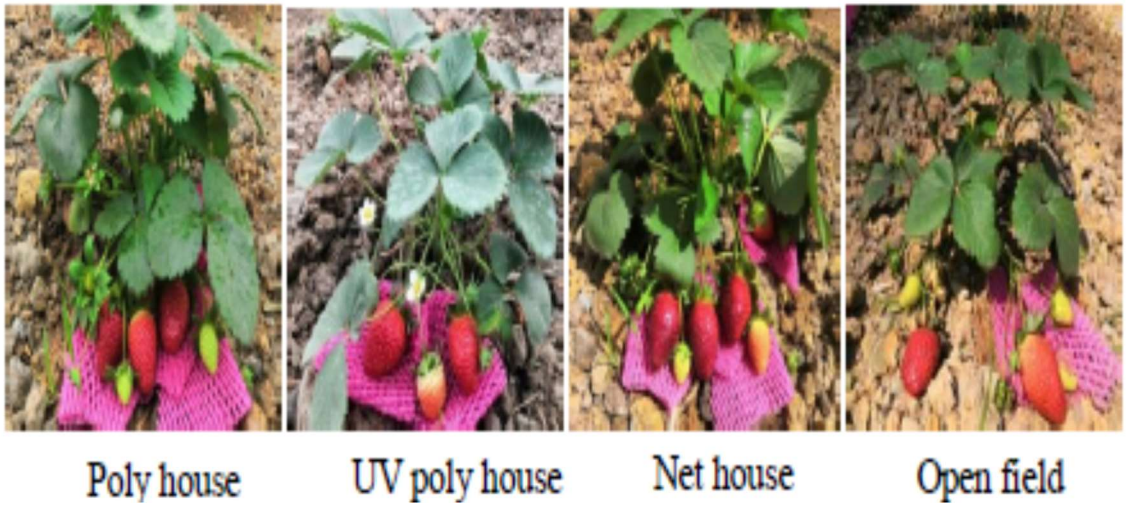

Plate 2: Fruit bearing strawberry plants under different shed houses

vi. 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*100

v. Total soluble solids (°Brix)

The TSS content of strawberry was measured by a 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.

vi. pH determination

The fruit juices of individual treatment strawberries were filtered separately, and pH was measured using digital pH meter.

vii. Titratable acidity (TA %)

Mortar and pestle were macerated for determination of 5g sample. Then filtered it and adding distilled water rendered 100ml of total volume. Then 10ml of stock solution was taken in conical flask and 2 drops of phenalpthelin was added. The solution was titrated with 0.1N NaOH. The titrate colour will be rosy pink and the reading was recorded. The titration was done for three times.

viii. 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 100ml 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. 5ml solution was taken for titration each time and pink colour determined the last point of titration which remains for 10seconds.The burette reading was recorded.

ix. Phenolic content

The content of phenols was calculated using Singleton, Orthofer and Lamuela-Raventós (1999) process. Fresh fruits (250 mg) were homogenized with methanol of 85 %. At 10℃ 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.

x. Reducing sugars

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 2ml of 98 % sulphuric acid. The test tubes were allowed to keep 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 (Plate 3). 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).

Plate 3: Chemical analysis in the laboratory

3.10 Statistical analysis

Data obtained for different parameters were statistically analyzed to observe the significant difference among the treatment. The data were analyzed using ANOVA technique with the help of computer package programme “Statistic 10 software” and mean difference among the treatments were adjudged with Least Significant Difference (LSD) at 0.01 level of probability as described by Gomez and Gomez (1984). Graphs were made by using Excel software.

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the study have been presented and discussed in this chapter with a view to investigating the effect of different growing environments on growth, yield and quality attributes of strawberry.

4.1 Environmental conditions

Among environmental factors, light intensity, temperature and relative humidity influence crop growth and development. Solar radiation consists of different wave-lengths of light, in which the visible portion is useful for crop growth; ultra-violet and infrared radiations are not beneficial for crop growth, as they change molecular levels which lead to cellular disorganization. Temperature is the major regulator of development processes. Higher temperatures have more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates above a certain temperature (Basu *et al*. 2019). Under protected conditions temperature can be monitored and managed, and better plant growth of strawberry 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 varies from approximately 21.03 to 30.41^{0}C as shown in Table 2. Experimental result revealed that the highest temperature at various days after planting was found in open field condition whereas the lowest and optimum temperature was obtained in net house.

Table 2. Monthly average air temperature (^{0}C) at 12 hrs in different shade house and open field

Month	12hrs			
	Poly shed	UV poly shed	Net house	Open field
November, 2019	28.19	30.03	26.87	29.33
December, 2019	22	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 varies between 67.09 to 76.21 % during November to April in day time (Table 3). Relative humidity increases availability of net energy for crop growth and improves survival of crops under moisture stress conditions. Relative humidity reduces evaporation loss from plants which lead to optimum utilization of nutrients. It also maintains turgidity of cells which is useful in enzyme activity leading to a higher yield. Relative humidity was always higher in the net house during the growing season, while the relative humidity was approximately similar in both poly shade and open field condition. Similar result also observed by Rajasekar *et al*. (2013) who reported that the relative humidity was higher inside the greenhouse than in the open field which influenced tomato growth and yield. The yield of sweet pepper was higher under shadenet house due to high relative humidity, which enhanced vegetative growth and improved fruit production.

Table 3. Monthly average relative humidity (%) at 12 hrs in different shade house and open field

Month	12hrs			
	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

4.2 Plant height

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different growing environments showed significant variation in plant height (Table 4). Despite the effects of various shade house treatments, there were large variations in plant height. In this experiment result showed that the maximum plant height (18.50 cm) was obtained in net house followed by poly shed house (17.00 cm) and the lowest height (15.50 cm) was obtained from open field condition (Table 3). This may be due to enhanced photosynthesis and respiration due to the favorable microclimatic conditions in the net house. Similar result also observed by

Gaurav *et al* (2016) who reported that the favorable environment and better moisture conservation resulted in better plant growth parameters.

4.3 SPAD value

Environmental conditions have a huge impact on crop growth and production of horticultural crops. Experimental result revealed that except for plants grown in net and poly shed house, there were no significant differences in leaf SPAD value among the growing environments condition in this study (Table 4). The plants grown in the net house showed the highest SPAD value (62.66), followed by poly shed house (60.80) and the lowest chlorophyll content (57.66) was showed in UV poly shade followed by Open field condition (58.33). SPAD value determine the chlorophyll concentration in the leaf. Net house modify the light concentration which affect the chlorophyll concentration. An increase in biomass (vegetative and reproductive) coincides with increases in leaf area and chlorophyll content thus increases SPAD value of leaves. In net house strawberry leaves contain more chlorophyll than leaves exposed to direct sun. Although net house grown leaves are not directly exposed to sunlight, they produce additional chlorophyll to capture diffuse radiation to produce the carbohydrates needed for a plant to grow. Even if sun-exposed leaves contain less chlorophyll than net house grown leaves but, they have a greater light saturation point and therefore can handle full exposure to the sun. Net house-grown leaves were of a softer texture and had a darker green colouration. Thus, the leaves grown under net house reduced levels of light but capture diffuse radiation to produce the carbohydrates needed for a plant to grow thus contains more chlorophyll than leaves grown under the open conditions. Similarly, Gent (2007) who reported that there was high total chlorophyll content in the leaves of tomato cultivated under the black and blue coloured shade nets as compared to the tomato plants cultivated in the open conditions.

Table 4. Average plant height and SPAD value of strawberry grown under different shades and open field condition.

Treatments	Plant height	SPAD reading
Poly shed	17.00 b	60.80 b
UV poly shed	16.00 c	57.66 c
Net house	18.50 a	62.66 a
Open field	15.50 c	58.33 c
$LSD_{(0.05)}$	**0.54**	**1.27**
CV (%)	**2.21**	**1.38**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.4 Number of fruits plant^{-1}

The number of fruit plant^{-1} of strawberry were significantly influenced by different shade houses (Table 5). Number of fruits plant^{-1} was the highest in net house (17) and the lowest in both UV poly shade (12.33) followed by open field condition (12.66). The number of fruit plant^{-1} was significantly higher in net house which could be due to the better availability of better environmental conditions especially the higher relative humidity which might have helped in maintaining the pollen viability and avoided desiccation of pollen on stigmatic surface. The result obtained from the present study was similar with the findings of Pandey *et al*. (2007) who reported that different capsicum varieties gave higher yield under protected condition as compared to open field condition.

4.5 Individual fruit weight

Different growing environments showed significant variation in individual fruit weight of strawberry (Table 5). The maximum fruit weight (17 g) was recorded in net house followed by poly house (15.66 g) and minimum weight was recorded from open field condition (13.83) followed by UV poly shed (14.66g). Weight and yield could be affected by changes in environmental conditions. The unfavorable environmental conditions, such as higher temperature and lower humidity, prevented the development of proper fruit size, resulting in a decrease in fruit weight. These might be due to higher temperatures during flowering and fruiting stages (Tables 2 and 3). In our result, favourable

environmental conditions, such as optimum temperature and humidity, were recorded in net house (Table 2 and 3), which resulted in faster fruit growth throughout the season. The result was similar with the findings of Takte *et al*. (2003) who that, plastic films and shade nets were used for protection of valuable crops against excess sunlight, cold, frost, wind and insect/birds. Further, they added that ventilation played an important role in crop production under controlled conditions. Which was provided naturally or mechanically to create optimum condition for crop growth.

4.6 Fruit yield plant^{-1}

There was a significant variation among different growing environment in response to fruit yield plant^{-1} (Table 5). The highest fruit yield (289.16 g) found in net house followed by poly shade (235 g) and the lowest yield (162.72 g) found from open field condition (175.16 g) followed by UV poly shade (181.33 g). The higher yield plant^{-1} under net house may be due to better photosynthetic efficiency of plant in comparison to other protected conditions and increased quantity of chlorophyll. Zoran *et al.* (2011) reported that, the use of color-shade nets improve the productivity by moderating climatic extremes. The total fruit yield (t/ha) under colour shadenet were higher by 113 to 131 percent relative to the open field. Panigrahi *et al.* (2010) also reported that the fruits yield and fruits found significantly better under green house as compared to open field condition (37.32%). Under protected environment the yield was two times more (5.18 kg/m^2) as compared to open field condition (2.46 kg/m^2).

Table 5. **Average number of fruits plant^{-1}, individual fruit weight and fruit yield plant^{-1} of strawberry grown under different shades and open field condition.**

Treatments	Number of fruits plant^{-1}	Individual fruit weight	Fruit yield plant^{-1}
Poly shed	15.00 b	15.66 b	235.00 b
UV poly shed	12.33 c	14.66 c	181.33 c
Net house	17.25 a	17.00 a	289.16 a
Open field	12.66 c	13.83 c	162.72 c
LSD$_{(0.05)}$	**0.76**	**0.89**	**18.88**
CV (%)	**3.45**	**3.79**	**5.65**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.7 Moisture content

No significant change of moisture content in strawberry fruits was found among poly shade, UV poly shade and open field conditions. The maximum moisture content in fruits (93.50 %) were found in net house followed by poly shade (92.33 %) and the minimum moisture content was found in fruits grown under open field condition (91 %) (Figure 1). The variation in moisture content may be due to reason that plants grown in different shade houses usually have shade cover over it. They are used to protect cultivated plants from excessive heat, light or dryness**.** Different poly shade may be available in different colours and percentages to protect plants from sun, frost and excess moisture loss via transpiration or evaporation due to high temperatures. In other words, it provides shelter from those elements, which helps the shade loving plants inside, to have maximum growth. Similar result also observed by Tayade *et al.* (2019) who reported that the moisture retention in shade net under the black, silver and transparent was found to be best than the open field.

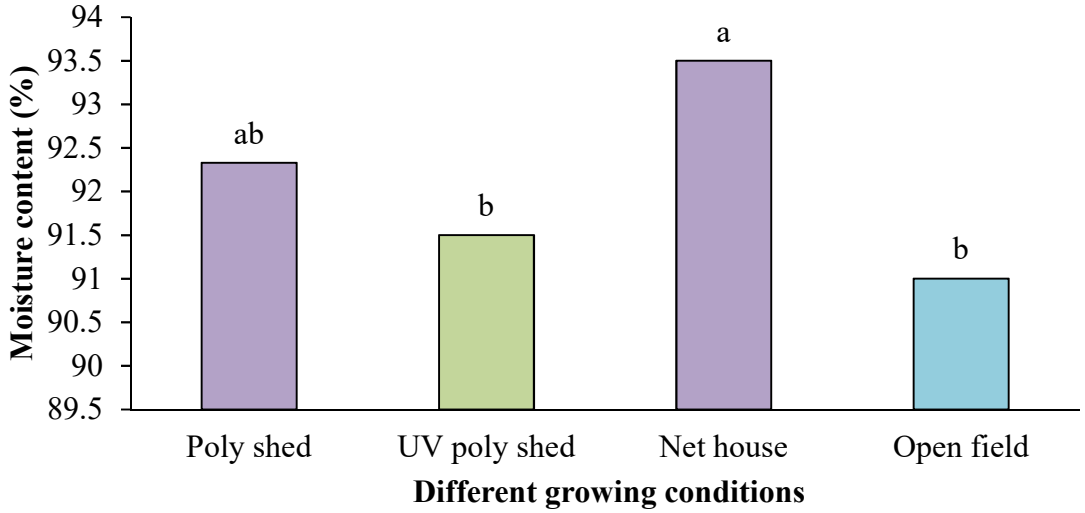

Figure 1. Average moisture content of strawberry grown under different shades and open field condition.

4.8 Ascorbic acid content

The ascorbic acid content of strawberry was significantly affected by different environmental condition (Figure 2). In this experiment the UV poly shed had the highest ascorbic acid content (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 fruits grown in open fields condition had the lowest ascorbic acid content (33.62 mg/100 g). Similar result also observed by Koley *et al.* (2013) who found significantly higher vitamin C in the tomato fruit produced under protected structures.

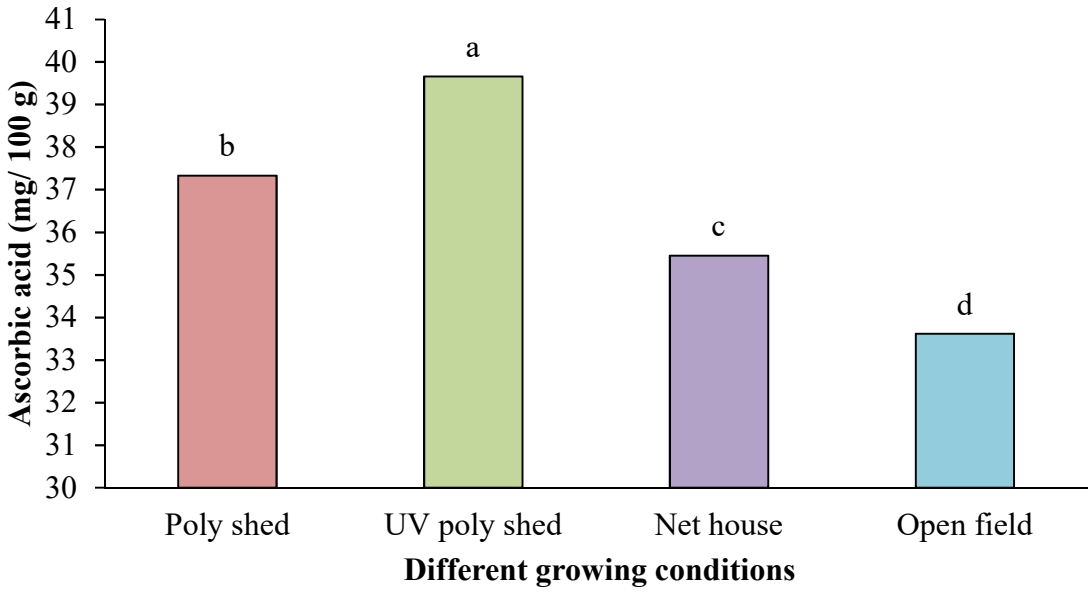

Figure 2. Average ascorbic acid content of strawberry grown under different shades and open field condition.

4.9 Total soluble solids

The strawberry fruit total soluble solid was found to be significantly impacted by the growing environmental condition (Figure 3). The TSS of strawberries grown in protected environments was higher than that of fruits grown in open fields. Experimental results revealed that the highest total soluble solids (°Brix) of strawberry (7.00 °Brix) was recorded in UV poly shed condition followed by Net house and Poly shed having 6.5 ºBrix both in poly shed and net house. Whereas the lowest total soluble solids (5.50 °Brix) of

strawberry was recorded in Open field condition. Voca *et al.* (2007) reported that the cultivation systems can have a greater influence on the chemical composition of the fruits of the strawberry. Jeevansab (2000) also reported that capsicum fruits obtained from protected condition had a higher ascorbic acid and total soluble solids (TSS) compared to fruits of open field.

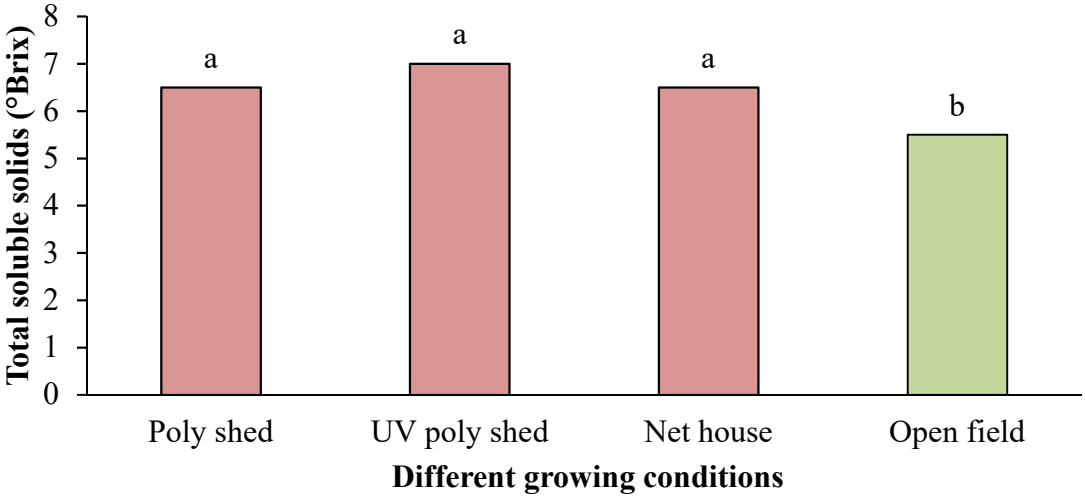

Figure 3. Average content of total soluble solids of strawberry grown under different shades and open field condition.

4.10 Titrable acidity

The titratable acidity of strawberry was significantly affected by different environmental condition (Figure 4). Experimental results revealed 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 %). 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. Spayd *et al.* (2002) titatable acidity was higher in protected condition than open field condition.

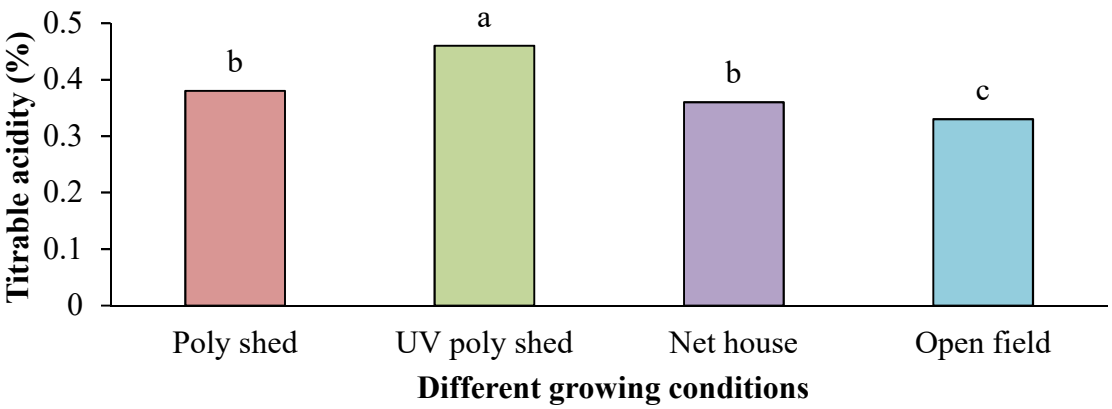

Figure 4. Average content of titrable acidity of strawberry grown under different shades and open field condition.

4.11 pH

UV poly shed had the lowest pH (3.4), whereas fruits cultivated in open fields had the highest pH (3.57), followed by poly shed (3.52) and net house (3.56). (Figure 5). The pH levels of strawberries cultivated in poly shed, net house, and open field conditions showed no significant variations, though. The low values might be explained by measuring fruit acidity at full maturity, when acidity decreases. The result was similar with the findings of Jessica and James (2006) who reported that the pH was slightly higher in exposed treatment (control) than the protected condition.

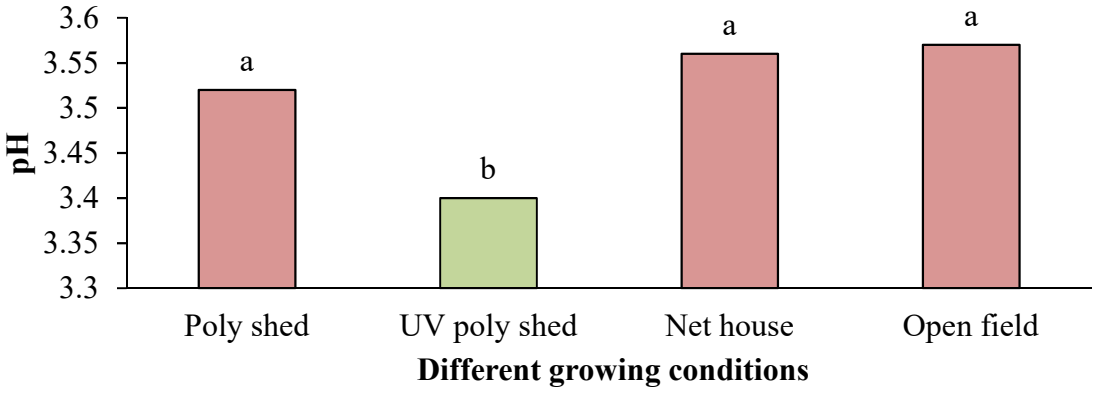

Figure 5. Average content of pH of strawberry grown under different shades and open field condition.

4.12 Total phenolic content

The antioxidant effect was directly facilitated by the phenolic components. The phenolic compound oxidation (reduction) induces the production of dark compounds (browning), that induces rejection by the consumers, and decreases the antioxidant capacity of foods. In this experiment the total phenolic content was greatly affected by the shading conditions. The maximum total phenolic content (2.44 mg/g FW) was found in plants grown in poly sheds, followed by UV poly sheds (2.33 mg/g FW) and net houses (2.10 mg/g FW), but the lowest total phenolic content (1.62 mg/g FW) was found in strawberry fruits grown in open fields (Figure 6). The result was similar with the findings of Hallmann (2012) found that the combined amount of the identified phenolic acids was 36% higher than the flavonoid concentration in conventionally grown, open-field tomatoes. Luthria *et al.* (2006) also reported that the large range could be explained by variable conditions such as cultivar, environmental conditions, and location, maturity, as well as storage conditions and duration. It was found that total phenolic and individual phenolic acid concentrations of tomato fruit at harvest increased by 20% when cultivated under a UV-transmitting (clear) covering, compared with UV-blocking covering.

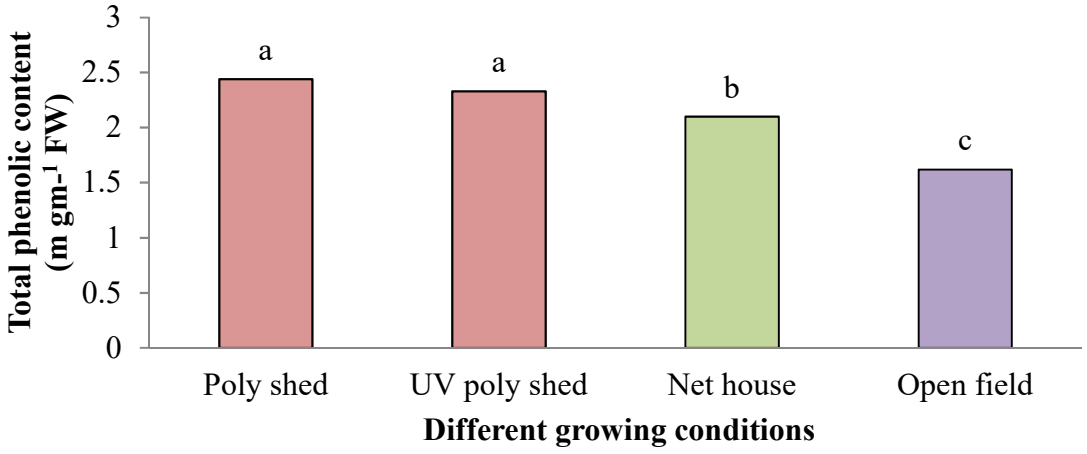

Figure 6. Average of total phenolic content of strawberry grown under different shades and open field condition.

4.13 Reducing sugar

Compared to the open field condition, strawberries grown in the shade conditions had significantly greater reducing sugar concentration (Figure 7). The plants grown in poly sheds had the maximum sugar content (7.74 mg/g FW), followed by plants produced in UV poly sheds (7.38 mg/g FW) and plants grown in net houses (6.68 mg/g FW), while the strawberries grown in open fields had the lowest sugar content (5.52 mg/g FW). The differences of reducing sugar content in the protected condition comparable to open shade condition might be attributed to its favourable weather condition. On the others hand decreasing reducing sugar due to increasing of fermentation process. Voca *et al*. (2009) reported that strawberry fruits grown under a tunnel had higher levels of reducing sugar than open field produced fruits.

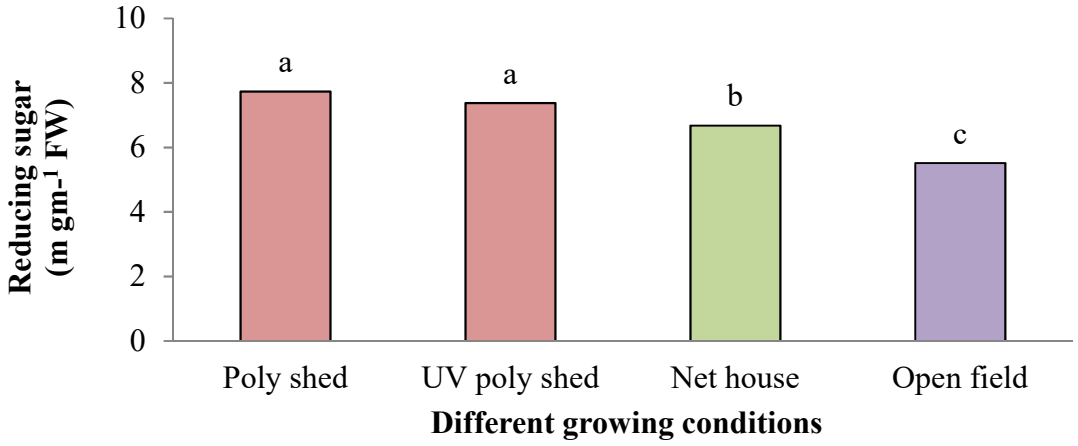

Figure 7. Average content of reducing sugar strawberry grown under different shades and open field condition.

CHAPTER V

SUMMARY AND CONCLUSION

An Experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka to investigate the effect of different growing environments on growth, yield and quality attributes of strawberry during the period from November-2019 to March-2020. The experiment was laid out in randomized complete block design (RCBD) with four environmental treatments *i.e.* Poly shed house, UV poly shed house, net house and open field condition with four replications for each treatment.

In this experiment observations were made on external and internal characteristics such as plant height, number of fruits plant^{-1} , individual fruit weight, fruit yield plant^{-1}, SPAD value, physiological attributes such as moisture content, ascorbic acid content, total soluble solids, titrable acidity, pH, total phenolic content and reducing sugar. Experimental results revealed that the strawberry's growth, yield, and quality were all greatly influenced by the environmental conditions. Fruits produced in shaded condition had a greater quality than those grown open field condition. Fruits grown under UV poly shade exhibited significantly higher total soluble solids (7.00 ºBrix), titrable acidity (0.46 %), ascorbic acid (39.33 mg/100 g), and lower pH (3.40) among the shade houses. Fruits grown in poly shade exhibited higher levels of total phenol (2.44 mg/g FW) and reducing sugar (7.74 mg/g FW). The strawberry's yield (289.16 g plant^{-1}) and characteristics that contribute to yield were higher in the net house, though.

Conclusion

Based on the results, we suggest that strawberry grown in UV poly shed and poly shed produced better-quality fruits, whereas strawberry grown in net house was the most ideal growing condition for yield and yield contributing characteristics of strawberry.

REFERENCES

Abdrabbo, M.A., Farag, A.A. and Abul-soud, M. (2013). The intercropping effect on potato under net house as adaption procedure of climate change impacts. *Researcher*. **5**(6): 1-7.

Ahmed, A.R. and Uddin A.S.M.M. (2012). Strawberry production in bangladesh. in: book of abstracts. Yun-tao Zhang (ed.). VII International Strawberry Symposium, ISHS, Beijing, China. p. 29.

Ambad, S.N., Sawant, S.S. and Nayakwadi, M.B. (2007). Effect of growing conditions on growth and yield of strawberry (*Fragaria ananassa* Duch.). *Asian J. Hort.* **2**(2): 122-125.

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

Andhale, R.P. (2012). Effect of shadenet intensities and colour on micro meteorological parameters, growth, yield and quality of capsicum. Ph.D. Thesis submitted to M.P.K.V. Rahuri. (M.S.). pp. 1-5.

Ban, T., Shiozaki, S., Ogata, T. and Horiuchi, S. (2000). Effects of abscisic acid and shading treatments on the levels of anthocyanin and resveratrol in skin of kyoho grape berry. *Acta Hort.* **514**(4): 83-90.

Basu, P., Pratap, A., Gupta, S., Sharma, K., Tomar, R. and Singh, N. (2019). Physiological traits for shortening crop duration and improving productivity of greengram (*Vigna radiata* L. Wilczek) under high temperature. *Front. Plant Sci.* **10**: 1.2.

Basu, S. and Singh, B. (2009). International conference on Horticulture (ICH-2009) Horticulture for Livelihood Security and Economic Growth November 09-12, 2009, Banglore. pp. 1-5.

Beniwal, V., Godara, A.K. Prince, A. and Sourabh, M. (2017). Propagation studies in strawberry (Fragaria X Ananassa Duch.) under protected conditions. *Chem. Sci. Rev. Lett.* **6**(23): 1795-1799.

Bhatti, S.M., Panhwar, M.A., Bughio, Z.R., Sarki, M.S. Gandahi, A.W. and Wahocho. N.A. (2021). Influence of foliar application of zinc on growth, yield and zinc concentration in strawberry. *Pakistan J. Agric. Res*. **34**(2): 486-493.

Chien, Y. and Chang, J. (2019). Net houses effects on microclimate, production, and plant protection of white-fleshed pitaya. *Hort. Sci*. **54**(4): 692-700.

Choudhury, S., Islam, N., Mustaki, S., Uddain, J., Azad, M.O.K., Choi, K.Y. and Naznin, M.T. (2022). Evaluation of the Different Low-Tech Protective Cultivation Approaches to Improve Yield and Phytochemical Accumulation of Papaya (*Carica papaya* L.) in Bangladesh. *Horticulture*. **8**: 210

Dhatt, A.S. and Kaler, H.S. (2009). Effect of Shade net and growing media on nursery raising of cauliflower in sub-tropical area. *Adv. in Hort. Sci.* **23**(2) : 118-122.

Elad, Y., Messika, Y., Brand, M., David, D.R. and Sztejnber, A. (2007). Effect of coloured nets on pepper powdery mildew *J. Phyto.* **35**(3): 285-299.

Fallik, E., Alkalai-Tuvia, S., Parselan, Y., Aharon, Z., Elmann, A., Offir, Y., Matan, E., Yehezkel, H., Ratner, K., Zur, N. and Shahak, Y. (2009). Can colored shade nets maintain sweet pepper quality during storage and marketing? *Acta Hort.* **830**: 37-44.

Fan, L., Dubé, C. and Khanizadeh, S. (2017). The effect of production systems on strawberry quality. *Phenolic Comp. Nat. Sour. Import. App.* pp.1-9.

Farhad, M., Hasanuzzaman, M., Biswas, B.K., Azad, A.K. and Arifuzzaman, M. (2008). Reliability of Yield Contributing Characters for Improving Yield Potential in Chilli (*Capsicum annum*). *Int. J. Sust. Crop Prod.* **3**(3): 30-38.

Farukh, M.A. Islam, M.A., Akter, L. and Khatun, R. (2019). Trend and Variability Analysis of Sunshine Duration in Divisional Headquarters of Bangladesh. *J. Environ. Sci. and Natural Res.* **12**(1&2):127-133.

Ganesan, M. (2003). Comparative evaluation of Low cost Greenhouse and its effect on the yield and Quality of two varieties of Tomato (*Lycopersicon esculentum* Mill.). *Indian Agric.* **6** : 161-168.

Ganiger, V.M. (2010). Morphological, biochemical and molecular characterization for genetic variability analysis of *capsicum annuum*. *Vegetos*. **32**(2): 131–141.

Gaurav, A.K, Raju, D.V.S., Janakiram, T., Singh-Bhupinder, J.R. and Krishnan, S.G. (2016). Effect of coloured shade net on production of Dracaena fragrans. *Indian J. Hort.* **73**(1): 94-98.

Gent, M.P.N. (2007). Effect of shade on quality of greenhouse tomato. Acta Hort. 747: 107-112.

Gindaba, J. and Wand, S.J. (2005). Comparative effects of evaporative cooling, kaolin particle film and shade net on the control of sunburn and fruit quality in apples. *Hort Sci.* **40**: 592-596.

Gomez, M.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. Pp. 97–129, 207–215.

Goren, A., Alakali-tuvia, S., Perzelan, Y., Aharon, Z., Fallik, E. and Shahak, Y. (2010). The effect of colored shade nets on sweet bell pepper quality after prolonged storage and shelf life. *Acta Hort*. **927**: 565-570.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. and Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Phil. Tran. Royal Soc. Bio. Sci.* **365**(1554): 2973-2989.

Hallmann, E. (2012).The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types. *J. Sci. Food Agric.* **92**: 2840–2848.

Ilic, S.Z., Milenkovic, L., Bodroza-solarov, M., Marinkovic, D. and Sunic, L.J. (2012). Tomato fruits quality as affected by light intensity using color shade nets. 47th Croatian and 7th International Symposium on Agriculture. Opatija. Croatia. pp. 414-418.

Islam, M., Akter, A., Akhi, M. and Debnath, B. (2020). Evaluation of growth and yield of Sweet pepper (*Capsicum annuum*) varieties under net protected conditions. *Ann.Bangladesh Agric.* **24**(2): 85-94.

Jeevansab, A. (2000). Effect of nutrient sources on growth, yield and quality of capsicum grown under different environments. M. Sc. (Agri) Thesis, University of Agricultural Sciences, Dharwad. pp. 1-5.

Jena, C. Pavani, K. and Pramanik, K. (2020). Structures, benches and containers used in protected cultivation. In: Protected Cultivation and Smart Agriculture edited by Sagar, M., Dinkar, J. G. and Tanmoy S. © New Delhi Publishers, New Delhi: pp. 76-86.

Jessica, M.C. and James, A.K. (2006). Effect of shading on accumulation of flavonoid compounds in (*Vitis vinifera* L.) Pinot Noir fruit and extraction in model system. *J. Agric. Food Chem.* **54**: 8510-8520.

Kadir, S., Carey, E. and Ennahli, S. (2006). Influence of high tunnel and field conditions on strawberry growth and development. *Hort. Sci.* **41**(2): 329-335.

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

Kaur, K. and Kaur, A. (2019). Impact of various cultivation systems on the growth and yield of strawberry cv. Chandler. *Int. J. Adv. Agric. Sci. Tech.* **6**(6): 12-19.

Koley, T.K., Chaurasia, S.N.S., Singh, S., Yadav, R.B. and Naik, P.S. (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; ICAR-Indian Institute of Horticultural Research: New Delhi, India. pp. 86.

Kumar, A. and Ahad, I. (2012). Growth, yield and fruit quality of strawberry under protected cultivation in South Kashmir. *Adv. Hort. Sci*. **26**(2): 88-91.

Kumar, A., Avasthe, R. K., Rameash, K., Pandey, B., Borah, T. R., Denzongpa, R. and Rahman, H. (2011). Influence of growth conditions on yield, quality and diseases of strawberry (*Fragaria x ananassa* Duch.) var Ofra and Chandler under mid hills of Sikkim Himalaya. *Sci. Hort.* **130**(1): 43-48.

Kurubetta, Y. and Patil, A.A. (2009). Performance of coloured capsicum hybrids under different protected structures. *Karnataka J. Agri. Sci*. **22**(5): 1058-1061.

Lamont, J. and Edward, E. (2009). Carey Horticultural Crop Production in High Tunnels in the United States: A Snapshot. *American Soc. Hort. Sci*. **19**: 137–43

Lizalo, A. and Demirsoy, L. (2020). Summer-fall strawberry production with day neutral strawberries. Conference: 4th International Eurasian Agriculture and Natural Sciences Congress At: Turkey. pp. 1-8.

Luthria, D.L., Mukhopadhyay, S. and Krizek, D.T. (2006). Content of total phenolics and phenolic acids in tomato (*Lycopersicon esculentum* Mill.) fruits as influenced by cultivar and solar UV radiation. *J. Food Compos. Anal*. **19**: 771–777.

Medany, A.M., Hassanein, M.K. and Farag, A.A. (2009). Effect of black and white nets as alternative cover in sweet pepper production under green house in Egypt. *Acta Hort.* **807**: 121-126.

Megharaja, K.M. (2000). Studies on the effect of growing conditions and growth regulators on growth and productivity of hybrid capsicum *cv.* Indira. M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore. pp. 1-4.

Milenkovic, L., Ilic, S.Z, Trajkovic, R., Sunic, L., Kapoulas, N., Durovka, M. (2012 b). Reducing of tomato physiological disorders by photoselective shade nets. 47th Croatian and 7th International Symposium on Agriculture. *Opatija*. **1**: 419-423.

Milosevic, T., Milosevic, N. and Glisic, I. (2009). Strawberry (*Fragaria* × *ananassa* Duch.) yield as affected by the soil pH. *Anais da Academia Brasileira de Ciências.* **81**(2): 265-269.

Mochizuki, Y., Umeda, H., Saito, T., Higashide, T. and Iwasaki, Y. (2017). Effect of low temperature and solar radiation on dry-matter production, fruit yield and emergence of malformed fruit in strawberry (*Fragaria*× *ananassa* Duch.). *Acta Hort.* **1227**: 313-316.

Nagamani, G.V., Kuma,r J.S., Reddy, T.B., Rajesh, A. M., Anjundeswara, A.M., Reddy, R.L. and Doddabasappa, B. (2019) Performance of different parthenocarpic cucumber (*Cucumis sativus* l.) hybrids for yield and yield attributing traits under shade net-house and under open-field conditions. *Int. J. Curr. Microbiol. App. Sci.* **8**: 978-982.

Naik, R.K. (2005). Influence of N-aubstitution levels through organic and inorganic sources on growth, yield and post harvest quality of capsicum under protected condition. Ph. D. Thesis, *Univ. Agric. Sci*., Dharwad, Karnataka, India. pp. 1-13.

Nami Goto-Yamamoto, Kentaro, M., Mineyo, N., Kazuya, K. and Masahiko, K. (2011). Effects of temperature and water regimes on flavonoid contents and composition in the skin of red-wine grapes. *J. Int. Sci. Vigme. Vin.* **13**(29): 75-80.

Negi V.S., Maikhuri R.K., Rawat L.S. and Parshwan D. (2013). Protected cultivation as an option of livelihood in mountain region of central Himalaya, India. Int. J. Sust. Develop. World Eco. **20**(5): 416–425.

Ngoune, L.T. and Shelton, C.M. (2020). Factors affecting yield of crops. agronomy - climate change and food security. *Agron*. **1**: 1-12.

Nordey, T., Basset-Mens, C., and De Bon, H. (2017). Protected cultivation of vegetable crops in sub-Saharan Africa: limits and prospects for smallholders. *A review. Agron. Sustain. Dev*. **37**: 53.

Nosipho, H.G.S. and Mpandeli, N. (2021). The Role of small-scale farmers in ensuring food security in africa. *Food Sec. Africa.* **1**: 1-18.

Pandey, S., Singh, J., Kumar, S., and Mourya, I.B. (2015). Influence of growing environment on growth, yield and chemical composition of Strawberry (*Fragaria x ananassa*) fruits under open vs. naturally ventilated polyhouse conditions. *Indian J. Agric. Sci.* **85**(12): 1540-1545.

Pandey, V., Panth, T. and Das, S. (2007). Performance of capsicum varieties under green house and open field condition *Phal Phul*, Jan-Feb. pp. 17-22.

Panigrahi, H.K., Tiwari, S. P., Agrawal, N., Agrawal, R. and Sharma, D. (2010. Comparative study of capsicum (*Capsicum annum* L.) Cv. California wonder under protected (green house) and open field condition, *Int. J. Agric. Stat. Sci.* **6** (2) : 659-662.

Paul C., Gomasta J. and Hossain, M.M. (2017). Effects of Planting Dates and Variety on Growth and Yield of Strawberry. *Int. J. Hort. Agric. Food Sci*. **1**(4): 1-12.

Pires, R.C.D.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. *Sci Agric.* **63**(5): 417-425.

Pires, R.C.D.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*. **63**(5): 417-425.

Prohens, J., Blanca, J.M. and Nuez, F. (2005) Morphological and molecular variation in a collection of eggplant from a secondary center of diversity: Implications for conservation and breeding. *J. Amer. Soc. Hort. Sci*. **130**: 54-63.

Rabbi, B., Chen, Z. and Sethuvenkatraman, S., 2019. Protected Cropping in Warm Climates: *A Rev. Hum. Con. Cool. Met. Ener*. **12**(14): 2737.

Rajasekar, M., Arumugam, T. and Ramesh, K.S. (2013). Influence of weather and growing environment on vegetable growth and yield. *Academic J*. **5**(10): 160-167.

Ramana Rao, K., Agaraval, V., Chourasia, L., Keshri, R and Patel, G. (2012). Performance evaluation of capsicum crop in open field and under covered cultivation. *Intl. Conf. on Agri. and Hort. Sci.* Organized by Hyderabad International Convention Center, India during Sept. 14-15, 2012.

Raza, A., Razzaq, A., Mehmood, S., Zou, X., Zhang, X., Lv, Y. and Xu, J. (2019). Impact of climate change on crops adaptation and strategies to tackle its outcome: *A Review. Plants.* **8**(2): 34.

Saridas, M., Simsek, O., Donmez, D., Kacar, Y. and Kargi, S. (2020). Genetic diversity and fruit characteristics of new superior hybrid strawberry (*Fragaria* × *ananassa* Duchesne ex Rozier) genotypes. *Gen. Res. Crop Evo*. **68**(2): 741-758.

Shahak, Y., Gussakovsky, E.E., Cohen, Y., Lurie, S., Stern, R., Kfir, S., Naor, A., Atzmon, I., Doron, I. and Greenblat-Avron, Y. (2004). Colour nets: A new approach for light manipulation in fruit trees. *Acta Hort*. **636**: 609-616.

Singh, A., Syndor, A., Deka, B., Singh, R. and Patel, R. (2012). The effect of microclimate inside low tunnels on off-season production of strawberry (*Fragaria*×*ananassa* Duch.). *Scientia Horticulturae*. **144**: 36-41.

Singh, D., Kaur, S., Dhillon, T.S., Singh, P., Hundai, J.S. and Singh, G.J. (2004). Protected cultivation of sweet pepper hybrids under net house in Indian conditions. *Acta Hor*t. **659**: 515-521.

Singh, R. and Singh, G.S.(2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energ. Ecol. Environ.* **2**: 296–316.

Spayd, S., Tarara, J., Mee, D.L. and Ferguson, J.C. (2002). Separation of sunlight and temperature effects on the composition of *Vitis vinifera* cv. Merlot berries. *American J. Eno. Viticul.* **53**: 171-182.

Swagatika Srichandan, Panda, S.C., Sahu, G.S., Mahapatra, P. and Mishra, R. (2006). Effect of shadenet on growth and yield of cauliflower. *Orissa J. Hort.* **34**(1): 28-31.

Swapnil, P., Singh, J., Singh, S.K. and Mourya, I. (2016). Influence of growing environment on growth, yield and chemical composition of strawberry (*Fragaria × ananassa*) fruits under open vs naturally ventilated polyhouse conditions. Indian J. Agric. Sci. **85**(12): 1540-1545.

Takeda, F., Glenn, D. M., Callahan, A., Slovin, J. and Stutte, G. W. (2010). Delaying flowering in short-day strawberry transplants with photo selective nets. *Int. J. Fruit Sci.* **10**(2): 134-142.

Takte, R.L., Ambad, S. N., Kadam, U.S. and Dhawale, B.C. (2003). Green house cladding material shade nets ventilation etc. Proceedings of All India Seminar on Potential and Prospects for Protective Cultivation, Organized by the Institute of Engineers, Ahmednagar. pp.117–119.

Tayade, R.G., Tipre, P.G., Dandge, A.R., Ingle S.D. and Bhagat A.K. (2019) Effect of environmental parameter on different colour mulches under shade net house and in open field condition over a chrysanthemum plant. *Int. J. Agric. Sci.* **11**(2): 7732-7736.

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

Thapa, U., Rai, R., Lyngdoh, Y.A., Chattopadhyay, S.B and Prasad, P.H. (2013). Assessment of producing quality sprouting broccoli (*Brassica oleracea* var. italica) under cover and open condition. *African J. Agri. Res.* **8**(15): 1315-1318.

Thenmozhi, M. and Kottiswaran, S.V. (2017). Effect of fertigation scheduling under drip irrigation with different black polyethylene mulching in Capsicum crop under polyhouse and open field conditions. *J. Pharma. Phytochem.* **6**(5): 2485-2490.

Tuzel, Y., Zwart, H.F., Sapounas, A., Hemming, S. and Stanghellini, C. (2017). Improvement of greenhouse design and climate control in mediterranean conditions. *J. Food Agric. Environ.* **15**: 74-79.

Voca, S., Duralija, B., Druzic, J., Skendrovic-Babojelic, M., Dobricevic, N., and Cmelik, Z. (2007). Influence of cultivation systems on physical and chemical composition of strawberry fruits cv. Elsanta. *Agric. Con. Sci.* **71**(4): 171-174.

Voca, S., Jakobek, L., Druzic, J., Sindrak, Z., Dobricevic, N., Seruga, M. and Kovac, A. (2009). Quality of strawberries produced applying two different growing systems. *J. Food*. **7**(3): 201-207.

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

Zoran, I., Lidija M., Mihal, D. and Nikolaos, K. (2011). The effect of colour shade nets on the greenhouse climate and pepper yield. Proc. 46th Croatian and 6th *Internationall. Symposium on Agriculture Opatija, Croatia.* pp. 529-532.

APPENDICES

Appendix I. Map showing location of the field

Appendix II. Analysis of variance of the data of plant height, SPAD reading, number of fruits plant^{-1}, individual fruit weight, fruit yield plant^{-1} of strawberry under different shades and open field condition.

		Mean square at				
Source	**DF**	Plant height	SPAD reading	Number of fruits plant^{-1}	Individual fruit weight	Fruit yield plant^{-1}
Treatment	3	7.00*	21.21*	21.02*	7.45*	12999.6*
Error	12	0.13	0.68	0.24	0.34	150.2

*: Significant at 5% level of probability

Appendix III. Analysis of variance of the data of moisture content, ascorbic acid content, total soluble solids content, titrable acidity and pH value of strawberry under different shades and open field condition.

		Mean square at				
Source	**DF**	Moisture content	Ascorbic acid	Total soluble solids	Titrable acidity	pH value
Treatment	3	4.75*	26.76*	1.58*	0.01*	0.024*
Error	12	0.83	0.17	0.17	0.0003	0.002

*: Significant at 5% level of probability

Appendix IV. Analysis of variance of the data of total phenolic content and reducing sugar of strawberry under different shades and open field condition.

		Mean square at	
Source	**DF**	Total phenolic content	Reducing sugar
Treatment	3	0.53*	3.82*
Error	12	0.007	0.06

*: Significant at 5% level of probability