

Program Based Research Grant (PBRG)
Sub-project Completion Report

on

**Development of Protective Culture Technology
for Safe and Quality Vegetable and Fruit
Production**

Sub-project Duration
October 2019 to December 2022

Coordinating Organization
Olericulture Division, Horticulture Research Center (HRC)
Bangladesh Agricultural Research Institute (BARI), Gazipur-1701



Project Implementation Unit
National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Implementing Organization

- 1. Olericulture Division, HRC, BARI, Gazipur
and**
- 2. Department of Horticulture, Sher-e-Bangla Agricultural
University, Dhaka**



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National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
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Abbreviation and Acronyms

ADI	Alternative Development Initiative
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BCR	Benefit Cost Ratio
cm	Centimeter
Co-PI	Co-Principal Investigator
CSO	Chief Scientific Officer
CV	Coefficient of Variation
DAS	Days After Sowing
DCIP	2,6-Dichloroindophenol
EC	Electrical conductivity
ESFB	Eggplant Shoot and Fruit Borer
FW	Fresh Weight
g	Gram
GA ₃	Gibberellic acid
GC-ECD	Gas Chromatographic-Electron Capture Detection
GoB	Government of Bangladesh
HLPE	High Level Panel of Experts
HRC	Horticulture Research Center
HSD	Honest Significant Difference
IFAD	International Fund for Agricultural Development
Kg	Kilogram
LoA	Letter of Aggrement
mg	Microgram
MRL	Maximum Residue Limit
NATP	National Agricultural Technology Project
NH	Net House
PBRG	Program Based Research Grant
PDI	Perpendicular Dryness Index
PGR	Plant Genetic Resource
pH	Potential of Hydrogen
PI	Principal Investigator
PIU	Project Implementation Unit
PSO	Principal Scientific Officer
RARS	Regional Agricultural Research Station
SAU	Sher-e-Bangla Agricultural University
SPAD	Soil Plant Analysis Development
T&C	Training and Communication
TSS	Total Soluble Solid
TYLCV	Tomato yellow leaf curl virus
UV	Ultra Violet
WB	World Bank

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Executive Summary

Protected culture is a modern and scientific method of farming, under which the plants are protected from adverse natural conditions or unfavorable environments such as strong heat, strong cold, strong wind, strong light intensity, excessive rain, drought, pests, etc. Plants are protected and provided with favorable conditions which help in their growth and in this way better quality and higher yields are obtained from them. To get these advantages in our farming system, a study entitled “Development of protective culture technology for safe and quality vegetables and fruit production” has been undertaken at Olericulture Division, HRC, BARI, Gazipur and Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during 2019 to 2022. The study was designed with seven research activities at BARI component and twelve research activities at SAU component. So, this report will provide an idea on protective culture technology for safe and quality vegetables and fruit production, which will ensure safe and quality high value vegetables and fruit production for both local and export market.

To produce a quality yield of any vegetables, it is need to ensure good quality seedling which would produce high quality yield. So, first activity was designed to identify suitable net house for different high value vegetables. Four types of vegetables were viz., tomato (V1), eggplant (V2), sweet pepper (V3), broccoli (V4) and 4 types of net house treatments [i) UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)] were included in this study. Maximum seed germination (93.58%) and lowest mortality (2.08 %) was observed in V2T1. The tallest seedlings were produced in V3T1 at every growth stage (15 days, 20 days, 25 days, 30 days). The maximum no. of leaves was produced in V3T2. Mulch paper produced higher fruit yield per plant and fruit yield per hectare than for the control, indicating that the mulch had a positive effect in generating increased fruit yield. Silver over black plastic mulch (T1) produced the highest fruit yield viz., 98.05 t/ha (tomato), 54.11 t/ha (eggplant), 34.33 t/ha (sweet pepper), 26.09 t/ha (broccoli) followed by black, while the control plot produced the lowest fruit yield.

The effect of different types of net houses [i) UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (NH1); ii) UV stabilized transparent polyethylene film with 60 mesh insect net (NH2); iii) 60 mesh insect net (NH3) and iv) Open field (control) (NH4)] was studied to observe the incidence of white fly, aphid, leaf miners, mites and eggplant shoot and fruit borer (ESFB). The lower infestation was observed in NH2 and NH3 for all vegetables. The protected net house conditions prepared with UV stabilized transparent polyethylene film with 60 mesh insect net (NH2), tomato, eggplant, sweet pepper, cucumber and netted melon production (95.04, 41.60, 31.27, 28.8, 25.87 t/ha, respectively) produced higher yield with good horticultural traits. The average BCR of these vegetables were 3.13, 1.85, 6.88, 3.69 and 12.55, respectively. The product were safe with good quality due to use of pesticide was absent. The study tried to determine the right maturity stages under transparent polyfilm nethouse in order to avoid product loss. The tomato was found to be an appropriate size (6.5 cm length and 6.2 cm diameter), weight (84 g), TSS (4.5 percent), pH (4.3), ‘turning red’, and ‘tasty’ at the week 5 stage, while the broccoli was found to be an appropriate size (12.0 cm length and 13.0 cm diameter), weight (360 g), and ‘green’ color at the 12 days stage. At the week 6 stage, netted melon was found to be of appropriate size (15.2 cm length and 14.5 cm diameter), weight (800 g), TSS (10.8 percent), pH (6.3), ‘net fully developed’ on the fruit skin and ‘much tasty’, while cucumber was found to be of appropriate size (8.8-10.8 cm length and 2.2-2.9 cm diameter), weight

(61-88 g), TSS (3.8-4.1 percent), pH (6.3), 'less powdery' at 10-12 days. As a result, establishing the optimal maturity of this study will benefit both consumers and the growers.

The different type of high value vegetables were cultivated under different protected net houses to evaluate the nutrition facts. The cultivation of vegetables in protected environments were viz., Poly green shed house (NH1), UV poly shed house (NH2), Net house (NH3), Open field (control). Protein contents of investigated growing conditions varied between 0.58 – 2.70g and dietary fiber contents between 0.44-3.50 g, while the range of sodium, calcium, magnesium content were obtained 2.6-20.3mg in cucumber under poly green shed house, 7.8 mg (cucumber in poly green shed house) - 47.0 mg (broccoli in UV poly shed house), 12.5 mg (sweet pepper in poly green shed house) 23.0 mg (tomato in poly green shed house, respectively. In maximum vegetables, the vitamins content was higher when cultivated in UV poly shed net house (NH2) compare to other conditions. To upscale the high value vegetables production under net house technology, the study was conducted at two farmers' fields, Narshingdi and Cumilla, during Oct 2021 to Jul 2022. Under this evaluation, cultivation under UV Poly nethouse (NH2) was found better in the Cumilla area compared to Narshingdi. It might be differences in management operations by different growers. For all crops, viz., tomato, sweet pepper, cucumber, netted melon, and okra, the production in the Cumilla area was very significant and higher.

So, with UV poly nethouse technology (NH2), high value thermos-sensitive vegetables (tomato, sweet pepper, cucumber, netted melon) can be commercially grown year-round successfully to produce a safe and quality product, while greater fruit yield/unit area will be achieved in a protected nethouse.

In SAU part, the protective cultivation approaches were studied for different fruit cultivation to mitigate the environmental factors to get safe and quality produces. Protected cultivation method like 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 polyhouse; fully covered with UV film sheet) were used in these experiments. Different shed houses performed differently for different fruit crops.

For strawberry, the most suitable growing conditions for yield and yield parameters were net house, whereas UV poly shed and poly house conditions were favorable for the production of better quality fruit. Cocopeat based growing media and net house shade may be recommended to obtain higher strawberry yield. Different mulch materials: black polythene, white polythene, saw dust and control (no mulch); and GA3 (0 and 200ppm) effect were studied under net house. Strawberries treated with GA3 grew faster, produced more, and had better quality than those not treated with GA3. Among the mulch materials, sawdust performed better than the other mulch materials in terms of yield and quality parameters. Therefore, sawdust and GA3 are beneficial for increasing the growth, yield, and quality attributes of strawberry plants under net house. Pesticide (cypermethrin) residues were quantified in strawberry at different harvest intervals of 0 (2h), 1, 3, 5, 7, 10 and 12 days after insecticide application (DAS). Strawberry fruits had the highest residual level (0.874 mg/kg) at 0 DAS. The detected residue level was higher than the MRL (Maximum residue limit) up to 7 DAS (0.101 mg/kg). The Pre-Harvest Interval (PHI) of was determined at 10 DAS for strawberry. Data indicated that no pesticide residues were identified after 12 DAS. The phenolic content in fruits were increased gradually 1-7 DAS of cypermethrin. As a

result, it can be concluded that delaying fruit harvesting after spraying (7 DAS) improves fruit quality by lowering residue levels below the MRL.

Foliar application of GA3, maleic hydrazide, ethephon and control (no growth regulator), and pruning (no pruning and apical bud pruning) on growth, flowering and yield of watermelon were studied under UV poly shed and found that GA3 with pruning had more significant effects on vegetative growth, increased the flowering, suppressed the staminate flowers and enhanced the pistillate flowers and fruit yield.

Papaya and banana fruits grown under different shed houses, including net house, poly shed house, UV poly shed house, and open field conditions (control). The study demonstrated that papaya can be cultivated successfully in a net house with increased yield and phytochemical accumulation whereas the most suitable growing condition for growth, yield and quality parameters of bananas is under the poly net house. The optimum maturity stages of papaya and banana were identified on the basis of different physico-chemical properties. Papaya fruits were collected at two growing conditions i.e. net house and open field, and at four maturity stages i.e. stage 1 (25% skin color), stage 2 (50% skin color), stage 3 (75% skin color) and stage 4 (90% skin color). The study found that papaya collected at maturation stage 3 from net houses performed better in terms of quality traits. Fruits harvested from open field, UV poly shed and net poly shed condition at three mature stage i.e. under mature (the angles are becoming less prominent), mature (disappeared angularity) and over mature stage (the skin colour changes from green to yellow). Results indicated that banana fruits harvested from poly net house at mature stage performed better in terms of quality traits.

Dragon fruit cultured in the net poly shed showed good yield and significantly higher percentage of total sugar, reducing and non-reducing sugar, anthocyanin, pH content and total soluble solids than those grown in other environments. According to the findings, different protective structures performed differently for different fruit crops to produce safe and quality fruit.

Key words: Mulch paper, Protective cultivation, Yield, Quality, Fruits, Vegetables.

PBRG Sub-project Completion Report (PCR)

A. Sub-project Description

1. **Title of the PBRG sub-project:** Development of protective culture technology for safe and quality vegetables and fruit production

2. **Implementing organization (s):**

Olericulture Division, Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur-1701
Sher-e-Bangla Agricultural University, Dhaka-1207

3. **Name and full address with phone, cell and E-mail of Coordinator, Associate Coordinator, PI/Co-PI (s):**

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4. **Sub-project budget (Tk.):**

4.1 Total:(in Tk. as approved): 170,00,000/-

4.2 Latest Revised (if any): NA

5. **Duration of the sub-project:**

5.1 Start date (based on LoA signed): 15 October 2019

5.2 End date: 29 December 2022

6. Background of the sub-project:

Protected cultivation systems are used throughout the world as a powerful instrument to produce crops. They protect the crops from unfavorable outdoor climate conditions and pests and offer the opportunity to modify the indoor climate to create an environment that is optimal for crop growth and production, both in terms of quality and quantity. With globalization of markets, shrinking land and climate change, the protected cultivation of high value crops has emerged as the single most important technology for ensuring high productivity, improved quality and profitable returns (Nordey *et al.*, 2017). Protected cultivation is a technique wherein the microclimate around the plant is controlled fully, partially or modified to protect the crop from adverse weather. Protected cultivation ensures: conservation of soil moisture, efficient use of energy mainly solar, higher yield, year round cultivation, better quality, off-season production, assured production, generate self-employment for the educated rural youth in the farm sector, least pesticide residues, controlled pollination, vagaries of weather, easier plant protection, weed free cultivation need of protected cultivation. The open field production of vegetables and fruits encounter with many production constrains like heavy rain, thunderstorms, excessive solar radiation, temperatures and humidity levels above plant growth optima, high insect pest infestation pressure (Ummyah *et al.*, 2017).

Environment is the most determinate factor in horticultural crop. Protected cultivation is being used to control the effect of environment. Protected cultivation is the sustainable approach towards the vegetables and fruits production under adverse climate. The micro climate can be changed inside the poly house. Certain insect require UV light for their vision purpose, the UV opaque covering material for poly house helps to restrict the insect to enter the house. Consequently, there is minimum use of insecticide. The production of vegetables and fruits in protected net house is higher than the open field condition due to congenial inside microclimate and that provided better price. The protected cultivation comprises different devices and technologies namely windbreaks, irrigation, soil mulches etc. and the structures which are greenhouse, tunnel, row covers made the production throughout the year by modifying the natural environment (Mukul *et al.*, 2017). It will further prolong the harvest period, increase yield, quality improvement, and keep the availability of commodities frequently. Protected agriculture has grown in popularity as a means of increasing agricultural productivity and lowering costs. In Bangladesh, very little study has been conducted on fruit cultivation in a low-tech protected setting.

7. Sub-project general objective (s)

To produce safe and quality vegetables and fruits for local and export market following protective cultivation techniques.

8. Sub-project specific objectives

BARI Component

- i. To develop protective culture technology for high value vegetables
- ii. To produce safe and quality vegetables for both local and export market

SAU Component

- i. Production of high value fruits following protected cultivation techniques.
- ii. To produce safe and quality fruits for both local and export market

9. Implementing location (s):

- I. Olericulture Division, Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh.
RHRS, BARI, Shibpur, Narshingdi
RARS, BARI, Cumilla
- II. Horticulture farm and postharvest laboratory of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

10. Methodology in brief

BARI Component

10.1 Effect of Different Net House on Quality Seedling Raising of High Value Vegetables

The experiment was designed at the research field of the Olericulture Division, HRC, BARI, Gazipur during November to December, 2019. Four vegetables varieties viz., tomato (V1), eggplant (V2), sweet pepper (V3), broccoli (V4) and 4 net house treatments [i) UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)] were included in this study. Total 16 treatment combinations were laid out in factorial design with three replications. Four types of vegetables were sown on polypot (12 cm × 10 cm) with fungicide treated seed on 15 November 2019 under four type of net house treatments. The polypots were filled up with fine sandy-loam soil and organic manure with 50:50 ratio. Different cultural operations such as irrigation, weeding, mulching etc. were done as and when needed. Data were collected on seed germination (%), seedling mortality (%), seedling height (at 15 days, 20 days, 25 days, 30 days), no. of leaves at (at 15 days, 20 days, 25 days, 30 days), insect infestation (%) (at 15 days, 20 days, 25 days, 30 days), from 5 randomly selected seedling from each of replication. The recorded data for different characters were analyzed statistically using MSTAT-C program to find out the variation among the different genotypes by F-test. Treatment means were compared using Duncan's Multiple Range Test (DMRT) and standard error and coefficient of variation (CV %) were also estimated for each character.



Plate 1: Different type of net houses for vegetable production

10.2 Effect of Different Mulch Paper on Growth and Yield of Different High Value Vegetables In Bangladesh

The experiment site was the farm of Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during November 2019 to March 2020. Three types of mulch paper viz., Silver over black (M1), Black (M2), No mulch- Control (M3) and 4 types of vegetables viz., tomato (BARI Tomato-15), eggplant (BARI Hybrid Begun-4), sweet pepper (BARI Mistimorich-1) and broccoli (BARI Broccoli-1) were planted under UV stabilized polyethylene film net house. The Experiment was laid out with three replications. The unit plot size was 3.0 x 1.00 m in a RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distance was maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. One third of the organic fertilizer and half of TSP and full of gypsum, zinc and borax were applied during final land preparation. Rest of organic fertilizer and TSP and 1/3 of MoP were applied as basal in pit. After land preparation, the land was covered with mulch paper. Then the proper sized seedlings were transplanted with proper distance. One third of urea and MoP were applied in liquid form after 20 days of transplanting in the hole where the plant is standing. Rest of urea and MoP was applied in equal two installments at flowering and fruiting condition. The required agronomic operations viz., irrigation, weeding, mulching, use of stick, crop protection measures and other intercultural operations were done as and when necessary following standard procedure.

Different types of yield and yield contributing data of 4 types of vegetables viz., tomato, eggplant, sweet pepper and broccoli were collected from 5 randomly selected plant from each of replication. For tomato the traits were- plant height (cm), days to first flowering, days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg), yield (t/ha) and TSS (%). For eggplant the traits were- plant height (cm), days to first flowering, days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg) and yield (t/ha). For sweet pepper the traits were- days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg) and yield (t/ha). For broccoli the traits were- days to 50% curd initiation, days to curd harvest, curd length (cm), curd breadth (cm), whole plant weight (kg), only curd wt. (g), marketable curd wt. (g), marketable curd yield (t/ha). The recorded data for different characters were analyzed statistically using MSTAT-C program to find out the variation among the different genotypes by F-test. Treatment means were compared using Tukey's test and standard error and coefficient of variation (CV %) were also estimated for each character.

10.3 Effect of Different Type of Nethouse on The Incidence of Insect and Diseases of High Value Vegetables

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) from Sep 2021 to Mar 2022. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and was characterized by scanty rainfall during the experimental period. Six vegetables [i] tomato, ii] eggplant, iii] sweet pepper, iv] broccoli, v] cucumber, and vi] okra, as well as four nethouse treatments [i] UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (NH1); ii] UV stabilized transparent polyethylene film with 60 mesh insect net (NH2); iii] 60 mesh insect net (NH3); and iv] Open condition (NH4) were

included in this study. A total of 24 treatment combinations were laid out in a factorial design with three replications. The unit plot size was 3.0 x 1.00 m in a RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distances were maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. During final land preparation, one-third of the organic manure, half of the P, and full of S, Zn, and B, was applied. Organic manure and P and 1/3 of K were applied as basal in the pit. After land preparation, the proper sized seedlings were transplanted at the proper distance. One third of N and K were applied after 20 days of transplanting. The remaining N and K were applied in two equal installments during flowering and fruiting. Irrigation, weeding, crop management and other intercultural operations were done following standard practice and done as and when needed. No plant protection was taken during the study time to get proper pest infestation data. Different types of growth and pest infestation data were collected from five randomly selected plants from each of the replications. The recorded data for various characters were statistically analyzed, with analysis of variance (ANOVA) and mean separation performed using R 3.6.3 statistical software.

10.4 Effect of Different Net House on Growth and Quality of High Value Vegetables

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) from Mar 2021 to Feb 2022. Data for the temperatures for each treatment was measured at 12 pm daily during the experimental period. During the experimental period, the relative humidity data for each treatment was measured at 12 pm daily. Five types of vegetables, viz., tomato, eggplant, sweet pepper, cucumber, and netted melon, were cultivated in 4 net house treatments [i) UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized transparent polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3); and iv) open field (control) (T4)] were included in this study. A total of 20 treatment combinations were laid out in factorial design. The unit plot size was 3.0 x 1.00 m in an RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distances were maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. During the final land preparation, one-third of the organic fertilizer, half of the P, and all of the S, Zn, and B were applied. The rest of the organic fertilizer and P and 1/3 of K were applied as basal in the pit. After land preparation, the properly sized seedlings were transplanted at a proper distance. Two rows of plants were grown per bed, and the spacing between plants was followed according to standard distance. One-third of N and K were applied after 20 days of transplanting. The remaining N and K were applied in two equal installments during flowering and fruiting. Irrigation, weeding, crop protection measures and other intercultural operations were done following standard practice and done as and when needed. Different types of growth, yield, and yield contributing parameters of five types of vegetables, viz., tomato, eggplant, sweet pepper, cucumber, and netted melon, were collected from five randomly selected plants from each replication. The recorded data for various characters were statistically analyzed, with ANOVA and mean separation performed using R 3.6.3 statistical software.

10.5. Effect of Maturity Indices on Growth and Quality of High Value Vegetables

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during Mar 2021 to Feb 2022. Data for the temperatures and RH were measured at 12 pm daily during the experimental period. Five types of vegetables, viz., tomato, broccoli, sweet pepper, cucumber, and netted melon, were cultivated in UV stabilized transparent polyethylene film with a 60 mesh insect nethouse. Different intervals of harvest were followed for different vegetables for this study. Fruit and quality related traits were visually observed and categorized. Fruits were selected randomly from tagged plants and picked to measure fruit length, diameter, average weight, TSS, and pH. Fruits were harvested on different days after flower opening.

Flowers were tagged at anthesis to determine the stage of fruit development, and 10 randomly selected fruits from 10 plants were harvested at specific day intervals according to the vegetable to determine their growth and maturity. At each harvesting date, 10 fruits were used to determine physicochemical properties like fruit length, diameter, weight, TSS, and pH. Fruit weight was determined using a digital electronic balance (Mettler PJ400, Switzerland) after transporting the harvested fruit in a closed plastic bag to the laboratory. Fruit length and diameter were measured with a digital vernier caliper. The total soluble solids and pH of the juice were determined by using a hand-held Kruss refractometer (Model HR 900, SN 1200793, brix range 0–90% at 20° C, Germany) and a glass electrode pH meter (Delta 320, Mettler, Shanghai), respectively. Sensory evaluation, based on general visual appeal, colour, crispiness, flavor, and taste, was conducted. The scores were: 7 = like extremely; 6 = like very much; 5 = like moderately; 4 = neither like nor dislike; 3 = dislike moderately; 2 = dislike very much and 1 = dislike extremely. Fruit scored above 4 was considered acceptable. Sensory evaluation was performed by a panel of judges consisting of 5 scientific personnel, including both male and female members. Different preferences, as indicated by scores, were evaluated by statistical methods. Using the R 3.6.3 statistical software, the data was subjected to analysis of variance (ANOVA). The results showing significant differences were then subjected to mean separation using Tukey's Studentized Range (HSD) Test at $P \leq 0.05$.

10.6. Study of Different Nutritional Facts of Vegetables Under Different Type of Protected Growing Condition

The evaluation site was the research farm of Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during Mar 2021 to Feb 2022. Data of the temperatures for each treatment was measured at 12 pm daily during the experimental period. During the experimental period the relative humidity data for each treatment was measured at 12 pm daily. Six types of vegetables viz., tomato, eggplant, sweet pepper, broccoli, cucumber and netted melon were cultivated in 4 net house treatments [i) UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized transparent polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)] were included in this study. Total 20 treatment combinations were laid out in factorial design. Fruits were selected randomly from tagged plants and picked for measuring the nutritional facts.

Vegetables were harvested at commercial mature stage from the experimental farm of Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) during 2021–22 (23.9920° N Latitude and 90.4125° E Longitude), washed,

sorted by color and size, and divided into two groups. The first group was used fresh for proximate and mineral analysis, whereas the second was freeze-dried and stored at -80 °C for further ascorbic acid evaluations. Moisture, ash, protein (N x 6.25), crude fibre, fat and carbohydrates (by difference) contents were determined according to AOAC methods (AOAC, 2002). The mass spectrometry method was used in mineral analyses. Minerals were made soluble through closed system microwave wet etching and concentrations were determined by using ICP-OES. AOAC (2002) was used to determine the sodium, potassium, calcium, magnesium, iron, and zinc contents of the bean genotypes. The water-soluble vitamins of retinol, thiamine, riboflavin, niacin, pyridoxine, folate and L-dehydroascorbic acid contents were determined in this study. Vitamin C content was determined as L-dehydroascorbic acid. Sample vitamin C contents were determined by measuring the area of peak obtained from the HPLC UV detector following the sample extraction with methaphosphoric acid (Bognar, 1998). Following an enzymatic incubation, B vitamins were determined in the HPLC HL detector (Gauch *et al.*, 1992). Vitamin A was determined by measuring the area of peak received from the reverse-phase analytical HPLC UV detector following direct extraction and placing the extract into the proper dissolvent (Genestar and Grases, 1995). In this study, mean values of the different biological assays were analyzed via one way Analysis of Variance (ANOVA). Significant differences among mean values were calculated at $p < 0.05$ by using the least significant difference test (Steel *et al.*, 1997).

10. 7. Upscaling of Protective Nethouse Technology at Farmers' Field

The evaluation sites were the farmers' fields of Shibpur, Narshingdi (24.050° N Latitude and 90.718° E) and Chowara Bazar, Cumilla (23.408° N Latitude and 91.244° E). The evaluation was conducted from Oct 2021 to Sep 2022. The fields were owned by Mr. Delwar and Mr. Anowar Hossain, respectively. The areas were situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental period.

Five types of vegetables, viz., tomato, sweet pepper, cucumber, netted melon, and okra, were cultivated in the UV poly nethouse. In both cases the UV poly nethouse size was 5x7.5m. On the first week of October, seeds of all vegetables were sown on polypot, and 30 day old seedlings of tomato and sweet pepper were transplanted on bed, while 20 day old seedlings of cucumber and netted melon were transplanted on bed with the required distance under the poly nethouse. The okra seeds were sown directly on the bed on the 1st week of October.

SAU Component

10.8. Effect of Different Growing Environments on Growth, Yield and Quality Attributes of Strawberry

Plant materials and growing conditions: During November 2019 to March 2020, the experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The strawberry cv. Festival planted under raised bed planting system at 60 cm × 30 cm spacing under four environments, i.e. open field condition (control), net house naturally ventilated polyhouse (entire roof and half the portion of four sides covered with poly sheet, the remaining half covered with 25% shade net) and Fan pad UV polyhouse (Fully covered with UV film sheet), between November 2019 and March 2020. The

experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication five plants were randomly selected for observations on fruit production, yield and physio-chemical parameters. Temperature and relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions to which the plants were grown.



Plate 2: Different shade houses for crop growth

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

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

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

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

$$\% \text{ Moisture content} = (\text{Fresh weight} - \text{dry weight}) / \text{dry weight} * 100$$

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

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

Titrateable 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 phenolphthelin was added. The

solution was titrated with .1N NaOH. The titrate colour will be rosy pink and the reading was recorded. The titration was done for three times.

Vitamin C determination: Oxidation Reduction Titration Method (Tee *et al.*, 1988) was used to calculate the Vitamin C content of strawberry. The single fruit was mixed and filtrated with filter paper Whatman No.1. The volume was made 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.

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

Reducing sugars content: Determination of reducing sugars was based on the phenol-sulphuric acid method (DuBois *et al.*, 1956). With deionized water a total of 0.2 g fresh fruit was homogenized and the extract was filtered out. 2 ml of the solution was combined with 0.4 ml of 5% of phenol. Subsequently, the mixture was rapidly added to 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 20min. Light absorption with the spectrophotometer was then measured at 540 nm. Similar to the above, blank solution (distilled water) was prepared (Ammar *et al.*, 2009). Reducing sugar content was expressed as mg g⁻¹ fresh weight (FW).

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

10.9. Impact of Different Shed Houses and Growing Media on Growth, Yield and Quality of Strawberry

Plant materials and growing conditions: The experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during 2019-2020, under natural lighting conditions. The present investigation was carried out in three different Shades i.e. net house, Plastic shade house, and open field condition (control), and different growing media were used in different ratio i.e. Soil: Cowdung (1:1), Soil: Vermicompost (1:1), and Soil: Cocopeat (1:1). The total nitrogen (N) content was determined using the method of Bremner (1960), while the phosphorus (P) and potassium (K) concentrations (Table 3) were determined using the Mostara and Roy (2008) method. The recommended dose of fertilizers was applied insoluble form based on the nutrient condition of the growing media.

Table 1: Initial nutrient composition of the growing substrates

Growing media	Nutrients		
	N (%)	P (%)	K (%)
Cowdung	0.85	0.12	1.49
Cocopeat	0.41	0.81	1.32
Vermicompost	1.25	1.14	1.19

The experiment was laid out in completely randomized design with six replications in plastic pots. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on growth, yield, and physicochemical parameters. Temperature and relative humidity were recorded during the growing period of November 2019 and March 2020 in all environments, to monitor the actual environmental conditions to which the plants were grown.

Measurement of growth parameters: Five plants in each treatment and each replication were used for plant height and leaf number at harvest. Plant height was measured from the base of the plant to the top of the main plant.

SPAD chlorophyll meter reading: 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. In different shed house, three randomly selected plants from each pot of each treatment and replication were measured.

Measurement of yield and yield traits: The yield/plant (g) was recorded by adding the yield of all the harvests obtained from five plants in each treatment and each replication. Strawberries were picked every two days for a total of five to seven pickings. The weight of fruits (g) from each selected plant was taken on each date of harvest with the help of an electronic top pan balance. The number of fruits/plants was recorded by counting the fruits that reached harvestable ripeness.

Measurement of quality parameters

Total soluble solids content: The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juices of individual treatment strawberries were filtered separately, and pH was measured using a digital pH meter (HI 2211; Romania).

Titrateable acidity (TA %): A 5 g sample was macerated with a mortar and pestle to determine titrateable acidity. Then filter it and adding distilled water rendered 100ml of total volume. Then 10 ml of stock solution was taken in a conical flask and 2 drops of phenolphthalein were added. The solution was titrated with 0.1N NaOH. Total acid content was determined in maleic acid equivalents and is reported as the mean value of triplicate analyses.

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 an unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic acid as the 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.

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

Anthocyanin content: 1 g fruit pulp mixed with 1 ml 85% ethanol + 15% HCl 1.5N. After the extraction 1 ml sample solution was taken and then dilutes to 10 ml. The absorbance reading was taken at 535nm. Then calculated the anthocyanin concentration as follows: Anthocyanin (mg per 100 g fresh wt.) = (absorbance at 535nm x volume of extraction solution x 100)/ wt. of the sample in g x 98.2. The same procedure is used to prepare reference solutions as described above, except that the fruit extract is replaced with distilled water (Lapornik *et al.*, 2005).

Statistical analyses

The experiments used a randomized complete block design (RCBD) with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with IBM SPSS Statistics 21 (IBM Corp, Armonk, NY, USA). The mean value among the treatments was considered to be statistically significant when $P < 0.05$. All results were presented with mean \pm SE from the replicates. Graphs were drawn using the Microsoft Excel program. We used ANOVA to test the effect of shade house, growing media and their interaction on biochemical parameters.

10.10. Effect of Various Mulch Materials and GA₃ on Strawberry Growth, Yield, and Quality Under Net House

Plant materials and growing conditions: Under natural lighting, the experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh in November 2020 to March 2021. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an average elevation of 4 meters (13.12 ft.). GA₃ (0 and 200 ppm) was employed in the present study with different mulch materials (no mulch, sawdust, white and black polythene). A randomized complete block design with four replications was used for the experiment. Strawberries of the cv. Festival were planted in raised beds at 60 cm x 30 cm spacing under a netting house. The average temperature was 23 \pm 2°C in daytime and 13 \pm 2°C at night, with a relative humidity of 65 to 80%. During the experiment, all essential cultural practices and plant protection measures were followed across all the plots. Growth, yield and physicochemical parameters were measured on randomly selected plants in each replication.

Measurements of growth parameters: Plant height and leaf number at harvest were measured using five plants in each treatment and replication. During the flowering and fruiting stages, the plant height was measured from the base to the top of the main plant.

SPAD chlorophyll meter reading: The chlorophyll content of the first fully expanded leaves was measured using a SPAD-502 chlorophyll meter (Minolta, Tokyo, Japan). On both treated and control plants, measurements were taken at the middle of the leaf lamina. In the flowering and fruiting stages, five randomly selected plants from each treatment and replication were measured.

Relative water content (RWC): According to Smart and Bingham (1974), the RWC was calculated. Second/third fully expanded leaves were pooled for each treatment and replication, and their fresh weight (FW) was determined. When the leaves were ready, they were soaked in water for 12 hours at room temperature in order to restore their turgidity. As soon as possible, all excess water was removed from the tissue, and the turgid weight (TW) was calculated. Afterwards, the samples were dried in an oven at 65°C for 24 hours in order to determine their dry weights (DW). RWC was calculated by using the following formula.
$$\text{RWC \%} = ((\text{FW}-\text{DW})/(\text{TW}-\text{DW})) * 100.$$



Plate 3: Strawberries grown with different type of mulches

Floral traits: Five randomly selected plants were chosen for each treatment and replication to record observations on flowering of the following attributes: days to flowering, number of flowers per plant, and flowering to fruit set period (in days).

Measurements of yield and yield traits: Yields per plant (g) were calculated by averaging the harvests of all five plants in each treatment and each replication to arrive at a total. Strawberry pickings were done every two days for a total of five to seven pickings. The weight of fruits (g) from each selected plant was measured using an electronic top pan balance on each date of harvest. The quantity of fruits/plants was determined by counting the ripe fruits.

Measurement of quality parameters

Total soluble solids content: The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: A digital pH meter was used to assess pH of individual treated strawberries' fruit juices (HI 2211; Romania).

Titrateable acidity (TA %): In order to measure titrateable acidity, a 5 g sample was macerated in a mortar and pestle. After filtering it and adding distilled water, the total volume was 100ml. A conical flask was then filled with 10 ml of the stock solution and 2 drops of phenolphthalein were added. 0.1N NaOH was used to titrate the solution. On the basis of triplicate analyses, the total acid content was calculated in maleic acid equivalents.

Vitamin C determination: The Oxidation-Reduction Titration Method (Tee *et al.*, 1988) was used to calculate the Vitamin C content of strawberries. The fruit was blended and filtered with Whatman No.1 filter paper. Oxalic acid (5%) was used to make a volume of 100ml. We used the dye solution 2, 6-dichlorophenol indophenol to carry out the titrations. L-ascorbic acid as the known sample, the mean observations provided the amount of dye required to oxidize an unknown concentration of a specific amount of L-ascorbic acid solution. 5ml of the solution was used for each titration, and the last point of titration was determined by the pink color, which lasted for 10 seconds. As a result, a burette reading was taken and stored.

Reducing sugars content: To measure reducing sugars, the phenol-sulfuric acid method was used (DuBois *et al.*, 1956). A total of 0.2 g fresh fruit was homogenized and the extract was filtered using deionized water. 0.4 ml of 5% phenol was added to 2 ml of the solution. The mixture was then quickly diluted with 2 ml of 98% sulphuric acid. The test tubes were kept at room temperature for 10 minutes before being placed in a water bath at 30°C for 20 minutes to allow for colour development. The spectrophotometer was used to measure the absorbance at 540 nm. The same method was used to make a blank solution, except that distilled water was used instead of fruit extract in this case. Reducing sugar content was expressed as mg g⁻¹ fresh weight (FW).

Anthocyanin content: 1.0 g fruit pulp mixed with 1 ml 85% ethanol + 15% HCl 1.5N. After the extraction, 1 mL of sample solution was taken and diluted to 10 ml. An absorbance measurement was performed at a wavelength of 535 nm. The anthocyanin concentration was calculated as follows: Anthocyanin (mg per 100 g fresh wt.) = (absorbance at 535nm x volume of extraction solution x 100)/ sample weight in g x 98.2. The same procedure as described above is used to prepare reference solutions, except that the fruit extract is replaced with distilled water (Lapornik *et al.*, 2005).

Phenolic content: The phenol content was determined by Singleton *et al.* (1999). Fresh fruits (250 mg) were homogenized in 85% methanol. The extract was centrifuged at 3,000 g for 15 minutes at 10°C and the supernatant was collected. A total of 2 ml of the supernatant has been added to 2 ml of Folin and Ciocalteu's reagent. Each test tube received a 7.5% sodium carbonate solution (2 ml), and after 30–45 minutes, the absorbance was measured at a wavelength of 725 nm against a reagent blank. A standard curve was created with gallic acid to determine the concentration of total phenols in the unknown sample.

Statistical analyses

A randomized complete block design (RCBD) was used in the experiments, with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with IBM SPSS Statistics 21 (IBM Corp, Armonk, NY, USA). When $P < 0.05$, the mean value across treatments was considered statistically significant. The replicated data was used to calculate the mean \pm SE for all results. The graphs were made with the Microsoft Excel program.

10.11. Effect of Pre-Harvest Cypermethrin Spray on Residual Level and Biochemical Attributes of Strawberry Fruit

Field Experiment: A supervised field trial was conducted in the experimental field of Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka. All the activities like seeding, transplanting and all other cultural operations were undertaken and performed by the field staffs of Horticulture Department of SAU. The synthetic pyrethroid pesticide, cypermethrin (ripcord 10EC) was selected for this experiment. When the fruits were at marketable size, ripcord 10EC was sprayed in the field by knapsac sprayer. The application rate was 1.5 mL/L of water. The pesticides were tank-mixed and applied to the plants following GAP.

Sampling and sample preservation: Samples of strawberry were collected at 0, 1, 3, 5, 7, 10 and 12 days after pesticide application from the experimental field of Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka. The samples were collected in clean transparent air tight polyethylene bag and each bag was properly labeled with sample number and the date of collection. Samples were collected in individual polyethylene bag to avoid across contamination. All the collected samples were carried to the Pesticide Analytical Laboratory, Entomology Division of Bangladesh Agricultural Research Institute (BARI), Gazipur. Pesticide standard stock solutions of cypermethrin was prepared in acetonitrile at a concentration of 1000 mg/L and stored at -20°C until use. A standard solution of 50 mg/L in acetonitrile was prepared by adding the appropriate volume of each individual stock solution in a 50 ml volumetric flask and made to volume by addition of acetonitrile. An intermediate standard solution of 10 mg/L in acetonitrile was prepared from the standard solution of 50 mg/L. Then working standard solutions of 0.1, 0.2, 0.5, 1.0, 2.0, 3.0, and 5.0 mg/L in acetonitrile were prepared by transferring the appropriate amount from 10 mg/L intermediate standard solution into seven separate 10-mL volumetric flasks. All the standard solutions were kept in a freezer at -20°C until use.



Plate 4: Homogenization of collected sample

Analysis of pesticide residue in strawberry: Pesticide residue analysis procedures are primarily divided into two parts. Extraction and cleaning of target analytes from the matrix, as well as detection of target analytes from the matrix.

Determination of the target analytes from the matrix: Determination of the selected pesticide (cypermethrin) was performed by Gas Chromatography (GC) with Electron Capture Detector (ECD).

Extraction and clean up: QuEChERS extraction method is one of the latest extraction and clean up techniques for pesticide residue analysis in food matrices which is an anagram for Quick, Easy, Cheap, Effective, Rugged and Safe. This techniques is gaining popularity day by day compared to the other existing techniques such as Supercritical Fluid Extraction (SFE), Liquid-liquid extraction (LLE), Solid phase extraction (SPE), Solid phase micro extraction (SPME), Stir bar sorptive extraction (SBSE), and Microwave assisted extraction (MAE). The technique uses a single extraction in acetonitrile and requires a very small amount of (10-15 gm) sample. A large excess of salts or buffers are added to extract to aid in the extraction of both polar and non-polar pesticide. This sample initial step simultaneously extract the pesticide from the samples and prepares it for the next dispersive solid phase extraction (d-SPE), the salts and SPE sorbents chosen for the d-SPE step serve to remove residual water and further remove matrix interference from the sample. The resulting acetonitrile extract is typically analyzed directly by gas chromatography (GC), gas chromatography-mass spectrometry (GC/MS) or liquid chromatography tandem mass spectrometry (LC/MS/MS) with proper dilution. In this study, the QuEChERS extraction technique was used for the extraction and clean-up of samples which was modified by Prodhan *et al.*, 2015. The chopped samples were grounded thoroughly with the fruit blender. A representative 10-g portion of thoroughly homogenized sample was weighted in a 50 mL polypropylene centrifuge tube. Then 10 mL of acetonitrile (MeCN) was added into the centrifuge tube. The centrifuge tube was closed properly and shaken vigorously for 30 s by the use of a vortex mixer. Then, 4 g of anhydrous MgSO₄ and 1 g of NaCl were added into the centrifuge tube, and it was shaken immediately by the vortex mixer for 1 minute to prevent the formation of magnesium sulfate aggregates. Afterwards, the extract was centrifuged for 5 min at 5000 rpm. An aliquot of 3 mL of the MeCN layer was transferred into a 15 mL micro centrifuge tube containing 600 mg anhydrous MgSO₄ and 120 mg Primary Secondary Amine (PSA). Then it was thoroughly mixed by vortex for 30 s and centrifuged for 5 minutes at 4000 rpm. (Centrifuges, Sigma-3K30, Germany). After centrifuge, a 1 mL supernatant was filtered by a 0.2 µm PTFE filter, and then it was taken in a clean HPLC vial for injection.

Table 2: The instrument parameters for GC-ECD

Instruments	Conditions
Injection port SPL	Injection mode: split; temperature:280°C; flow control mode: linear velocity; split ratio: 10:0
Detector channel 1 ECD	Temperature:300°C; current: 0.50 Pa; make up flow: 30 mL/min;

Table 3: Conditions for column oven temperature for cypermethrin determination

Column oven	Rate	Temperature (°C)	Hold time (min)
Initial temperature: 160°C	-	160	1
	10	270	8

Detection and Quantification of pesticide residue in samples: The concentrated extracts were subjected to analysis by GC-2010 (Shimadzu) with Electron Capture Detector (ECD) for the detection of cypermethrin. The capillary column was Rtx-CL Pesticides, with a length of 30 m, ID of 0.32 mm, and film thickness of 0.25 µm. Nitrogen was used as carrier and make up gas for GC-ECD. The identification of suspected pesticide was performed by peak retention times in samples to those of peaks in the pure analytical standards (Figure 1). Prior to injection of the sample extract, standard solutions of different concentrations were prepared and injected with the above instrument parameters. The samples were calibrated (retention

time, peak area etc.) against five pointed calibration curve of standard solution of concerned pesticide. Each peak was characterized by its retention time. Sample results were expressed in mg/kg automatically by the GC software. A typical chromatogram using all of the selected insecticides injected in GC-ECD is presented in figure 1.

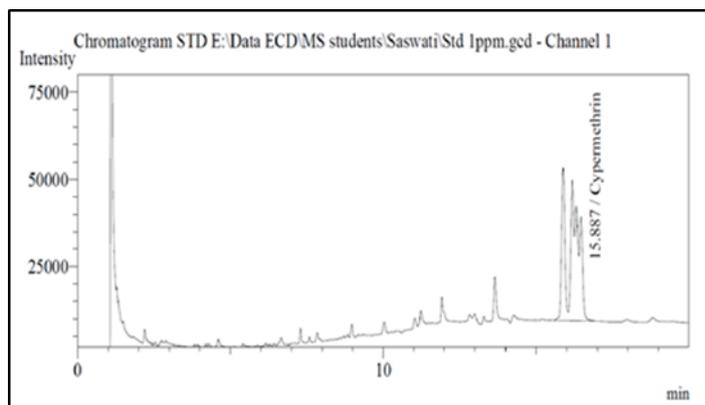


Figure 1: Typical Chromatogram of cypermethrin standard run by GC-ECD

Calibration curve preparation: Prior to the injection of the sample extract, standard solutions of different concentrations of cypermethrin were prepared and injected with suitable instrument parameters. The samples were calibrated (retention time, peak area etc.) against four pointed calibration curve of standard solution of concerned pesticide (Figure 2). Each peak was characterized by its retention time. Sample results were expressed in mg/kg automatically by the GC software. At first, the level of residues in all of the collected samples for tested pesticide was determined and the PHI was calculated by the following procedures. Firstly, the sampling day which was next following MRL was selected. That selected day was chosen as PHI, since the level of residue on that day was below MRL.

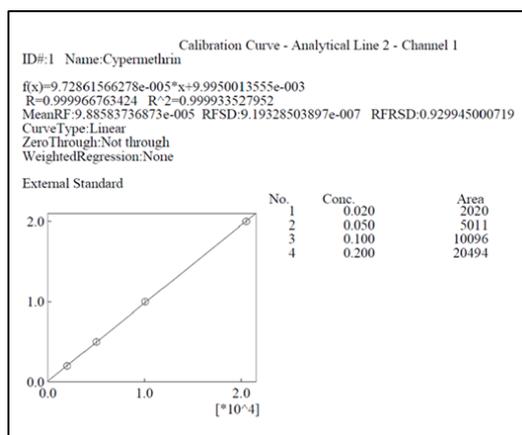


Figure 2: Calibration curve of cypermethrin standard ranging from 0.02 mg/kg to 0.2 mg/kg.

Determination of Pre Harvest Interval **Quality parameters**

Total soluble solids content: The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained with a dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

Titrate acidity (TA %): The mortar and pestle were macerated for the determination of the 5g sample. Then they filtered it and added distilled water, which rendered 100ml of total volume. Then 10ml of stock solution was taken in a conical flask and 2 drops of phenolphthalein were added. The solution was titrated with .1N NaOH. The titrate colour will be rosy pink and the reading was recorded. The titration was done three times.

Ascorbic acid determination: Tee *et al.* (1988) method was used to calculate the Vitamin C content of papaya. The single fruit was mixed and filtrated with filter paper Whatman No.1. The volume was made up to 100ml with a 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 an unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic acid as a known sample. A 5ml solution was taken for titration each time, and the pink colour determined the last point of titration, which remained for 10 seconds. The burette reading was recorded.

Phenolic content: The content of phenols was calculated using the Singleton *et al.* (1999) process. Fresh fruits (250 mg) were homogenized with methanol (85%). At 10°C, the extract was centrifuged at 3,000 g for 15 min and separated the supernatant. Folinand 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.

Statistical analyses

Statistical analyses were conducted with IBM SPSS Statistics 21 (IBM Corp, Armonk, NY, USA). When $P < 0.05$, the mean value across treatments was considered statistically significant. The replicated data was used to calculate the mean \pm SE for all results. The graphs were made with the Microsoft Excel program.

10.12. Effect of Maleic Hydrazide and Potassium Foliar Spray on Sex Expression, Yield and Quality Enhancement of Muskmelon

Plant materials and growing conditions: The experiment was carried out in a net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh under natural lighting conditions, with different day/night temperatures. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The seed of F1 hybrid muskmelon (crystal) was obtained from Siddique Bazar, Dhaka, Bangladesh. The seeds were sown in Poly (vinyl) chloride (PVC) tanks (1.2×0.6×0.6 m) using soil mixture with slow releasing mixed fertilizers. At 20th days after sowing (DAS), healthy uniform seedlings were transplanted to the net house under raised bed at 90 cm × 90 cm spacing. The average minimum and maximum temperatures were 18.5 and 30.4°C respectively, and the average relative humidity was 60% during the experimental period February-May 2020. All essential cultural practices and plant protection measures were followed uniformly for all the plots throughout the experiment.

Treatments and sample collection: The experiment was laid out in a randomized block design with three replications and consisted of four treatments; namely maleic hydrazid (150ppm), potassium (800 ppm), maleic hydrazid + potassium (150 ppm + 800 ppm) and control. Two

foliar sprays of maleic hydrazide were done at 3 and 5 true leaf stages of crop and potassium was given 3 times at 10 days interval after fruit set till the fruit maturation. The foliar solutions were formulated in accordance with manufacturer recommendations. Control plants were sprayed with distilled water together with ensuring all essential cultural practices and plant protection measures uniformly for all the plots of each treatment. Four vines were selected randomly from each treatment of each replication to record the observations on growth, flowering, sex expression, yield and quality attributes.

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

Morphological traits: Four plants in each treatment and each replication were used for plant height, number of leaf and number of branch at harvest. Plant height was measured from the base of the plant to the top of the plant.

Floral traits: Four vines were selected randomly from each treatment and each replication to record the observations on flowering and sex expression covering the following attributes: number of pistillate flowers per plant, number of staminate flowers per plant, period from sowing to the emergence of the first pistillate flower (in days), period from sowing to the emergence of the first staminate flower (in days).

Fruit yield and yield traits: The yield/plant (kg) was recorded by adding yield of all the harvests obtained from five plants in each treatment and each replication. The weight of fruits (kg) 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.

Total soluble solids content: The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juices of individual treatment strawberries were filtered separately, and pH was measured using a digital pH meter (HI 2211; Romania).

Titrate 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 phenolphthelin was added. The solution was titrated with .1N NaOH. When the titrate colour turned rosy pink, the reading was recorded. The titration was repeated for three times.

Vitamin C determination: Oxidation Reduction Titration Method (Tee *et al.*, 1988) was used to calculate the Vitamin C content of muskmelon. 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. Solution measuring 5ml was taken for titration each time and pink colour determined the last point of titration which remains for 10seconds. The burette reading was recorded.

β-carotene content: β-carotene in muskmelon pulp was determined according to the method of (Nagata and Yamashita, 1992). One gram of pulp was mixed with 10 ml of acetone: hexane mixture (4:6) and vortex for 5 minutes. The mixture was filtered and absorbance was measured at 453nm, 505nm and 663nm wave length. The calculation was done by following formula:

$$\beta\text{-carotene (mg/100gm)} = 0.216 A_{663} - 0.304 A_{505} + 0.452 A_{453}$$

Reducing sugars content: Determination of reducing sugars was based on the phenol-sulphuric acid method (DuBois *et al.*, 1956). With deionized water a total of 0.2 g fresh fruit was homogenized and the extract was filtered out. 2 ml of the solution was combined with 0.4 ml of 5% of phenol. Subsequently, the mixture was rapidly added to 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 20min. Light absorption with the spectrophotometer was then measured at 540 nm. A blank solution was prepared in the same manner as described above, except that the fruit extract was replaced with distilled water. Reducing sugar content was expressed as mg g⁻¹ fresh weight (FW).

Statistical analyses

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

10.13. Effect of Plant Growth Regulators and Pruning Levels on Sex Expression, Yield and Quality in Watermelon

Plant materials and growing conditions: The experiment was carried out in a net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh under natural lighting condition. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The seeds of water melon variety (Red star) were obtained from Siddique Bazar, Dhaka, Bangladesh. The seeds were sown in Poly vinyl chloride (PVC) tanks (1.2×0.6×0.6 m) using soil mixture with slow releasing mixed fertilizers. At 20th days after sowing (DAS), healthy uniform seedlings were transplanted to the net house under raised bed at 90 cm × 90 cm spacing. The average minimum and maximum temperatures were 21±2°C and 31±2°C respectively, and the average relative humidity was 65% during the experimental period February-May 2021. All essential cultural practices and plant protection measures were followed uniformly for all the plots throughout the experiment.

Treatments and sample collection: The treatment comprised of two pruning and three growth regulators treatments. The experiment was conducted in randomized complete block design (RCBD) with three replications of each treatment. The plants were pruned at fourth week after planting. Secateurs were used to prune the main branch of the plant. Three growth regulators namely, GA3 (150 ppm), ethephon (100 ppm) and maleic hydrazide (MZ) (200 ppm) were used. Two sprays of plant growth regulators were done at 2nd and 4th true leaf stages during morning hours till the both sides of leaves completely wet. The plants

were pruned at fourth week after planting. Secateurs were used to prune the main branch of the plant. Total six treatments were tried including control. The treatments were consisted of T₀ (control), T₁ (GA₃+no pruning), T₂ (MZ + no pruning), T₃ (ethephon + no pruning), T₄ (vine pruning), T₅ (GA₃+ pruning), T₆ (MZ + pruning), T₇ (Ethephon + pruning).

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

Morphological traits: Four plants in each treatment and each replication were used for vine length and number of branch at harvest. Plant height was measured from the base of the plant to the top of the plant.

Floral traits: Four vines were selected randomly from each treatment and each replication to record the observations on flowering and sex expression covering the following attributes: number of pistillate flowers per plant, number of staminate flowers per plant, period from sowing to the emergence of the first pistillate flower (in days), period from sowing to the emergence of the first staminate flower (in days).

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

Quality parameters

Total soluble solids content (TSS): The TSS content of watermelon was measured by a digital refractometer (MA871; Romania). A drop of watermelon juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juices of individual treatment watermelons were filtered separately, and pH was measured using a digital pH meter (HI 2211; Romania).

Titrate 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 10 ml of stock solution was taken in conical flask and 2 drops of phenolphthelin was added. The solution was titrated with 0.1N NaOH. When the titrate colour turned rosy pink, the reading was recorded. The titration was repeated for three times.

Vitamin C determination: Oxidation Reduction Titration Method (Tee *et al.*, 1988) was used to calculate the Vitamin C content of watermelon. 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. Solution measuring 5ml was taken for titration each time and pink colour determined the last point of titration which remains for 10seconds. The burette reading was recorded.

β-carotene content: β-carotene in watermelon pulp was determined according to the method of (Nagata and Yamashita, 1992). One gram of pulp was mixed with 10 ml of

acetone: hexane mixture (4:6) and vortex for 5 minutes. The mixture was filtered and absorbance was measured at 453nm, 505nm and 663nm wave length. The calculation was done by following formula:

$$\beta\text{-carotene (mg/100gm)} = 0.216 A_{663} - 0.304 A_{505} + 0.452 A_{453}$$

Total sugar: Two banana pulps were cut into small pieces and immediately plunged into boiling ethyl alcohol and were allowed to for 10 minutes (10 ml of alcohol was used per g of pulp). The extract was filtered through two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3ml of alcohol per g of tissue. The extract was cooled and passed through two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to 25% of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

$$\text{Total sugar (\%)} = \text{Amount of sugar obtained / Weight of sample} \times 100$$

Reducing sugar: Aliquot of 3ml of the extract was pipette into a test tube and 3ml of DNS reagent was added to each of those solutions and mixed well. The test tube was heated for 5 minutes in a boiling water bath. After the colour has developed, 1ml of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter.

$$\text{Reducing sugar (\%)} = \text{Amount of reducing sugar obtained / Weight of sample} \times 100$$

Non-reducing sugar: Non-reducing sugar content of banana pulp was calculated by using the following formula:

$$\% \text{ non-reducing sugar} = \% \text{ total sugar} - \% \text{ reducing sugar}$$

Statistical analyses: The experiments used a randomized complete block design (RCBD) with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with version 9.4 of the Statistical Analysis System (SAS) (SAS Institute, Cary NC, USA). The mean value among the treatments were considered to be statistically significant when $P < 0.05$. All results were presented with mean \pm SE from the replicates. Graphs were drawn using the Microsoft excel. ANOVA was used to test the effect of maleic hydrazide and potassium on sex expression, yield and quality parameters of watermelon.

10.14. Effect of Different Sheds on Growth, Yield and Quality of Papaya

Plant materials and growing conditions: During February to October 2020, the experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an average elevation of 4 meters (13.12 ft.) according to the National Mapping Organization of Bangladesh. The papaya cv. Red Lily was planted at 1.2 m \times 1.2 m spacing under four environments, i.e. open field condition (control), net house naturally ventilated polyhouse (entire roof and half the portion of four sides covered with poly sheet, the remaining half covered with 25% shed net) and Fan pad UV polyhouse (fully covered with UV film sheet). The experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on fruit production, yield, and physio-chemical parameters. Temperature and

relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions in which the plants were grown.

Measurement of Growth Parameters: Five plants in each treatment and each replication were used for plant height, leaf number, plant diameter, and leaf chlorophyll content at flowering, fruiting, and harvesting stages. Plant height was measured from the base of the plant to the top of the main plant. The diameter of each plant was measured from a height of 10 cm above the ground.

SPAD chlorophyll meter reading: Leaf chlorophyll content was measured using a SPAD-502 chlorophyll meter on the first fully expanded leaves (Minolta, Tokyo, Japan). In each shed house, the measurements were obtained from the center of the leaf lamina of five randomly selected plants.

Measurement of yield Parameters: Days to flower initiation were recorded for all the selected five plants in each treatment and each replication. The number of fruits/plant was recorded by counting the fruits that reached harvestable ripeness. The weight of fruits (g) from each selected plant was taken on each date of harvest with the help of an electronic top pan balance. The yield/plant (kg) was recorded by adding the yield of all the harvests obtained from selected plants in each treatment and each replication.

Measurement of biochemical Parameters

Total soluble solids content: The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained with a dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juices of individual treated strawberries were filtered separately, and pH was measured using a digital pH meter (HI 2211; Romania).

Titrate acidity (TA %): The mortar and pestle were macerated for the determination of the 5g sample. Then they filtered it and added distilled water, which rendered 100ml of total volume. Then 10ml of stock solution was taken in a conical flask and 2 drops of phenolphthalein were added. The solution was titrated with .1N NaOH. The titrate colour will be rosy pink and the reading was recorded. The titration was done three times.

Ascorbic acid determination: Tee et al. (1988) method was used to calculate the Vitamin C content of papaya. The single fruit was mixed and filtrated with filter paper Whatman No.1. The volume was made up to 100ml with a 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 an unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic acid as a known sample. A 5ml solution was taken for titration each time, and the pink colour determined the last point of titration, which remained for 10 seconds. The burette reading was recorded.

Phenolic content: The content of phenols was calculated using the Singleton *et al.* (1999) process. Fresh fruits (250 mg) were homogenized with methanol (85%). At 10°C, the extract was centrifuged at 3,000 g for 15 min and separated the supernatant. Folinand Ciocalteu's reagent (2 ml) has been added to the supernatant per 2 ml. A sodium carbonate solution was applied to each test tube (7.5%, 2 ml) and after 30–45 min, the absorbance was read against a

reagent blank at a wave length of 725 nm. To determine the concentration of total phenols in the unknown sample, a standard curve was generated using gallic acid.

Reducing sugars content: Reducing sugars were determined based on the method of phenol-sulphuric acid (DuBois *et al.*, 1956) with a few modifications such as the assay volume and wavelength. 0.2 g fresh leaf was homogenized with deionized water, and the extract was filtered. 2 ml of the solution was mixed with 0.4 ml of 5% phenol. Subsequently, 2 ml of 98% sulphuric acid was added rapidly to the mixture. The test tubes were allowed to rest for 10 min at room temperature and placed in a water bath at 30°C for 20 min for color development. Light absorption at 540 nm was then recorded with the spectrophotometer. A blank solution (distilled water) was prepared in the same way as above. The content of reducing sugars was expressed as mg g⁻¹ FW.

β-carotene content: The amount of beta-carotene in tomatoes was determined using the method of (Nagata and Yamashita 1992). One gram of pulp was combined with 10ml of an acetone-hexane (4:6) mixture and vortexed for 5 minutes. The mixture was filtered, and absorbance was measured at wave lengths of 453nm, 505nm, and 663nm. The estimation was done by following method:

$$\beta\text{-carotene (mg/100gm)} = 0.216 A_{663} - 0.304 A_{505} + 0.452 A_{453}$$

Color measurement: The papaya skin colors were measured nondestructively using a Minolta Chroma meter (Model CR400), which was set up with a D65 illuminant and 10° observer angle. The color values were recorded as L*, a*, b* and C*. The reading was set to take an average of 6 random points per fruit. The instrument must be completely in contact with the fruits to avoid any light leakage from the light emitted by the colorimeter.

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

10.15. Effect of Maturity Stage of Papaya on Physiological and Biochemical Parameters Under Protective Cultivation

Papaya fruit (cv. Red Lady) were harvested in September, 2021 grown in net house and open field condition from Horticulture Farm, Sher-e-Bangla Agricultural University at maturity stage 1, 2, 3 and 4. Fruits were then transported at the Postharvest Laboratory of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The maturity stages were visually defined according to the skin color as: 25% skin color (stage 1), stage 2-50% skin color (stage 2), 75% skin color (stage 3) and 90% skin color (stage 4). The experiment was laid out in a completely randomized design (CRD) with 3 replications of 5 fruits per replication. Fruits were kept in room temperature (23 ± 2°C) until fruit skin color reach at stage 4 and inspected daily for visual change in color. Measurement of color, TSS, pH, vitamin c, reducing sugar, titratable acidity, β-carotene were performed when all the fruits reached at stage 4 (fully ripen).

Fruit weight (g): A top loading electric balance was used for measuring total fruit weight in grams (g).

Total weight loss: Weight losses of fruits as influenced by maturity stages were estimated using the following formula:

$$\text{Weight loss (\%)} = \frac{IW-FW}{FW} \times 100$$

Where,

IW = Initial fruit weights (g) and

FW= Final fruit weight (g)

Color: The changes of external color of papaya was determined by HunterLab Colorimeter and data reported as L*, a* and b* values of Cielab scale (McGuire, 1992). Skin color was measured with six readings near the peduncle, the center and the apex on opposite sides of the fruit.

Total soluble solid (TSS%): At room temperature, the total soluble solids of well mixed papaya fruit pulp were directly measured using a hand refractometer (Model BS Eclipse 3-45) as suggested by Ranganna (1986). A drop of fruit pulp was placed on the refractometer's prism, and the reading was taken. The percentage soluble solids (°Brix) was used to express the results.

p^H: pH was measured using a phs-25 p^H meter. An electrolytic cell comprise of two electrodes (calomel electrode and glass electrode) was standardized with buffer solution of p^H 7.00 and 4.01.

Titrateable acidity of pulp: The acidity of fruit was estimated by titrating the fruit pulp extract with 0.1 N sodium hydroxide using phenolphthalein as indicator (Ranganna, 2004).

Ascorbic acid content: Ascorbic acid content (ascorbic acid) was estimated by using 2, 6-Dichlorophenol indophenol (DCPIP) visual titration method (Ranganna, 2004).

Reducing sugar content: The di-nitro-salicylic acid technique was used to measure the reducing sugar content of papaya pulp (Miller, 1972).

β-carotene content: β-carotene in mango pulp was determined according to the method of (Nagata and Yamashita, 1992). One gram of pulp was mixed with 10 ml of acetone: hexane mixture (4:6) and vortex for 5 minutes. The mixture was filtered and absorbance was measured at 453nm, 505nm and 663nm wave length. The calculation was done by following method:

$$\beta\text{-carotene (mg/100gm)} = 0.216 A_{663} - 0.304 A_{505} + 0.452 A_{453}$$

Statistical analysis: The collected data were statistically analyzed by STATISTIX 10 software. The significance of difference between the pairs of means was compared by least significant difference (LSD) test at the 1% level of probability.

10.16. Effect of Different Growing Environment on Growth Yield and Quality of Banana

Plant materials and growing conditions: This experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from February to October 2021. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an

average elevation of 4 meters (13.12 ft.) according to the National Mapping Organization of Bangladesh. The banana cv. BARI khola 1 was planted at 1.2 m × 1.2 m spacing under four protected cultivation system, those are open field condition (control), net house (60 mesh), poly shed house (naturally ventilated polyhouse; 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 polyhouse; fully covered with UV film sheet). The experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on fruit production, yield, and physio-chemical parameters. Three fruits from each plant and each treatment were harvested for various biochemical analyses. Temperature and relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions in which the plants were grown.

Measurement of Growth Parameters: Five plants in each treatment and each replication were used for pseudo stem length, stem diameter, and leaf chlorophyll content at flowering stages. Plant height was measured from the base of the plant to the top of the plant. The stem diameter of each plant was measured from a height of 10 cm above the ground.

SPAD chlorophyll meter reading: Leaf chlorophyll content was measured using a SPAD-502 chlorophyll meter on the first fully expanded leaves (Minolta, Tokyo, Japan). In each shed house, the measurements were obtained from the center of the leaf lamina of five randomly selected plants.

Measurement of yield contributing parameters: Days to flower initiation were recorded for all the selected five plants in each treatment. The number of hands/bunch, number of fingers/hand, number of fingers/bunch was recorded by counting the fruits that reached harvestable ripeness. The weight of individual fruits (g), fruit length, breadth, diameter and pulp: peel from each selected hand was taken with the help of an electronic top pan balance and slide calipers.

Measurement of biochemical Parameters

Total soluble solids (TSS) content: The TSS content of banana was measured by a digital refractometer (MA871; Romania). A drop of banana juice was obtained with a dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH determination: The fruit juices of individual treated strawberries were filtered separately, and pH was measured using a digital pH meter (HI 2211; Romania).

Titrateable acidity (TA %) : The fruit samples (5g) were macerated by the mortar and pestle for the determination of the TA. After macerated, samples were filtered and added water to make 100 ml of volume. Then 10 ml of stock solution was taken in a conical flask and 2 drops of phenolphthelin were added. The solution was titrated three time with 1N NaOH. The titration was stopped until the pink color appeared.

Vitamin C determination: The Vitamin C content of banana was calculated using the technique of Tee *et al.* (1988). A 5gm banana fruit sample was blended, and the juice was sieved with filter paper (Whatman No. 1). The volume was made up to 100 ml by adding 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 an unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic

acid standard. A 5ml solution was taken for titration each time, and the pink color determined the last point of titration, which remained for 10 seconds.

Total sugar: Two banana pulps were cut into small pieces and immediately plunged into boiling ethyl alcohol and were allowed to for 10 minutes (10 ml of alcohol was used per g of pulp). The extract was filtered through two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3ml of alcohol per g of tissue. The extract was cooled and passed through two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to 25% of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

Total sugar (%) = Amount of sugar obtained/ Weight of sample×100

Reducing sugar: Aliquot of 3ml of the extract was pipette into a test tube and 3ml of DNS reagent was added to each of those solutions and mixed well. The test tube was heated for 5 minutes in a boiling water bath. After the colour has developed, 1ml of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter.

Reducing sugar (%) = Amount of reducing sugar obtained/ Weight of sample×100

Non-reducing sugar: Non-reducing sugar content of banana pulp was calculated by using the following formula:

% non-reducing sugar = % total sugar - % reducing sugar

Color measurement: The banana skin colors were measured nondestructively using a Minolta Chroma meter (Model CR400), which was set up with a D65 illuminant and 10° observer angle. The color values were recorded as L*, a*, b* and C*. The reading was set to take an average of 6 random points per fruit. The instrument must be completely in contact with the fruits to avoid any light leakage from the light emitted by the colorimeter.

Statistical analyses: The experiments used a randomized complete block design (RCBD) with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with version 9.4 of the Statistical Analysis System (SAS) (SAS Institute, Cary NC, USA). The mean value among the treatments was statistically significant when P 0.05. All results were presented with the mean standard error (SE) from the replicates.

10.17. Effect of Maturity Stage of Banana on Physiological and Biochemical Parameters Under Protective Cultivation

Banana fruit (cv. BARI Khola 1) were harvested in October, 2021 grown in open field, uv poly shed and net poly shed condition from Horticulture Farm, Sher-e-Bangla Agricultural University at under mature (the angles are becoming less prominent), mature (disappeared angularity) and over mature stage (the skin colour changes from green to yellow). Fruits were then transported at the Postharvest Laboratory of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in a completely randomized design (CRD) with 3 replications of 5 fruits per replication. Fruits were kept in room temperature (25 ± 2°C) until fruit skin color reach to yellow and inspected daily for visual change in color.

Total soluble solid (TSS%): At room temperature, the total soluble solids of well mixed papaya fruit pulp were directly measured using a hand refractometer (Model BS Eclipse 3-45) as suggested by Ranganna (1986). A drop of fruit pulp was placed on the refractometer's prism, and the reading was taken. The percentage soluble solids (°Brix) was used to express the results.

p^H: pH was measured using a phs-25 p^H meter. An electrolytic cell comprise of two electrodes (calomel electrode and glass electrode) was standardized with buffer solution of p^H 7.00 and 4.01.

Titrateable acidity of pulp: The acidity of fruit was estimated by titrating the fruit pulp extract with 0.1 N sodium hydroxide using phenolphthalein as indicator (Ranganna, 2004).

Ascorbic acid content: Ascorbic acid content (ascorbic acid) was estimated by using 2, 6-Dichlorophenol indophenol (DCPIP) visual titration method (Ranganna, 2004).

Total sugar :Two banana pulps were cut into small pieces and immediately plunged into boiling ethyl alcohol and were allowed to for 10 minutes (10 ml of alcohol was used per g of pulp). The extract was filtered through two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3ml of alcohol per g of tissue. The extract was cooled and passed through two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to 25% of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

Total sugar (%) = Amount of sugar obtained/ Weight of sample×100

Reducing sugar: Aliquot of 3ml of the extract was pipette into a test tube and 3ml of DNS reagent was added to each of those solutions and mixed well. The test tube was heated for 5 minutes in a boiling water bath. After the colour has developed, 1ml of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter.

Reducing sugar (%) = Amount of reducing sugar obtained/ Weight of sample×100

Non-reducing sugar: Non-reducing sugar content of banana pulp was calculated by using the following formula:

% non-reducing sugar = % total sugar - % reducing sugar

Color: The changes of external color of papaya was determined by HunterLab Colorimeter and data reported as L*, a* and b* values of Cielab scale (McGuire, 1992). Skin color was measured with six readings near the peduncle, the center and the apex on opposite sides of the fruit.

Statistical analysis: The collected data were statistically analyzed by STATISTIX 10 software. The significance of difference between the pairs of means was compared by least significant difference (LSD) test at the 1% level of probability.

10.18. Effect of Different Planting Materials and Nutrient Management of Banana Fruits

Experimental site: The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka 1207 during the period from March 2020 to April 2021. The location of the experimental site is situated in 23⁰74' N latitude and 90⁰35' E longitude with an elevation of 8 meter from sea level (Anon, 1989) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

Characteristics of soil: The soil of the experimental area belongs to the Modhupur Tract (UNDP-FAO, 1988) under AEZ No. 28. The selected plot was medium high land and the soil series was Tejgaon. The *soil texture of the experimental soil was sandy loam.*

Climatic condition of the experimental site: The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October.

Planting materials: The corm and tissue culture plantlet of variety BARI kola-1 was collected from Bangladesh Agricultural Research Institute (BARI), Joydepur, Gajipur.

Treatments of the experiment

The experiment comprised of two factors.

Factor A: Planting materials

In experiment, two different planting materials were used. These were –

- i. Tissue culture plantlets
- ii. Corm

Factor B: Organic and inorganic fertilizers

- i. Cowdung
- ii. Vermicompost
- iii. Spent mushroom compost
- iv. NPK

Treatment combination: P₁M₁, P₁M₂, P₁M₃, P₁M₄, P₂M₁, P₂M₂, P₂M₃, P₂M₄.

Fertilizers were collected from Jannat Nursery, Agargaon, Dhaka except Spent mushroom compost. Spent mushroom compost was collected from National Mushroom Development and Extension center, Savar, Dhaka.

Design and layout of the experiment: The experiment was set in Factorial experiment with a Randomized Block design with 3 replications.

Production methodology

The experimental field was thoroughly ploughed up to depth of 30 cm and harrowed twice to get a fine tilth. The field was levelled and divided into plots as per the experimental layout.

Digging of pits: Pits of 45 x 45 x 45 cm size were dug at a spacing of 1.5 x 1.5 m and were allowed to expose to the sunlight for one week before planting of corm and tissue culture saplings.

Soil analysis: To determine soil type, pH, organic matter content and macro and micro nutrients of soil, composite soil samples were collected from 0 to 20 cm depth of the experimental field and were analyzed in soil testing laboratory, SRDI, Dhaka.

Quantities of organic manures and inorganic fertilizers: The recommended dose of organic manures and inorganic fertilizers were applied twice. 3 kg cowdung, 3 kg vermicompost, 3

kg spent mushroom compost and (55: 30: 30 g NPK) per pit were applied before planting and second dose of 2 kg cowdung, 2 kg vermicompost, 2 kg spent mushroom compost and (30: 25: 25 g NPK) per plant were applied after 4 months of transplanting. The amount of organic manures required was calculated as per the available nitrogen content in the respective organic manures and were applied as per the treatments.

Method of manure and fertilizer application: All organic fertilizers used were applied twice, mixed in with the top 20 cm of the soil in the planting hole ('Mixed application') before planting and in a ring at a depth of 20 cm in the planting hole ('Ring application'), four month prior to planting of corm and tissue culture plantlets. The holes were then irrigated once to allow for initial release of nutrients. Inorganic fertilizers (N: urea; P: triple super phosphate; and K: muriate of potash) were applied spreading on the soil surface around the plant at a distance of approx. 30 cm from the base of the plant and mixed into the top layer of the soil by hand ('Mixed application').

Planting of saplings: Corm and tissue culture plantlets were planted in the pits during the months of March after application of manures like cowdung, vermicompost and spent mushroom compost and NPK fertilizers and light irrigation was given after planting.

Inter cultural operations

Weeding: The field was properly hoed and weeds were removed. The base of the plant was made weed free. Weeding was done at monthly interval.

De-suckering: The suckers arising from the base of the plants were discouraged for its growth and only main plant was allowed to grow. The dried and matured leaves were removed from the plants at monthly interval

Earthing up: The base of the plants was properly hoed and the soil was applied to the base of the plant. The basin was prepared from time to time as per growth of the plant.

Plant protection measure: Plant protection measures against leaf spot disease of banana were taken at monthly interval by spraying Indofil-M-45 @ 30g/10l of water.

Parameters

Data were collected in respect of following parameters:

- i. Growth related parameters
 - a) Number of leaves
 - b) Chlorophyll content
 - c) Stem diameter (cm)
 - d) Days to inflorescence initiation
 - e) Days to maturation
 - f) Length of inflorescence (cm)
 - g) First hand to last hand length (cm)
- ii. Yield related parameters
 - a) Total number of hands
 - b) Total number of fingers
 - c) Individual fruit weight (g)
- iii. Quality related parameters
 - a) TSS%
 - b) pH
 - c) Titratable acidity %
 - d) Ascorbic acid content (mg/100g)

- e) Total sugar %
- f) Reducing sugar %
- g) Peel colour

Data collection

Number of green leaves: Number of green leaves per plant was recorded at harvesting stage of banana on the tagged plant as per experimental treatments.

Pseu-stem diameter: Pseudo-stem diameter was measured in centimeter (cm) through the measuring tape and data were taken at harvesting stage of banana.

Chlorophyll content: Before measurement SPAD-502 meter was calibrated using the reading checker supplied by the manufacturer. Each leaf SPAD value obtained was the average of 10 readings (5 on each side of leaf midrib), and then for each extract, two chlorophyll determinations were performed (Leon *et al.*, 2007).

Days to inflorescence initiation and days to maturation: Days to inflorescence initiation (visual observation), and maturation were counted the days from the date of corm sowing and tissue culture plantlets transplanting.

First hand to last hand length: First hand to last hand length was measured through measuring tape at harvesting stage.

Total number of fingers: The number of fingers per bunch was recorded by counting all the fingers in each bunch of tagged plants and the average number of fingers per bunch were calculated and expressed in number.

Total soluble solid (TSS%): At room temperature, the total soluble solids of well mixed papaya fruit pulp were directly measured using a hand refractometer (Model BS Eclipse 3-45) as suggested by Ranganna (1986). A drop of fruit pulp was placed on the refractometer's prism, and the reading was taken. The percentage soluble solids (°Brix) were used to express the results.

p^H: pH was measured using a phs-25 p^H meter. An electrolytic cell comprise of two electrodes (calomel electrode and glass electrode) was standardized with buffer solution of p^H 7.00 and 4.01.

Titrateable acidity of pulp: The acidity of fruit was estimated by titrating the fruit pulp extract with 0.1 N sodium hydroxide using phenolphthalein as indicator (Ranganna, 2004).

Ascorbic acid content: Ascorbic acid content (ascorbic acid) was estimated by using 2, 6-Dichlorophenol indophenol (DCPIP) visual titration method (Ranganna, 2004).

Total sugar: Two banana pulps were cut into small pieces and immediately plunged into boiling ethyl alcohol and were allowed to for 10 minutes (10 ml of alcohol was used per g of pulp). The extract was filtered through two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3ml of alcohol per g of tissue. The extract was cooled and passed through two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to 25% of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

Total sugar (%) = Amount of sugar obtained/ Weight of sample×100

Reducing sugar: Aliquot of 3ml of the extract was pipette into a test tube and 3ml of DNS reagent was added to each of those solutions and mixed well. The test tube was heated for 5 minutes in a boiling water bath. After the colour has developed, 1ml of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter.

Reducing sugar (%) = Amount of reducing sugar obtained/ Weight of sample×100

Colour measurement: The changes of external color of banana was determined by HunterLab Colorimeter and data reported as L*, a* and b* values of Cielab scale (McGuire, 1992). Skin color was measured with six readings near the peduncle, the center and the apex on opposite sides of the fruit.

Statistical analysis: The collected data were statistically analyzed by STATISTIX 10 software. The significance of difference between the pairs of means was compared by least significant difference (LSD) test at the 1% level of probability (Gomez and Gomez, 1984).

10.19. Yield and Quality of Dragon Fruits as Influenced by Different Protective Cultivation Approaches

Plant Materials, growing conditions and treatment: This experiment was carried out at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the summer of 2019. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and has an average elevation of 4 m (13.12 ft.) according to the National Mapping Organization of Bangladesh. One-year-old red-fleshed dragon fruits cv. 'Da Hong' pitaya plants were planted on a single-pole system (three plants per pole) at 3 × 2.5 m spacing under four protected cultivation systems, namely open field condition (control), net house (60 mesh), net poly house (entire roof covered with poly sheet and full portion of four sides covered with net), and UV poly shed house (Fan pad UV poly house; fully covered with UV film sheet). The experiment was laid out with 4 treatments with 3 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the replications. Fruits from each plant and each treatment were harvested for various biochemical analyses. Temperature and relative humidity were recorded during the growing period in all environments to monitor the actual environmental conditions in which the plants were grown.

Measurement of Yield Parameters: Days to flower initiation were recorded in three poles plant in each treatment. The number of fruits/plants was recorded by counting the fruits that reached harvestable ripeness. The weight of fruits (g) from each selected plant was taken on each date of harvest with the help of an electronic top pan balance. The number of fruits/three plants/pole was recorded by counting the fruits that reached harvestable ripeness. The yield/three plants/pole (kg) was recorded by adding the yield of all the harvests obtained from the plants/pole in each treatment.

Measurement of Biochemical Parameters

Total Soluble Solids (TSS) Content: The TSS content of dragon fruit was measured by a digital refractometer (MA871; Bucharest, Romania). A drop of dragon fruit juice was

obtained with a dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

pH Determination: The fruit juices of individual treated dragon fruit plants were filtered separately, and pH was measured using a digital pH meter (HI 2211; Bucharest, Romania).

Titrateable Acidity (TA %): The leaf samples (5 g) were macerated by the mortar and pestle for the determination of the TA. After maceration, samples were filtered, and water added to make 100 mL of volume. Then, 10 mL of stock solution was taken in a conical flask and 2 drops of phenolphthalein were added. The solution was titrated three times with 1N NaOH. The titration was stopped until the pink color appeared.

Ascorbic acid content: The vitamin C content of dragon fruit was calculated using the technique of Tee *et al.* (1988). A 5 g dragon fruit fruit sample was blended, and the juice was sieved with filter paper (Whatman No. 1). The volume was made up to 100 mL by adding 5% oxalic acid solution. Titration was performed with dye solution 2, 6-dichlorophenol indophenol. The mean observations provided the amount of dye required to oxidize an unknown concentration of a definite amount of L-ascorbic acid solution, using L-ascorbic acid standard. A 5 mL solution was taken for titration each time, and the pink color determined the last point of titration, which remained for 10 s.

Anthocyanin content: 1g fruit pulp mixed with 1 ml 85% ethanol + 15% HCl 1.5N. After the extraction 1 ml sample solution was taken and then dilutes to 10 ml. The same procedure is used to prepare reference solutions as described above, except that the fruit extract is replaced with distilled water (Lapornik *et al.*, 2005).The absorbance reading was taken at 535nm. Then calculated the anthocyanin concentration as follows:

Anthocyanin (mg/100 g fresh wt.) = (absorbance at 535nm x volume of extraction solution x 100)/ wt. of the sample in g x 98.2.

Total sugar: Two banana pulps were cut into small pieces and immediately plunged into boiling ethyl alcohol and were allowed to for 10 minutes (10 ml of alcohol was used per g of pulp). The extract was filtered through two layers of cloths and the ground tissue was re-extracted for 3 minutes in hot 80% alcohols, using 2 to 3ml of alcohol per g of tissue. The extract was cooled and passed through two layers of cloths. Both of the extracts were filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to 25% of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

Total sugar (%) = Amount of sugar obtained/ Weight of sample×100

*Reducing sugar:*Aliquot of 3ml of the extract was pipette into a test tube and 3ml of DNS reagent was added to each of those solutions and mixed well. The test tube was heated for 5 minutes in a boiling water bath. After the colour has developed, 1ml of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter.

Reducing sugar (%) = Amount of reducing sugar obtained/ Weight of sample×100

Non-reducing sugar: Non-reducing sugar content of banana pulp was calculated by using the following formula:

% non-reducing sugar = % total sugar - % reducing sugar

Color Measurement: The dragon fruit skin colors were measured nondestructively using a Minolta Chroma meter (Model CR400, Sakai site, Japan), which was set up with a D65 illuminant and 10° observer angle. The color values were recorded as L*, a*, b*, and C*. The reading was set to take an average of 6 random points per fruit. The instrument must be completely in contact with the fruits to avoid any light leakage from the light emitted by the colorimeter.

Statistical Analyses: The experiments used a randomized complete block design (RCBD) with three replications for each treatment and three plants in each replicate. Statistical analyses were conducted with version 9.4 of the Statistical Analysis System (SAS) (SAS Institute, Cary NC, USA). The mean value among the treatments was statistically significant when $p = 0.05$. All results were presented with the mean standard error (SE) from the replicates.

11. Results and Discussion

BARI Component

11.1. Effect of Different Net House on Quality Seedling Raising of High Value Vegetables

Effect of vegetable crops

The data presented in Table 4 depicted that different vegetables [tomato (V1), eggplant (V2), sweet pepper (V3), broccoli (V4)] showed significant effect on performance of growth development under different net house treatments [i) UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)].

Eggplant (V2) resulted the maximum seed germination (93.58%) compared to tomato (91.83%), broccoli (91.08%), while the lowest germination was observed in sweet pepper (88.33%) (Table 4). In case of seedling mortality during the 30 days, lowest mortality was observed in eggplant (5.58%), followed by tomato (6.58%), while the highest mortality was observed in sweet pepper (9.08%). It might be due to susceptible to pest and disease. The tallest seedlings were produced in sweet pepper at 15 days (10.1 cm), 20 days (12.4 cm), 25 days (14.53 cm), 30 days (17.7 cm) of seedling age, while the shortest seedlings were observed in eggplant at 15 days (9.4 cm), 20 days (11.31 cm), 25 days (13.83 cm) and 30 days (16.65 cm). It might be due to slow growth of eggplant seedling.

Table 4: Effect of vegetable crops on seed germination, seedling height, seedling mortality and insect infestation

Vegetable	Seed germination (%)	Seedling mortality (%)	Seedling height at			
			15 days (cm)	20 days (cm)	25 days (cm)	30 days (cm)
Tomato (V1)	91.83 b	6.58 c	9.8 b	11.78 ab	14.23 ab	17.4 a
Eggplant (V2)	93.58 a	5.58 d	9.4 c	11.31 b	13.83 b	16.65 b
Sweet pepper (V3)	88.33 c	9.08 a	10.1 a	12.08 a	14.53 a	17.7 a
Broccoli (V4)	91.08 b	7.33 b	9.6 bc	11.51 b	14.03 b	16.85 b
CV (%)	1.85	8.21	3.62	5.40	3.42	2.82

The maximum leaves were produced in sweet pepper at 15 days (2.86), 20 days (3.96), 25 days (3.99), 30 days (4.71), while the minimum leaves were observed in broccoli at 15 days

(2.46), 20 days (3.01), 25 days (3.02) and 30 days (3.36). It might be due to slow growth of leaves. The minimum insect infestation was observed in broccoli seedling at 15 days (2.00%), 20 days (4.33%), 25 days (6.17%), 30 days (49.42%) and the maximum insect infestation was observed in eggplant at 15 days (4.94%), 20 days (6.58%), 30 days (13.20%), while at 25 days, it maximum in tomato (9.17%). It might be due to prone to insect (Fig 3).

Table 4 (contd.)

Vegetable	No. of leaves at			
	15 days	20 days	25 days	30 days
Tomato (V1)	2.56 b	3.66 b	3.69 b	4.41b
Eggplant (V2)	2.56 b	3.66 b	3.69 b	4.41b
Sweet pepper (V3)	2.86 a	3.96 a	3.99 a	4.71a
Broccoli (V4)	2.46 b	3.01 c	3.02 c	3.36c
(CV%)	7.87	0.82	6.52	4.87

CV: coefficient of variation

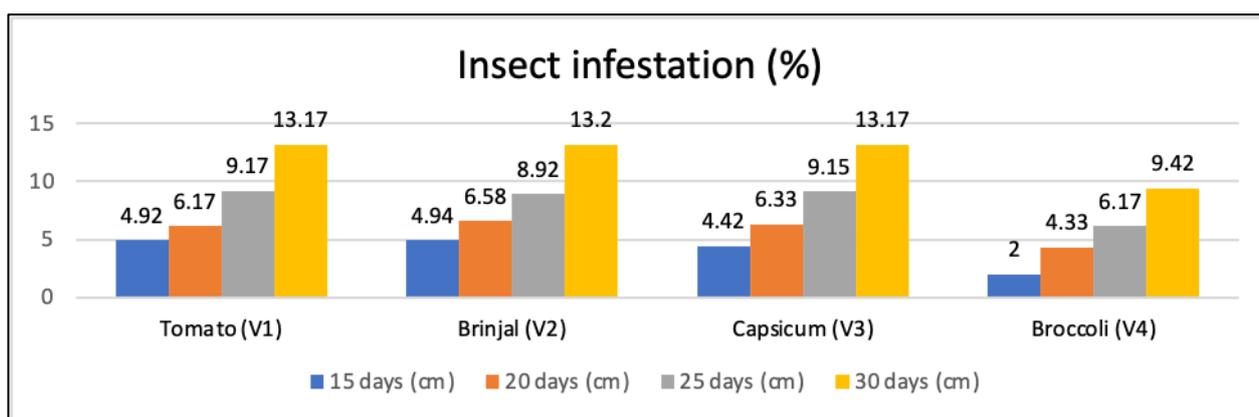


Figure: 3 Effect of vegetables crops on insect infestation (%)

Effect of different net house treatments

The results revealed that among the different net house treatments [i) UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4), The net house treatment T1 resulted the maximum seed germination (94.83%) closely followed by T2 (94.58 %), while the lowest germination was observed in control treatment T4 (84.58%) (Fig. 4). In case of seedling mortality during the 30 days, lowest mortality was observed in T1 (3.33 %), closely followed by T2 (5.33 %), while the highest mortality was observed in T4 (12.33 %) (Fig. 5). It might be due to open condition of the seedling producing area. The tallest seedlings were produced by T1 at 15 days (11.13 cm), 20 days (13.21 cm), 25 days (15.73 cm), 30 days (18.68 cm) of seedling age, while the shortest seedlings were observed in T4 condition at 15 days (8.28 cm), 20 days (10.16 cm), 25 days (12.43 cm) and 30 days (15.58 cm). It might be due to slow growth of seedlings in open condition.

Table 5: Effect of different net house treatments on seed germination, seedling mortality, seedling height and insect infestation

Vegetable	Seedling height at			
	15 days	20 days	25 days	30 days
T1	11.13 a	13.21 a	15.73 a	18.68 a
T2	10.18 b	12.21 b	15.03 b	17.73b
T3	9.33 c	11.11 c	13.43 c	16.63 c
T4	8.28 d	10.16 d	12.43 d	15.58 d
CV (%)	3.2	5.40	3.42	2.82

T1: UV stabilized polyethylene film with 60 mesh insect net along with green shade net

T2: UV stabilized polyethylene film with 60 mesh insect net

T3: 60 mesh insect net

T4: Open field (control)

The maximum no. of leaves was produced in T2 at 15 days (3.08), 20 days (3.93), 25 days (3.89), 30 days (4.81), while the minimum no. of leaves were observed in T4 at 15 days (2.08), 20 days (3.11), 25 days (3.03) and 30 days (3.81). It might be due to less production of leaves. The minimum insect infestation was observed in T1 at 15 days (0.65%), 20 days (1.17%) and in T2 it was observed at 25 days (2.42%), 30 days (4.92%) and the maximum insect infestation was observed in T4 at 15 days (13.83%), 20 days (19.33%), 30 days (23.63%), 25 days (31.92%). It might be due to open condition which favors insect for infestation.

Table 5 (Contd.)

Vegetable	No. of leaves at				Insect infestation (%)			
	15 days	20 days	25 days	30 days	15 days	20 days	25 days	30 days
T1	2.88 b	3.68 b	3.69 b	4.21 b	0.65 b	1.17 b	2.92 c	5.17 c
T2	3.08 a	3.93 a	3.89 a	4.81 a	0.67 b	1.25 b	2.42 c	4.92 c
T3	2.38 c	3.56 c	3.49 c	4.06 b	1.08 b	1.67 b	4.42 b	6.92 b
T4	2.08 d	3.11 d	3.32 c	3.81 c	13.83 a	19.33 a	23.67 a	31.92 a
CV (%)	7.87	0.82	6.52	4.87	18.08	17.16	12.26	8.38

T1: UV stabilized polyethylene film with 60 mesh insect net along with green shade net

T2: UV stabilized polyethylene film with 60 mesh insect net

T3: 60 mesh insect net

T4: Open field (control)

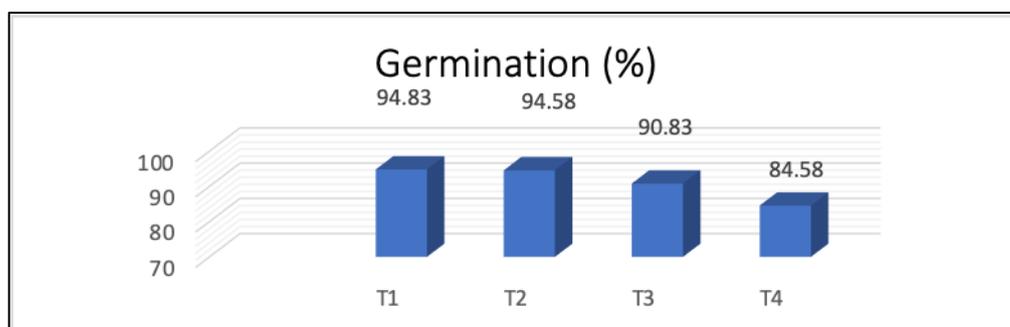


Figure 4: Effect of different net house treatments on seed germination

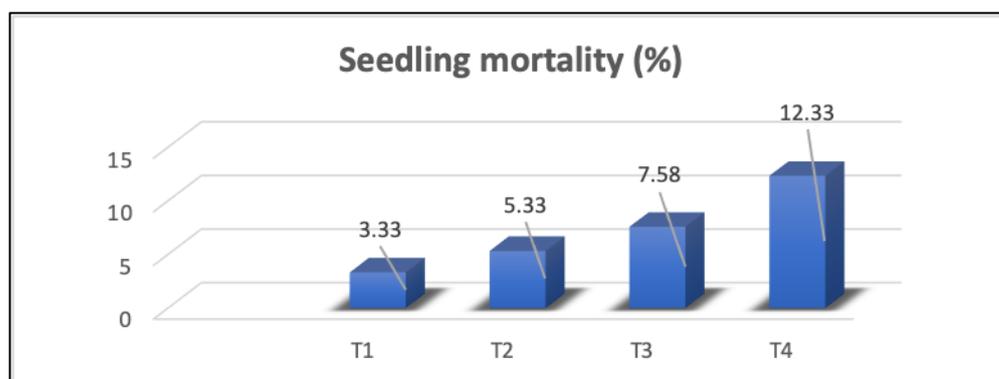


Figure 5: Effect of different net house treatments on seedling mortality

Effect of interaction of different vegetables and net house treatments

The maximum seed germination (93.58%) was observed in V2T1 compared to V1T2, V4T1 (95.83 %), while the lowest germination was observed in V3T4 (81.83%). In case of seedling mortality during the 30 days, lowest mortality was observed in V2T1 (2.08 %), followed by V1T1, V4T1 (3.08 %), while the highest mortality was observed in V3T4 (15.08 %). It might be due to susceptible to pest and disease. The tallest seedlings were produced in V3T1 at 15 days (11.50 cm), 20 days (13.73 cm), 25 days (16.15 cm), 30 days (19.25 cm) followed by V1T1 at 15 days (11.20 cm), 20 days (13.43 cm), 25 days (15.85 cm), 30 days (18.95 cm) while the shortest seedlings were observed in V2T4 at 15 days (8.00 cm), 20 days (9.93 cm), 25 days (12.15 cm) and 30 days (15.15 cm). Seedling growth was slow due to open condition.

Table 6: Interaction effect of different vegetables and net house treatments

Vegetable	Germination (%)	Seedling mortality (%)	Seedling height at			
			15 days	20 days	25 days	30 days
V1T1	94.83 a-c	3.08 i	11.20 ab	13.43 ab	15.85 ab	18.95 ab
V1T2	95.83 ab	5.08 g	10.30 de	12.33 c-e	15.15 b-d	18.05 cd
V1T3	91.83 def	6.08 f	9.40 g-i	11.23 f-i	13.45 ef	16.85 e-g
V1T4	84.83 h	12.08 b	8.30 kl	10.13 j	12.45 gh	15.75 h-j
V2T1	95.83 ab	2.08 j	10.80 b-d	12.73 a-d	15.35 a-d	18.15 b-d
V2T2	96.83 a	4.08 h	9.80 e-g	11.83 d-g	14.65 d	17.15 ef
V2T3	93.83 b-d	6.08 f	9.00 ij	10.73 h-j	13.15 e-g	16.15 g-i
V2T4	87.83 g	10.08 c	8.00 l	9.93 j	12.15 h	15.15 j
V3T1	92.83 c-e	5.08 g	11.50 a	13.73 a	16.15 a	19.25 a
V3T2	90.83 ef	7.08 e	10.60 cd	12.63 b-d	15.45 a-d	18.33 bc
V3T3	87.83 g	9.08 d	9.70 f-h	11.53 e-h	13.75 e	17.15 ef
V3T4	81.83 i	15.08 a	8.60 jk	10.43 ij	12.75 f-h	16.05 g-i
V4T1	95.83 ab	3.08 i	11.00 a-c	12.93 a-c	15.55 a-c	18.35 bc
V4T2	94.83 a-c	5.08 g	10.00 ef	12.03 c-f	14.85 cd	17.35 de
V4T3	89.83 fg	9.08 d	9.20 hi	10.93 g-j	13.35 ef	16.35 f-h
V4T4	83.83 hi	12.08 b	8.20 kl	10.13 j	12.35 gh	15.35 ij
CV (%)	1.85	8.21	3.62	5.40	3.42	2.82

The maximum number of leaves was produced in V3T2 at 15 days (33.33), 20 days (4.33), 25 days (4.27), 30 days (5.33), followed by V3T1 at 15 days (3.13), 20 days (4.03), 25 days (4.07), 30 days (4.63), while the minimum no. of leaves were observed in V4T4 at 15 days (1.93), 20 days (2.43), 25 days (2.57) and 30 days (2.83). It might be due to less production of leaves at open condition. The minimum insect infestation was observed in V1T1, V1T2, V2T1, V2T2, V3T1, V3T2, V4T1, V4T2 (0.67% at 15 days and 20 days), while 2.17% was

at 25 days and 4.17% at 30 days and the maximum insect infestation was observed in V3T4 at 15 days (17.33 %), 20 days (22.33 %), 30 days (27.17 %), 25 days (35.17 %). It might be due to open condition which favors insect for infestation.

Table 6 (Contd.)

Vegetable	No. of leaves at				Insect infestation (%)			
	15 days	20 days	25 days	30 days	15 days	20 days	25 days	30 days
V1T1	2.83 b-d	3.73 d	3.77 b-d	4.33 b-d	0.67 d	0.67 d	3.17 ef	5.17 de
V1T2	3.03 a-c	4.00 b	3.97 ab	5.03 a	0.67 d	0.67 d	2.17 f	5.17 de
V1T3	2.33 ef	3.63 e	3.57 c-e	4.23 cd	1.00 d	1.00d	4.17 de	7.17 c
V1T4	2.03 fg	3.23 h	3.47 d-f	4.03 de	17.30 a	22.30 a	27.15 a	35.15 a
V2T1	2.83b-d	3.73 d	3.77 b-d	4.33 b-d	0.67 d	1.33 d	2.17 f	5.17 de
V2T2	3.03 a-c	4.01 b	3.97 ab	5.03 a	0.67 d	2.33 d	3.17 ef	5.17 de
V2T3	2.33 ef	3.63 e	3.57 c-e	4.23 cd	1.00 d	2.33 d	5.17 d	7.17 c
V2T4	2.03 fg	3.23 h	3.47 d-f	4.03 de	15.33 b	20.33 b	25.17 b	35.17 a
V3T1	3.13 ab	4.03 b	4.07 ab	4.63 b	0.67 d	1.33 d	3.17 ef	5.17 de
V3T2	3.33 a	4.33 a	4.27 a	5.33 a	0.67 d	0.67 d	2.17 f	5.17 de
V3T3	2.63 de	3.93 c	3.87 bc	4.53 bc	1.00 d	1.00 d	4.17 de	7.17 c
V3T4	2.33 ef	3.53 f	3.77 b-d	4.33 dcd	17.33 a	22.33 a	27.17 a	35.17 a
V4T1	2.73 cd	3.23 h	3.17 fg	3.53 fg	0.67 d	1.33 d	3.17 ef	5.17 de
V4T2	2.93 b-d	3.33 g	3.37 ef	3.83 ef	0.67 d	1.33 d	2.17 f	4.17 e
V4T3	2.23 fg	3.03 i	2.97 g	3.23 g	1.33 d	2.33 d	4.17 de	6.17 cd
V4T4	1.93 g	2.43 j	2.57 h	2.83 h	5.33 c	12.33 c	15.17 c	22.17 b
CV (%)	7.87	0.82	6.52	4.87	18.08	17.16	12.26	8.38

V1: Tomato, V2: eggplant, V3: sweet pepper, V4: broccoli

T1: UV stabilized polyethylene film with 60 mesh insect net along with green shade net

T2: UV stabilized polyethylene film with 60 mesh insect net

T3: 60 mesh insect net

T4: Open field (control)

11.2 Effect of Different Mulch Paper on Growth and Yield of Different High Value Vegetables in Bangladesh

Tomato

The plant height was measured on days to last harvest and it varied significantly due to different plastic mulches. T1 mulches showed better performance than T2 and control, indicating T1 mulches had a positive effect on the growth and development of tomatoes (Table 7). Table 7 reflects, the tallest plant (159 cm) was observed in T1, followed by T2 (144 cm), while the shortest plant (129 cm) was observed in the control plot. The earliest days to first harvest (98 days) were observed in T1 plot compared to the rest two treatments. There were significant changes in the fruit length, fruit breadth of tomato. Longest fruit (7.2 cm) was produced in T1 followed by T2 (6.9 cm) and control (6.5 cm). The maximum breadth fruit was also produced in T1 (5.8 cm). Number of fruits/ plant was highest in T1 (33) followed by T2 (26) and control (23). The maximum fruit weight was also produced in T1 (90 g). The highest yield/ plant (2.94 kg) and yield (98.05 t/ha) were obtained in T1 followed by T2 (2.10 kg and 70.13 t/ha, respectively) (Table 7). The control plot was the lowest performer in all cases. Mulched plants with T1 had a higher performance than that of Black (T2) at all growing stages.

Table 7: Effect of different mulch on yield and yield contributing characters of tomato

Treatment	Plant height (cm)	Days to first flowerin g	Days to first harvest	Fruit length (cm)	Fruit breadth (cm)	No. of fruits/ plant	Fruit weight (g)	Yield/ plant (kg)	Yield (t/ha)	TSS (%)
Silver over black (T1)	159 a	62.33 a	98 b	7.2 a	5.8 a	33 a	90 a	2.94 a	98.05 a	4.0 a
Black (T2)	144 b	65.33 a	100 ab	6.9 ab	5.5 ab	26 b	82 ab	2.10 b	70.13 b	4.0 a
No mulch (T3) (control)	129 c	66.33 a	103 a	6.5 b	5.2 b	23 b	72 b	1.63 c	54.34 c	3.8 a
CV (%)	3.72	3.91	2.21	3.23	3.71	8.19	6.19	1.89	1.89	20.73

Means followed by the same letter in a column do not significantly differ from each other at 5% level by HSD.

Eggplant

Plant height was measured on days to last harvest and it varied significantly due to different plastic mulches. T1 mulches showed better performance in plant height than T2 and control, indicating T1 mulches had a better effect on the growth and development of eggplant. Table 8 reflects, the tallest plant (139 cm) was observed in T1, followed by T2 (131 cm), while the shortest plant (119 cm) was observed in the control plot. The increased plant height in mulched plants was performed due to better availability of soil moisture and optimum soil temperature provided by the plastic mulches. Shinde *et al.*, 1999] mentioned there were changes in the increased plant height of chilli, while using different mulches and plastic mulch. The earliest days to first flowering and first harvest (63 days and 94 days, respectively) were observed in T1 plot compare to the rest of two treatments. There were significant changes in the fruit length, fruit breadth of eggplant. Longest fruit (8.9 cm) was produced in T1 followed by T2 (8.2 cm) and control (7.5 cm), while the maximum breadth fruit was also produced in T1 (6.7 cm) followed by T2 (6.3 cm) and control (6.1 cm). Number of fruits/ plant was highest in T1 (35) followed by T2 (30) and control (25), while the maximum average fruit weight was also produced in T1 (130 g) (Table 8). It meant that mulch had a positive influence on fruit set in eggplant. Mulching significantly improved the number of fruits per plant and reduced the percentage of fruit abortion compared to non-mulched control [Ravinder *et al.*, 1997] that supported the present experimental results. The increase in the number of fruits per plant of the mulched plot was probably related to the conservation of optimum moisture and improved microclimate both beneath and above the soil surface. The highest yield/ plant (4.51 kg) and yield (54.11 t/ha) were obtained in T1 followed by T2 (3.47 kg and 41.66 t/ha, respectively). The control plot was the lowest performer in all cases. Mulched plants with T1 had a higher performance than that of Black (T2) at all growing stages. At all growth stages, the plant without mulch (control) had the lowest performer. This result was similar to the report of Easson and Fearnough, (2000) on forage maize. Fruit yield increased in the mulched plot because of an increased number of fruits per plant. These results also similar with Siborlabane, (2000), who pointed out that the yield and quality of the fruit for the fresh tomato market varies according to the type of mulch.

Table 8: Effect of different mulch on yield and yield contributing characters of eggplant

Treatments	Plant height (cm)	Days to first flowerin g	Days to first harvest	Fruit length (cm)	Fruit breadth (cm)	Number of fruits/ plant	Average fruit weight (g)	Yield/ plant (kg)	Yield (t/ha)
Silver over black mulch (T1)	139 a	63 b	94 b	8.9 a	6.7 a	35 a	130 a	4.51 a	54.11 a
Black mulch (T2)	131 a	65 b	96 b	8.2 b	6.3 ab	30 b	117 b	3.47 b	41.66 b
No mulch (T3)	119 b	72 a	102 a	7.5 c	6.1 b	25 c	114 b	2.81 b	33.73 c
CV (%)	4.14	3.78	2.28	2.68	3.21	7.46	4.19	10.05	3.17

Means followed by the same letter in a column do not significantly differ from each other at 5% level by HSD.

Sweet pepper

Table 9 reflects that the earliest days to first harvest (72 days) were observed in T1 plot preceded by T2 (75 days), while the delayed flowered treatment was T3 (no mulch) (79 days). There were significant changes in the fruit length, fruit breadth of sweet pepper. Longest fruit (8.7 cm) was produced in T1 followed by T2 (8.4 cm) and control (7.7 cm), while the maximum breadth fruit was also produced in T1 (4.8 cm) followed by T2 (4.4 cm) and control (4.0 cm). Number of fruits/ plant was highest in T1 (8.7) followed by T2 (7.7) and control (6.0), while the maximum average fruit weight was also produced in T1 (120 g). It meant that mulch had a positive influence on fruit set in sweet pepper. Mulching significantly improved the number of fruits per plant and reduced the percentage of fruit abortion compared to non-mulched control [Ravinder *et al.*, 1997] that supported the present experimental results. The increase in the number of fruits per plant of the mulched plot was probably related to the conservation of optimum moisture and improved microclimate both beneath and above the soil surface. The highest yield/ plant (1.03 kg) and yield (34.33 t/ha) were obtained in T1 followed by T2 (0.76 kg and 25.24 t/ha, respectively). The control plot was the lowest performer in all cases. Mulched plants with T1 had a higher performance than that in Black (T2) at all growing stages. At all growth stages, the plant without mulch (control) had the lowest performer. This result was similar to the report of Easson and Fearnough, (2000) on forage maize. Fruit yield increased in the mulched plot because of an increased number of fruits per plant. These results also similar with Siborlabane, (2000), who pointed out that the yield and quality of the fruit for the fresh tomato market varies according to the type of mulch.

Table 9: Effect of different mulch on yield and yield contributing characters of sweet pepper

Treatments	Days to first harvest	Fruit length (cm)	Fruit breadth (cm)	Number of fruits/plant	Average fruit weight (g)	Yield/ plant (kg)	Yield (t/ha)
Silver over black mulch(T1)	72 b	8.7 a	4.8 a	8.7 a	120 a	1.03 a	34.33 a
Black mulch (T2)	75 ab	8.4 a	4.4 a	7.7 a	100 b	0.76 ab	25.24 ab
No mulch (T3)	79 a	7.7 b	4.0 b	6.0 a	75 c	0.44 b	14.77 b
CV (%)	2.95	2.67	4.62	28.60	5.13	24.33	24.71

Means followed by the same letter in a column do not significantly differ from each other at 5% level by HSD.

Broccoli

The earliest days to 50% curd initiation and days to curd harvest (77 days and 92 days, respectively) were observed in T1 plot compared to the rest two treatments (Table 10). There were significant changes in curd length, curd breadth of broccoli. Maximum curd length (19.3 cm) was produced in T1 followed by T2 (18.5 cm) and control (16.6 cm), while the maximum breadth fruit was also produced in T1 (17.2 cm) followed by T2 (16.8 cm) and control (15.7 cm). Only curd weight was highest in T1 (635 g) which is statistically identical with T2 (617 g) and the lowest curd weight was produced by control (510 g). The highest marketable curd weight (785 g), followed by T2 (690 g) and T3 (610 g) while the marketable curd yield was maximum in T1 (26.09 t/ha), followed by T2 (22.93 t/ha) and T3 (20.28 t/ha). In the study, mulched plants with T1 had a higher performance than that in Black (T2), while the plants without mulch (control) were the lowest performer at all growth stages. This result was similar to the report of [Easson and Fearnough, (2000)] on forage maize.

Table 10: Effect of different mulch on yield and yield contributing characters of broccoli

Treatments	Days to 50% curd initiation	Days to curd harvest	Curd length (cm)	Curd breadth (cm)	Whole plant weight (kg)	Only curd wt. (g)	Marketable curd wt. (g)	Marketable curd yield (t/ha)
Silver over black mulch (T1)	77 a	92 b	19.3 a	17.2 a	1.52 a	635 a	785 a	26.09 a
Black mulch (T2)	79 ab	95 ab	18.5 ab	16.8 b	1.46 a	617 a	690 b	22.93 b
No mulch (T3)	82 b	97 a	16.6 b	15.7 c	1.25 a	510 b	610 c	20.28 c
CV (%)	3.18	2.65	6.23	7.64	15.74	2.48	2.09	2.57

Means followed by the same letter in a column do not significantly differ from each other at 5% level by HSD.

The increased plant height in mulched plants was performed due to better availability of soil moisture and optimum soil temperature provided by the plastic mulches. [Shinde *et al.*, 1999] mentioned there were changes in the increased plant height of chilli, while using different mulches and plastic mulch. Longest fruit was produced in T1 followed by T2 and control, while the maximum breadth fruit was also produced in T1. Number of fruits/ plants was highest in T1 followed by T2 and control, while the maximum average fruit weight was also produced in T1. It meant that mulch had a positive impact on the tomato fruit set. Mulching significantly improved the number of fruits per plant and reduced the percentage of fruit abortion compared to non-mulched control [Ravinder *et al.*, 1997] that supported the present experimental results. The increase in the number of fruits per plant of the mulched plot was probably related to the conservation of optimum moisture and improved microclimate both beneath and above the soil surface. The highest yield/ plant and yield per hectare were obtained in T1 followed by T2. The control plot was the lowest performer in all cases. Mulched plants with T1 had a higher performance than that in Black (T2) at all growing stages. At all growth stages, the plant without mulch (control) had the lowest performer. This result was similar to the report of [Easson and Fearnough, (2000)] on forage maize. Fruit yield increased in the mulched plot because of an increased number of fruits per plant. These results also similar with [Siborlabane, (2000)], who pointed out that the yield and quality of the fruit for the fresh tomato market varies according to the type of mulch.

11.3 Effect of Different Type of Nethouse on The Incidence of Insect and Diseases of High Value Vegetables

In this study, the effects of different types of nethouses, viz., NH1 (UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net), NH2 (UV stabilized transparent polyethylene film with 60 mesh insect net) and NH3 (60 mesh insect net) were investigated and compared to control NH4 (open field) in terms of the incidence of white fly, aphid, leaf miners, mites and eggplant shoot and fruit borer (ESFB) of tomato, eggplant, sweet pepper, broccoli, cucumber, and okra. A significant amount of infestation of white fly, aphids, leaf miners, mites, and ESFB was observed under different types of nethouses and control field.

White fly

A significant number of whiteflies infestation were observed under the protected cultivation treatments during the 20 weeks of total crop period. However, from the start of the plant developmental stage, an increased infestation of whiteflies was observed from the NH1 and NH4 (control) in all of the six crops viz., tomato, eggplant, sweet pepper, broccoli, cucumber,

okra, with white fly infestation was 8.25%, 7.5%, 8.75%, 1.2%, 4.75, 2.25% in NH1, respectively and 11.0%, 8.5%, 9.75%, 1.5%, 7.75%, 6.25% in NH4, respectively (Fig 6).

The NH1 was made of UV stabilized transparent polyethylene film, a 60 mesh insect net, and a green shade net, which encouraged high temperatures and relative humidity percentages. The net house effect provided by the green colored net appears to have provided the right conditions for the rapid multiplication of white fly population under this specific protected structure (Sotelo-Cardona *et al.*, 2021). The control treatment NH4 condition encourages more infestation of white fly due to its open condition. That is why the white fly infestation was higher in NH1 and NH4 compared to NH2 and NH3. The NH2 is made of UV stabilized transparent polyethylene film with a 60 mesh insect net, and the NH3 is made of only a 60 mesh insect net, which ensures a higher temperature and a lower relative humidity percentage, resulting in a lower infestation in these NH2, NH3.

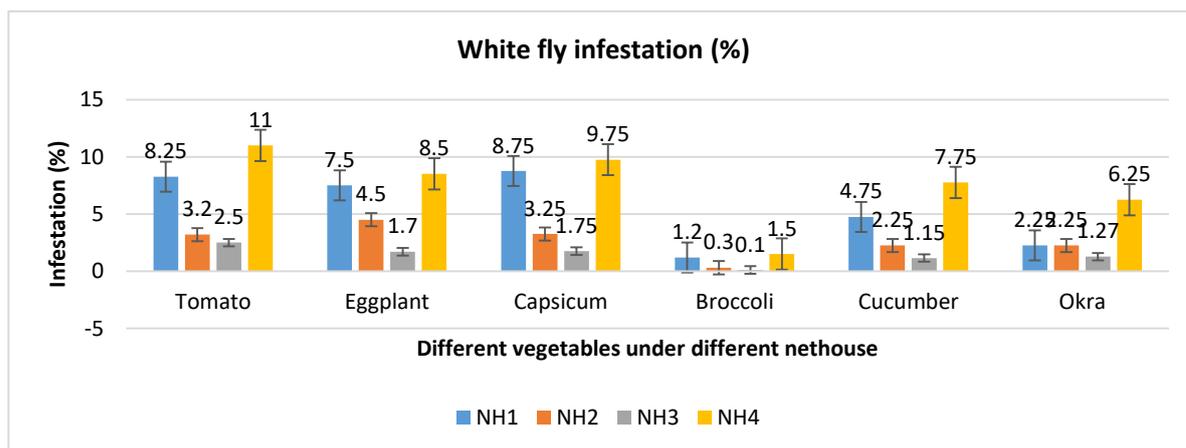


Figure 6: White fly infestation (%) in tomato, eggplant, sweet pepper, broccoli, cucumber and okra under different type of net house

Aphid

Wide variation of aphid infestation was observed under the protected cultivation treatments during the entire crop cultivation period. In case of tomato cultivation, highest infestation (12.0%) was observed in control treatment (NH4) compare to other treatments viz., NH1 (7.25%), NH2 (2.25%), while lowest infestation was observed in NH3 (2.0%), which was prepared with only insect exclusion net (Fig 7). Same trend was observed in eggplant with highest aphid infestation in NH4 (9.5%) followed by NH1 (8.75%), NH2 (3.75%) and lowest infestation was observed in NH3 (1.5%). In capsicum, the aphid infestation was higher compare to tomato and eggplant, which was 10.75%, 9.5%, 2.75%, 1.5% in NH4, NH1, NH2, NH3, while the aphid infestation was lower in broccoli in all cases viz., NH4 (1.25%), NH1 (1.0%), NH2 (0.75%), NH3 (0.5%). The aphid infestation of cucumber and okra was more or less similar and the infestation was 6.75% and 9.25%, respectively in NH4, followed by 4.5% and 3.75%, respectively in NH1, 2.5% and 1.3%, respectively in NH2 and the lowest was observed in NH3 (1.5%, 1.1%). Over all the aphid infestation was higher in NH4 (control) in all six crops viz., tomato, eggplant, sweet pepper, broccoli, cucumber and okra with 12.0%, 9.5%, 10.75%, 1.25%, 6.75%, 9.25% in NH4, while the lowest was in all NH3 condition (2.0%, 1.5%, 1.5%, 0.5%, 1.5%, 1.1%, respectively) (Fig 7).

The NH1 was made of UV stabilized transparent polyethylene film, a 60 mesh insect net, and a green shade net, which encourages high temperatures and relative humidity percentages. The net house effect provided by the green colored net appears to have provided the right

conditions for the rapid multiplication of aphid population under this specific protected structure (Sotelo-Cardona *et al.*, 2021). The control treatment NH4 condition encourages more infestation of aphids due to its open condition. That is why the aphid infestation was higher in NH1 and NH4 compared to NH2 and NH3. The NH2 is made of UV stabilized transparent polyethylene film with a 60 mesh insect net, and the NH3 is made of only a 60 mesh insect net, which ensures a higher temperature and a lower relative humidity percentage, resulting in a lower infestation in these NH2, NH3.

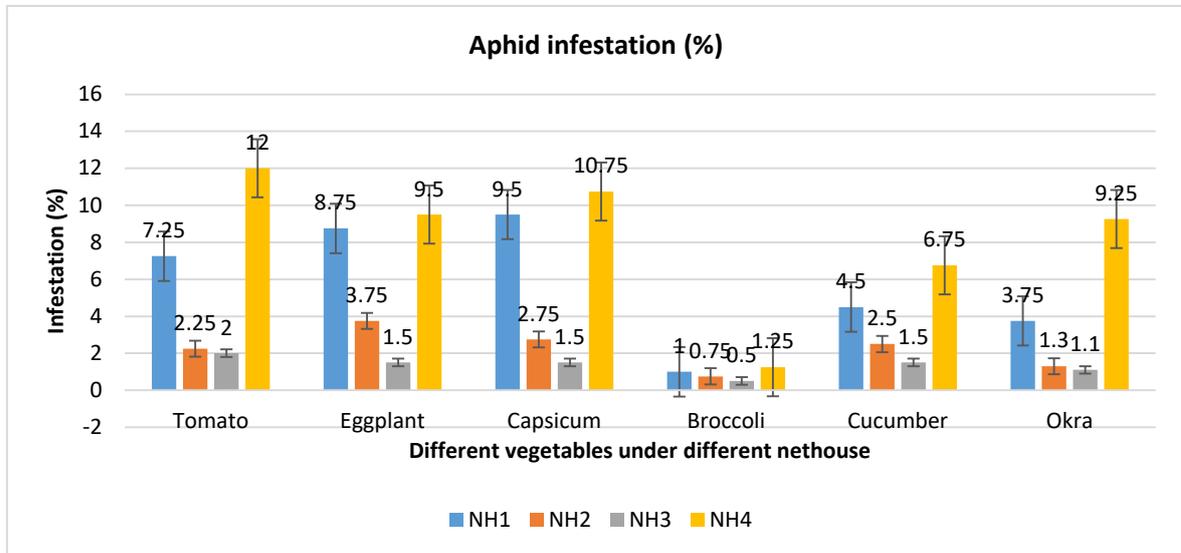


Figure 7: Aphid infestation (%) of tomato, eggplant, sweet pepper, broccoli, cucumber and okra under different type of nethouse

Mite

A significant variation of mite infestation was observed under the protected cultivation during the entire crop cultivation period. An increased infestation of mites was observed in two vegetables, viz., eggplant and sweet pepper from the NH4 (9.25% and 12.5%, respectively), followed by NH1 (4.3% and 7.5%, respectively), NH2 (2.8% and 2.55%, respectively) and the lowest infestation was in NH3 (2.0% and 2.05%, respectively) (Fig 8).

The NH1 was made of UV stabilized transparent polyethylene film, a 60 mesh insect net, and a green shade net, which encourages the high temperature and relative humidity percentage. The net house effect provided by the green colored net appears to have provided the right conditions for the rapid multiplication of mite population under this specific protected structure (Sotelo-Cardona *et al.*, 2021). The control treatment NH4 condition encourages more infestation of mites due to its open condition. That is why the mite infestation was higher in NH1 and NH4 compared to NH2 and NH3. The NH2 was made of UV stabilized transparent polyethylene film with a 60 mesh insect net, and the NH3 was made of only a 60 mesh insect net, which ensures a higher temperature and a lower relative humidity percentage, resulting in a lower infestation in these NH2, NH3.

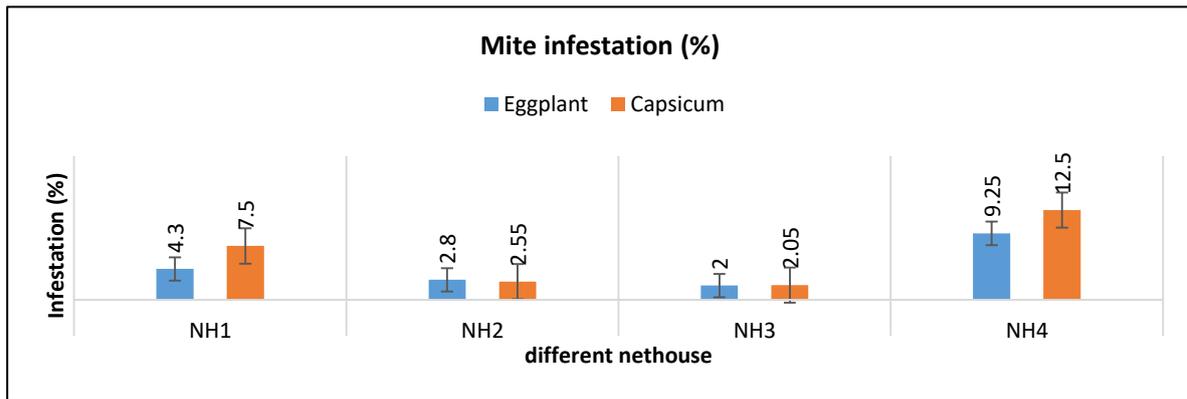


Figure 8: Mite infestation of eggplant and sweet pepper under different type of nethouse

Leaf miners

Maximum leaf miner infestation (15.3%) in tomato was observed in NH4 due to its open condition, which provided free leaf miner movement to the crops (Fig 9). In contrast, the high temperature and low relative humidity recorded under protected conditions seemed to deter the presence of leaf miners, as damage levels were very low, whereas the second highest damage levels (7.2%) were observed under more mild temperature and higher relative humidity conditions offered by NH1 in this study. Infestation was lower in NH2 (3.4%) and NH3 (2.7%). The NH2 was made of UV stabilized transparent polyethylene film with 60 mesh insect net, while the NH3 is made of only 60 mesh insect net, which ensures a higher temperature and lower relative humidity percentage, resulting in a lower infestation of tomato leaf miner (Kumari *et al.*, 2021).

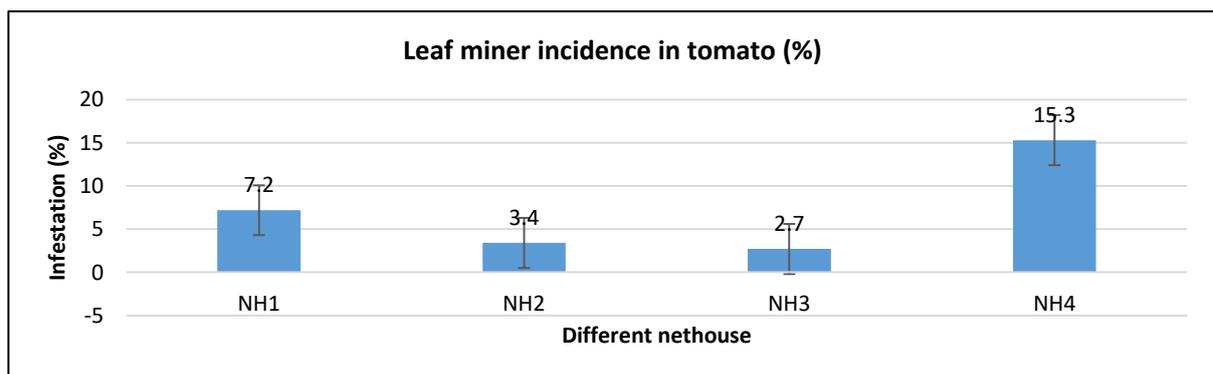


Figure 9: Leaf miner infestation of tomato under different type of nethouse

Eggplant shoot and fruit borer

Generally, eggplant shoot and fruit borer infestations are seen in the shoot and fruit. The shoot infestation starts earlier than fruit. In this study, a significant variation of infestation was seen among the shoot and fruit. Maximum infestation for both fruit and shoot was calculated in NH4 due to open condition cultivation, though fruit infestation (22.0%) was higher compared to shoot (15.0%). The second highest infestation was calculated in NH1, which consists of UV stabilized transparent polyethylene film with a 60 mesh insect net along with a green shade net, which favors the high temperature with a high relative humidity percentage. But in this case, the fruit infestation (4.3%) was lower compared to the shoot (7.3%) (Fig 10). Lower fruit infestation and shoot infestation were counted in NH2 (3.3% and 2.3%, respectively) and NH3 (2.2% and 1.2%, respectively). The lower infestation was due to

the NH2 being made of UV stabilized transparent polyethylene film with a 60 mesh insect net and the NH3 being made of only a 60 mesh insect net, which ensures a higher temperature and a lower relative humidity percentage, resulting in a lower infestation of eggplant shoots and fruit borer in eggplant.

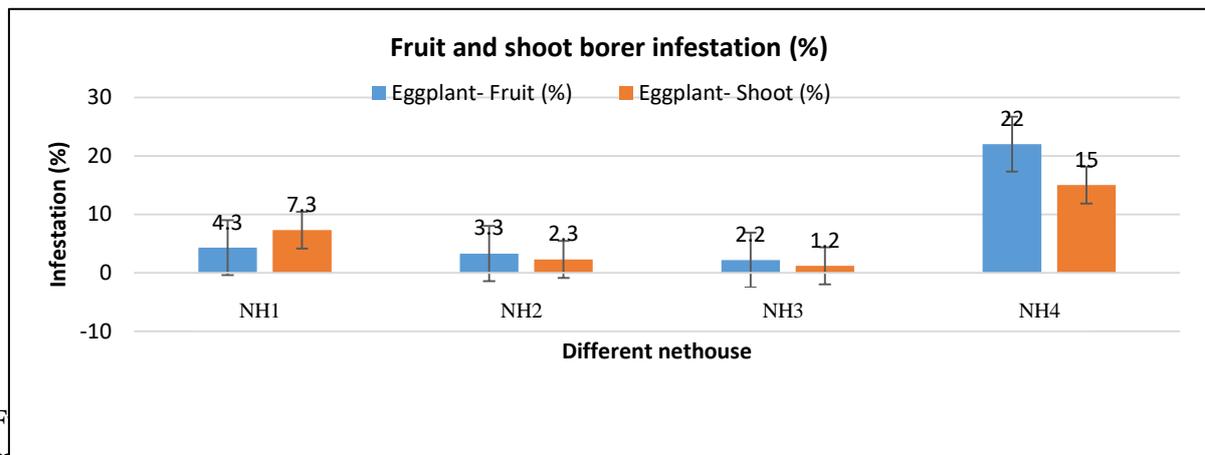


Figure 10: Eggplant shoot and fruit borer infestation (%) of eggplant fruit and eggplant shoot under different type of Nethouse.

may decrease air flow and lower the warm air removal rate, leading to significant greenhouse effect (Mupambi *et al.*, 2018). 24 mesh screens blocked invasion by scarab beetles, stink bugs, and melon flies and reduced damage caused by these pests. So, the size of the insects is another important aspect to consider, as it has been previously shown that these tiny pests can easily enter through the nets, even if they are 50–60 mesh size (Kaur *et al.*, 2010). In addition, several studies have also indicated the need to optimize the mesh size to reduce adverse climatic conditions by allowing better ventilation, and reducing heat while offering effective protection against insect pests (Saidi *et al.*, 2013; Nordey *et al.*, 2017).

11.4. Effect of Different Net House on Growth and Quality of High Value Vegetables

The effect of different net houses on the growth and quality of tomatoes

Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019). The favorable environmental conditions in protective net houses were the result of greater net photosynthesis, which resulted in faster fruit growth throughout the season (Bastias *et al.*, 2011).

There were significant differences among different growing conditions (T1=NH1, T2=NH2, T3=NH3, T4=NH4) in leaf chlorophyll content (Fig 11). The highest chlorophyll content was found in plants during the flowering stage in all growing conditions, followed by the fruiting and harvesting stages. However, the plants during flowering stage T2 showed the highest chlorophyll content (49), followed by T3 (47), T4 (43) and the lowest chlorophyll content was found in open field condition T1 (40). The same trend was observed in the fruiting and harvesting stages. In the study, leaf chlorophyll content was found to be significantly lower in open T1 compared to T2, T3 and T4. Hörtensteiner (2006) stated that the catabolic pathway of chlorophyll during senescence and fruit ripening leads to the accumulation of colorless breakdown products. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Bita and Gerats

(2013)). In spite of the many studies related to chlorophyll content varying with growth conditions of tomato leaves (Blunden *et al.*, 1996; Al-aghabary *et al.*, 2005; Takayama *et al.*, 2006; Wu and Kubota, 2008).

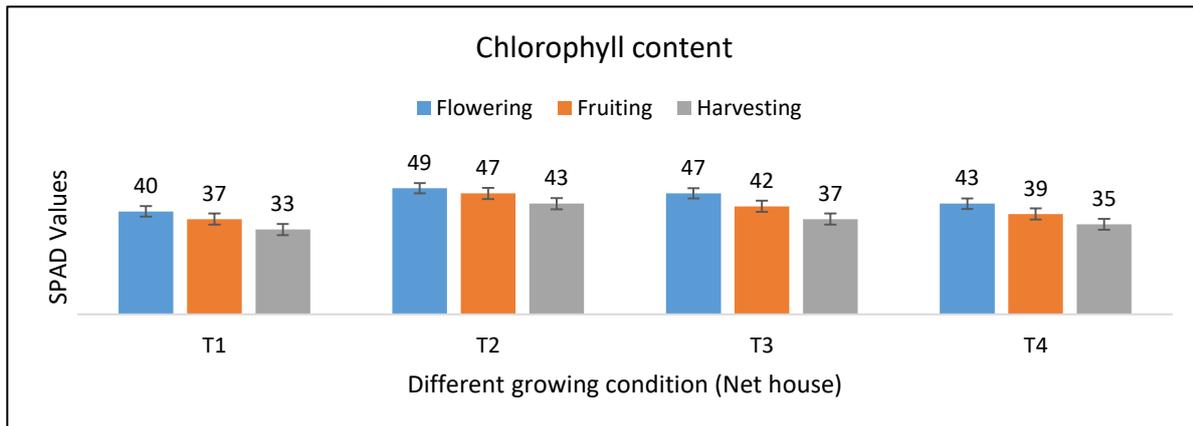


Figure 11: Chlorophyll content of tomato leaves at different growing stages in different growing conditions (Net houses).

Data showed significant differences in growth and yield parameters between four treatments of net house for tomato cultivation in different figures. Significantly, the maximum days required to first flowering were calculated in T1 (58 days), followed by T3 (56 days), and T4 (53 days) (Fig 12). Similar trend was observed for days to 50% flowering also (Fig 13). The days required for the first harvest were greatest in T1 (113 days), followed by T3 (108 days), and shortest in T4 (105 days) (Fig 14). The harvesting duration varied among the net house treatments; it was 22–35 days (Fig 15).

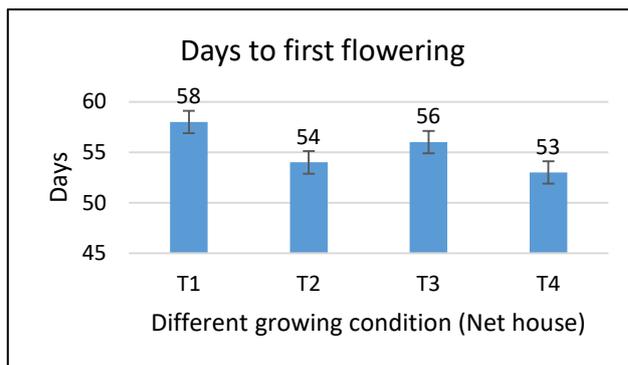


Figure 12: Days to first flowering of tomato in different growing condition.

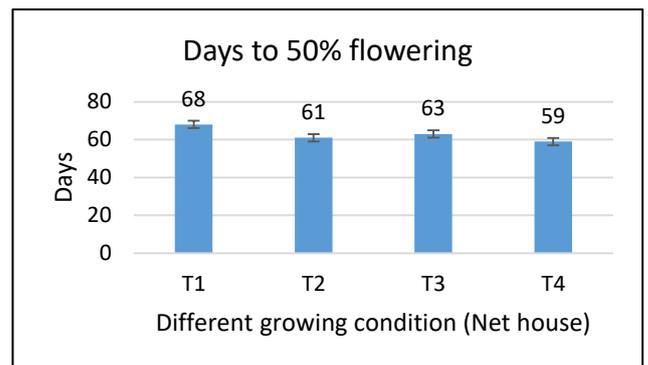


Figure 13: Days to 50% flowering of tomato in different growing condition.

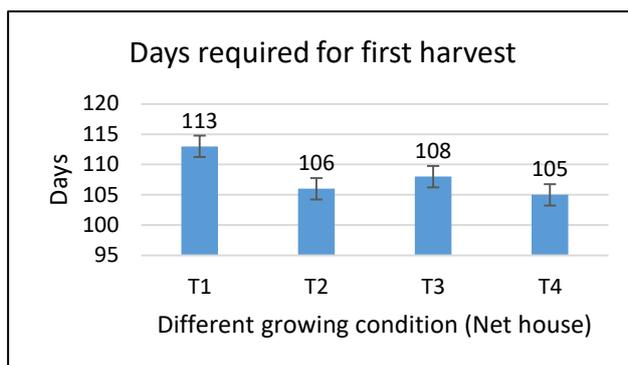


Figure 14: Days required for first harvest of tomato in different growing condition.

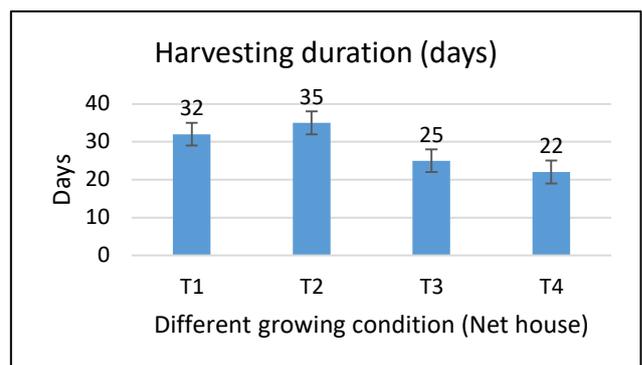


Figure 15: Harvesting duration of tomato in different growing condition.

Plant height at last harvest (235 cm) was maximum in T2, followed by T1 (201 cm), while the minimum plant height was in T4 (155 cm) (Fig 16). According to Abu-Zahra and Mazen (2016), maximum plant height was observed in T2 (net house with transparent poly film), which favored plant growth because plants were less stressed, humidity was higher, evapotranspiration was low, and light transmission was supportive. The T2 net house (having transparent poly film) allowed a favorable light spectrum as compared to T1 (having green shade net), which resulted in better plant growth. Cockshull *et al.* (1992) observed that protected structures expedited the crop growth in tomatoes for high profits, which was affected by the better growth parameters. The findings are in accordance with the results of Bhatia *et al.* (2007). Different growing conditions affect the different growing parameters of a crop and enhance the plant height (Bai and Sudha, 2015). The results also collaborated with the findings of Mantur *et al.* (2007) in sweet pepper and Wani *et al.* (2011) in cucumber.

T2 had the most flower clusters per plant (Fig 17) and the most flowers per cluster (Fig 18) (15 and 5.5, respectively), followed by T4 (14 and 5.3, respectively). In case of flowering parameters, protected structures resulted in more assimilation of photosynthates and accelerated flower initiation. Mukul *et al.* (2017) also observed that the relatively high temperature in the white shade net favors the flowering of cucumber. The difference in light intensity permeability in white and green shade net affects the male and femaleness of lowers. Similar results have been shown by Sahu *et al.* (2016) in sweet pepper. In this study, the number of fruits per plant was also higher in T2 (48), followed by T3 (42) (Fig 19). Maximum fruit setting might be due to transparent UV polyfilm net houses providing required light, its intensity and favorable conditions for fruit setting and fruit retention. Temperature and light intensity played a significant role in plant growth and development. The superiority of the T2 net house (having transparent poly film) with respect to temperature and light management over T1 net house (having green shade net), T3 (only insect net), and T4 (control) resulted in good vegetative growth, which in turn produced a greater number of fruits per plant (Ganesan, 2004). These results are in conformity with the findings of Sandri *et al.* (2003) in tomato and Abu Zahra and Mazen (2016) in cucumber.

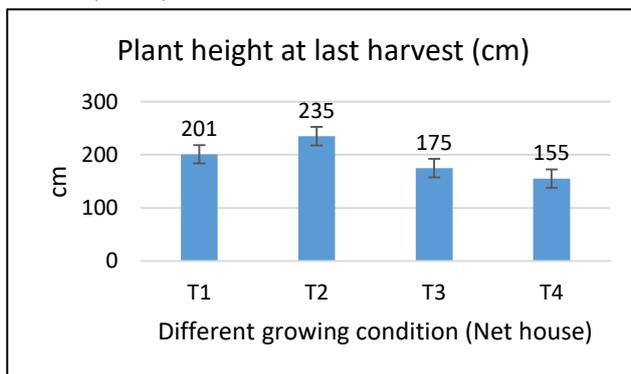


Figure 16: Days to first flowering of tomato in different growing condition

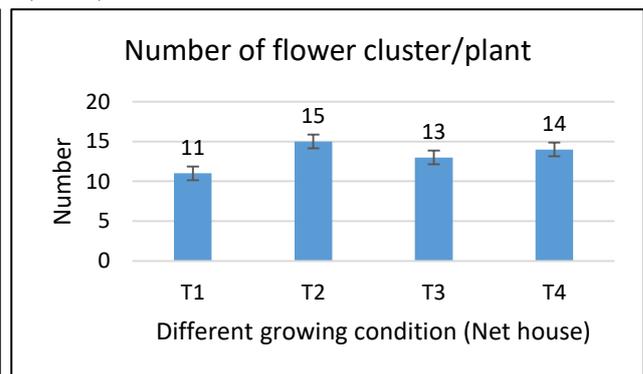


Figure 17: Days to 50% flowering of tomato in different growing condition

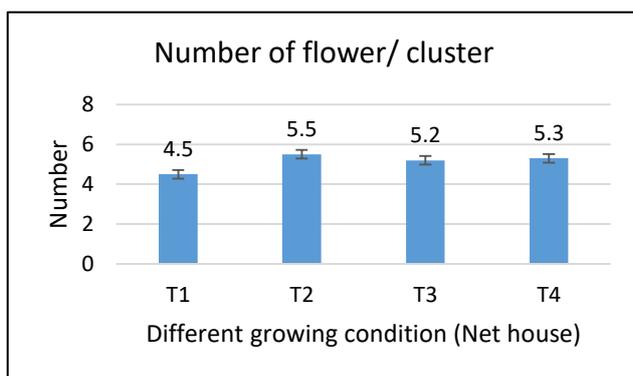


Figure 18: Number of flower/ cluster of tomato in different growing condition

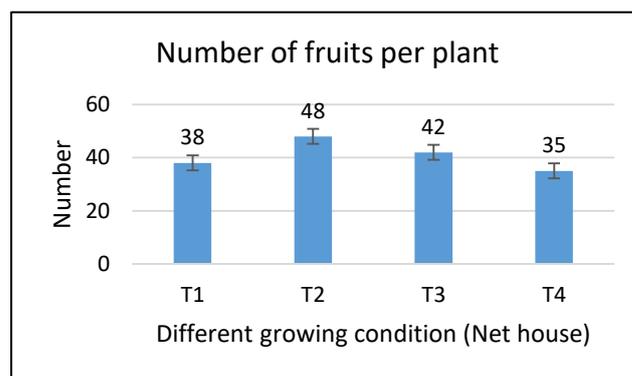


Figure 19: Number of fruits per plant of tomato in different growing condition

The average fruit weight was also higher in T2 (66), followed by T3 (62) and lowest in T4 (57) (Fig 20). T2 net house produced the highest fruit yield per hectare (95.04 t), followed by T3 (78.12 t) and T1 (66.12 t), while T4 (60.9 t) produced the lowest (Fig 21). Higher fruit weight might occur under protected conditions because of the better light interception. The performance of the crop grown inside the protected structure had several beneficial roles on crop growth, yield, and yield attributing characteristics when compared to open field conditions (Patil and Bhagat, 2014). The increasing yield could be attributed to better growth and yield attributes which helped in better yield. These results are in conformity with the findings of Anjanappa *et al.* (2012) and Fukuda and Anami (2002) in cucumber.

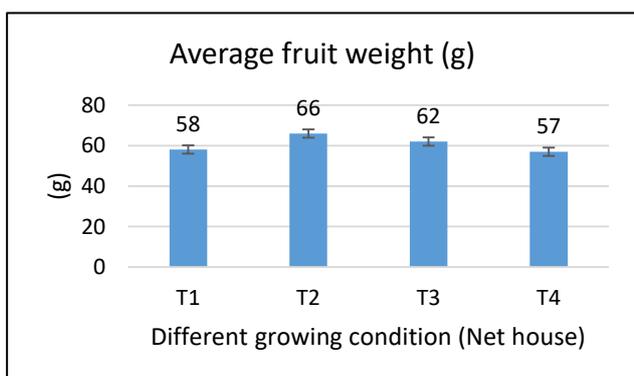


Figure 20: Average fruit weight of tomato in different growing condition

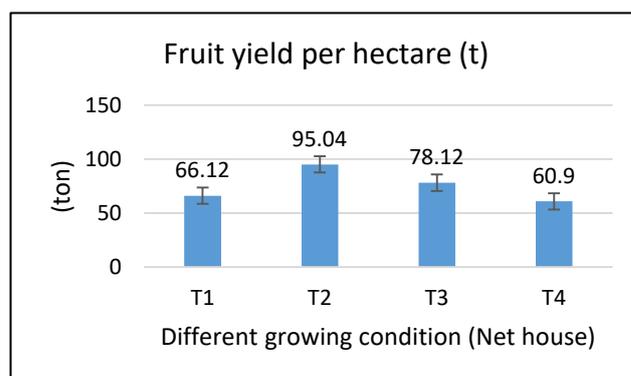


Figure 21: Fruit yield per hectare of tomato in different growing condition

Better fruit length (4.40 cm) (Fig 22), fruit diameter (4.2 cm) (Fig 23), pericarp thickness (5.4 cm) (Fig 24), number of seeds/ fruit (97) (Fig 25) and shelf life (14 days) (Fig 26) were recorded in fruits grown under the T2 net house (having transparent poly film). Fruit length was 4.30 cm in T1, fruit diameter was 4.15 cm in T3, pericarp thickness was 5.3 cm in T1, number of seeds/ fruit was 96 in T4 and shelf life was 13 days in T1. Significantly, the open field (T4) had the highest TSS (5.3% Brix), followed by T2 (5.2% Brix), T3 (5.1% Brix), and T1 (4.9% Brix) (Fig 27).

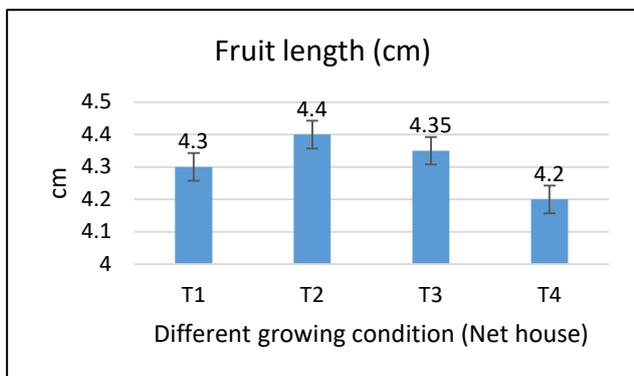


Figure 22: Fruit length of tomato in different growing condition

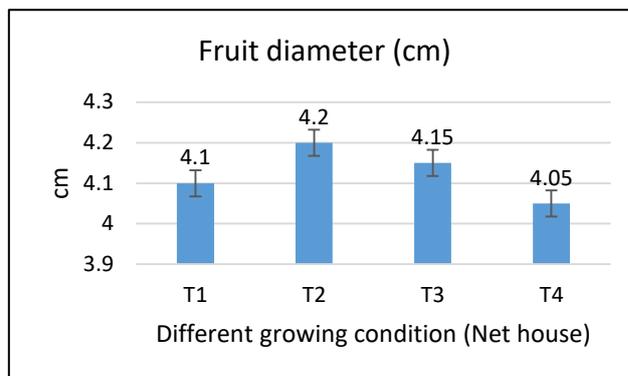


Figure 23: Fruit diameter of tomato in different growing condition

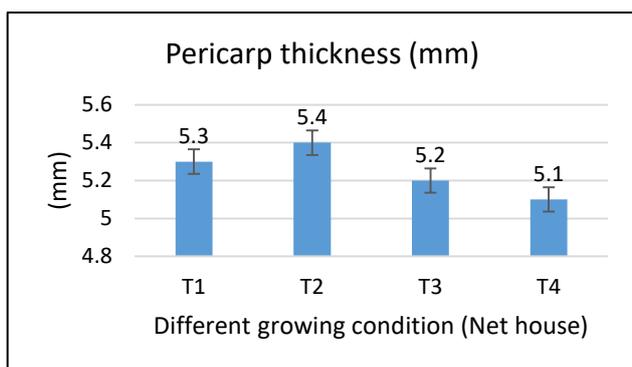


Figure 24: Pericarp thickness of tomato in different growing condition

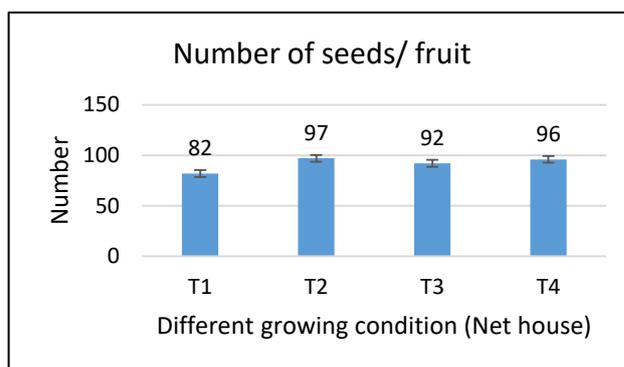


Figure 25: Number of seeds/ fruit of tomato in different growing condition

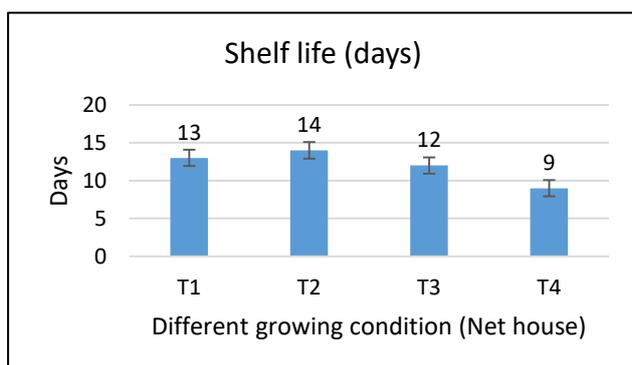


Figure 26: Shelf life of tomato in different growing condition

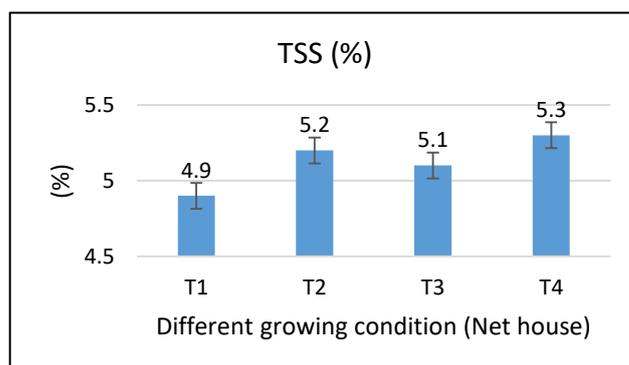


Figure 27: TSS of tomato in different growing condition

Virus infection (in 75 DAS) (0 %) was recorded with T2 net house, followed by T3 (2 %), T1 (5%), while the highest was in control T4 (12 %) (Fig 28). This higher infestation was due to tomato cultivation in open conditions, which favors a lot of leaf sucking pests, especially white fly, to disseminate TYLCV infestation. María and Juan (2014) reported that whiteflies can be considered the second most important type of vector due to their capacity to transmit

many plant viruses, while Chakraborty (2008) reported that whitefly-transmitted gemini viruses cause epidemics in vegetable, staple, and fiber crops.

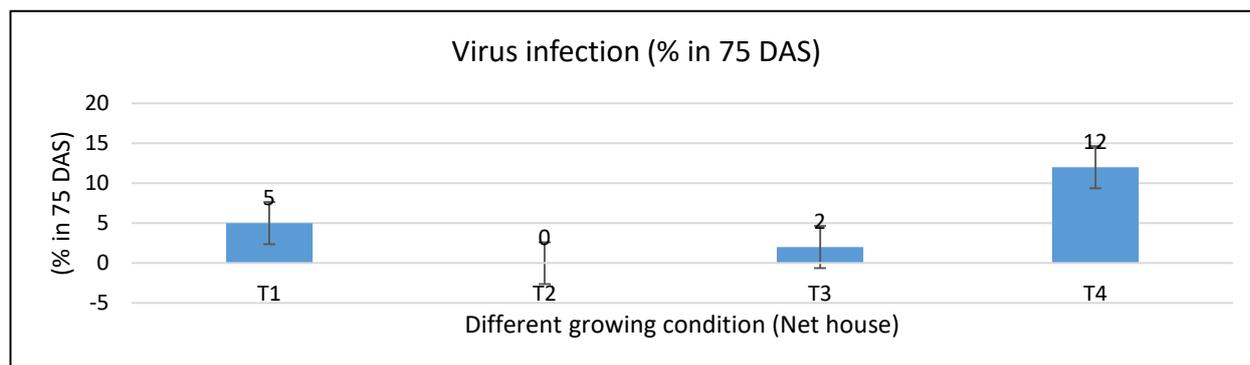


Figure 28: Virus infection of tomato in different growing condition

BCR is an important part of crop production, and it was calculated for this crop over a three-year period. In this study, the BCR values in the first year were lower compared to the 2nd and 3rd years. The best BCR was calculated in T2 (2.11, 5.97, and 5.15 in consecutive 3 years, respectively), followed by T3 (1.73, 4.90, 4.22), and T1 (1.33, 4.15, and 3.58), while T4 was calculated with lower BCR values in the 2nd and 3rd years, viz., 3.17, and 2.68 (Fig 29). In terms of average three-year BCR values, T2 was the highest (4.41), followed by T3 (4.22), T4 (3.20), and T1 (3.02). The main inputs were used viz., seed, fertilizers, vermicompost, bio fertilizer, micronutrients, labor, plant protection chemicals, packing cost, other incidental charges, polyhouse structure (bamboo + poly sheet + insect net), and plant support system during the crop production time. Vethamoni (2017) stated that the highest BCR (2.58) was observed with tomato hybrid CO3 under insect proof net house, followed by shade net house (2.45). The lowest BCR of 1.31 was recorded with the cultivation of coriander variety CO4 under open field conditions.

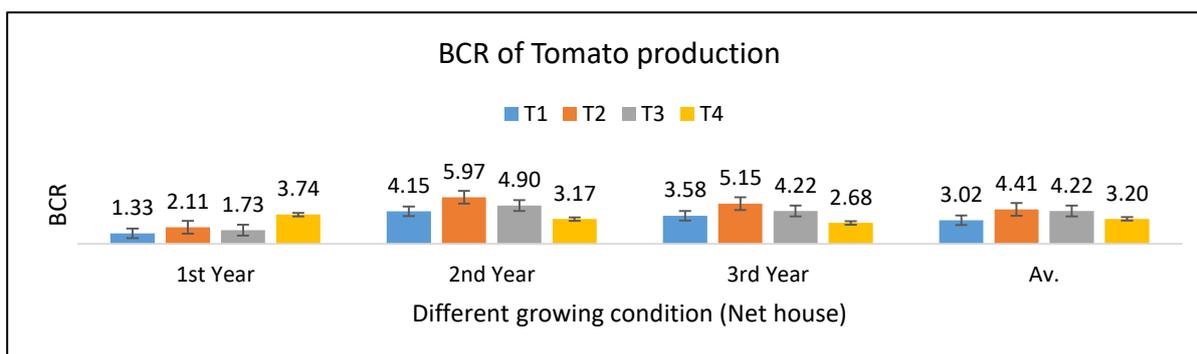


Figure 29: BCR of tomato cultivation in different growing condition

It was mentioned that T2, which was (UV stabilized transparent polyethylene film with 60 mesh insect net) performed best, viz., higher chlorophyll content at three different stages (49, 47, 43 SPAD values), earlier days to first flowering (54 days), earlier days to 50% flowering (61 days), earlier days to first harvest (106 days), longer harvesting duration (35 days), higher plant height at last harvest (235 cm), number of flower clusters/plant (15), number of flowers/plant (5.5), number of fruits per plant (48), average fruit weight (66 g), fruit yield per hectare (95.04 t), fruit length (4.4 cm), fruit diameter (4.2 cm), number of seeds/ fruit (97), shelf life (14 days), TSS (5.2%), zero virus infection (0.0 % in 75 DAS) and higher average BCR of three years (3.13). Fruit weight and fruit yield were found to be linearly related to the

percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

On the other hand, in most cases, the control treatment (T4), which was an open condition, performed inferior compared to the other three treatments. The inferior performances were viz., chlorophyll content at different stages (43, 39, 35), harvesting duration (22 days), plant height at last harvest (155 cm), number of fruits per plant (35), average fruit weight (57 g), fruit yield per hectare (60.9 t), fruit length (4.2 cm), fruit diameter (4.05 cm), pericarp thickness (5.1 mm), shelf life (9 days), virus infection (12.0% in 75 DAS), average BCR of three years (2.32). It might be due to the effects of scorching sunlight, uncontrolled rainfall, infestation of insects and infection of diseases. The cultivation of vegetables in net houses can play a better role in improving quality, advancing maturity, increasing fruiting span, as well as fruit size in sweet pepper (Ilić *et al.*, 2017). These results are in conformity with the findings of Singh and Asrey (2005) in tomato and sweet pepper (Vidyadhar *et al.*, 2014) and Abu-zahra and Mazen (2016) in cucumber.

Effect of different net houses on the growth and quality of eggplant

Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019). The favorable environmental conditions in protective net houses were the result of greater net photosynthesis, which resulted in faster fruit growth throughout the season (Bastias *et al.*, 2011).

There were significant differences among different growing conditions (T1, T2, T3, T4) in leaf chlorophyll content (Fig 30). The highest chlorophyll content was found in plants during the flowering stage in all growing conditions, followed by the fruiting and harvesting stages. However, the plants during flowering stage T2 showed the highest chlorophyll content (52.0), followed by T3 (45.5), open field condition T4 (44.0), and the lowest chlorophyll content was found in T1 (38.0). The same trend was observed in the fruiting and harvesting stages. In the study, leaf chlorophyll content was found to be significantly lower in T1 compared to T2, T3, and T4. The lower chlorophyll content in T1 was due to the low light content for green shade. Hörtensteiner (2006) stated that the catabolic pathway of chlorophyll during senescence and fruit ripening leads to the accumulation of colorless breakdown products. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Bita and Gerats (2013)) in spite of the different studies related to chlorophyll content varying with the growth conditions of tomato leaves (Blunden *et al.*, 1996; Al-Aghabary *et al.*, 2005; Takayama *et al.*, 2006; Wu and Kubota, 2008).

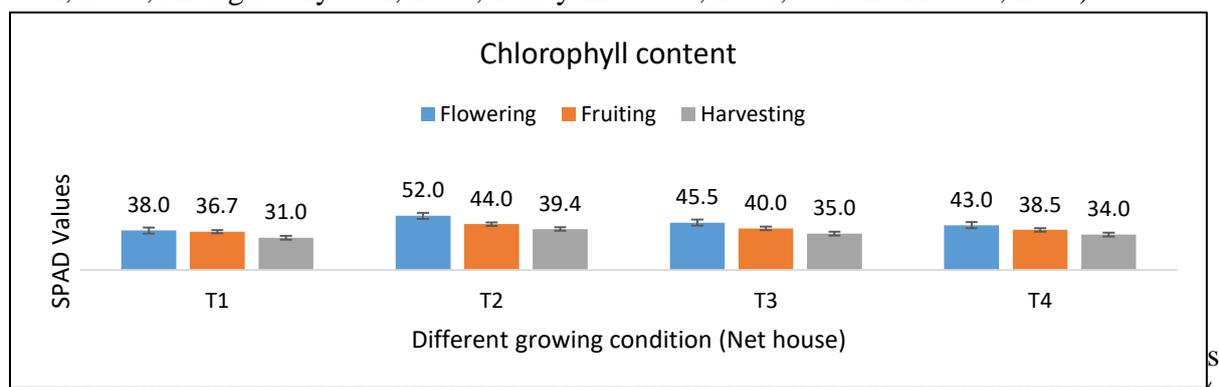


Figure 30: Chlorophyll content of eggplant leaves at different growing stages in different growing condition

Similar trend was observed for days required for first harvest and it was earliest in T2 (103 days), preceded by T4 (104 days), while the delayed days were required in T1 (110 days) (Fig 31). Maximum plant height at last harvest (156 cm) was calculated in T2, followed by T1 (150 cm), while the minimum plant height was in T4 (125 cm) (Fig 31). According to Abu-Zahra and Mazen (2016), maximum plant height is observed in T2 net house (with transparent poly film), which favors plant growth because plants are less stressed, humidity is moderate, evapotranspiration is low, and light transmission is supportive. Hashem *et al.*, (2011) and Cockshull *et al.*, (1992) discovered that protected structure accelerates crop growth in tomato for high profits, which is influenced by better growth parameters are in accordance with the results of Bhatia *et al.* (2007). Different growing conditions affect the different growing parameters of a crop and enhance the plant height (Gilsha Bai and Sudha, 2015). The results also collaborated with the findings of Mantur *et al.* (2007) in sweet pepper and Wani *et al.* (2011) in cucumber.

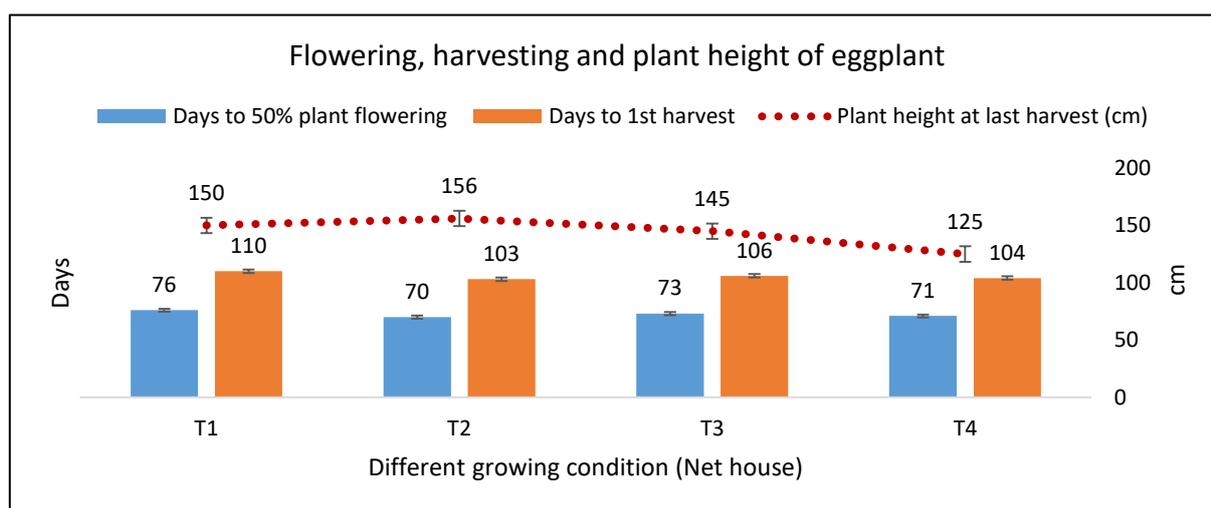


Figure 31: Flowering, harvesting and plant height of eggplant in different growing condition

In this study, the number of fruits per plant was higher in T3 (29) followed by T1 (28) and T2 (26) while the minimum was calculated in T4 (25) (Fig 32). Maximum fruit setting could be attributed to the net house providing the necessary light, intensity, and favorable conditions for fruit setting and retention. Temperature and light intensity played a significant role in plant growth and the development superiority of T3 net house (only insect net) over T1 net house (having green shade net), T2 (transparent polyethylene film), and T4 (control). T2 produced a comparatively lower amount of fruit due to the casing condition of the net house. Because eggplant is a self-pollinated crop, cross pollination was required to some extent for maximum fruit setting. These results are in conformity with the findings of Sandri *et al.* (2003) in tomato, and Abu Zahra and Mazen (2016) in cucumber. The average fruit weight was also higher in T2 (160 g), followed by T3 (122 g), T1 (115 g) and lowest in T4 (106 g) (Fig 32).

T2 net house produced the highest fruit yield per hectare (41.60t), followed by T3 (35.38 t) and T1 (32.20 t), while control T4 produced the lowest (26.50 t) (Fig 33). Higher fruit weight might have occurred under protected conditions because of the better light interception with T2 treatment, i.e., having a transparent UV poly film net house. The performance of the crop grown inside the protected structure had several beneficial roles on crop growth, yield, and yield attributing characteristics when compared to open field conditions (Patil and Bhagat, 2014). The increasing yield could be attributed to better growth and yield attributes which

helped in better yield. These results are in conformity with the findings of Anjanappa *et al.* (2012) and Fukuda and Anami (2002) in cucumber.

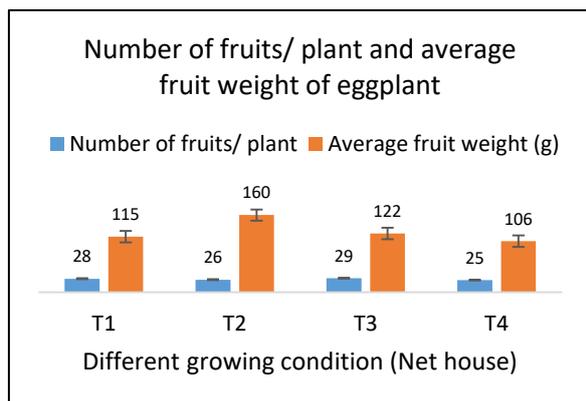


Figure 32: Number of fruits per plant and average fruit weight of eggplant in different growing condition

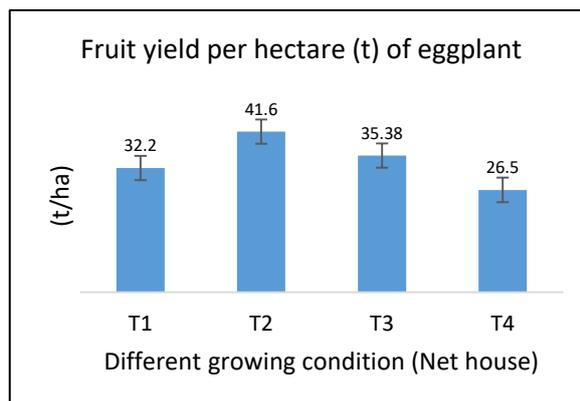


Figure 33: Fruit yield (t/ha) of eggplant in different growing condition

Fruits grown under T2 net house (with transparent UV poly film) had the greatest maximum fruit length (10.90 cm) and fruit diameter (9.2 cm), followed by T3 (fruit length was 10.65 cm, fruit diameter was 9.10 cm) and T1 (fruit length was 10.50 cm, fruit diameter was 9.00 cm) (Fig 34).

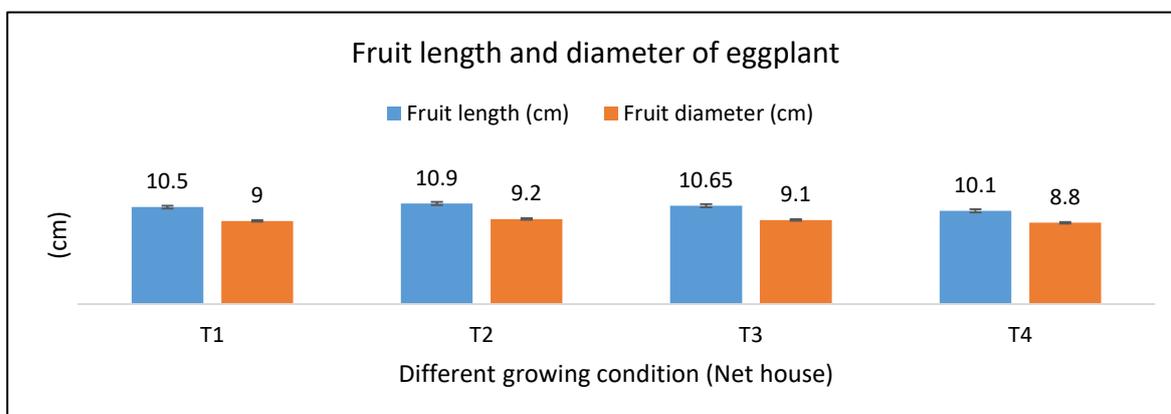


Figure 34: Fruit length and fruit diameter of eggplant in different growing condition

The eggplant shoot and fruit borer are the most important pests for eggplant cultivation. Maximum infestation for both fruit and shoot was calculated in T4 due to open condition cultivation, though fruit infestation (22.0%) was higher compared to shoot (15.0%). The second highest infestation was calculated in T1, which consists of UV stabilized transparent polyethylene film with a 60 mesh insect net along with a green shade net, which favors the high temperature with a high relative humidity percentage. But in this case, the fruit infestation (4.3%) was lower compared to the shoot (7.3%) (Fig 35). Lower fruit infestation and shoot infestation were counted in T2 (3.3% and 2.3%, respectively) and T3 (2.2% and 1.2%, respectively). The lower infestation was due to the T2 being prepared of UV stabilized transparent polyethylene film with 60 mesh insect net and T3 being prepared of only 60 mesh insect net, which ensures higher temperature and lower relative humidity percentage, ultimately resulting in lower infestation of eggplant shoot and fruit borer in eggplant. In addition, several studies have also indicated the need to optimize the mesh size to reduce adverse climatic conditions by allowing better ventilation and reducing heat while offering

effective protection against insect pests (Saidi *et al.*, 2013; Nordey *et al.*, 2017). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

In the case of bacterial wilt infection, zero percent mortality was observed in T2, preceded by T1 (3.3%) and T3 (6.6%), while the maximum mortality was observed in T4 (10.0%) (Fig 36). It might be due to the effects of scorching sunlight, uncontrolled rainfall.

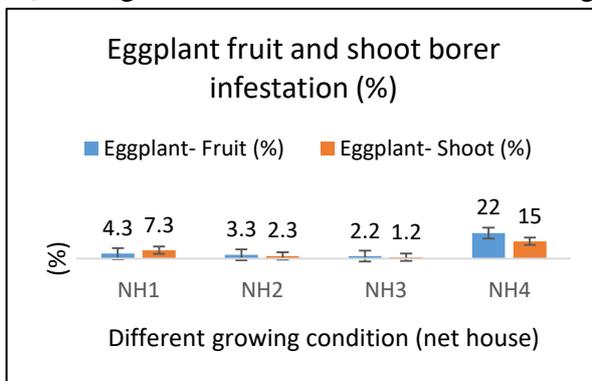


Figure 35: Eggplant shoot and fruit borer infestation (%) of eggplant fruit and eggplant shoot under different type of net house

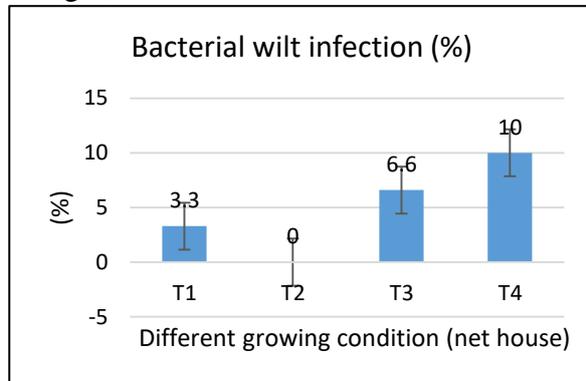


Figure 36: Bacterial wilt infection (%) of eggplant under different type of net house

BCR is an important part of crop production, and it was calculated for this crop over a three-year period. In our study, the BCR values in the first year were lower compared to the 2nd and 3rd years. The best BCR was calculated in T2 for the 2nd and 3rd years (2.51 and 2.19, respectively) except T4 for the 1st year (1.06) due to no involvement of permanent structure. Among the rest of the net houses, the T3 performed well where BCR values were 0.61, 1.72, and 1.50, respectively, in consecutive 3 years, followed by T1 (0.60, 1.75, and 1.52, respectively, in consecutive 3 years), while T4 was calculated with lower BCR values in the 2nd and 3rd years, viz., 0.88, and 0.77 (Fig 37). In terms of average three-year BCR values, T2 had the highest (1.85), followed by T3 (1.50), T1 (1.29), and T4 (0.90). The main inputs were used viz., seed, fertilizers, vermicompost, bio fertilizer, micronutrients, labor, plant protection chemicals, packing cost, other incidental charges, polyhouse structure (bamboo + poly sheet + insect net), and plant support system during the crop production time. Rahman *et al.* (2016) estimated BCR at 3.29 in eggplant production, while Irene (2017) stated that the highest BCR (2.58) was observed with tomato hybrid CO3 under insect proof net house, followed by shade net house (2.45). The lowest BCR of 1.31 was recorded with the cultivation of coriander variety CO4 under open field conditions.

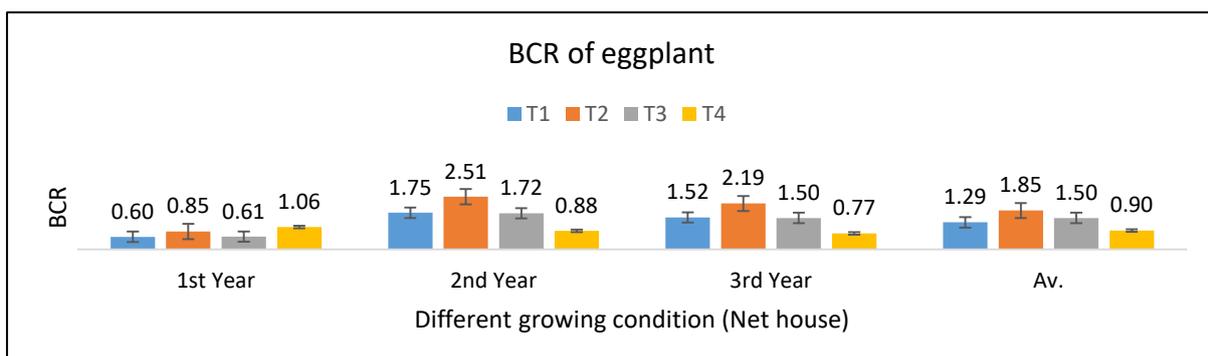


Figure 37: BCR of eggplant cultivation in different growing condition

In most cases, the control treatment (T4), which was an open condition, performed inferior compared to the other three treatments. The inferior performances were viz., chlorophyll content at different stages (43.3, 38.5, 34.0), days to 50% plant flowering (71 days), days to 1st harvest (104 days), plant height at last harvest (125 cm), number of fruits per plant (25), average fruit weight (106 g), fruit yield per hectare (26.50 t), fruit length (10.10 cm), fruit diameter (8.8 cm), fruit infestation (22.0%), shoot infestation (15.0%), bacterial wilt infection (10.0%), and average BCR of three years (0.90). It might be due to the effects of scorching sunlight, uncontrolled rainfall, infestation of insects and infection of diseases. The cultivation of vegetables in net houses can play a better role in improving quality, advancing maturity, increasing fruiting span, as well as fruit size in sweet pepper (Zoran *et al.*, 2017). These results are in conformity with the findings of Singh and Asrey (2005) in tomato and sweet pepper (Vidyadhar *et al.*, 2014) and Abu-zahra and Mazen (2016) in cucumber.

Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.* 2019). Fruit weight and fruit yield could be affected by changes in environmental conditions beneath the protective net house system. The unfavorable environmental conditions prevented the development of proper fruit size, resulting in a decrease in fruit weight. This might be due to higher temperatures during flowering and fruiting stages. The unfavorable environmental conditions prevented the development of proper fruit size, resulting in a decrease in fruit weight. The favorable environmental conditions in protective net houses were the result of greater net photosynthesis, which resulted in faster fruit growth throughout the season (Bastias *et al.*, 2011). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

The effect of different net houses on the growth and quality of sweet pepper

The greater growth and fruit set of plants grown under favorable conditions may be explained by the higher rate of photosynthesis that these plants exhibit (Fraga *et al.*, 2019). Greater net photosynthesis occurred from the favorable environmental conditions in protected net homes, which sped up fruit growth throughout the season (Bastias *et al.*, 2011). The amount of chlorophyll in the leaves of sweet pepper under various growing circumstances (T1, T2, T3, T4) varied significantly (Fig 38). In all growing conditions (net houses), the flowering stage of the plant had the maximum chlorophyll concentration, which was followed by the fruiting and harvesting periods. However, the plants during flowering stage T2 showed the highest chlorophyll content (48.0), followed by T3 (42.5) and open field condition T4 (39.6), while the lowest chlorophyll content was found in T1 (37.8). The same trend was observed in the fruiting and harvesting stages. In this study, leaf chlorophyll content was found to be significantly lower in T1 compared to T2, T3, and T4. The lower chlorophyll content in T1 is due to the low light content for green shade. Hörtensteiner (2006) stated that the catabolic pathway of chlorophyll during senescence and fruit ripening leads to the accumulation of colorless breakdown products. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Bita and Gerats, 2013). Despite numerous research showing that tomato leaves' chlorophyll content varies depending on the development environment (Al-aghabary *et al.*, 2005; Blunden *et al.*, 1996; Wu and Kubota, 2008; Takayama *et al.*, 2006).

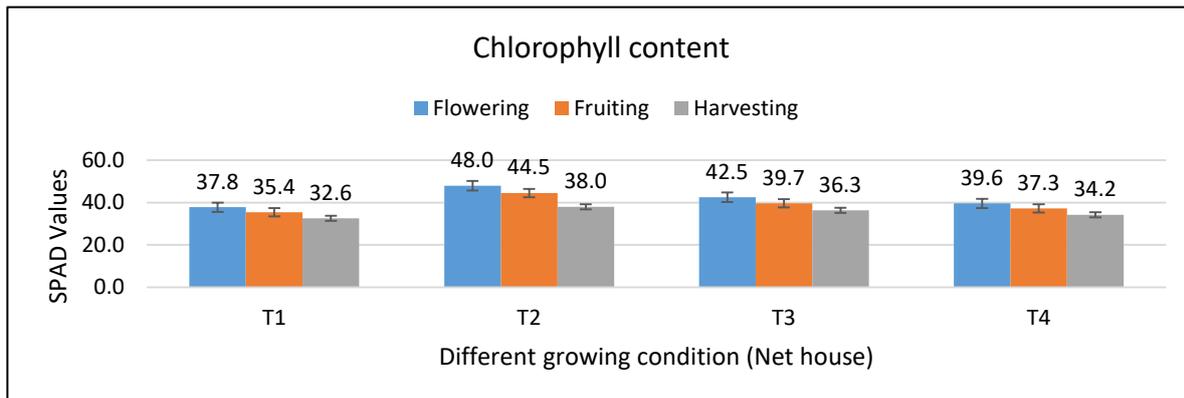


Figure 38: Chlorophyll content of sweet pepper leaves in different growing condition

Data showed a significant difference in growth and yield parameters among four treatments of net house for sweet pepper cultivation. The minimum days were required for 50% flowering in T2 (68 days), preceded by T4 (69 days), while the highest days were required by T1 (74 days). The same trend was observed for days required for first harvest, while it was earliest in T2 (100 days), followed by T4 (102 days), and the delayed days required in T1 (106 days) (Fig 39). At last harvest, maximum plant height (82 cm) was calculated in T1, followed by T2 (76 cm), while minimum plant height was in T4 (65 cm) (Fig 39). Maximum plant height (82 cm) was observed in T1 net house (having transparent poly film with green shade net), which favors plant growth because plant cells were elongated in some types of shade, which agrees with Abu-Zahra and Mazen (2016). T1 net house (having transparent poly film with green shade net) allowed a favorable 20% light cut spectrum as compared to T2 (having transparent poly film), which resulted in better plant growth. Mantur *et al.* (2007) obtained that protected structures expedite the crop growth in sweet pepper for high profits, which is affected by the better growth parameters. Different growing conditions affect the different growing parameters of a crop and enhance the plant height (Bai and Sudha, 2015). Hashem *et al.* (2011) and Cockshull *et al.* (1992) obtained that protected structures expedite the crop growth in tomatoes for high profits, which is affected by the better growth parameters.

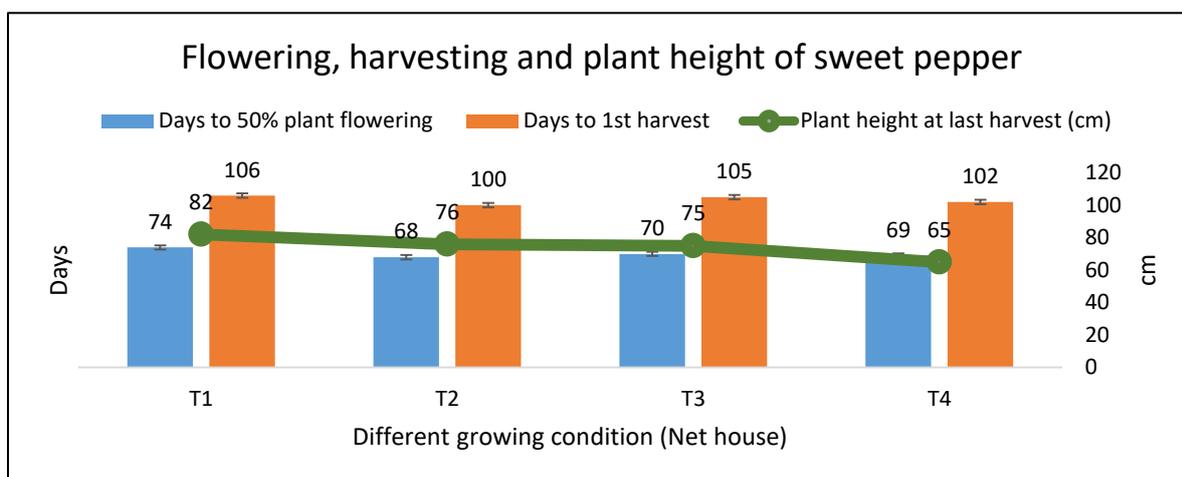


Figure 39: Flowering, harvesting and plant height of sweet pepper leaves in different growing condition

In this study, the number of fruits per plant was also higher in T2 (9) followed by T1 and T3 (8), while the minimum was calculated in T4 (7) (Fig 40). Maximum fruit setting might be due to transparent UV polyfilm net houses providing required light, its intensity and favorable conditions for fruit setting and fruit retention. Temperature and light intensity played a significant role in plant growth and development. The superiority of the T2 net house (having transparent poly film) with respect to temperature and light management over T1 net house (having green shade net), T3 (only insect net), and T4 (control) resulted in good vegetative growth, which in turn produced a greater number of fruits per plant (Ganesan, 2004). These results are in conformity with the findings of Sandri *et al.* (2003) in tomato and Abu Zahra and Mazen (2016) in cucumber. The average fruit weight was also higher in T2 (139 g), followed by T1 (115 g), T3 (112 g) and lowest in T4 (95 g) (Fig 40).

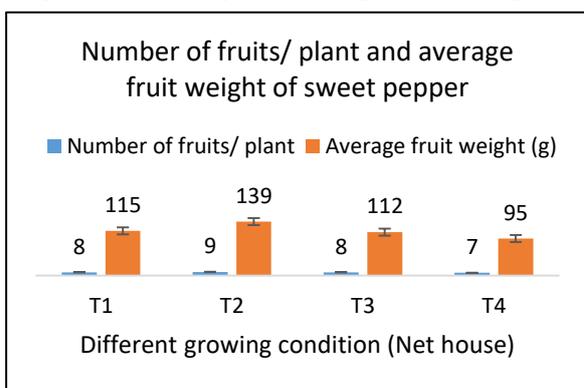


Figure 40: Number of fruits per plant and average fruit weight in different growing condition

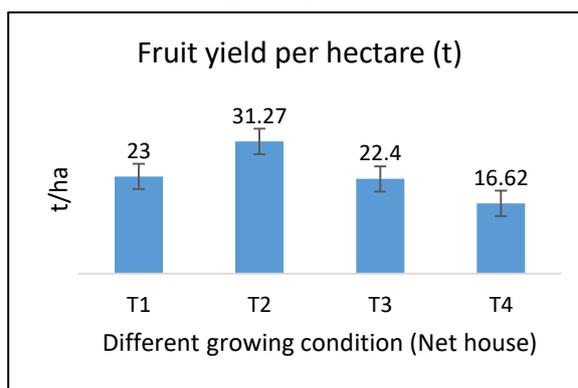


Figure 41: Fruit yield (t/ha) of sweet pepper in different growing condition

T2 net house produced the highest fruit yield per hectare (31.27 t), followed by T1 (23.00 t), T3 (22.40 t), and control T4 (16.62 t) (Fig 41). Higher fruit weight might have occurred under protected conditions because of the better light interception with T2 treatment, i.e., having a transparent UV poly film net house. The performance of the crop grown inside the protected structure has several beneficial roles on crop growth, yield, and yield attributing characteristics when compared to open field conditions (Patil and Bhagat (2014)). The increasing yield could be attributed to better growth and yield attributes which helped in better yield. These results are in conformity with the findings of Anjanappa *et al.* (2012); Fukuda and Anami (2002) in cucumber.

Fruits grown under T2 net house (with transparent UV poly film) had the maximum fruit length (9.90 cm) and fruit diameter (6.2cm) (Fig 42), followed by T1 (8.50 cm and 6.00 cm, respectively) and T3 (8.05 cm and 5.80 cm, respectively).

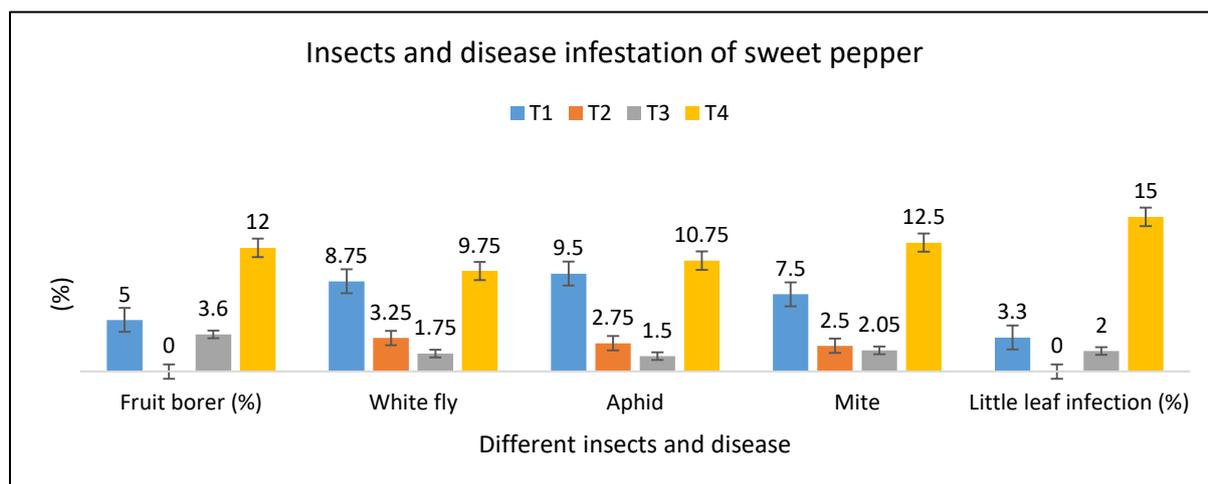


Figure 43: Different insects and disease infestation of sweet pepper in different types of growing conditions

T2 net house (with transparent poly film) had 0% fruit borer infestation, preceded by T1 (5.0%), and T4 had 12.0% infestation of white flies, the lowest infestation was recorded in T3 (1.75%), preceded by T2 (3.25%), T1 (8.75%), and T4 recorded the highest infestation (9.75%). The same trend was observed in aphid infestation, where T3 showed the lowest infestation with 1.5%, followed by T2 (2.75%), T1 (9.5%), and T4 was the maximum with 10.75%. The net house was an important pest while we cultivated. Due to its infestation, the leaves were stunted with restricted leaf growth. The infestation trend was as earlier pest, while the lowest was in T3 with 2.05%, followed by T2 (2.5%), T1 (7.5%), and the highest was in T4 (12.5%) (Fig 43). The lower infestation was due to the T2 being prepared of UV stabilized transparent polyethylene film with a 60 mesh insect net and T3 being prepared of only a 60 mesh insect net, which ensures higher temperature and lower relative humidity percentage, ultimately resulting in lower infestation of different insects and diseases in sweet pepper. In addition, several studies have also indicated the need to optimize the mesh size to reduce adverse climatic conditions by allowing better ventilation and reducing heat while offering effective protection against insect pests (Saidi *et al.*, 2013; Nordey *et al.*, 2017). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

Among all the diseases, the little leaf disease was significantly harmful, while the zero percent infection was in T2, preceded by T3 (2.0%), T1 (3.3%), and the maximum was in T4 (15.0%) (Fig 43). This is because open fields are not protected against scorching sunlight, heavy rainfall, cold wind, and high humidity. The open field condition also promotes disease (Singh *et al.*, 2003, 2005).

BCR is an important part of crop production, and it was calculated for this crop over a three-year period. In our study, the BCR values in the first year were lower compared to the 2nd and 3rd years. The best BCR was calculated in T2 (2.73, 9.09, and 8.81 in consecutive 3 years, respectively), followed by T3 (2.06, 6.87, 6.74), and T1 (1.93, 6.62, 6.13), while T4 was calculated with lower BCR values at 1.73, 1.81, and 1.68 (Fig 44). In terms of average three-year BCR values, T2 was the highest (6.88), followed by T3 (6.74), T1 (4.79), and T4 (1.76). The lower BCR in T4 (open condition) was due to sweet pepper production only one season a year, whereas the T1, T2, and T3 produced 2 seasons a year. The main inputs were used viz., seed, fertilizers, vermicompost, bio fertilizer, micronutrients, labour, plant protection chemicals, packing cost, other incidental charges, polyhouse structure (bamboo + poly sheet + insect net), and plant support system during the crop production time. Singh *et al.* (2011) observed BCR was (4.72) in polyhouse, (3.68) in poly-tunnel, and (3.03) in poly mulching, while it was lowest in open field conditions (2.12). Vethamoni (2017) stated that

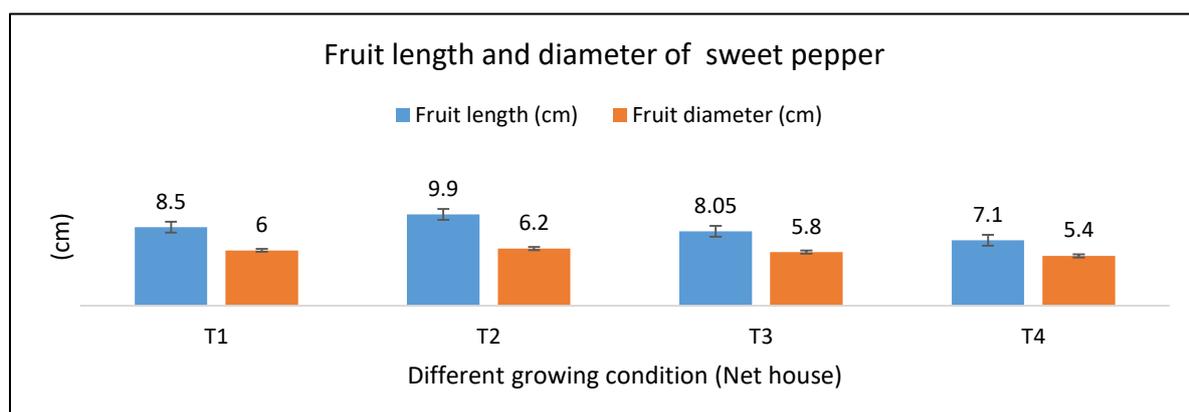


Figure 42: Fruit length and diameter of sweet pepper leaves in different growing condition

the highest BCR (2.58) was observed with tomato hybrid CO3 under insect proof net house, followed by shade net house (2.45). The lowest BCR of 1.31 was recorded with the cultivation of coriander variety CO4 under open field conditions.

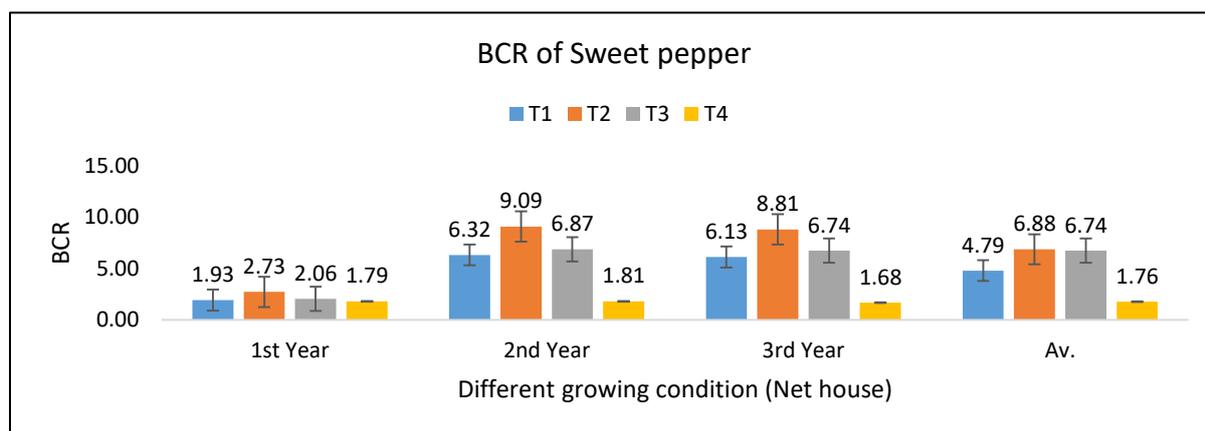


Figure 44: Fruit length and diameter of sweet pepper leaves in different growing condition

In maximum cases the control treatment (T4) which was open condition performed inferior except early flowering and harvesting compare to other three treatments. Plant height at last harvest (65 cm), number of fruits/plant (7), average fruit weight (95 g), fruit yield per hectare (16.62 t), fruit length (7.10 cm), fruit diameter (5.40 cm), fruit borer, white fly, aphid, and mite infestation were respectively 12.0%, 9.75, 10.75, and 12.5%, and little leaf infection was 15.0%. It might be due to the effects of scorching sunlight, uncontrolled rainfall, infestation of insects and infection of diseases. BCR is also lower (1.76) on average over 3 years. The cultivation of vegetables in net houses can play a better role in improving quality, advancing maturity, increasing fruiting span, as well as fruit size in sweet pepper (Zoran *et al.*, 2017). These results are in conformity with the findings of Singh and Asrey (2005) in tomato and sweet pepper, Vidyadhar *et al.* (2014) in tomato, and Abu-Zahra and Mazen (2016) in cucumber.

Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019). Fruit weight and fruit yield could be affected by changes in environmental conditions beneath the protective net house system. The unfavorable environmental conditions prevented the development of proper fruit size, resulting in a decrease in fruit weight. This might be due to higher temperatures during flowering and fruiting stages. The unfavorable environmental conditions prevented the development of proper fruit size, resulting in a decrease in fruit weight. The favorable environmental conditions in protective net houses were the result of greater net photosynthesis, which resulted in faster fruit growth throughout the season (Bastias *et al.*, 2011). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

The effect of different net houses on the growth and quality of cucumber

Greater net photosynthesis occurred from the favorable environmental conditions in protected net homes, which sped up fruit growth throughout the season (Bastias *et al.*, 2011). Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019). There were significant differences among different growing conditions (T1, T2, T3, T4) in leaf chlorophyll content (Fig 45). The highest chlorophyll content was found in plants during the flowering stage in all growing conditions (net houses), followed by the fruiting and harvesting stages. However, the plants during flowering stage T2 showed the highest chlorophyll content (49.6), followed by T3 (44.8), T4 (41.4) and the lowest chlorophyll content was found in T1 (40.4). The same trend was observed in the fruiting and harvesting stages. In the study, leaf chlorophyll content was found to be significantly lower in T1 compared to T2, T3, and T4. The lower chlorophyll content in T1 is due to the low light content for green shade. Hörtensteiner (2006) stated that the catabolic pathway of chlorophyll during senescence and fruit ripening leads to the accumulation of colorless breakdown products. Jenkins *et al.*, 1981 also stated a large decrease was observed in the chlorophyll content of the primary leaves. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Bita and Gerats, 2013). In spite of the many studies related to chlorophyll content varying with growth conditions of tomato leaves (Blunden *et al.*, 1996; Al-aghabary *et al.*, 2005; Takayama *et al.*, 2006; Wu and Kubota, 2008).

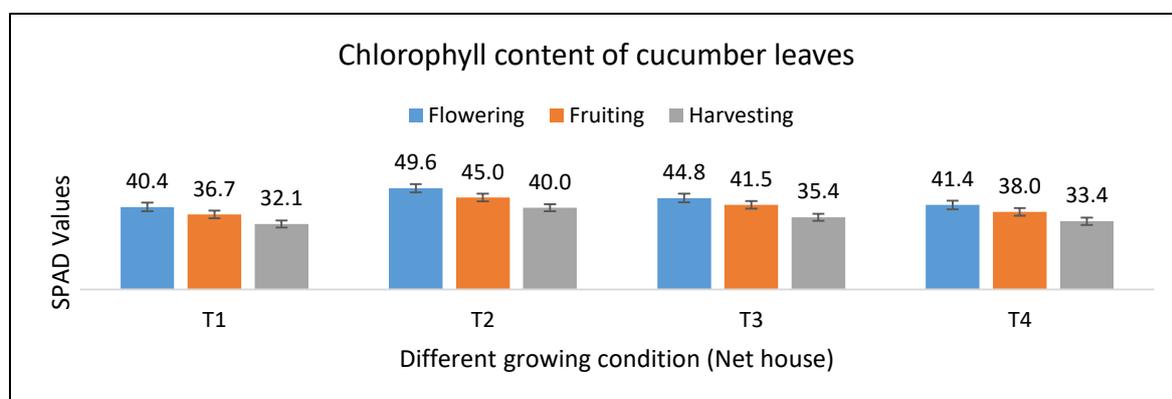


Figure 45: SPAD values of cucumber leaves in different growing condition

Data in Fig 46 showed significant differences in growth and yield parameters between four treatments of net house. Maximum vine length at 30 DAS (40.3 cm) was calculated in T2, followed by T1 (30.5 cm), while minimum length was in T4 (27.0 cm). The vine length at 60 DAS followed the same pattern, with T2 producing the longest (210.5cm). Maximum vine length was observed in T2 net house (with transparent poly film), which favors plant growth because plants are less stressed, humidity is moderate, evapotranspiration is low, and light transmission is favorable, as Abu-Zahra and Mazen (2016) found that T2 net house (having transparent poly film) that allowed a favorable light spectrum as compared to T1 (having green shade net), which resulted in better plant growth.

T2 had the shortest days to first male and female flowering (35.0 and 43.0 days, respectively), while T1 took the longest time to first male and female flowering (38.0 and 49.0 days, respectively) (Fig 47). The delay may be due to light cuts having green shade nets in T1. Bhatia *et al.* (2007) found that protected structures expedite the crop growth in the

early season of muskmelon crop for high profits, which is affected by the better growth parameters.

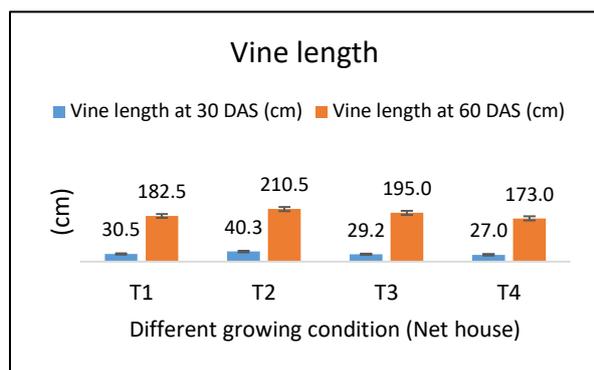


Figure 46: Vine length at 30 DAS and 60 DAS of cucumber in different types of growing conditions

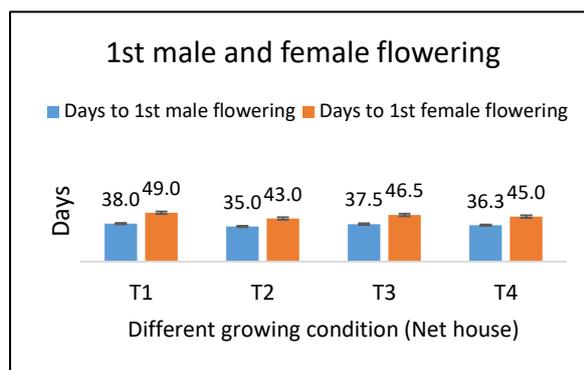


Figure 47: Days to 1st male and female flowering of cucumber in different types of growing conditions

T2 had the highest number of male flowers per plant (65), and the lowest number of female flowers per plant (24), while T2 had the shortest time from fruit set to edible maturity (12.5 days) (Fig 48). Different growing conditions affected the growing parameters of a crop and enhance the plant height (Gilsha Bai and Sudha, 2015). The results also collaborated with the findings of Wani *et al.* (2011) in cucumber.

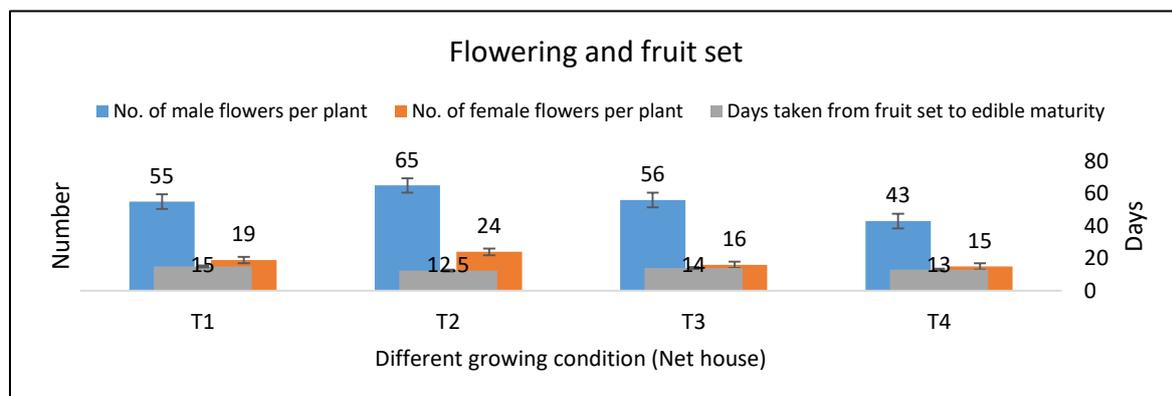


Figure 48: Number of male flowers per plant, number of female flowers per plant days taken from fruit set of cucumber in different types of growing conditions

Treatment T2 (Fig 49) had the lowest sex ratio (2.71) while the highest percent fruit set (37.0) was observed in T4. It was also mentioned that due to the nature of cross-pollination of cucumbers, it is needed to out-cross with the help of pollinators. But due to protected net houses in T1, T2, and T3, the cross pollination was hampered. So, to overcome this issue, hand pollination was done for sufficient fruit set. In the case of flowering parameters, protected structures resulted in more assimilation of photosynthates and accelerated the flower initiation. The flowers appear on every node of the vine, and therefore, increased vine length resulted in more flowering. Kumar *et al.* (2017) also observed that the relatively high temperature in the white shade net favours the flowering of cucumber. The difference in light intensity permeability in white and green shades has a net effect on the male and femaleness of lowers. Similar results have been shown by Sahu *et al.* (2016) in sweet pepper. Also, maximum fruit setting might be due to that white shade net providing required light, its

intensity, and favorable conditions for fruit setting and fruit retention. These results are in conformity with the findings of Abu Zahra and Mazen (2016) in cucumber.

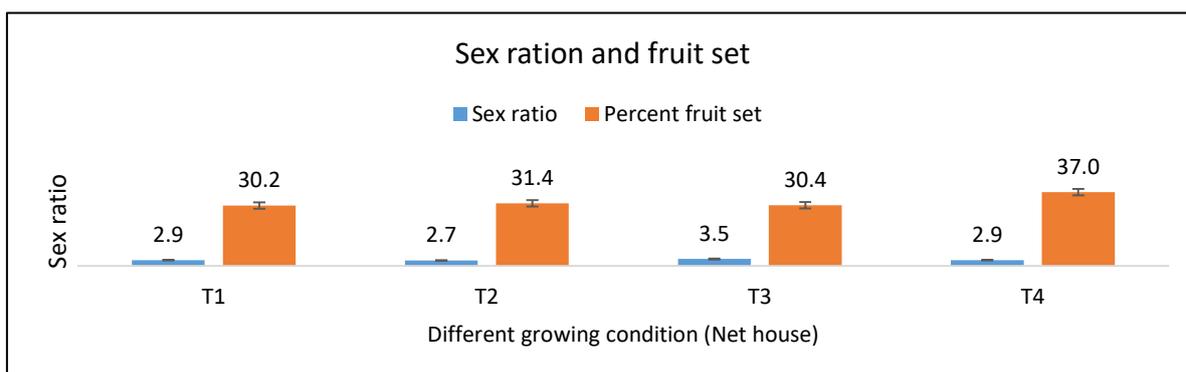


Figure 49: Sex ration and fruit set of cucumber in different types of growing conditions

T2 net house had the highest number of fruits per plant (9.0), individual fruit weight (160 g), and per hectare fruit yield (28.8 t), followed by T1 net house (7.5, 150 g, 1.13 kg, and 22.5 t, respectively) (Fig 50). Temperature and light intensity played a significant role in plant growth and development. The superiority of the T2 net house (having transparent poly film) with respect to temperature and light management over T1 net house (having green shade net), T3 (only insect net), and T4 (control) resulted in good vegetative growth, which in turn produced a greater number of fruits per plant (Ganesan, 2004). These results are in conformity with the findings of Fukuda and Anami (2002) in muskmelon. Greater fruit weight might occur under protected conditions because plants avoid large gaps between plants and rows while simultaneously optimizing light interception in muskmelon (Rodriguez *et al.*, 2007). The performance of the crop grown inside the protected structure has several beneficial roles on crop growth, yield, and yield-attributing characteristics compared to open field conditions (Patil and Bhagat, 2014). The above results are in conformity with those of Patil and Bhagat (2014) and Anjanappa *et al.* (2012) in cucumber.

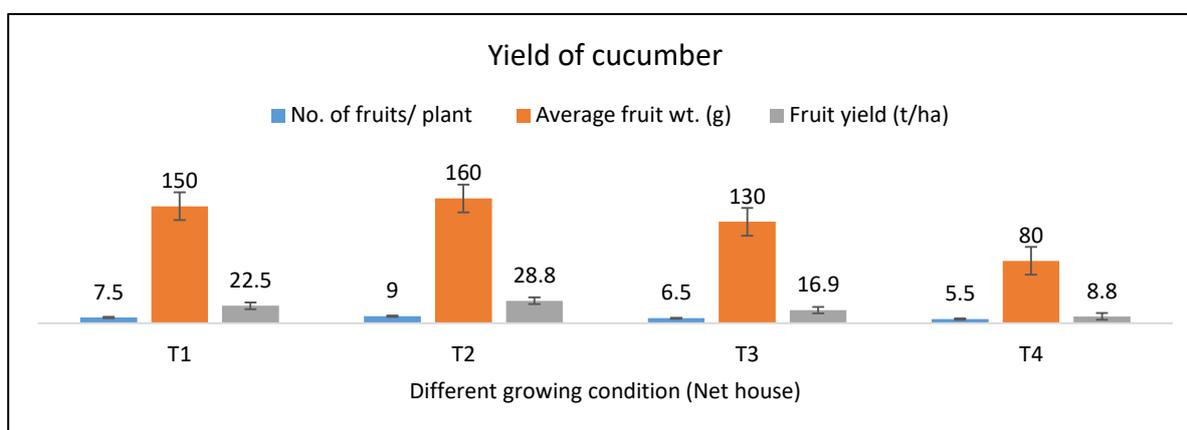


Figure 50: Number of fruits per plant, individual fruit weight and per hectare fruit yield of cucumber in different types of growing conditions

Maximum fruit length (16.2 cm) and fruit diameter (5.2 cm) were recorded in fruits grown under the T2 net house (having transparent poly film), followed by T1 (14.5 cm and 4.8 cm, respectively) having green shade net (Fig 51). In the case of thickness of pulp (0.9 cm) and diameter of seed cavity (3.4 cm), the T2 net house (having transparent poly film) performed better, followed by T1 (0.8 cm and 3.2 cm, respectively) having green shade net (Fig 52). In

all the cases, the control treatment, which was left open, performed inferior compared to the other three treatments. It might be due to the effects of scorching sunlight, uncontrolled rainfall, infestation of insects and infection of diseases.

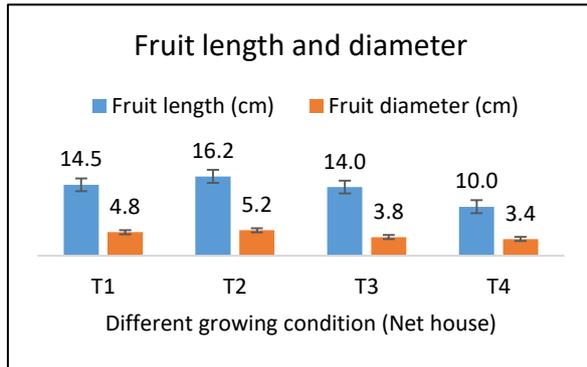


Figure 51: Fruit length and fruit diameter of cucumber in different types of growing conditions

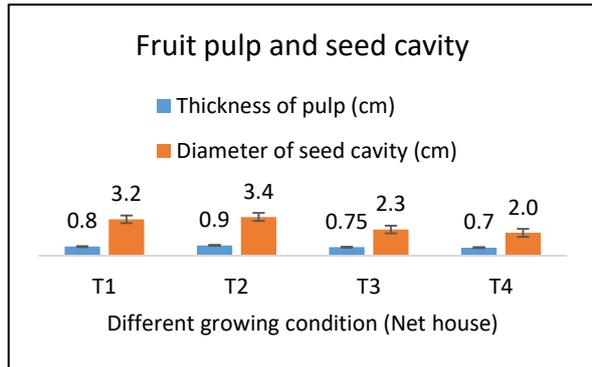


Figure 52: Thickness of fruit pulp and diameter of seed cavity of cucumber in different types of growing conditions

Minimum fruit fly infestation (2%) was recorded in T2 net house (having transparent poly film), preceded by T1 (3.0%), while T4 exhibited highest infestation (15.5%). In case of alternaria leaf spot, the lowest infection was recorded in T2 (2.5%), preceded by T3 (5.0%), T1 (5.0%), and T4 (which recorded the highest infection (10.0%). The same trend was observed in mosaic virus infection, where T2 showed a zero per cent infection, followed by T3 (2.0%), T1 (5.0%), and T4 was maximum with 12.5% (Fig 53). This is because open fields are not protected against scorching sunlight, heavy rainfall, cold wind, and high humidity. The open field condition also promotes disease (Singh *et al.*, 2003, 2005). The lower infestation was caused by T2 being made of UV stabilized transparent polyethylene film with a 60 mesh insect net and T3 being made of only a 60 mesh insect net, which ensures a higher temperature and lower relative humidity percentage, resulting in a lower incidence of various insects and diseases in cucumber. In addition, several studies have also indicated the need to optimize the mesh size to reduce adverse climatic conditions by allowing better ventilation and reducing heat while offering effective protection against insect pests (Saidi *et al.*, 2013; Nordey *et al.*, 2017). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

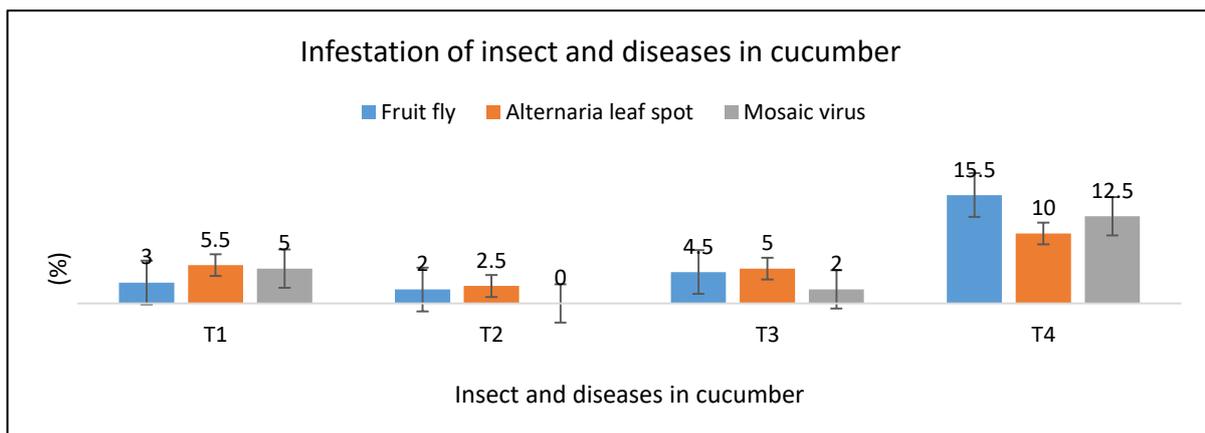


Figure 53: Incidence of insect and diseases in cucumber cultivation in different growing condition

BCR is an important part of crop production, and it was calculated for this crop over a three-year period. In this study, the BCR values in the first year were lower compared to the 2nd and 3rd years. The best BCR was calculated in T2 (1.53, 4.92, and 4.63 in consecutive 3 years, respectively), followed by T1 (0.91, 3.57, 3.63), T3 (0.71, 2.62, 2.29), and T4 was calculated with lower BCR values with 0.65, 0.69, and 0.67 (Fig 54). In terms of average three-year BCR values, T2 had the highest (3.69) followed by T1 (2.71), T3 (2.29) and T4 (0.67). The lower BCR in T4 (open condition) was due to cucumber production only two seasons in a year, whereas the T1, T2, and T3 produced 3 seasons in a year. The main inputs were used viz., seed, fertilizers, vermicompost, bio fertilizer, micronutrients, labor, plant protection chemicals, packing cost, other incidental charges, polyhouse structure (bamboo + poly sheet + insect net), and plant support system during the crop production time. Singh *et al.* (2011) observed BCR was (4.72) in polyhouse, (3.68) in poly-tunnel (3.03) in poly mulching, while it was lowest in open field conditions (2.12) in sweet pepper. Irene (2017) stated that the highest BCR (2.58) was observed with tomato hybrid CO3 under insect proof net house, followed by shade net house (2.45). The lowest BCR of 1.31 was recorded with the cultivation of coriander variety CO4 under open field conditions.

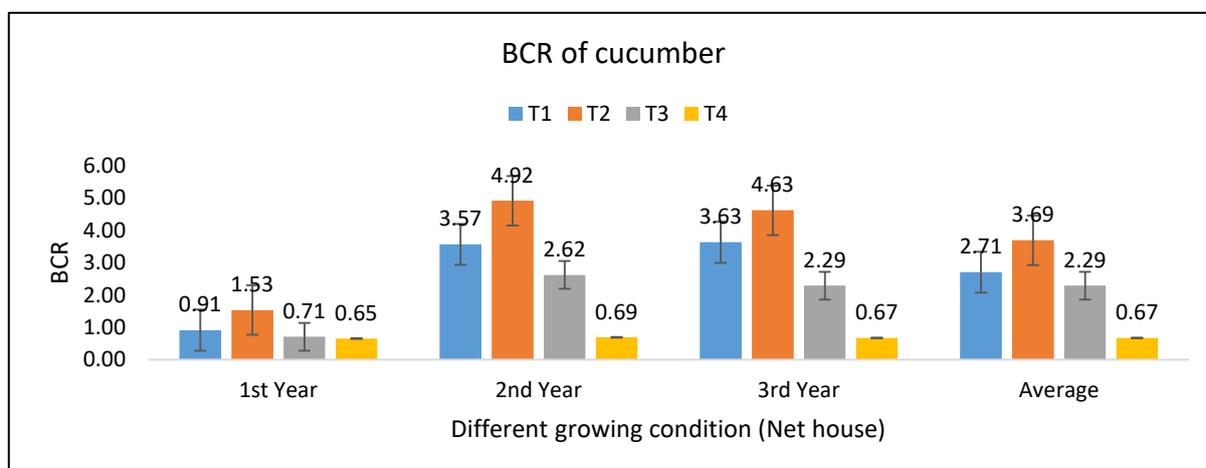


Figure 54: BCR of cucumber cultivation in different growing condition

Effect of different net houses on growth and quality of netted melon

Higher net photosynthesis occurred from the favorable environmental conditions in protected net homes, which sped up fruit growth throughout the season (Bastias *et al.*, 2011). Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019). There were significant differences among different growing conditions (T1, T2, T3, T4) in leaf chlorophyll content (Fig 55). The highest chlorophyll content was found in plants during the flowering stage in all growing conditions (net houses), followed by the fruiting and harvesting stages. However, the plants during flowering stage T2 showed the highest chlorophyll content (53.5), followed by T3 (43.4), T4 (41.0) and the lowest chlorophyll content was found in T1 (40.0). The same trend was observed in the fruiting and harvesting stages. In the study, leaf chlorophyll content was found to be significantly lower in T1 compared to T2, T3, and T4. The lower chlorophyll content in T1 is due to the low light content for green shade. Hörtensteiner (2006) stated that the catabolic pathway of chlorophyll during senescence and fruit ripening leads to the

accumulation of colorless breakdown products. Jenkins *et al.* (1981) also stated a large decrease was observed in the chlorophyll content of the primary leaves. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Bita and Gerats, 2013).

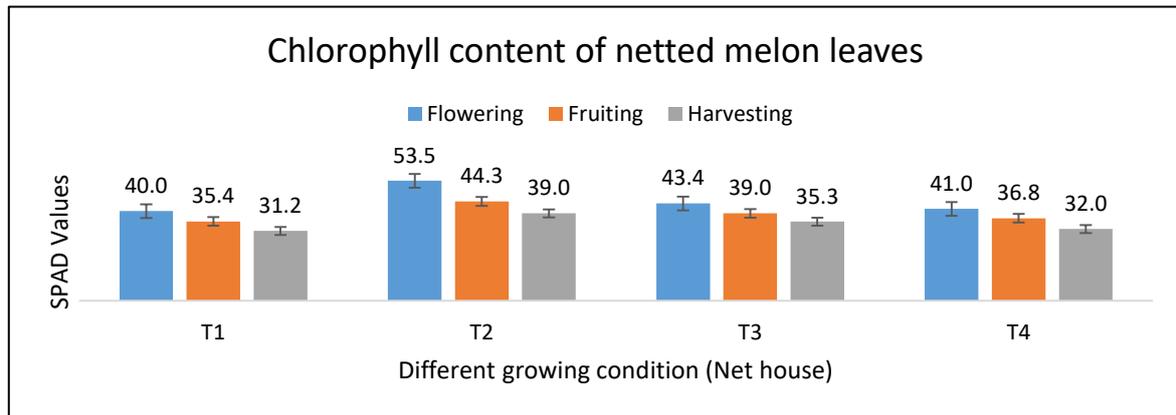


Figure 55: SPAD values of netted melon leaves in different growing condition

Data in (Fig 56) showed a significant difference in growth and yield parameters between four treatments of net house. Maximum vine length at 30 DAS (44.3 cm) was calculated in T2 followed by T1 (36.6 cm), while minimum length was in T4 (25.5 cm). The vine length at 60 DAS followed the same pattern, with T2 producing the longest (240cm). Maximum vine length was observed in a T2 net house (with transparent poly film), which favors plant growth because plants were less stressed, humidity was moderate, evapotranspiration was low, and light transmission was favorable, as Abu-Zahra and Mazen (2016) found the T2 net house (having transparent poly film) that allowed a favorable light spectrum as compared to T1 (having green shade net), which resulted in better plant growth.

T2 took the shortest time to first male and female flowering (38 and 47 days, respectively), while T1 took the longest time to first male flowering (41 days) and longest time to first female flowering (51 days) (Fig 57). The lateness may be due to light cuts having green shade net in T1. T2 had the maximum male flowers per plant (68), as well as the maximum female flowers per plant (22). T2 took the shortest time from fruit set to edible maturity (39 days) (Fig 58).

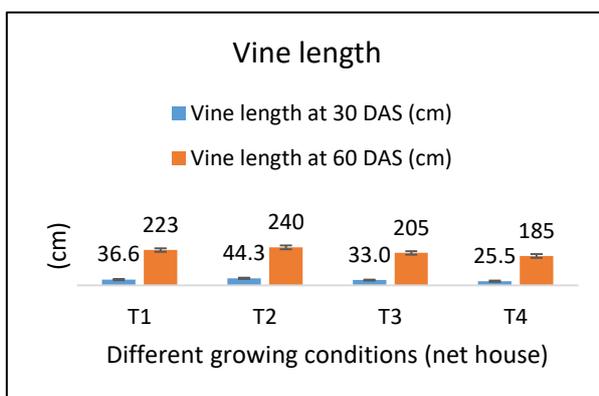


Figure 56: Vine length at 30 DAS and 60 DAS of netted melon in different types of growing conditions

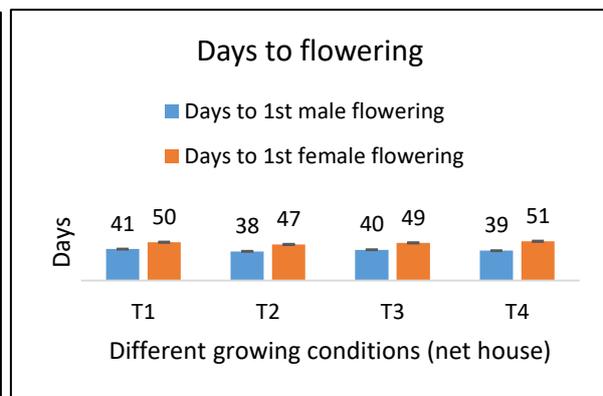


Figure 57: Days to 1st male flower and days to 1st female flower of netted melon in different types of growing conditions

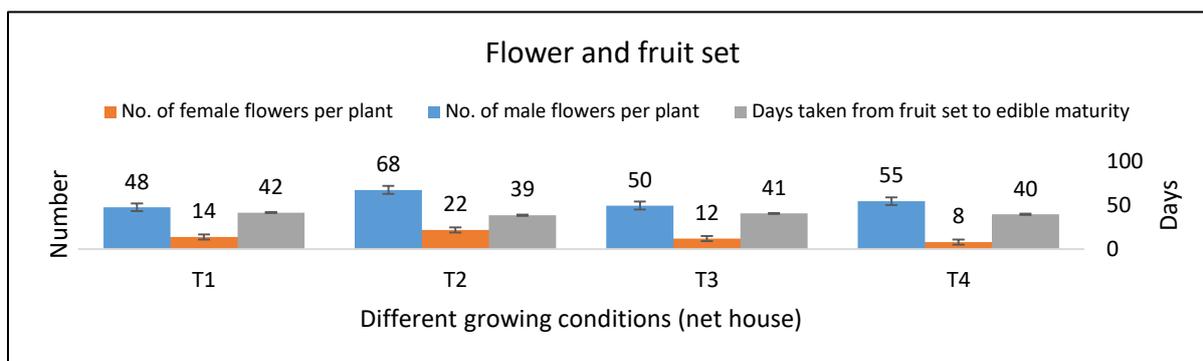


Figure 58: Number of male flowers per plant, number of female flowers per plant and days taken from fruit set to edible maturity of netted melon in different types of growing conditions

The lowest sex ratio (3.09) and highest fruit set (9.6%) were found in T2 (Fig. 59). Also emphasized was the requirement for out-crossing with pollinators because of the nature of cross-pollination in netted melon. However, cross-pollination was impeded in T1, T2, and T3 due to protected net houses. In order to overcome this problem and ensure an adequate fruit set, hand pollination was done. Protected structures increased the assimilation of photosynthates and sped up the beginning of flowers when it came to flowering parameters. Because the flowers grow on every node of the vine, longer vines produced more blossoming. According to Mukul *et al.* (2017), the relatively warm temperature in the white shade net encourages the flowering of melon that has been netted. The male and femaleness of lowers is ultimately influenced by the differential in light intensity permeability between white and green colors. Sahu *et al.* (2016) found comparable outcomes in sweet pepper. Additionally, the white shade net's ability to provide the necessary light, its intensity, and ideal conditions for fruit setting and fruit retention may be the cause of the highest amount of fruit setting. These findings are consistent with those of Abu Zahra and Mazen (2016) who studied cucumber.

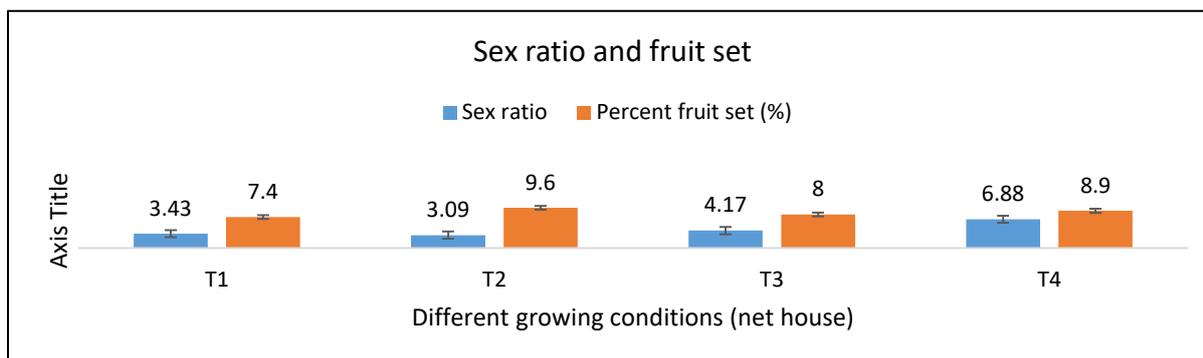


Figure 59: Sex ration and percent fruit set of netted melon in different types of growing conditions

Maximum number of fruits per plant (2.3) and average fruit weight (0.75 kg) was recorded with T2 net house followed by T1 net house (1.9, 0.70 kg, respectively) (Fig 60), while highest per hectare fruit yield (25.87 t) was recorded with T2 net house followed by T1 net house (19.95 t) (Fig 61). Temperature and light intensity played a significant role in plant growth and development. The superiority of the T2 net house (having transparent poly film) with respect to temperature and light management over T1 net house (having green shade net), T3 (only insect net), and T4 (control) resulted in good vegetative growth, which in turn produced a greater number of fruits per plant (Ganesan, 2004).

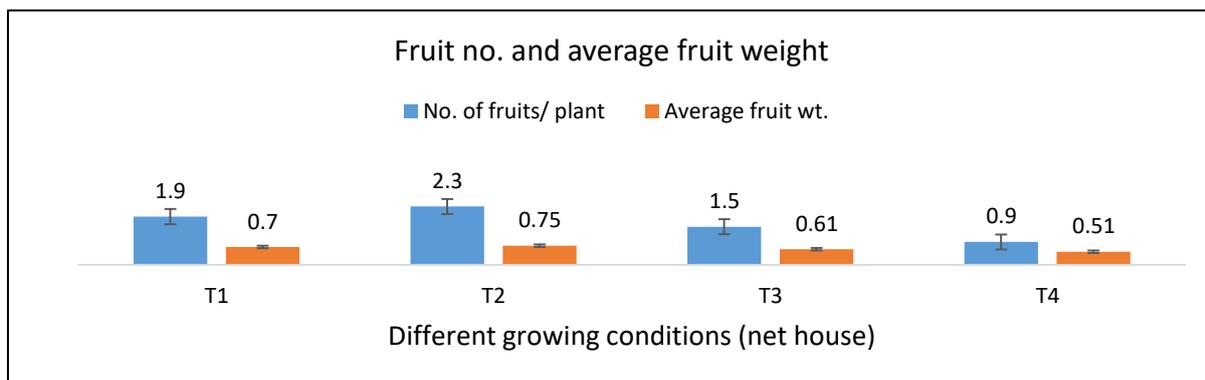


Figure 60: Number of fruits per plant and average fruit weight of netted melon in different types of growing conditions

These results are in conformity with the findings of Fukuda and Anami (2002) in muskmelon. Greater fruit weight might occur under protected conditions because plants avoid large gaps between plants and rows while simultaneously optimizing light interception in muskmelon (Rodriguez *et al.*, 2006). The performance of the crop grown inside the protected structure has several beneficial roles on crop growth, yield, and yield-attributing characteristics compared to open field conditions (Patil and Bhagat, 2014). The above results are in conformity with those of Patil and Bhagat (2014), Anjanappa *et al.* (2012) in cucumber.

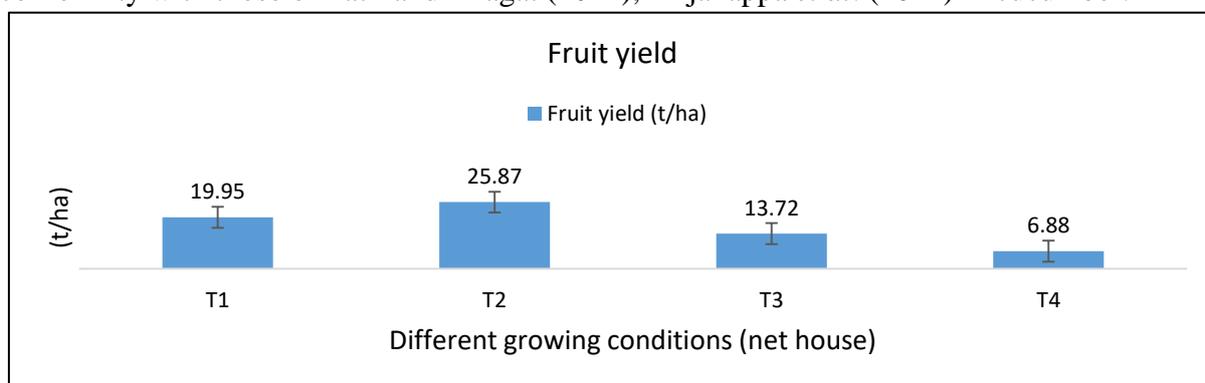


Figure 61: Per hectare fruit yield of netted melon in different types of growing conditions

Maximum fruit length (15.2 cm) and diameter of fruit (16.3 cm) were recorded in fruits grown under the T2 net house (having transparent poly film), followed by T1 (14.5 cm and 15.0 cm, respectively) having a green shade net house (Fig 62). T2 net house (with transparent poly film) had the largest diameter of seed cavity (13.3 cm) and thickness of pulp (1.4 cm), followed by T1 (1.2 cm and 12.4 cm, respectively) with green shade net, and T2 (11.2), T3 (10.5%), and T4 (10.2%) (Fig 63). In all the cases, the control treatment, which was left open, performed inferior compared to the other three treatments. It might be due to the effects of scorching sunlight, uncontrolled rainfall, infestation of insects and infection of diseases.

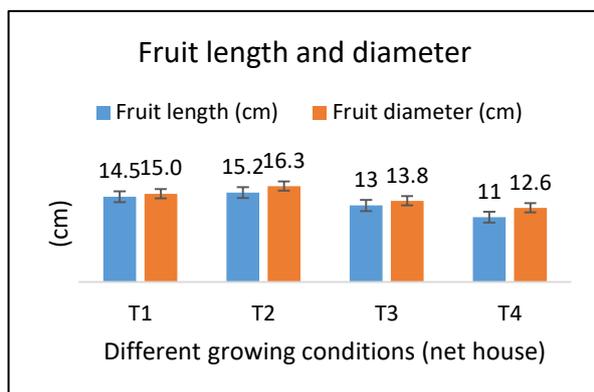


Figure 62: Fruit length and fruit diameter of netted melon in different types of growing conditions

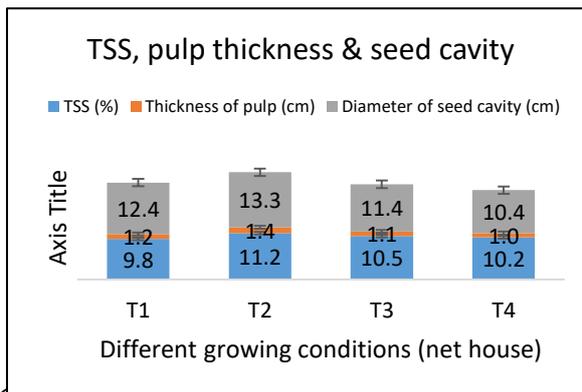


Figure 63: Diameter of seed cavity, thickness of pulp and TSS of netted melon in different types of growing conditions

T1 and T2 net houses had zero fruit fly infestation, preceded by T3 (5.0%), and T4 had the highest infestation (17.5%). In case of alternaria leaf spot, the lowest infection was recorded in T2 (4.0%), followed by T3 (6.6%), T1 (8.5%), and T4 (which recorded the highest infection, 15.0%). The same trend was observed in mosaic virus infection, where T2 showed 2.0% infection, followed by T3 (5.0%), T1 (7.5%), and T4 was maximum with 18.5% (Fig 64). This is because open fields are not protected against scorching sunlight, heavy rainfall, cold wind, and high humidity. The open field condition also promotes disease (Singh *et al.*, 2003, 2005). The lower infestation was due to the T2 being prepared of UV stabilized transparent polyethylene film with a 60 mesh insect net and T3 being prepared of only a 60 mesh insect net, which ensures higher temperature and lower relative humidity percentage, ultimately resulting in lower infestation of different insects and diseases in netted melon. In addition, several studies have also indicated the need to optimize the mesh size to reduce adverse climatic conditions by allowing better ventilation and reducing heat while offering effective protection against insect pests (Saidi *et al.*, 2013; Nordey *et al.*, 2017). Fruit weight and fruit yield were found to be linearly related to the percentage of full sunlight received by trees (Robinson *et al.*, 1993). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and fruit yield (Mupambi *et al.*, 2018).

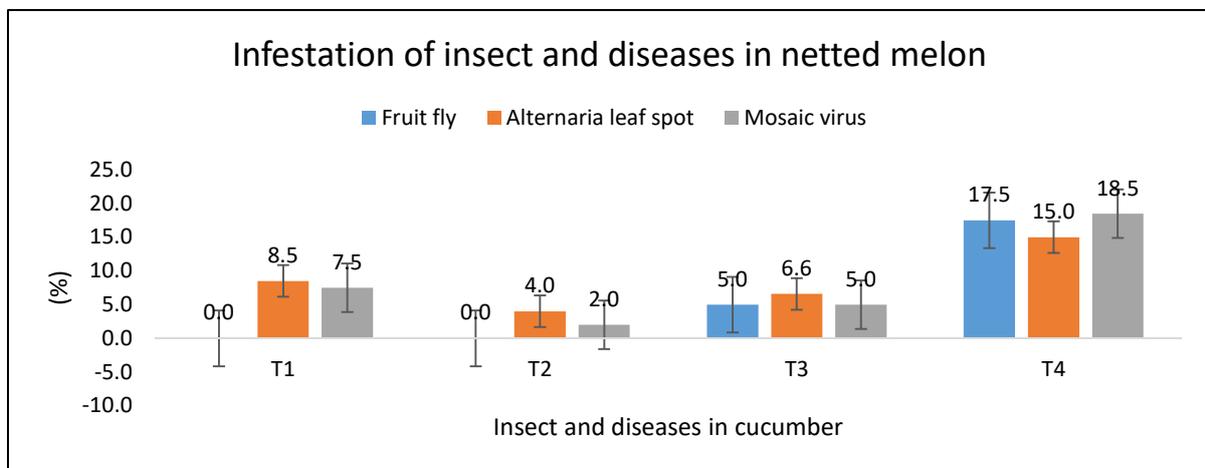


Figure 64: Different insects and disease infestation of netted melon in different types of growing conditions

BCR is an important part of crop production, and it was calculated for this crop over a three-year period. In our study, the BCR values in the first year were lower compared to the 2nd and 3rd years. The best BCR was calculated in T2 (5.11, 16.67, and 15.86 in consecutive 3 years, respectively), followed by T1 (3.39, 12.18, 11.59), T3 (2.78, 8.46, and 7.74), while T4 was calculated with lower BCR values with 1.80, 1.94, and 1.89 (Fig 65). In terms of average three-year BCR values, T2 was the highest (12.55), followed by T1 (9.05), T3 (7.74), and T4 (1.87). The lower BCR in T4 (open condition) was due to netted melon production only two seasons in a year, whereas the T1, T2, and T3 produced 3 seasons in a year. The main inputs were used viz., seed, fertilizers, vermicompost, bio fertilizer, micronutrients, labor, plant protection chemicals, packing cost, other incidental charges, polyhouse structure (bamboo + poly sheet + insect net), and plant support system during the crop production time. Singh *et al.* (2011) observed BCR was (4.72) in polyhouse, (3.68) in poly-tunnel, and (3.03) in poly mulching, while it was lowest in open field conditions (2.12). Under naturally ventilated polyhouse, netted melon gave maximum net return of 81020 INR/1000m² and BC ratio 1:1.36 compared to other treatments.

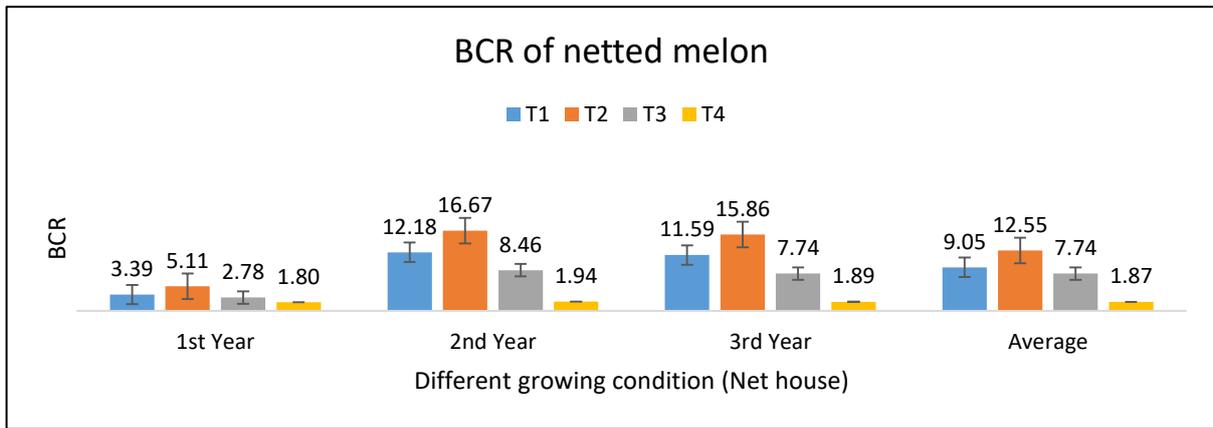


Figure 65: BCR of netted melon cultivation in different growing condition

There was a direct, positive correlation between marketable yield and fruit size (length and diameter), pericarp thickness, total number of fruit per plant, and number of marketable fruit per plant. These characters directly influence marketable fruit yield per plant (Venkatesan *et al.*, 2016). Total yields of 4.3 to 5.9 kg/sqm are generally achieved under tunnels and greenhouses. Since most melons are sold on a per-fruit basis, an increased number of fruits produced because of increased plant density is economically important only if they are of marketable size and quality (Rodriguez *et al.*, 2007).

In a high-tunnel production system, marketable yield per unit area and melon quality were higher than in an open field (Vescera and Brown, 2016). With protective cropping, melon would occupy the structure for a period of 3 to 4 months (Jovicich and Wiggerhauser, 2015). For maximum returns under protected culture, other high value crops may be grown during the year. Investment and production costs are substantially higher under protected culture than in the field, as methodologies used to produce crops in high-tunnel production systems require more efficiency than those used in traditional field systems (Rodriguez *et al.*, 2007). Low tunnel's cost is less than high tunnels, and generally require less labor (Vescera and Brown, 2016), even though they are more problematic to work in and around.

11.5. Effect of Maturity Indices on Growth and Quality of High Value Vegetables

Harvesting at an optimal stage gives the productive and commercial sectors greater flexibility for their management (Caron *et al.*, 2013). Climacteric fruits develop their full characteristic flavor, taste, and color during storage if picked during optimum period. These fruits, harvested at an early stage of maturity, are susceptible to shriveling and mechanical damage and develop poor flavor and taste, despite having a long storage life (Mattheis and Fellman, 1999; Beckles, 2012). Harvesting at an advanced stage of maturity produces fruits that have good taste and flavor but have a short storage life and are not suitable for transporting long distances (Dadzie and Orchard, 1997). The climacteric is a stage of fruit ripening associated with increased ethylene production and a rise in cellular respiration. (Alexander and Grierson, 2002) stated that broccoli are climacteric vegetables, whereas eggplant, cucumber, okra, and sweet pepper are not (they ripen without ethylene and respiration bursts).

Tomato

Measurement of tomato fruits

Fruit size is a quality parameter used to determine maturity stage at different times of harvest. Generally, at the early stage of growth development, fruits remain small and

immature, and at the later stage, the fruits become bigger to attain maturity. An increase in fruit length, fruit diameter, and fruit weight was observed in parallel in this study.

The fruit development curve for tomatoes was determined (Fig 66). Following fruit setting, there was a slow increase in fruit diameter and length in the first week. After that, it increased in week 2. Further increases in fruit length and diameter occurred in week 3, reaching a maximum towards the end of week 5 of fruit maturation. The lowest fruit size was at the week 1 stage (1.7 cm and 1.5 cm), followed by week 2, week 3, week 4, week 5 and week 6 (2.4 and 2.1 cm; 3.8 and 3.3 cm; 5.2 and 4.9 cm; 6.5 and 6.2 cm), while the highest fruit size was 6.6 and 6.3 cm at a later stage of harvest (week 6). But this stage was not suitable for fresh consumption; the fresh consumption stage was week 5 (6.5 and 6.2 cm). The changes in fruit diameter and length are expected as tomatoes mature. Zhang and McCarthy (2012) stated that tomato ripening is usually associated with a number of variations in the cellular structure and internal structure of the fruit. In addition, the most significant visual changes in the morphological characteristics of the fruit during maturation occur in size, shape, length, and volume of the fruit as it advances in age (Dadzie and Orchard, 1997). This implies that fruit length and diameter are significant indicators of tomato ripeness. The fruit weight was gradually increased with the increase of maturity. At the earliest stage (week 1), the individual fruit weight was only 15g, while the maximum weight (91g) was at the week 6 stage. The weight was increased by 32g, 45g, and 65g at week 2, 3, and 4, respectively. The optimum weight was obtained at the week 5 stage with 84g.

According to Wu and Kubota (2008), tomato fruit enlarge with time after anthesis during the green stage, reach maximum size at around the end of the green stage, and hardly change in size after the breaker stage through the red stage, as demonstrated in this study. Chester (2004) and Lovejoy (2016) indicated that several tomato varieties are ready for harvest between 6–11 weeks following transplanting. This study indicated that fruit development trends were consistent with earlier findings by Robinson (1996), Dadzie and Orchard (1997), and Mattheis and Fellman (1999). Suryawanshi (2014) indicated that tomatoes should be ready for harvest at least 8.5 weeks following transplanting. The variation in times of harvest may be explained by the differences in soil, weather, and pest and disease incidence across study sites.

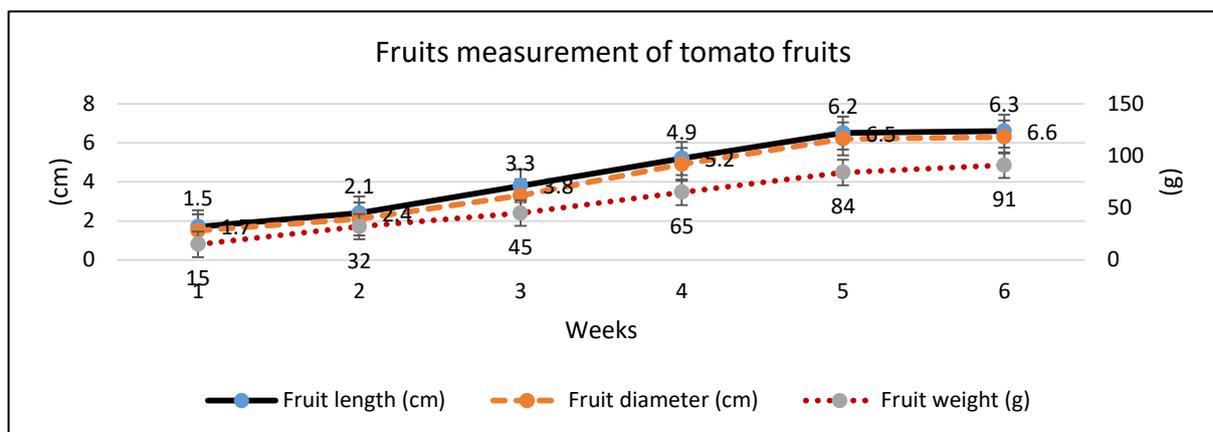


Figure 66: Fruits measurement of tomato fruits at different intervals of weeks

Chemical properties

The total soluble solids (TSS) index is a quality parameter used to determine the sweetness, ripeness, and marketability of tomatoes. For the commercial market, tomatoes' TSS should be

≥4% Brix, and below that, tomatoes are not usually suitable. The results (Fig 67) revealed that overall mean values of TSS in different stages varied from 3.0–4.6 percent. At the earlier stages, viz., week 1 to week 3, they were immature stages, while the TSS was 3.0 to 3.9%, with green color, and the taste was astringent. At the week 4 stage, the TSS was 4.1% and the tomato color breaker stage with a slightly astringent taste. Maximum TSS was obtained at week 6 (4.6%), but it was over matured at a fully red colored stage. This stage is better for fresh table purposes, but not for long distance purposes. The second highest TSS value was at the week 5 stage (4.5%), while it was the optimum matured turning red stage, the fresh eaten taste was slightly good. This stage was better for longer distance purposes, not for fresh table purposes. The optimal harvest TSS values at breaker and red agree with Pinho *et al.* (2011) that observed between 4.0 (early harvest) and 6.00 Brix (late harvest) from tomatoes. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration. The variation in fruit soluble solids content may be due to differences in metabolism and respiration rate between maturity stages. High soluble solids contents are indicators of high sugar content (Saftner and Lester, 2009). Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference (Pardo *et al.*, 2000). Harvest at the proper maturity stage is crucial to good eating quality (Artes *et al.*, 1993).

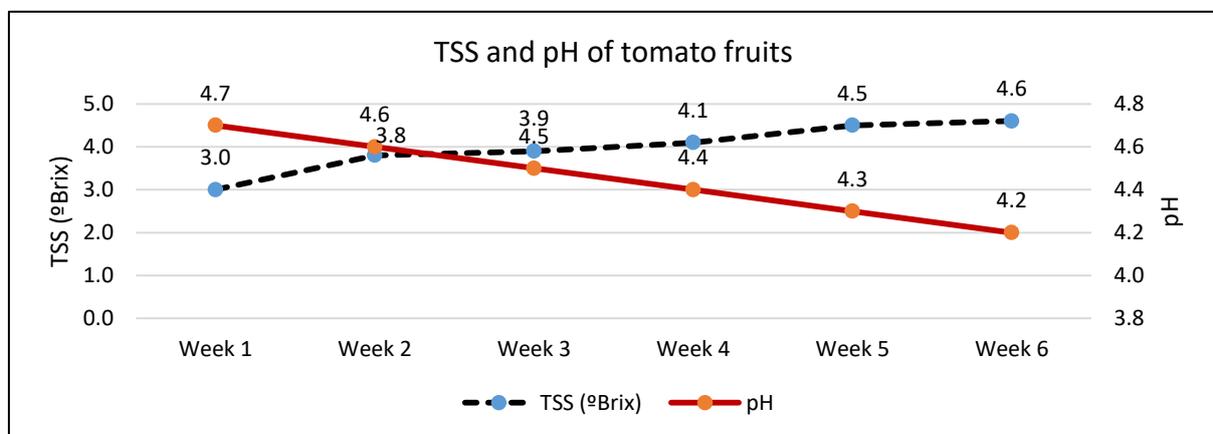


Figure 67: TSS and pH of tomato fruits at different intervals of harvest

The pH of fruit did not change appreciably during maturity stages. However, little difference was observed among the maturity stages. The change in pH was consistent with the passage of time, but there was an increasing trend for all stages gradually. The pH values within treatments varied from 4.2 to 4.7 (Fig. 67). These results coincide with those of Augustin *et al.* (1988) and Beaulieu and Lea (2007), who reported a similar pattern of pH values (5.25, 6.51, and 6.79) at different maturity stages. There is a slight variation in pH value of fruit harvested at an immature stage as compared to half matured and fully matured fruit that is attributed to low metabolic rate. There was significant variation among all treatments that showed a decline in pH with advancement of maturity. The TSS and pH content vary as fruit matures (Matsuda and Kubota, 2010), making these parameters indispensable maturity indices. Therefore, the maturity indices of tomato fruit are morphological features including length, diameter, age, and color and physico-chemical parameters, notably, TSS and pH.

The fruit color of tomato was found to be "light green", "green", "breaker", "turning red" and "red" colored at week 1, 2, 3, 4, 5, and 6 stages, respectively, while the organoleptic taste was found to be "astringent" at week 1 to week 4, and "slightly tasty" and "tasty" were found at week 5 and week 6 stages, respectively (Table 11).

Table11: Fruit color and organoleptic taste of tomato at different harvest stages

Parameter	Qualitative unit	Harvest stage					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Fruit color	Observed color	Light green	Green	Green	Breaker	Turning red	Red
Organoleptic taste	Feeling taste	Astringent	Astringent	Astringent	Astringent	Slightly taste	Tasty

Broccoli

Broccoli should be harvested when the head is fully developed, but before the loose head and small yellow flower buds start to open. At harvest, the terminal head should be tight, green, and of an appropriate size. Several smaller side heads (about 1 to 3 inches across) may develop in the axils of the leaves after the central head is removed.

The broccoli head size is a quality parameter used to determine the maturity stage at different times of harvest. Generally, at the early stage of growth development, the head remains small and immature, and at the later stage, the head becomes bigger to attain maturity. An increase in head length, head diameter, and head weight was observed in parallel. The lowest head size (length and breadth) was at the 6 days stage (6.2 cm and 6.8 cm), preceded by 8 days, 10 days, 12 days and 14 days (9.2 cm and 9.2 cm; 9.8 cm and 11.0 cm; 12.0 cm and 13.0 cm; 13.0 cm and 15.0 cm), while the highest head size was 13.2 cm and 15.5 cm at the later stage of harvest (16 days) (Fig 68). But this stage was not suitable for fresh consumption. The fresh consumption stages were 12 days and 14 days (12.0 cm and 13.0 cm; 13.0 and 15.0 cm).

The head weight and head color were gradually increased with the increase in maturity. At the earliest stage (6 days), the head weight was only 86g with 'dark green' color, while the maximum weight was 420g at 16 days stage and the color was 'green with loose head' (Fig 68 and Table 9). The head weight was increased by 173g, 221g, 320g, and 400g at 8 days, 10 days, 12 days and 14 days stages, respectively. The optimum head weight was obtained at 12 days with a 360g 'green' colored head, which was found the best quality for consumption. No sprouting or looseness was found at this stage. After that, the increase in weight and size occurred in broccoli, but that was not quality due to looseness. At 14 days and 16 days stage the head of broccoli was observed to be "green with slight looseness of head" and "green with loose of head", respectively (Table 12).

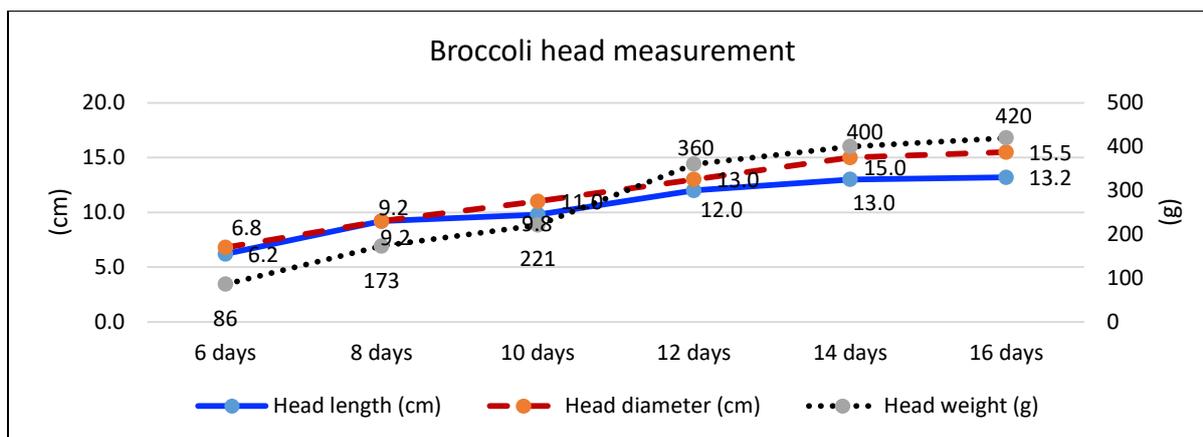


Table 12: Head color of broccoli at different harvest stages

Parameter	Qualitative unit	Harvest stage					
		6 days	8 days	10 days	12 days	14 days	16 days
Head color	Observed color	Dark green	Dark green	Dark green	Green	Green with slight loose of head	Green with loose of head

Harvesting of broccoli heads at the proper stage is a common problem for growers. If heads are picked when immature, they may stay green longer but may not develop to an acceptable size, which may lead to a loss of consumer confidence. Moreover, since head growth

Figure 68: Head measurement of broccoli at different intervals of harvest

continues until harvest, the size of immature heads will be smaller than more mature heads, resulting in a loss of harvest yield. Over matured broccoli heads quickly lose their attractiveness and shininess, and become slimy in texture (Pareek, 2001). Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, broccoli head maturity is assessed on the basis of subjective evaluations of visual colour (Howard *et al.*, 1994), size, and hand pressing to evaluate firmness or days from anthesis (Sanchez *et al.*, 1993).

Netted melon

Netted melon (*Cucumis melo* L.) characteristics include external color, flesh color, firmness, seed cavity tissue, soluble solids content, flavor, aroma, size, and shape (Miccolis and Saltveit, 1995; Pardo *et al.*, 2000). Melons typically fetch high prices due to their distinctive flavor, shape, and color. These factors determine eating quality and consumer preference (Hoberg *et al.*, 2003), and extended seasons could increase grower income.

The melon fruit remains small and immature at the earlier stage, and at the later stage, the melon fruit becomes bigger to attain maturity. An increase in fruit length, fruit diameter, and fruit weight was observed in parallel in this study. The lowest fruit length and diameter were at the week 1 stage (3.5 cm and 3.2 cm, respectively), followed by week 2, week 3, week 4, and week 5 stages (6.2 and 6.0 cm; 8.4 and 8.0 cm; 10.6 and 10.3 cm; 12.5 and 12.7 cm, respectively), while the highest fruit length, diameter were 15.2 cm and 14.5 cm, respectively, at the later stage of harvest (week 6) (Fig 69). This stage was the right mature stage. The average fruit weight was gradually increased with the increase in maturity. At the earliest stage (week 1). The fruit weight was only 41g, while the maximum weight was 800g

at the week 6 stage (Fig 69). The fruit weight was increased by 135g, 244g, 397g, and 577g at week 2, week 3, week 4, and week 5 stages, respectively. The optimum fruit weight was obtained at the week 6 stage with 800g.

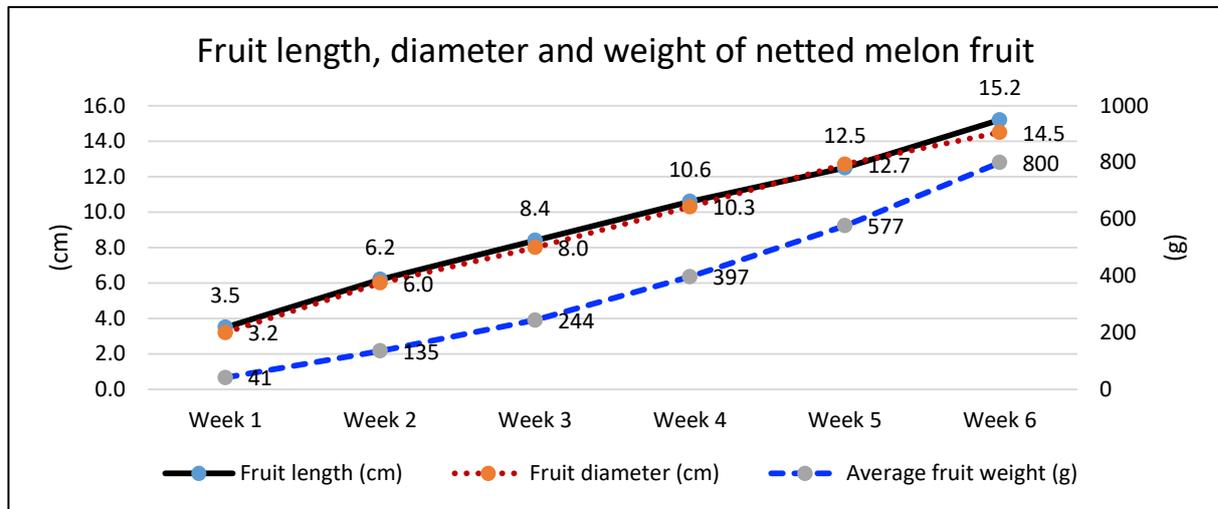


Figure 69: Fruit length, diameter and weight of netted melon fruit at different intervals of harvest

The Total soluble solids index is a quality parameter used to determine the sweetness, ripeness, and marketability of netted melon. For the commercial market, netted melon's TSS should be $\geq 10\%$ Brix and below that, netted melon is not usually suitable (Burger *et al.*, 2000; Paris *et al.*, 2012). The findings (Fig 70) revealed that the overall mean value of TSS in various stages ranged from 4.5 to 10.8 percent. TSS was 4.5 to 5.3 percent at the earlier stages, namely week 1 to week 4, when the fruit was immature. At week 5 stage, the TSS started to increase (9.2%) and it was at its maximum at the week 6 stage, with 10.8%. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. Beaulieu and Lea (2007) also reported an increase in sugar of 5-11 percent during ripening in melon. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration. The deviation in the soluble solid content of fruit might be due to variation in metabolism and respiration rate among maturity stages. High soluble solids contents are indicators of high sugar content (Saftner and Lester, 2009). Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference (Pardo *et al.*, 2000). Harvesting of melon at the proper maturity stage (when TSS is about 8–10%) is crucial to good eating quality (Artes *et al.*, 1993). Since the amount of TSS in fruits usually increases as they mature and ripen, the soluble solids content of the fruit can be a useful index of maturity or stage of ripeness for netted melon.

The pH of fruit did not change appreciably during maturity stages. However, little difference was observed among the maturity stages. The change in pH was consistent with the passage of time, but there was an increasing trend for all stages gradually. The pH values within treatments varied from 5.0 to 6.4 (Fig. 70). These results coincide with those of Augustin *et al.* (1988) and Beaulieu and Lea (2007), who reported a similar pattern of pH values (5.25, 6.51, and 6.79) at different maturity stages. A pH of 6.55 occurs at the fruit maturity of melon (Villanueva *et al.*, 2004). Cantaloupes had a higher pH than honeydew melons. Sweet melons are unique among fleshy fruits with pH values near neutral (Cohen *et al.*, 2014). There is a

slight variation in pH value of fruit harvested at an immature stage as compared to half matured and fully matured fruit that is attributed to low metabolic rate. There was significant variation among all treatments that showed a decline in pH with advancement of maturity. A pH of 6.5 and high soluble solids content are indicators of high sugar content (Saftner and Lester, 2009). Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference (Pardo *et al.*, 2000). The TSS and pH content vary as fruit matures (Matsuda and Kubota, 2010), making these parameters indispensable maturity indices. Therefore, the maturity indices of fruit are morphological features including length, diameter, age, and color and physico-chemical parameters, notably TSS and pH.

The net development on the fruit skin of netted melon is a quality parameter used to

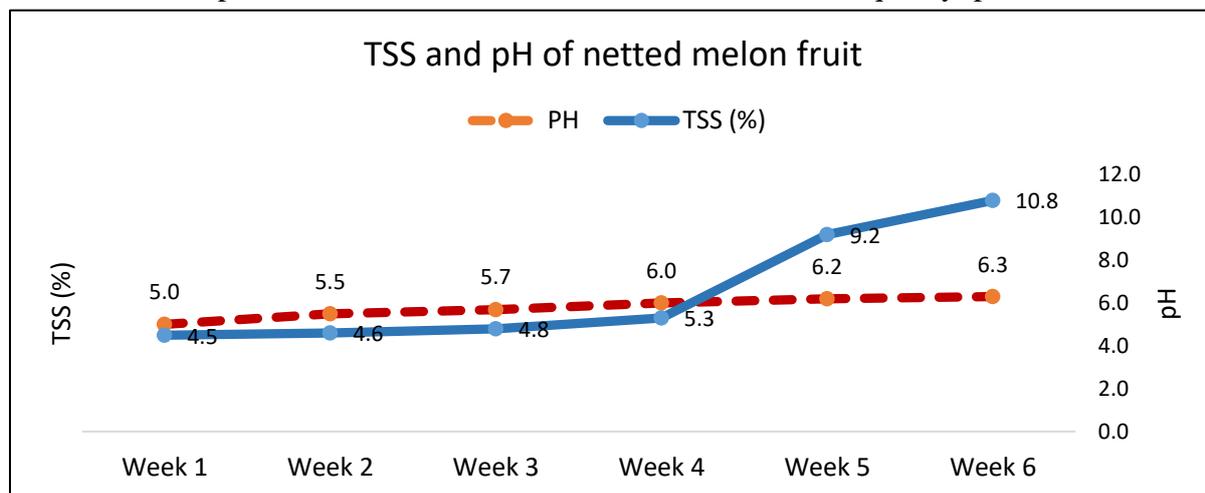


Figure 70: TSS (%) and pH of netted melon fruit at different intervals of harvest

determine maturity stage at different times of harvest. Generally, at the early stage of growth, the net does not develop well. The net development on fruit skin was gradually increased with the increase of maturity. At the earliest stages (week 1 and week 2) the fruit had a plain surface, while at the mid development stage (week 3), the fruit skin had a "rough surface". The net development starts at week 4, while the full development of the net was observed at week 5 and week 6 stages (Table 13). The melon fruits were tasted at different stages of maturity. The fruit had an "astringent taste" during weeks 1 to week 3, while it was "slightly tasty," "tasty," and "Much tasty" during weeks 4, week 5 and week 6, respectively. So, from week 5 to week 6 is the appropriate time of maturity to harvest.

Table 13: Net development on fruit skin and organoleptic taste of netted melon at different harvest stages

Parameter	Unit	Harvest stage					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Net development on fruit skin	Observed color	Plain surface	Plain surface	Rough surface	Net developed	Net fully developed	Net fully developed
Organoleptic taste	Feeling taste	Astringent	Astringent	Astringent	Slightly tasty	Tasty	Much tasty

Precise determination of netted melon fruit maturity is difficult at harvest. Fruits are harvested at different degrees of maturity, and a proportion of fruits may be immature. Thus, harvesting of netted melon fruits of different maturities at the same time is a common

problem, even though fruits may have the same skin color at harvest (Tadesse *et al.*, 2002). If fruits are picked immature, they may stay green longer but may not develop an acceptable colour and flavour upon ripening (Boonyakiat *et al.*, 1987), which may lead to a loss of consumer confidence. Moreover, since fruit growth continues until harvest, the size of immature fruit will be smaller than more mature fruit, resulting in a loss of harvest yield. On the other hand, overripe fruits lose their attractiveness and shininess and become slimy in texture within a very short time (Pareek, 2001). Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, netted melon fruit maturity is assessed on the basis of subjective evaluations of visual colour (Lin *et al.*, 1993; Sanchez *et al.*, 1993; Howard *et al.*, 1994), size, and hand pressing to evaluate firmness or days from anthesis (Sanchez *et al.*, 1993; Manandhar *et al.*, 1995).

Cucumber

Cucumber for fresh consumption is one of the most popular vegetables worldwide and is a rich source of vitamins, minerals, and antioxidants (Patel and Panigrahi, 2019). It is estimated that one-third of global production is lost or wasted (FAO, 2013; 2018). These losses occur throughout the value chain, from production and collection, transport and storage, to marketing and distribution to the consumer due to postharvest management, while improper maturity is one of the factors among all the steps (Prusky, 2011; HLPE, 2014). To facilitate and improve this process, there are easily applicable indicators that allow the selection of proper maturity stages of cucumbers. Therefore, the objective of this study was to demonstrate the proper maturity stages, which can be effective indicators of the probability of marketability of cucumbers.

The cucumber remains smaller in size and immature at an earlier stage, and at the later stage, the cucumber becomes bigger to attain maturity. In this study, the lowest fruit length and diameter were obtained at the day 6 stage (5.2 cm and 1.3 cm, respectively), preceded by day 8, day 10, day 12, day 14 stages (6.9 cm and 1.8 cm; 8.8 cm and 2.2 cm; 10.8 cm and 2.9 cm; 13.2 cm and 3.8 cm, respectively), while the highest fruit length and diameter were 14.6 cm and 4.3 cm, respectively, at the later stage of harvest (day 16) (Fig 71). The average fruit weight was gradually increased with the increase in maturity. At the earliest stage (day 6), the fruit weight was only 30g, while the maximum weight was 148g at the day 16 stage (Fig 71). The fruit weight was increased by 45g, 61g, 88g, and 125g at day 8, day 10, day 12, and day 14 stages, respectively. The maximum fruit weight was obtained at the day 16 stage with 148g. Cucumber fruits are ready for harvest at the fruit maturity stage of day 10 to day 12 after fruit setting, and it is done at the immature stage of the fruit. In cucumbers, the proper stage of maturity is judged by size and not by the age of the fruit. Cucumbers should be picked when they are 9–11 cm long. Another marketable stage is when the spines on fruit become soft and fall down. In general, cucumbers may be picked at any stage of fruit growth, provided yellowish has not started. The fruit should be picked at frequent intervals in order to avoid losses due to oversized or overripe fruits. They are typically picked every 2 to 3 days, depending on variety and weather.

The results (Fig 71) revealed that overall mean values of TSS in different stages varied from 3.1–4.4 percent. At the earlier stages, viz., day 6 to day 8, were immature stages, while the TSS was 3.1 to 3.4 percent (Fig 71). At a moderate stage of harvest, viz., day 10 to day 12 stage, the TSS was 3.8 to 4.1% and the maximum was at day 14 and day 16 stage with 4.3 to 4.4%. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration.

The variation in fruit soluble solid content may be due to differences in metabolism and respiration rate between maturity stages.

The powdery surface and spine development on cucumber fruit is a quality parameter used to determine maturity stage at different times of harvest. Generally, at the early stage of growth, the powdery surface and spine development are well developed. The amount of powdery surface and spine development on fruit skin was gradually decreased with the increase of maturity. At the earliest stages (day 6 and day 8), the powdery surface of fruit and spine development were well developed, while at the mid-development stage (day 10 and day 12), the powdery surface of fruit and spine development were less developed. At later development stages (day 14 and day 16), the powdery surface of the fruit was absent and spine development was very low (Table 14). The cucumber fruits were tasted at different stages of maturity. The fruit was 'less astringent in taste' during the day 6 stage, while it was "slightly tasty" at day 8, "tasty" at day 10 and day 12, and slightly matured and over matured at day 14 and day 16 stages, respectively. So, on day 10 and day 12, the appropriate times of maturity to harvest were set.

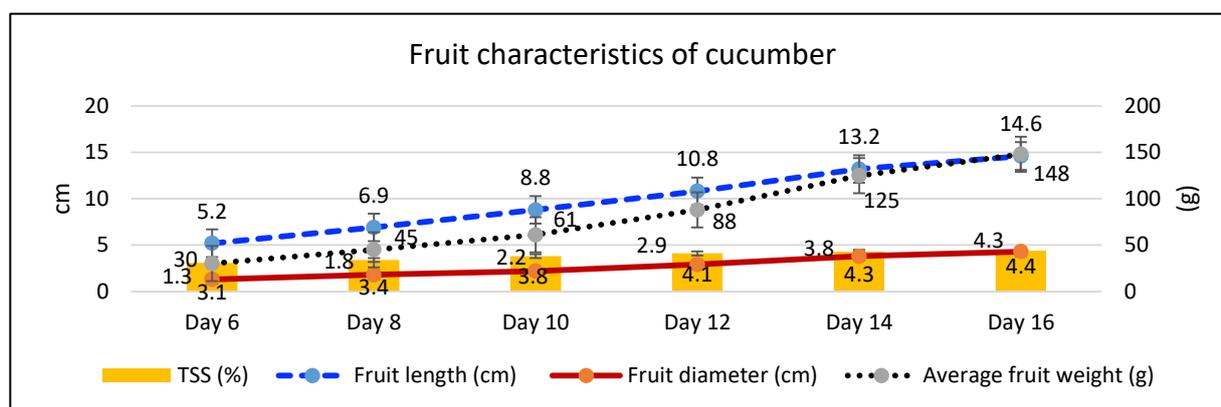


Figure 71: Fruit length, diameter, average fruit weight and TSS of cucumber at different intervals of harvest

Table 14: Powdery surface of fruit and spine development and organoleptic taste of cucumber at different harvest stages

Parameter	Unit	Harvest stage					
		Day 6	Day 8	Day 10	Day 12	Day 14	Day 16
Fruit skin color	Observed color	Powdery surface with spine	Powdery surface with spine	Less powdery with less spine	Less powdery with less spine	Very less powdery with less spine	No powdery and very less spine
Organoleptic taste	Feeling taste	Less astringent taste	Slightly tasty	Tasty	Tasty	Slightly matured	Over matured

Precise determination of cucumber fruit maturity is difficult at harvest. Fruits are harvested at different degrees of maturity, and a proportion of fruits may be immature. Thus, harvesting of cucumber fruits of different maturities at the same time is a common problem, even though fruits may have the same skin colour at harvest (Tadesse *et al.*, 2002). Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, cucumber fruit maturity is assessed on the basis of subjective evaluations of visual colour (Lin *et al.*, 1993; Sanchez *et al.*, 1993; Howard *et al.*, 1994), size).

Sweet pepper

Sweet pepper is a non-pungent fruit that is valued for its color, flavor, and nutritional attributes, including ascorbic acid, polyphenolics, and various carotenoids. It comes in a wide variety of colors (ranging from green, yellow, orange, red, and purple), shapes, and sizes, as well as a high content of ascorbic acid, polyphenols, and other antioxidants. Generally, the harvest of sweet peppers is determined by the size, color, and texture of the fruit. Traditionally, the harvest of this fruit is done by reaching physiological maturity when the pericarp becomes thick and the fruit reaches its typical size. However, estimating proper maturity at the green stage can be difficult, even for fruit with similar physical attributes [Tadesse *et al.*, 2002]. The sweet peppers reach their optimum state of maturity for use in the kitchen when they are a solid color. Consumers prefer this fruit at its best stage of maturity, more so than its physical appearance and nutritional content [Frank *et al.*, 2001]. Dutch researchers specializing in the sensory area, reported that study groups have considered that more ripe sweet peppers are sweeter and have a red pepper aroma, while those in the green stage were rated for the bitterness and aroma of herbs and cucumber (Luning *et al.*, 1994). At the mentioned stage, sweet peppers will progress through the normal ripening process to degrade chlorophyll while simultaneously synthesizing carotenoids. For determining an appropriate harvest time, different attributes like surface colour, fruit firmness, soluble solids content, acid content are used as indicators (Tadesse *et al.*, 2002), so that products develop acceptable taste and flavor characteristics as well as maintain structural integrity during subsequent storage and/or shelf life (Meredith *et al.*, 1989; Wills *et al.*, 1998).

In our study, the length and diameter of sweet pepper fruits significantly increased with the increase of harvesting time from anthesis (Fig. 72). The minimum length and diameter of fruits (3.8 and 3.3cm, respectively) were obtained from harvesting after week 3 of anthesis preceded by week 4 (5.2 and 4.9cm, respectively), week 5 (9.2 and 6.0cm, respectively), and week 6 (9.5 and 6.2cm, respectively), while the maximum length and diameter were obtained at week 7 (9.7 and 6.3cm, respectively). In an experiment, Tadesse *et al.* (2002) reported that sweet pepper fruit (cv. Domino) had attained almost 75% of its final length after three weeks of anthesis but continued to elongate at a slower rate until 10 weeks after anthesis.

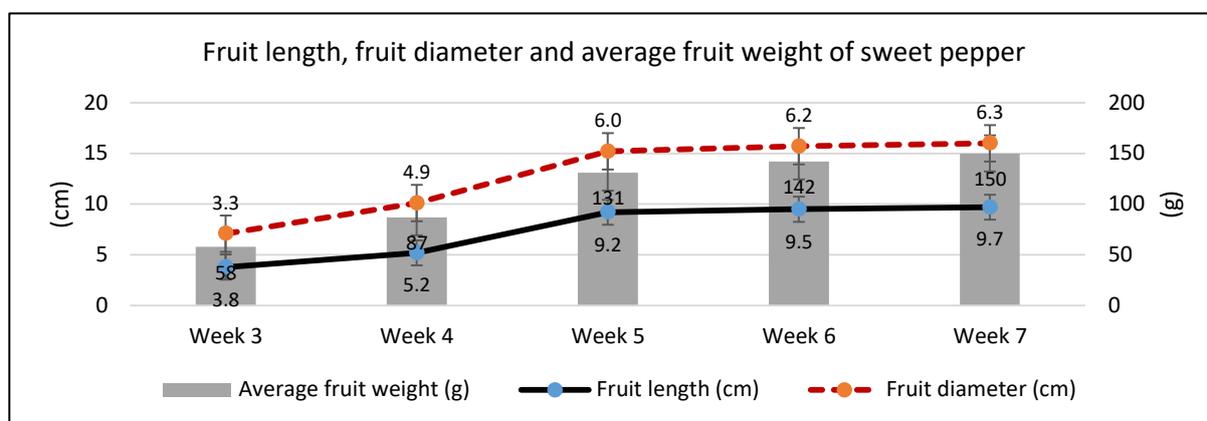


Figure 72: Fruit length, diameter and average fruit weight of sweet pepper at different intervals of harvest. Vertical bars indicate standard deviation.

Sweet pepper fruits under this experiment showed a gain in weight as the harvest time was extended (Fig. 72). The lighter fruits (58 g) were harvested after week 3 of anthesis, which increased steadily until week 4 (87 g). After this period, fruit weight increased sharply with

the extension of the harvesting time until week 5 (131 g). However, the maximum fruit weight of 150 g was obtained after week 7 of anthesis. Rahman *et al.* (2014) and Tadesse *et al.* (2002) reported that sweet pepper (cv. Domino) fruit fresh weight was linearly increased until eight weeks after anthesis.

Total soluble solids (TSS) are a classical tool to determine the maturity of fruits in the food industry, even though it is a destructive technique. The TSS content consists of 80–95% sugars, and the measure of TSS is associated with the dissolved sugars in the cell of juice (Osterloh *et al.*, 1996). The TSS content showed a constant increase as the fruit maturity increased, which could be seen with an increase in color fastness in the sample sweet peppers. The ascending behavior of TSS content is consistent with that reported in the literature (Wills *et al.*, 1998). The changes in TSS content of sweet pepper fruits with harvesting length. The TSS of fruit samples harvested after week 3 of anthesis was fairly low (3.0%), which was slowly increased with the increase of harvesting time. The TSS content reached a maximum level of 5.1% when fruits were harvested after week 7 of anthesis. The increase in TSS of sweet pepper fruit with maturity is probably a result of increased hexose sugar accumulation during fruit ripening (Rahman *et al.*, 2014), as there is a close positive correlation between the rise in TSS and soluble sugars (Mendlinger *et al.*, 1992). The results of the present experiment are in agreement with Rahman *et al.* (2014) and Tadesse *et al.* (2002), who found that the TSS of sweet pepper increased slightly from 3 to 5% and 5 to 6% during the period 2 to 6 weeks after anthesis, respectively.

The changes in pH of sweet pepper fruits as a function of different harvesting times are shown in Fig 73. From the results, it was found that the pulp pH of sweet pepper fruit was not much affected by different harvest maturity. The pH ranged from 5.40 to 5.70 was found during harvesting from week 3 to week 7, which was not significantly different among harvesting times. Similar results were also found (5.71 to 5.79%) by Rahman *et al.* (2014); Fox *et al.* (2005) also reported that sweet pepper pH was not affected by different harvesting times, which ranged from 4.9 to 5.1.

The maturity of the sweet pepper fruit was determined by a combination of different

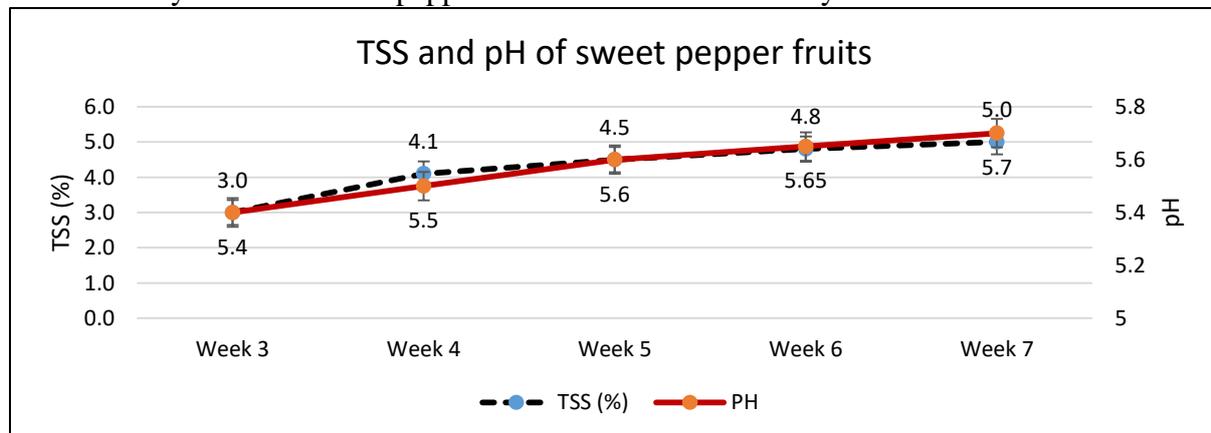


Figure 73: TSS and pH of sweet pepper fruits at different intervals of harvest.

attributes. In this study, TSS, surface color change, and firmness were found to be good indicators for sweet pepper fruit maturity. Based on the results of the present study, sweet pepper fruits reached physiological maturity at week 5 to week 6. At this stage of maturity, fruit attained 9.2-9.5 cm in length, 6.0-6.2 cm in diameter, and 131g-142g in weight (Fig 72).

Besides, fruits were more shiny green, crispy, pleasant flavored, and tasty at this stage (Table 15).

Table 15: Fruit color and taste of sweet pepper fruits at different harvest stages

Parameter	Harvest stage				
	Week 3	Week 4	Week 5	Week 6	Week 7
Fruit color	Green	Green	Shiny green	Shiny green	Less shiny green
Taste	Astringent taste	Astringent taste	Crispy pleasant flavored taste	Crispy pleasant flavored taste	Slightly flavored taste

11.6. Study of Different Nutritional Facts of Vegetables Under Different Type of Protected Growing Condition

Temperatures may be monitored and controlled in protected environments, and higher plant development may be anticipated. The air temperature and relative humidity were affected by the different net buildings and open field situations. The nutritional value of various crops may change when grown under various types of protected conditions.

Nutritional facts content of different vegetables in different growing environments

There were significant differences among different growing environments for energy content (Table 16 and 17). The highest energy content was found in netted melon in all growing environments (61.0, 65.0, 58.0 and 60.0 Kcal/ 100g, respectively, while the lowest was in cucumber (14.1, 14.5, 16.5 and 14.0 Kcal/ 100g, respectively). In maximum cases nethouse 2 (UV poly shed house) performed the higher amount of energy (eggplant: 19.0, sweet pepper: 32.0, cucumber: 16.5, netted melon: 65.0 Kcal/ 100g) compare to another growing environment. In this study, protein content 0.58 – 2.70g was found in different vegetables under different growing environments. The higher amount was observed in broccoli which was 2.20, 2.70, 2.50, 2.20 g in poly green shed house, UV poly shed house, net house and open field, respectively, while lower in cucumber which was 0.80, 0.85, 0.60, 0.58 g, respectively. In all crops, maximum cases the higher amount was measured in UV poly shed house.

The dietary fiber content was varied in different crops under different growing environments and the range was 0.44-3.50 g in different vegetables under different growing environments. The higher amount was calculated in sweet pepper which was 3.00, 3.50, 3.20, 3.15 g in poly green shed house, UV poly shed house, net house and open field, respectively, while lower in cucumber which was 0.46, 0.55, 0.45, 0.39 g, respectively. In all crops, maximum cases the higher amount was measured in UV poly shed house. The total carbs content of the fruit responded significantly differently to the different growing environments (Table 16). The total carbs were maximum in the fruits of netted melon which was 12.5, 14.7, 13.5 and 13.7 g, while the minimum was in cucumber (3.00, 3.50, 3.40 and 3.55 g). In all cases, the higher carbs content was calculated in UV poly shed house condition viz., tomato (4.10 g), eggplant(4.70g), sweet pepper (7.20g), broccoli (5.00g), cucumber (3.00g), netted melon 12.5g . Similar results were revealed by Cheema *et al.* (2013) in tomato cultivars under the net house. This might be due to the congenial micro-climatic conditions maintained in net house which influenced the production of more photosynthates that might result in fruits with maximum total carbs. Pérez de Camacaro *et al.* (2017) reported that greater accumulation of carbs in fruit has been observed in net house conditions.

Table 16: Average Nutritional facts content of different vegetables in different growing environments

Nutritional facts	Tomato				Eggplant				Sweet pepper			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Energy (Kcal/ 100g)	16.5	18.5	20.0	18.0	18.0	19.0	18.5	18.7	29.0	32.0	30.0	28.0
Protein (g)	0.85	1.10	1.00	0.80	1.00	1.10	1.00	1.10	1.10	1.40	1.15	1.20
Dietary fiber (g)	1.10	1.40	1.00	0.80	2.40	2.70	2.65	2.20	3.00	3.50	3.20	3.15
Total Carbs (g)	3.70	4.10	3.90	3.60	4.60	4.70	4.20	0.43	6.80	7.20	7.00	6.40

Table 16 (Contd.): Average Nutritional facts content of different vegetables in different growing environments

Nutritional facts	Broccoli				Cucumber				Netted melon			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Energy (Kcal/ 100g)	33.0	32.0	31.0	27.5	14.5	16.5	14.0	14.1	61.0	65.0	58.0	60.0
Protein (g)	2.20	2.70	2.50	2.20	0.80	0.85	0.60	0.58	1.44	1.52	1.40	1.38
Dietary fiber (g)	2.20	2.56	2.40	2.30	0.46	0.55	0.45	0.39	1.55	1.63	1.50	1.42
Total Carbs (g)	5.00	6.25	6.00	5.60	3.00	3.50	3.40	3.55	12.5	14.7	13.5	13.7

Mineral contents of different vegetables in different growing environments

The seven mineral concentrations (mg/kg) of tomato, eggplant, sweet pepper, broccoli, cucumber and netted melon in different growing environments are given in Table 15 and Table 16. The mineral concentrations varied significantly among the studied crops. The maximum sodium content was obtained in netted melon (28.0, 30.3, 29.5, 28.8mg) followed by broccoli (26.0, 30.0, 28.7, 26.4mg), while the lowest was obtained in cucumber (2.6, 3.2, 3.0, 2.7 mg). The range of sodium content was obtained 2.6-20.3mg in cucumber under poly green shed house and netted melon under UV poly shed house, respectively (Table 18, 19). The highest potassium content was detected in netted melon (470, 492, 468, 480 mg) followed by tomato (405, 427, 388, 392mg), while the lowest was detected in eggplant (125, 135, 110, 112mg) in different growing environments, respectively.

There was a wide range in calcium content which was 7.8 mg (sweet pepper in poly green shed house) - 47.0 mg (broccoli in UV poly shed house), since cultivation of different vegetables under different growing environments. The higher amount was observed in broccoli which was 45.0, 47.0, 43.0, 35.0 mg in poly green shed house, UV poly shed house, net house and open field, respectively, while lower in sweet pepper which was 7.8, 10.3, 10.3, 8.1 mg, respectively. In all crops, maximum cases the higher amount was measured in UV poly shed house. The lower magnesium content was detected in sweet pepper and cucumber compare to other four crops. The range of magnesium content was 12.5 mg (sweet pepper in poly green shed house) - 23.0 mg (tomato in poly green shed house), which was varied due to cultivation of different vegetables under different growing environments. This might be due to the congenial micro-climatic conditions maintained in net house which influenced the production of more photosynthates that might result in fruits with maximum magnesium.

The higher iron amount was observed in eggplant which was 1.42, 1.55, 1.42, 1.46 mg in poly green shed house, UV poly shed house, net house and open field, respectively, while lower in cucumber which was 0.27, 0.33, 0.30, 0.23 mg, respectively. In all crops, maximum cases the higher amount was measured in UV poly shed house. The higher zinc amount was detected in tomato, sweet pepper, broccoli, netted melon which range was 0.22 – 0.35 mg,

while lower in eggplant and cucumber which was 0.18 - 0.24 mg. In all crops, maximum cases the higher amount was measured in UV poly shed house. The copper content was significantly higher in tomato and eggplant with range value 0.08 - 0.16 mg, while other four crops were with lower content with range value 0.02 - 0.09 mg. Arivalagan *et al.* (2012) found the mineral content viz., iron (IC249323 - 0.813 mg), zinc (IC090822 - 0.270 mg) and copper (IC261785 - 0.144 mg) was found to be significantly with respect to all micro-minerals. This is also in line with the observation reported by Raigon *et al.* (2008). The levels of iron, zinc and copper were consistent with the levels reported earlier (Chen and Li, 1996; Gopalan *et al.*, 2007; Raigon *et al.*, 2008; Ferdausi *et al.*, 2009; Muhammad *et al.*, 2010; Prasad, 2010). These results confirm previous findings that fruit contains high concentrations of K, Mg, Ca and P (Flick *et al.*, 1978; Kowalski *et al.*, 2003; Raigón *et al.*, 2008; Chinedu *et al.*, 2011; Das *et al.*, 2011; Arivalagan *et al.*, 2012; Amadi *et al.*, 2013].

Table 17: Minerals content of different vegetables in different growing environments

Nutritional Facts (mg/100g)	Tomato				Eggplant				Sweet pepper			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Sodium	7.8	9.2	9.1	7.6	4.2	4.4	4.1	4.0	4.5	5.0	4.4	4.6
Potassium	405	427	388	392	125	135	110	112	178	225	198	210
Calcium	17.5	18.2	17.4	17.8	28.0	33.0	27.0	25.0	7.8	10.3	10.3	8.1
Magnesium	23.0	20.0	18.2	19.5	18.0	20.1	18.5	18.2	12.5	17.0	16.0	13.6
Iron	0.40	0.71	0.60	0.53	1.42	1.55	1.42	1.46	0.53	0.76	0.67	0.51
Zinc	0.25	0.31	0.23	0.22	0.20	0.23	0.18	1.70	0.25	0.32	0.31	0.27
Copper	0.12	0.12	0.09	0.08	0.14	0.16	0.14	0.15	0.02	0.04	0.03	0.03

Table 18: Minerals content of different vegetables in different growing environments

Nutritional Facts (mg/100g)	Broccoli				Cucumber				Netted melon			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Sodium	26.0	30.0	28.7	26.4	2.6	3.2	3.0	2.7	28.0	30.3	29.5	28.8
Potassium	270	298	288	273	142	156	143	150	470	492	468	480
Calcium	45.0	47.0	43.0	35.0	14.5	17.3	16.0	14.0	15.6	16.3	15.7	14.5
Magnesium	21.0	22.0	19.0	16.0	15.3	16.2	15.2	15.60	21.0	22.3	22.0	18.0
Iron	0.60	0.72	0.70	0.64	0.27	0.33	0.30	0.23	0.35	0.41	0.33	0.35
Zinc	0.28	0.35	0.32	0.30	0.20	0.24	0.22	0.18	0.30	0.34	0.29	0.25
Copper	0.03	0.04	0.04	0.03	0.05	0.05	0.05	0.04	0.07	0.09	0.07	0.07

Vitamins

Different type of vitamins were analyzed for different vegetables under different growing environments. The environments were viz., Poly green shed house, UV poly shed house, Net house, Open field (control) and the vegetables were viz., tomato, eggplant, sweet pepper, broccoli, cucumber, netted melon. The variation of vitamin content was varied significantly under different growing environments. There was a wide range in Vitamin A content which was 0.6 mcg (eggplant in open field) - 1860 mcg (sweet pepper in UV poly shed house), since cultivation of vegetables under different growing environments. The higher amount of beta Carotene was observed in netted melon which was 1472, 1645, 1510, 1367 mcg in poly green shed house, UV poly shed house, net house and open field, respectively (Table 19).

Table 19: Vitamins A and Beta Carotene content per 100 g fresh of tomato, eggplant, sweet pepper in different growing environments

Nutritional facts (mcg/100 g)	Tomato				Eggplant				Sweet pepper			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Vitamin A	69	71	68	63	0.7	0.8	0.7	0.6	165	186	174	181
Beta Carotene	668	755	660	702	11	10	9.0	7.2	1179	1334	1112	957

Table 19 (Contd.). Vitamins A and Beta Carotene content per 100 g fresh of broccoli, cucumber, netted melon in different growing environments

Nutritional facts (mcg/100g)	Broccoli				Cucumber				Netted melon			
	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)	Poly green shed house	UV poly shed house	Net house	Open field (control)
Vitamin A	16.2	19.3	18	15.7	4.9	5.4	3.8	4.2	96	117	105	101
Beta Carotene	100	123	115	104	50	57	54	48	1472	1645	1510	1367

Vitamin B complex viz., Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B5, Vitamin B6 were estimated in tomato, eggplant, sweet pepper, broccoli, cucumber, netted melon under Poly green shed house, UV poly shed house, Net house, Open field, while in maximum cases the vitamins were found higher in UV poly shed house compare to other conditions. This might be due to the congenial micro-climatic conditions maintained in net house which influenced the production of more photosynthates that might result in fruits with higher vitamins B complex (Fig 74).

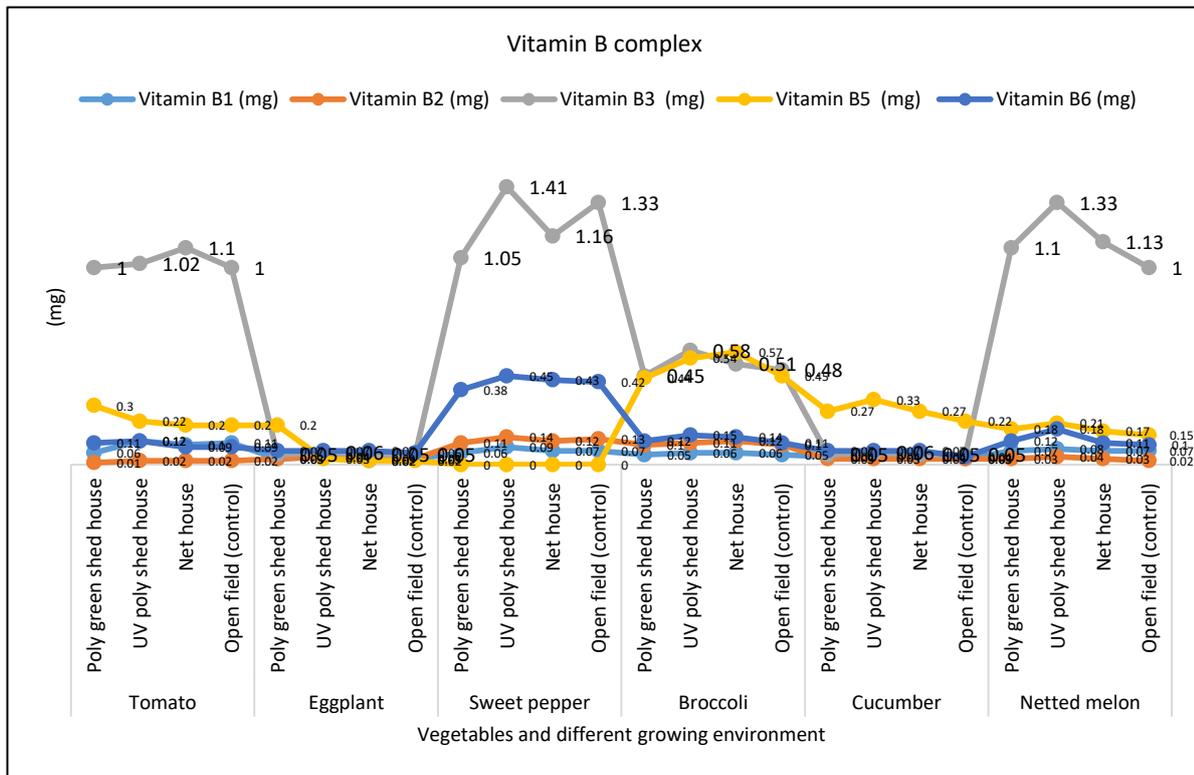


Figure 74. Vitamins B complex content of different vegetables in different growing environments

Folate and Vitamin C were found higher in sweet pepper and netted melon, respectively under UV poly shed house (Fig 75).

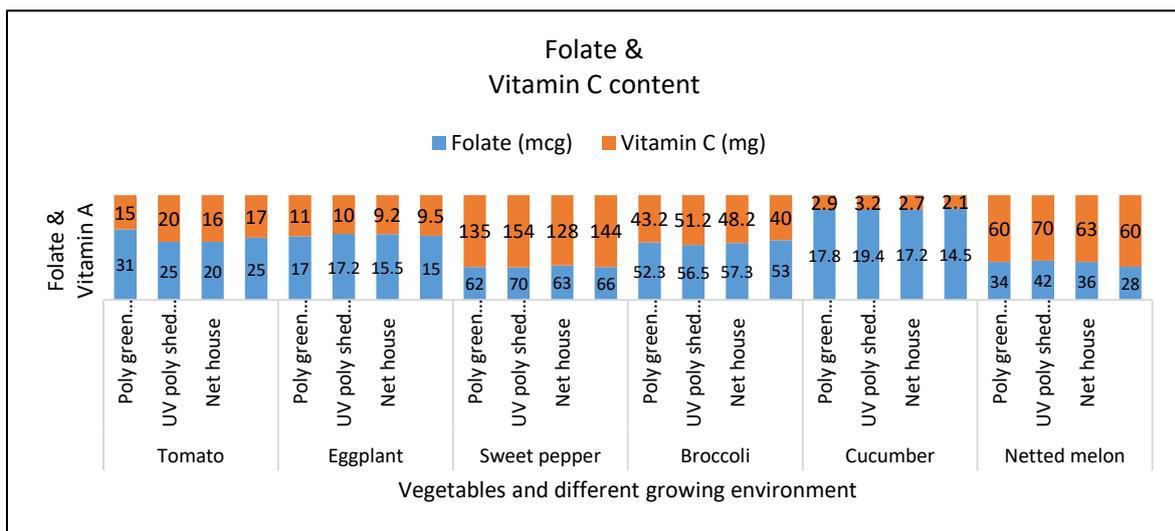


Figure 75. Folate and Vitamins C content of different vegetables in different growing

11. 7. Upscaling of Protective Nethouse Technology at Farmers' Field

The yield and yield contributing parameters of tomato, sweet pepper, cucumber, netted melon and okra varied with the different farmers field viz., Cumilla and Narshingdi (Table 20).

Tomato

In case of tomatoes, a higher number of fruits per plant (32) was produced in Cumilla compared to Narshingdi (25), while the average fruit weight was 85g and 80g, respectively (Table 20). The fruit yield/ plant and fruit yield/plot showed the same trend, while Cumilla condition was higher (2.72kg, 32.64kg, respectively) compared to Narshingdi condition (2.00kg and 24.00kg, respectively). There were significant differences in fruit yield (t/ha), which was 90.67 t/ha and 66.67 t/ha, respectively. Cumilla had the highest insect control (96.0%) compared to Narshingdi (92.5%). Less insect infestation was observed due to the use of nethouse cultivation. The BCR was also higher (2.05) in Cumilla compared to Narshingdi (1.75), the lower BCR is due to the 1st year calculation. After that, it will be higher over the years (Fig 76).

Sweet pepper

Sweet is a non-pungent fruit that is valued for its color, flavor, and nutritional attributes. The higher number of fruits (8.5) was produced in Cumilla compared to Narshingdi (6.0), while the average fruit weight was 95g and 85g, respectively (Table 20). The fruit yield/ plant and fruit yield/plot had the same trend, while Cumilla condition was higher (0.81kg and 9.69kg, respectively) compared to Narshingdi condition (0.51kg and 6.12kg, respectively). There were significant differences in fruit yield (t/ha), which was 26.92 t/ha and 17.00 t/ha, respectively. The insect control was maximal (97.5%) in Cumilla compared to Narshingdi (95.5%). Less insect infestation was observed due to the use of nethouse cultivation. The BCR was also higher (2.53) in Cumilla compared to Narshingdi (1.92), the lower BCR is due to the 1st year calculation. After that, it will be higher over the years (Fig 76).

Cucumber

Cucumber for fresh consumption is one of the most popular vegetables worldwide and is a rich source of vitamins, minerals, and antioxidants (Patel and Panigrahi, 2019). Though cucumber is a summer vegetable, it was cultivated during the winter season under nethouse conditions. The higher number of fruits (9.0) was produced in Cumilla compared to Narshingdi (6.5), while the average fruit weight was 132g and 121g, respectively (Table 20). The fruit yield/plant and fruit yield/plot showed the same trend, while Cumilla condition was higher (1.19kg and 11.88kg, respectively) compared to Narshingdi condition (0.79kg, 7.87kg, respectively). There were significant differences in fruit yield (t/ha), which was 24.75 t/ha and 16.39 t/ha, respectively. The insect control was maximal (92.0%) in Cumilla compared to Narshingdi (90.0%), The less insect infestation was observed due to the use of nethouse cultivation. The BCR was also higher (1.42) in Cumilla compared to Narshingdi (1.21), the lower BCR is due to the 1st year calculation. After that, it will be higher over the years (Fig 76).

Netted melon

Netted melon is a very popular fruit among consumers due to its unique flavor, shape, and color, and nowadays it is getting popular among the local growers due to its high prices. Since it is a special type of crop and needs special attention during its growing time, there was significant variation observed at different locations. Though cucumber is a summer vegetable, it was cultivated during the winter season under nethouse conditions. The higher

number of fruits (3.0) was produced in Cumilla compared to Narshingdi (0.8), while the average fruit weight was 720g and 675g, respectively (Table 20). The fruit yield/ plant and fruit yield/plot had the same trend, while Cumilla condition was higher (2.16kg and 17.28kg, respectively) compared to Narshingdi condition (0.54kg and 4.32kg, respectively). There were significant differences in fruit yield (t/ha), which was 36.00 t/ha and 9.00 t/ha, respectively. The insect control was maximal (96.5%) in Cumilla compared to Narshingdi (94.5%). The less insect infestation was observed due to the use of nethouse cultivation. The BCR was also higher (2.63) in Cumilla compared to Narshingdi (2.20), the lower BCR is due to the 1st year calculation. After that, it will be higher over the years (Fig 76).

Okra

Since okra is a summer vegetable, but it was cultivated during the winter season under nethouse condition. The higher number of fruits (46) was produced in Cumilla compare to Narshingdi (31), while average fruit weight was 11.5g and 10.5g, respectively (Table 21). The and fruit yield/ plant and fruit yield/ plot was same trend, while Cumilla condition was higher (0.53kg, 8.46kg, respectively) compare to Narshingdi condition (0.33kg, 5.21kg, respectively). There were significant differences in fruit yield (t/ha), which was 22.04t/ha and 13.56t/ha, respectively. The insect control was maximum (98.5%) in Cumilla compared to Narshingdi (96.7%). The less insect infestation was observed due to the use of nethouse cultivation. The BCR was also higher (1.35) in Cumilla compare to Narshingdi (1.22), the lower BCR is due to 1st year calculation, afterword it will be higher over the years (Fig 76).

Table 20: The yield related data and insect control parameter of different high value vegetables in Cumilla and Narshingdi area

Yield contributing parameters	Tomato		Sweet pepper		Cucumber		Netted melon		Okra	
	Cumilla	Narshingdi	Cumilla	Narshingdi	Cumilla	Narshingdi	Cumilla	Narshingdi	Cumilla	Narshingdi
Number of fruits	32	25	8.5	6.0	9.0	6.5	3.0	0.8	46	31
Average fruit weight (g)	85	80	95	85	132	121	720	675	11.5	10.5
Fruit yield/ plant (kg)	2.72	2.00	0.81	0.51	1.19	0.79	2.16	0.54	0.53	0.33
Fruit yield/ plot (kg)	32.64	24.00	9.69	6.12	11.88	7.87	17.28	4.32	8.46	5.21
Fruit yield (t/ha)	90.67	66.67	26.92	17.00	24.75	16.39	36.00	9.00	22.04	13.56
Insect control (%)	96.0	92.5	97.5	95.5	92.0	90.5	96.5	94.5	98.5	96.7

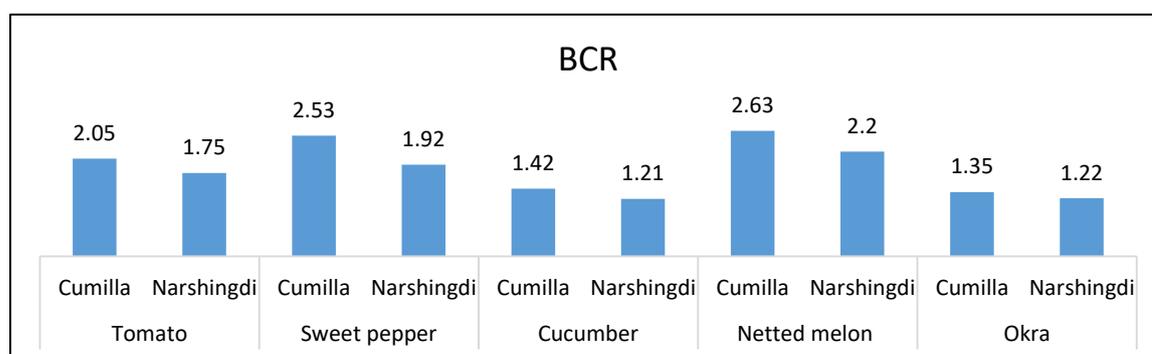


Figure 76. BCR of different high value vegetables in Cumilla and Narshingdi area



Plate 5. Farmer of Narshingdi



Plate 6. Director HRC and T&C visited the farmers nethouse of Narshingdi



Plate 7. Farmer of Cumilla



Plate 8. CSO, RARS, Cumilla visited the farmers nethouse of Cumilla

SAU component

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

Environmental conditions: Under protected conditions temperature can be monitored and managed, and better plant growth of 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 31.41°C as shown in Table 21. 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 22). 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.

Table 21: Monthly average air temperature ($^{\circ}$ c) at 12 hrs in different shade house and open field

Month	Average temperature ($^{\circ}$ C)			
	Poly shed	UV Poly shed	Net house	Open field
November, 2019	28.19	30.03	26.87	29.33
December, 2019	22.00	25.93	21.45	25.03
January, 2020	22.50	25.41	21.03	24.65
February, 2020	24.21	26.96	23.09	26.48
March, 2020	28.85	31.05	27.55	30.41

Table 22: Monthly average relative humidity (%) at 12 hrs in different shade house and open field

Month	Average relative humidity (%)			
	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	74.6
February, 2020	71.17	70.03	73.01	70.72
March, 2020	68.90	67.09	70.19	68.51

Plant height: Different growing conditions showed substantial variability with respect to strawberry plant height. Regardless of the influence of different shade house treatments, plant height varied significantly. The maximum plant height (18.5cm) was obtained in net house followed by poly house (17 cm) and the lowest height (15.5cm) was obtained from open field condition (Table 23).

SPAD value: In this study, there were no significant differences of different growing environment in leaf chlorophyll content except net houses plants (Table 23). The plants in the net house showed the highest chlorophyll content (62.73), and the lowest chlorophyll content (57.66) was showed in UV poly shade preceded by Open field condition (58.33).

Number of fruits/plant: Number of fruits/plant was significant among the shed houses (Table 23). Number of fruits plant⁻¹ was the highest in net house (17) and the lowest in both UV poly shade (12.33).

Individual fruit weight: Different growing environment showed significant variation in respect of individual fruit weight (Table 23). The maximum fruit weight (17g) was recorded in net house followed by poly house (15.66 g) and minimum weight was recorded from open field condition (13.83g) .

Fruit yield/plant: There was a significant variation among shade houses in response to fruit yield plant⁻¹. The highest fruit yield (289.16 g) found in net house followed by poly shade (235 g) and lowest yield (162.72 g) found from open field condition (175.16g) (Table 23). The benefit cost ratio of strawberry production in open field, Uv poly shed, poly shed and net house was estimated as 1.4, 1.6, 2.5 and 3.1 respectively (Table 23).

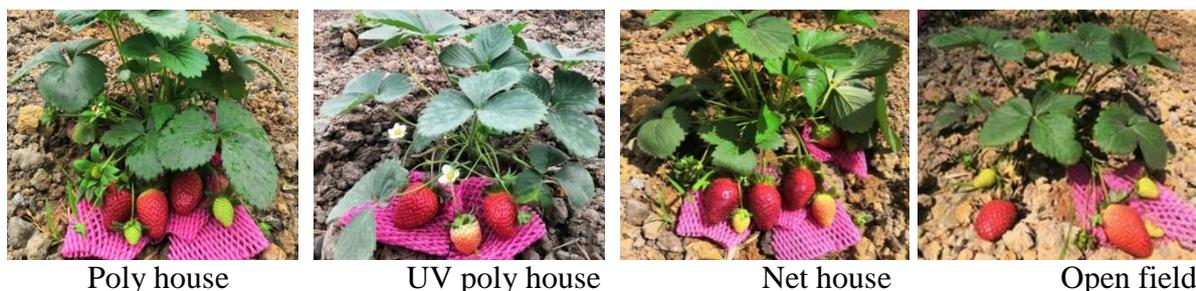


Plate 9: Fruit bearing strawberry plants under different shed houses

Moisture content: No significant change of moisture content in strawberry fruits were found among different shade treatments. 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%) (Table 23).

Ascorbic acid: The higher ascorbic acid was found in UV poly shed (39.66 mg/100 g), followed by naturally ventilated polyhouse (37.33mg/100 g) and net house (35.45 mg/100 g) and the lowest ascorbic acid was found in the fruits grown in open field condition (33.62 mg/100 g) (Table 24).

Table 23. Average plant height, SPAD value, Number of fruits/plant, Individual fruit weight, fruit yield/plant and moisture content of strawberry fruits grown under different shades and open field conditions.

Treatments	Plant height (cm)	SPAD value	Moisture content (%)	Number of fruits/plant	Individual fruit weight (g)	Fruit yield/plant (g)	BCR
Open Field	15.50c	58.33 c	91.00b	12.66 c	13.83c	175.17 c	1.7c
UV Poly shed	15.66c	57.66 c	91.66b	12.33 c	14.66bc	181.33c	1.8c
Poly shed	17.00 b	60.76 b	92.33ab	15.00 b	15.66ab	235.00 b	2.5b
Net House	18.50 a	62.66 a	93.50a	17.00 a	17.00 a	289.17a	3.1a
LSD (0.01)	0.57	1.24	1.57	1.59	1.79	4.99	0.8
CV (%)	1.73	1.04	0.85	5.61	5.87	3.23	4.1

BCR: Benefit cost ratio; Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Total soluble solids (TSS): It was observed that there was a significant effect of growing environment on fruit TSS of strawberry (Table 24). Strawberry growing in protected

environment had higher TSS than fruits produced in open field condition (Table 24). TSS content of 7.0 °Brix in UV poly shed, 6.5 °Brix both in poly shed and net house and 5.5 °Brix for strawberry grown in the open field were recorded

Titration acidity (TA): Fruits produced in the open field was less acidic than those produced in protected environments. The highest titration 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%) (Table 24).

pH value: The lower pH was found in UV poly shed (3.4) and the higher pH was found in fruits grown in open field condition (3.57) followed by poly shed (3.52) and net house (3.56) (Table 24). However, no significant differences were observed in the pH values of strawberry fruits grown in poly shed, net house and open field conditions. Determining fruit acidity at complete maturation, when acidity decreases, is possibly the explanation for the low values.

Total phenolic content: The phenolic compounds directly contributed to the antioxidant action. Shading conditions were significantly different for total phenolic content. The total phenolic content in the plants grown under poly shed was highest (2.44 mg/g FW) followed by UV poly shed (2.33 mg/g FW) and net house (2.10 mg/g FW), whereas the total phenolic content in strawberry fruits in open field was lowest (1.62 mg/g FW) (Table 24).

Reducing sugar: The reducing sugar content of strawberries in shade treatments were significantly higher compared to the open field condition. The highest sugar content in the plants grown under poly shed was seen (7.74 mg/g FW), followed by UV poly shed (7.38 mg/g FW) and net house (6.68 mg/g FW), while the lowest sugar content in open field strawberry fruits (5.52 mg/g FW) was observed (Table 24).

Table 24 : Average content of ascorbic acid , total soluble solid , titratable acidity, pH, total phenolic content and reducing sugar of strawberry fruits grown under different shades and open field condition.

Treatment	Ascorbic acid (mg/100g)	TSS (°Brix)	TA (%)	pH	Total phenolic content (mg/g)	Reducing sugar (mg/g)
Open Field	33.45d	5.50b	0.33b	3.57a	1.62c	5.69c
UV Poly shed	39.66a	7.00a	0.46a	3.41b	2.33a	7.57a
Poly shed	37.33 b	6.66a	0.38b	3.53 a	2.40a	7.38a
Net House	35.45c	6.83 a	0.36b	3.56a	2.10b	6.68b
LSD _{0.05}	0.79	1.06	0.64	0.064	0.17	0.68
CV %	1.09	8.21	8.33	0.91	4.06	5.02

Different letters mean significant differences between the treatments according to Duncan’s multiple range test (p <0.05).

Discussion

Temperature is primary environmental factor controlling short-day strawberry plant growth and development (Palencia *et al.*, 2013). In this experiment, it was found that air temperature in UV poly shade and open field was always more than that in other poly and net houses condition. The optimal temperatures in strawberries for photosynthesis range from 15 to 23°C (Hancock, 1991). Higher temperatures affect net photosynthesis more adversely than lower temperatures, leading to lower photosynthesis output above a certain temperature (Reddy *et al.*, 1999). Relative humidity increases the net energy availability for crop growth and

enhances crop survival under conditions of moisture stress. Shading enhanced the fruit fresh weight, resulting in fruits with higher moisture content. Compared to other growing conditions the relative humidity was comparatively lower in UV poly shade condition. The lower relative humidity inside the UV poly house may be due to fully covered with UV film sheet. Relative humidity retains cell turgidity that is useful in enzyme activity leading to greater yield (Reddy *et al.*, 1999). A relative humidity level of 65 to 75% during the day was considered to be optimal for good growth and yield of strawberries in the greenhouse (Lieten, 2000). In our experiment, the relative humidity was therefore at an optimum level in all the growing conditions.

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

The environmental impact on fruit acidity is complex, and some studies support the presumption that organic acids are derived from stored carbohydrates in the fruit itself, although some of these acids may be translocated from the leaves and roots to the fruits (Bertin *et al.*, 2000). Thus, the higher acidity of the fruits grown in a protected environment may result from the plant's higher photosynthetic activity in this environment, and consequently from a higher accumulation of carbohydrates in the fruits. Yanagi *et al.* (1995) stated that the titratable acidity also increases with shading. High fruit quality is associated with low pH. Biosynthesis of ascorbic acid can be highly affected by environmental conditions, influencing the ascorbic acid content in strawberry fruits. The amount of ascorbic acid in fruit is also affected by the availability of light to the crop and to the fruits. Under shed house, the plants received proper intensity of light which could have improved the ascorbic acid content in fruits compared to open condition. Koley *et al.* (2013) investigated quality parameters of tomato under protected and open cultivation and found significant higher vitamin C in the fruit produced under protected structures at full ripe stage over the open field cultivation. Under poly shed, the plants obtained sufficient light intensity which may have increased the amount of ascorbic acid in the fruit compared to open environment. Loures (2001) found a lower TSS content for tomato field-grown tomatoes than tomatoes grown in a protected area. Pérez de Camacaro *et al.* (2017) reported that greater accumulation of TSS in fruit has been observed in shading conditions due to reduced sugar degradation. In present results, there was no significant difference of phenolic content between UV poly shed and poly shed. This results revealed that shading conditions significantly influenced total phenolic content of strawberry fruits. Koley *et al.* (2013) investigated quality parameters of tomato under protected and open cultivation and found significantly higher antioxidant

activity in the fruit produced under protected structures at full ripe stage over open field cultivation. Reducing sugar content was considerably higher in fruits cultivated under shade houses. This result is similar to that of Voca *et al.* (2009) found that fruits grown under a tunnel were usually more reducing sugar than in open field cultivated fruits. Therefore, under shade treatments growing strawberry may be profitable for quality point of view as it increased reducing sugar.

11.9. Impact of Different Shed Houses and Growing Media on Growth, Yield and Quality of Strawberry

Environmental conditions

Temperature is the primary environmental factor controlling short-day strawberry plant growth and development (Palencia *et al.*, 2013). In this experiment, it was found that air temperature in UV poly shade was always more than that in the open field and net houses condition (Table 25). The optimal temperatures in strawberries for photosynthesis range from 15 to 23°C (Hancock, 1991). Higher temperatures affect net photosynthesis more adversely than lower temperatures, leading to lower photosynthesis output above a certain temperature (Reddy *et al.*, 1999). Relative humidity increases the net energy availability for crop growth and enhances crop survival under conditions of moisture stress. A relative humidity level of 65 to 75% during the day was considered to be optimal for good growth and yield of strawberries in the greenhouse (Lieten, 2000). In our experiment, the relative humidity was therefore at an optimum level in all the growing conditions.

Table 25: Average monthly temperature and relative humidity (%) at 12 hrs in different shade house and open field

Month	Shed house					
	Open field		UV Poly shed		Net house	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)
November, 2019	29.33	66.98	30.03	60.07	26.87	69.19
December, 2019	24.03	68.75	24.93	62.95	20.45	70.01
January, 2020	23.58	70.6	24.12	66.53	21.03	72.21
February, 2020	26.48	66.72	27.21	65.93	23.09	69.01
March, 2020	31.41	62.51	32.05	61.9	27.55	66.19

Effect of different shade houses and growing media on plant growth

According to table 26, the various plant growth parameters such as plant height, number of leaves, and SPAD reading were found significant among different treatments. The highest plant height (20.33 cm) was found in UV poly shade with cocopeat treatment and the lowest (14.66 cm) was observed in vermicompost treatment in both net house and open field conditions (Table 26). However, the maximum number of leaves (13) was observed in the net house with cocopeat treatment whereas the minimum number of leaves (9) was observed in vermicompost treated plants grown under UV poly shed (Table 26).



Plate 10: Strawberry plants growing in pots under different shed houses

The plants grown in the net house with cocopeat treated soil showed the highest chlorophyll content (46.10), and the lowest chlorophyll content (41.50) was shown in UV poly shade with vermicompost treated soil (Table 26). Under cocopeat substrate, plant growth and development were accelerated, resulting in greater chlorophyll content in leaves. This could be owing to the availability of nutrients in cocopeat-based media. Sweet pepper growth parameters were much greater in peat-treated pots than in control pots (100% soil) (Rekani *et al.*, 2016). Due to different temperatures, aeration, and soil moisture availability, different growing media can impact water and mineral uptake in the plant; thus, influence plant growth. Improvement in plant growth may be attributable to improvement in the soil's physiochemical properties; an increase in enzymatic activity, microbial population, and also an increase in plant growth hormones through the use of sufficient increasing media. It was also reported that the water holding capacity is better cocopeat compared to other growing media (Ozgumus, 1985). In the present experiment, open field conditions and UV poly shed showed a significant decrease in leaf chlorophyll content. The higher temperature is likely to play an important role in limiting plant growth by reducing photosynthetic activity and increasing the rate of respiration.

Effect of different shade houses and growing media on yield and yield traits

From the data presented in Table 26, it is apparent that the differences among various treatments were found to be significant in respect of the number of flowers, fruits, individual fruit weight, and fruit yield per plant. The data revealed that the maximum number of flowers (19) and fruits (17 g) per plant was observed under in net house with cocopeat treatment. However, the lowest number of flowers (11) and fruits per plant (8) was recorded in a vermicompost treated plant grown under UV poly shed (Table 26). The maximum fruit weight (18.03 g) was recorded in cocopeat treated plants grown under the net house and the minimum fruit weight was recorded in vermicompost treated plants grown in all growing conditions i.e. open field, net house and UV poly shed (approximately 12 g) (Table 26). There was a significant variation among shade houses and different growing media in response to fruit yield/plant. The highest fruit yield (307.11 g) was found in cocopeat treated plants grown in net house and the lowest yield (108 g) was found in vermicompost treated plants under UV poly shade condition (Table 26). Temperature above 25 °C can reduce fruit set of strawberry (Abdelrahman, 1984). In this experiment, air temperature in open field and UV poly shade was higher during January and February (flowering and fruiting stage) than that in the net houses condition, thus, affected the yield of strawberry. Strawberry fruit yield and quality can be affected by higher temperatures after bloom. High temperatures harm fruit set in strawberries, decreasing pollen viability and inhibiting pollen tube growth and pollen tube elongation (Ledesma and Sugiyama, 2005). In order to boost aeration resulting in the

development of a better root system, various combinations of increasing media have been recorded (Verdonck and Demeyer, 2004) and result in higher yields (Albaho *et al.*, 2009). Rostami *et al.* (2014), also reported that when substrates composed of different growing media were used, the yield of strawberry significantly differed. The positive impact of cocopeat and its mixtures on improved root growth may lead to improved aeration, thereby creating a higher root system that may have facilitated shoot nutrient uptake leading to increased berry yield.

Table 26. Average plant height, leaf number/plant, SPAD value, Flower number/plant, Fruit number/plant, Individual fruit weight and fruit yield/plant of strawberry grown with different growing media under different shade houses.

Treatments	Plant height (cm)	Leaf number/plant	SPAD value	Flower number/plant	Fruit number/plant	Individual fruit weight (g).	Fruit yield/plant (g)
Cowdung+open field	17.33 cd	11.00 de	42.93 d	16.33 c	14.00 c	14.43 c	201.85 c
Cocopeat+open field	18.00 bc	11.33 cd	46.10 a	18.00 b	15.33 b	16.15 b	247.69 b
Vermicompost+open field	15.67 e	10.00 f	42.13 ef	13.00 d	11.67 e	13.02 d	151.91 e
Cowdung+Net house	19.00 ab	12.33 b	43.73 c	17.00 bc	13.33 cd	15.43 b	200.49 c
Cocopeat+ Net house	20.33 a	13.33 a	44.90 b	19.67 a	17.00 a	18.05 a	307.11 a
Vermicompost+ Net house	16.00 de	10.33 ef	42.37 de	16.33 c	13.00 d	12.92 d	171.93 d
Cowdung+UV poly shed	14.67 e	12.00 bc	43.76 c	11.00 e	9.67 g	12.21 de	117.43 g
Cocopeat+ UV poly shed	15.33 e	12.00 bc	44.80 b	12.67 d	10.67 f	12.43 de	132.69 f
Vermicompost+ UV poly shed	14.67 e	9.00 g	41.50 f	11.00 e	8.67 h	12.00 e	103.00 h
LSD _(0.01)	1.58	0.79	0.76	1.22	0.79	0.81	2.55
CV (%)	3.97	2.95	0.79	3.42	2.64	2.43	1.28

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Effect of different shade houses and growing media on fruit quality

The higher ascorbic acid was found in both cocopeat treated plants grown under UV poly shed and open field condition (approximately 46 mg/100 g), and the lowest ascorbic acid was found in the fruits grown in vermicompost treated plants grown under net house condition (35.83 mg/ 100 g) (Table 27). The quality of crops has also been improved by increasing the content of vitamin C in the fruit and, in particular, by increasing the sugar content. The higher TSS content was found in fruits grown with vermicompost treated soil and the lowest TSS content was found in fruits grown in cowdung treated soil in all growing environments (Table 27). The increased TSS and ascorbic acid content of fruit could be attributed to better growing media which helped in better uptake of NPK nutrients including micronutrients which influence the quality traits in fruits (Lata *et al.*, 2018). The higher titrable acidity was

found in cocopeat treated fruit plants grown in the net house (0.62%) and the lowest was found in the fruits grown with cowdung treated soil in UV poly shade (0.37%) (Table 27). Relatively high acid content is required for good strawberry flavor (Kader, 1990). However, the higher pH was found in UV poly shed with cowdung treated plant (3.69) and the lower pH was found in the net house with cocopeat and vermicompost treated plants (approximately 3.45) (Table 27). High fruit quality is associated with low pH (Davies and Hobson, 1981). Loss of organic acids from ripe fruit tends to be largely due to respiration.

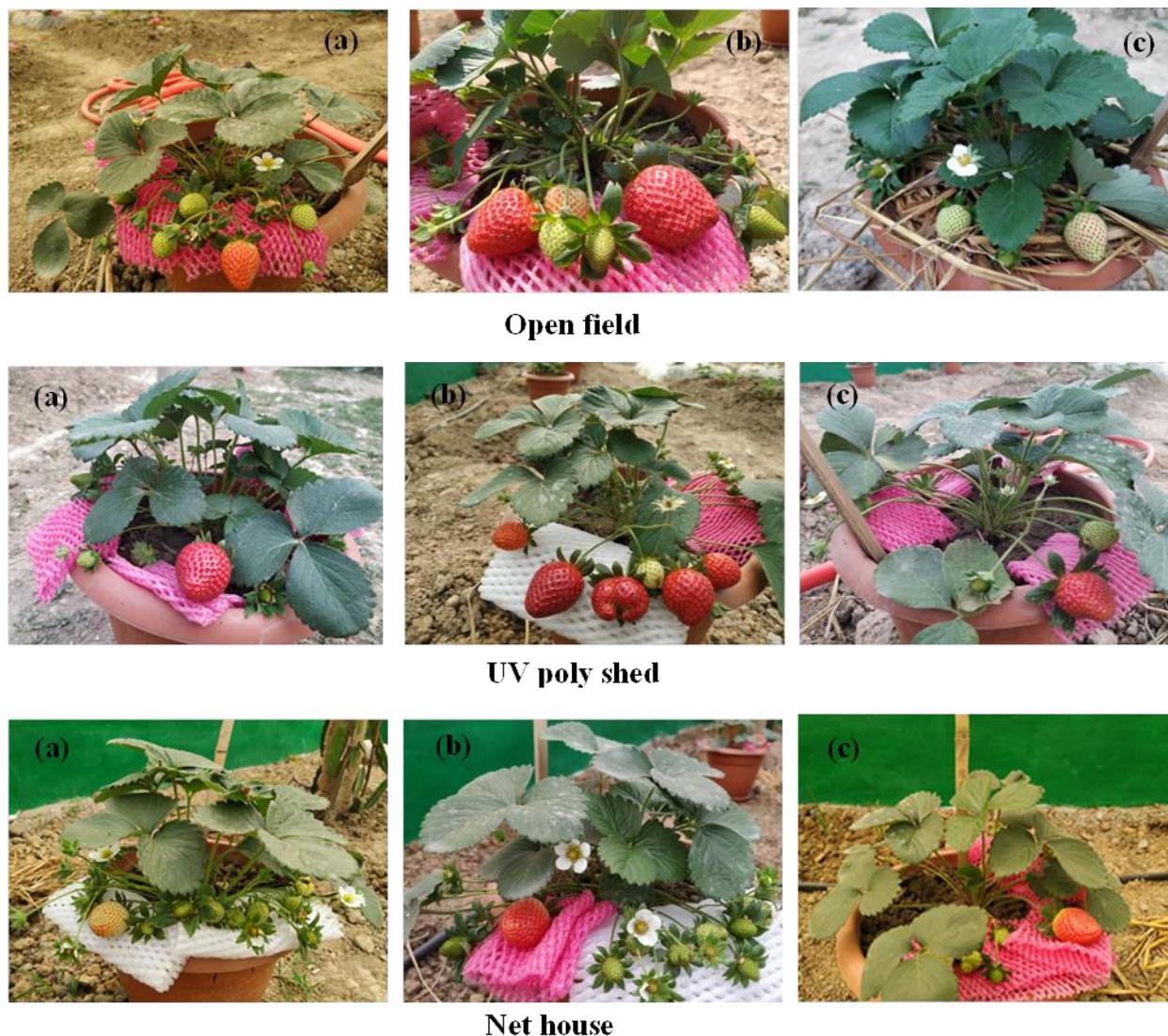


Plate 11: Strawberry production in plastic pots using various growing media (a: cowdung, b: cocopeat, c: vermicompost) and shed houses

Table 27. Average content of ascorbic acid, total soluble solid (TSS), titratable acidity, pH (D), reducing sugar and anthocyanin of strawberry grown with different growing media under different shade houses.

Treatments	Ascorbic acid (mg/100g)	TSS (%)	Titratable acidity	pH	Reducing sugar (mg/g)	Anthocyanin (mg/100g)
Cowdung+open field	43.75 c	6.50 d	0.42 e	3.54 b	8.10 f	27.50 f

Cocopeat+open field	48.75 a	6.50 d	0.41 e	3.53 b	8.20 e	28.65 de
Vermicompost+open field	39.97 d	6.00 e	0.37 f	3.69 a	8.40 c	29.67 b
Cowdung+Net house	46.84 b	7.00 c	0.53 b	3.53 b	8.38 c	28.33 e
Cocopeat+ Net house	49.00 a	7.50 b	0.62 a	3.45 c	8.58 b	29.23 c
Vermicompost+ Net house	40.88 d	6.50 d	0.47 c	3.56 b	8.75 a	30.80 a
Cowdung+UV poly shed	40.43 d	7.50 b	0.41 e	3.55 b	8.27 d	27.80 f
Cocopeat+ UV poly shed	40.50 d	8.00 a	0.47 c	3.46 c	8.36 c	28.77 d
Vermicompost+ UV poly shed	35.84 e	7.50 b	0.45 d	3.53 b	8.57 b	29.92 b
LSD _(0.01)	1.68	0.17	0.02	0.03	0.06	0.33
CV (%)	1.65	1.01	1.53	0.38	0.31	0.49

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

There was a significant difference in reducing sugar content in fruits grown with different growing media under different shade houses. The higher reducing sugar was found in cocopeat treated plants grown under the net house (8.75 mg/ g FW), and the lower reducing sugar was found in the fruits grown in cowdung treated plants under open field conditions (8.1 mg/g FW) (Table 27). In this study, plants grown under net house had significantly increased content of reducing sugar in susceptible cultivars. Likewise, Voca *et al.* (2009) showed that fruits grown under a tunnel had usually more reducing sugar than in open field cultivated fruits. The acid and sugar content of the fruit is related to its ripeness (Pérez *et al.*, 1997), and higher sugar content is required for good strawberry flavor (Kader, 1990). The red-colored strawberry attracts buyers and hence serves as an effective fruit marketing criterion. The content of anthocyanin is influenced by many factors, such as temperature, light, food, hormones, etc. (Karanjalker *et al.*, 2018). In the present result, the growing media and shade houses had significantly influenced the total content of anthocyanin. As observed in Table 27, anthocyanin content decreased in strawberry fruit grown with cowdung under open field conditions (27.50 mg/100g). Meanwhile, anthocyanin content significantly increased in fruits grown in the net house with cocopeat treated soil (30.80 mg/100g). Increased content of anthocyanins was observed in fruits from plants grown on the peat-coconut substrate (Wysocki, 2017). This study showed the positive influence of shade on the total anthocyanin content of the strawberry. It was speculated that the content of anthocyanin could be related to ambient air temperature.

11.10. : Effect of Various Mulch Materials and GA₃ on Strawberry Growth, Yield, and Quality Under Net House

Plant height (cm)

In comparison to non-GA₃ treated plants, the height of all GA₃ sprayed plants was increased. At flowering stage, the highest plant height (19.5 cm) was found in sawdust mulching with GA₃ treated plant followed by white polyethylene with GA₃ (19.33 cm) treated plant and the

lowest (14.66 cm) was observed in black polythene with no GA₃ (Table 28). A similar trend was found for the plant height during fruiting stage. The highest plant height (21.5 cm) was found in sawdust mulching with GA₃ treated plant whereas the lowest (13.73 cm) was found in control plants (Table 28).

Chlorophyll content (SPAD value)

At the flowering stage, sawdust mulching plants treated with GA₃ had the highest chlorophyll content (46.33), while control plants had the lowest (42.00) (Table 28). However, at fruiting stage, the highest chlorophyll content (46.50) was found in GA₃ treated plants without mulching, while the lowest chlorophyll content (41.00) was found in black polythene with no GA₃ treated plants.

Leaf area (cm²)

The maximum leaf area was found in sawdust mulching plants treated with GA₃ (81 cm²), which was statistically similar to sawdust mulching plants (79 cm²), whereas the minimum leaf area was found in black polythene mulch plants (66 cm²) (Table 29).

Relative water content (RWC)

The data in Table 29 shows that the differences between various mulching treatments were found to be insignificant in terms of RWC. Sawdust mulching with GA₃-treated plants resulted in a higher RWC (76.45%), whereas control (no mulch and GA₃) plants resulted in a lower RWC (61.16%).

Table 28: Average plant height and SPAD value of strawberry grown under different mulching and GA₃

Treatments	Plant height (cm)		SPAD value	
	50% flowering	50% fruiting	50% flowering	50% fruiting
No mulch+ no GA ₃	14.00 de	16.66 d	42.00 c	43.66 abc
No mulch+GA ₃	17.50 bc	19.50 bc	44.33 abc	46.50 a
Black polythene + no GA ₃	13.50 e	13.73 e	42.66 bc	41.00 c
Black polythene+GA ₃	17.90 ab	18.33 cd	43.33 abc	41.83 bc
White polythene+ no GA ₃	15.75 cd	16.83 d	44.33 abc	43.83 abc
White polythene+GA ₃	19.33 ab	19.83 abc	45.33 ab	44.50 ab
Sawdust+no GA ₃	18.00 ab	20.66 ab	44.33 abc	43.16 bc
Sawdust+GA ₃	19.50 a	21.50 a	46.33 a	42.66 bc
LSD _{0.05}	1.913	1.626	2.704	1.554
CV%	6.45	5.05	3.50	2.40

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p <0.05).

Table 29: Average leaf area (cm²) (A) and relative water content (%) (B) of strawberry grown with different mulching GA₃

Treatments	Leaf area (cm ²)	Relative Water Content (%)
------------	------------------------------	----------------------------

No mulch+ no GA ₃	69.33 ef	61.16 d
No mulch+GA ₃	71.66 de	65.90 c
Black polythene + no GA ₃	66.08 f	70.99 b
Black polythene+GA ₃	67.97 ef	73.87 ab
White polythene+ no GA ₃	73.06 cd	72.23 b
White polythene+GA ₃	76.00 bc	73.16 ab
Sawdust+no GA ₃	79.06 ab	72.18 b
Sawdust+GA ₃	80.97 a	76.45 a
LSD _{0.05}	2.92	2.80
CV%	3.693	3.425

Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Days to flowering

All plants sprayed with GA₃ required a minimum number of days to flower compared to the non-GA₃-sprayed plants. The minimum (31.83) days were required in black polyethylene mulch treated with GA₃ plants, closely followed by sawdust mulching with GA₃ plants (32.16 days). The plants that needed the most time to flower were those that had no mulch or GA₃ (43.66 days) (Table 30).

Number of flowers/plant

All plants treated with GA₃ gave the maximum number of flowers compared to the non-GA₃-treated plants. GA₃ treated sawdust mulching plants had the most flowers (20), followed by black polyethylene (18.5) and white polyethylene plants (18.33) that had statistically similar numbers of flowers per plant. The minimum number of flowers (11) was observed in control plants (no mulch and GA₃) (Table 30).

Days from flowering to fruit set

All plants treated with GA₃ took minimum number of days for flowering to fruit setting compared to the non-GA₃ sprayed plants. The minimum (4.83) days were required in sawdust mulching plants treated with GA₃, while the maximum (7.5) days were required in control plants (no mulch and GA₃) (Table 30).

Number of fruits/plant

The maximum number of fruits per plant (17.33) was found in sawdust mulching with GA₃ treated plants while the minimum number of fruits (8) was found in control plants (no mulch and GA₃) (Table 30).

Fruit set (%)

The maximum fruit set (89.15%) was found in sawdust mulched plants treated with GA₃, whereas the minimum fruit set (61.95%) was observed in black polythene mulch plants sprayed with GA₃ (Table 30).

Individual fruit weight

The individual fruit weight of all GA₃-treated plants was comparatively lower than the non-GA₃-treated plants. Individual fruit weight (18g) was the maximum in sawdust mulching with no GA₃ treated plants and the minimum (11g) fruit weight was found in plants in GA₃ treated plants with black polyethylene mulch (Table 30).

Fruit yield/plant

The fruit yield per plant of all GA₃ treated plants was the maximum compared to the non GA₃ sprayed plants. The maximum fruit yield (283.33g) per plant was found in sawdust mulch plants treated with GA₃, whereas the minimum fruit yield (92.00g) was found in black polyethylene with no GA₃ (Table 30).

Table 30: Average flower number/plant, fruit number/plant, Individual fruit weight (g) and fruit yield/plant of strawberry grown under different mulching and GA₃.

Treatments	Days to flowering	No. of flowers/plant	Days to flowering to fruiting	No. of fruits/plant	Fruit set %	Individual fruit weight (g)	Yield/plant (g)
No mulch+ no GA ₃	43.67 ab	11.00 e	7.50 a	8.00 de	72.56 bc	13.83 cd	110.83 d
No mulch+GA ₃	39.40 c	15.00 c	6.66 bc	10.66 c	71.03 bc	13.00 de	138.00 d
Black polythene + no GA ₃	38.40 cd	12.50 de	8.23 a	7.66 d	61.95 c	12.00 ef	91.67 f
Black polythene+GA ₃	32.20 f	18.50 b	7.50 abc	11.33 c	61.34 c	11.00 f	125.00 de
White polythene+ no GA ₃	42.22 ab	13.00 d	7.61 ab	10.50 c	81.18 ab	16.00 ab	167.83 c
White polythene+GA ₃	36.12 de	18.33 b	7.01 bc	14.00 b	76.31 ab	14.16 cd	197.83 b
Sawdust+no GA ₃	39.55 bc	16.83 b	6.55 c	14.33 b	85.33 a	17.33 a	248.33 a
Sawdust+GA ₃	35.47 e	20.66 a	5.52 d	16.66 a	80.90 ab	15.66 bc	261.00 a
LSD(0.01)	2.783	1.810	1.004	1.356	4.392	1.540	4.730
CV%	4.17	6.65	8.28	6.73	8.13	6.30	5.77

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p < 0.05).

Ascorbic acid (mg/100g)

All GA₃ sprayed plants showed increased ascorbic acid compared to the non GA₃ treated plants. The maximum ascorbic acid (50.56 mg/100g FW) content was found in sawdust mulch treated with GA₃ plants, whereas the minimum ascorbic acid (26.88 mg/100g FW) content was found in white polyethylene plants treated with no GA₃ (Table 31).

Total soluble solids (TSS °Brix)

All GA₃ sprayed plants showed increased total soluble solids (TSS) compared to the non GA₃ sprayed plants. The maximum TSS (8.9 °Brix) was found in sawdust mulching treated with GA₃ plants and the minimum TSS (6.3 °Brix) was found in black polyethylene mulch with no GA₃ (Table 31).

Table 31: Average content of ascorbic acid, total soluble solid (TSS), pH and titratable acidity plant height and SPAD value of strawberry grown under different mulching and GA₃

Treatments	Ascorbic acid (mg/100g)	TSS (°Brix)	pH	TA (%)
No mulch+ no GA ₃	27.52 c	7.81 b	3.33 a	0.36 c
No mulch+GA ₃	37.33 b	8.06 ab	3.25 b	0.40 abc

Black polythene + no GA ₃	37.70 b	6.30 c	3.08 d	0.44 ab
Black polythene+GA ₃	44.80 a	6.53 c	3.17 c	0.48 a
White polythene+ no GA ₃	26.88 c	6.76 c	3.18 c	0.38 bc
White polythene+GA ₃	45.43 a	7.70 b	3.12 cd	0.41 abc
Sawdust+no GA ₃	31.14 c	8.00 b	3.26 b	0.35 c
Sawdust+GA ₃	50.56 a	8.90 a	3.35 a	0.37 bc
LSD _{0.05}	6.133	0.931	0.064	0.079
CV%	9.30	7.08	1.15	11.23

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

pH

In Table 31, it is apparent that the differences among various mulching treatments were found to be insignificant in respect of pH. Sawdust mulching treated with GA₃ plants had a greater pH (3.35) closely followed by control plants treated with GA₃ (3.33) while black polyethylene had a lower pH (3.08).

Titrateable Acidity (%)

From the data presented in Table 31, it is apparent that the differences among various mulching treatments were found to be insignificant in respect of titrateable acidity (%). Black polyethylene treated with GA₃ plants had a higher TA (0.48%) while sawdust mulching plants with no GA₃ had a lower TA (0.35%).

Anthocyanin (mg/100g FW)

From the data presented in Table 32, it is found that the differences among various mulching treatments were shown to be insignificant in the case of anthocyanin. Anthocyanin content (30.37 mg/100g FW) was found to be the maximum in white polyethylene mulch treated with GA₃ plants, whereas anthocyanin content (23.84 mg/100g FW) was observed to be the minimum in black polyethylene treated with no GA₃ plants.

Total Sugar (%)

When compared to non GA₃-treated plants, the total sugar content of all GA₃-treated plants was found to be the highest. The maximum content of total sugar (6.84%) was found in sawdust mulching plants treated with GA₃, which was followed by black polyethylene plants (6.78%), whereas the minimum content of total sugar (5.5%) was found in black polyethylene plants treated with no GA₃ plants (Table 32).

Phenol (mg GAE/100 g)

From the data represented in Table 32, it was found that all GA₃-treated plants showed maximum phenol content compared to the non-treated GA₃ plants. The maximum phenol content (641.67) was observed in sawdust mulch plants sprayed with GA₃ and the minimum phenol content (487.13) was found in white polyethylene plants treated with no GA₃.

Table 32: Average content of anthocyanin (mg/100g FW), total sugar (%) and total phenol (mg/100g FW) of strawberry grown with different mulching GA₃.

Treatments	Anthocyanin Content (mg/100g)	Total Sugar (%)	Phenolic Compound (mg/100g)
No mulch+ no GA ₃	24.55 c	5.63 d	496.38 e
No mulch+GA ₃	26.32 b	6.28 b	545.96 cd
Black polythene + no GA ₃	23.84 c	5.51 d	570.36 bc
Black polythene+GA ₃	26.45 b	6.28 b	594.99 b
White polythene+ no GA ₃	29.74 a	5.82 c	487.14 e
White polythene+GA ₃	30.37 a	6.78 a	517.08 de
Sawdust+no GA ₃	30.06 a	6.41 b	504.55 e
Sawdust+GA ₃	30.23 a	6.84 a	641.77 a
LSD _{0.05}	3.85	2.63	1.42
CV%	6.696	1.273	0.154

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p <0.05).

Discussion

It is common for gibberellins to be applied to young leaves because these hormones are naturally synthesized in young leaves and are then carried throughout the plant in both an acropetal and basipetal direction (Dayan *et al.*, 2012). GA₃ treatments improved a variety of morphological and physiological characteristics. Temperature extremes have a negative impact on newly growing plant roots, reducing nutrient and water uptake. Mulches improve soil microclimates, resulting in increased plant growth and yield over control (Rachel, 2018). As a result, maintaining and regulating soil temperature in a sensible manner is essential for optimal plant growth and development.

Plant growth characteristics were improved due to a favorable environment and better moisture conservation (Qureshi *et al.*, 2012). Sawdust mulched plants treated with GA₃ had considerably increased chlorophyll content in their leaves during the flowering stage of the present experiment. Photosynthetic pigments such as chlorophyll play a major role in plant growth and photosynthetic capacity. Present findings are similar to those found in a study of marigold (*Calendula officinalis* L.) plants in which GA₃ sprayed plants had higher chlorophyll content (Sardoei and Shahdadneghad, 2014). However, control plants showed a considerable increase in chlorophyll content during the fruiting stage. The increased chlorophyll content in that stage primarily endures vegetative growth, resulting in a lower fruit yield. All GA₃ sprayed plants grew taller than non-GA₃ sprayed plants. GA₃ stimulates enzymes that accelerate plant development during the growing season. Strawberry plants grew taller in sawdust mulch. Optimal soil nutrition, appropriate temperature, and strawberry plant cell elongation may be responsible for the higher plant height. There was a significant increase in leaf area on GA₃-treated sawdust mulching plants compared to other treatments. For strawberry plants, sawdust mulched plots had higher leaf area compared to those that had been mulched with paddy straw or clear polyethylene mulch. Due to increased soil attributes such as cation exchange capacity and soil microbial activity, the leaf expanded and gained more surface area after the usage of sawdust (Angrej and Gaur, 2013).

All GA₃-treated plants that were mulched with sawdust required fewer days to blossom and set fruit than the control plants, and produced more flowers and fruits. GA₃ has a significant

impact on strawberry flower and fruit (Sharma and Singh, 2009). In the present study, mulching with sawdust may have enhanced canopy temperature and provided proper soil moisture and temperature, resulting in early flowering, fruiting, and maximum blooms for the plants. Gibberellic acid stimulated and induced early flowering and fruit setting by activating the florigen hormone, which expanded buds and thus increased flower number (Khalid, 2016). In this experiment, Individual fruit weight was determined to be highest in sawdust with no GA₃ and lowest in black polyethylene with GA₃ plants. An increase in the number of flowers and fruits per plant in a short amount of time could have resulted in increased competition for food material, resulting in smaller fruits. An increase in nutrient availability as well as a decrease in weed development is attributed with improved yields (Soliman et al., 2015). Sawdust mulch plants treated with GA₃ had the highest yield per plant, while black polyethylene plants without GA₃ had the lowest. The soil temperature was not ideal for strawberry fruiting and production due to the presence of black polyethylene. It has been observed that synthetic mulches (plastics, textiles, and asphalt) do not effectively regulate soil temperature, and can even raise it.

Sawdust and white poly mulch plants treated with GA₃ showed no significant differences in total sugar or anthocyanin. The acid and sugar content of the fruit is related to its ripeness (Pérez et al., 1997), and higher sugar content is required for good strawberry flavor (Kader, 1990). GA₃ treatments on strawberry plants grown in sawdust and white poly mulch may be profitable in terms of quality because they increase total sugar. Application of gibberellic acid to strawberry plants increased anthocyanin concentration (Roussos *et al.*, 2009). Anthocyanin levels found in the present study may have been higher because of increased photosynthesis under the impact of plant growth regulator, which could have led to higher carbohydrate accumulation. When strawberries were cultivated in sawdust mulch, their phenolic content was much higher than when they were grown in other mulches employed in this study. An increased phenolic content in strawberries could be due to the mulch material and root zone temperature (not mentioned). An antioxidant activity is enhanced by phenolic substances and is affected by various environmental factors including mulching systems (Jin *et al.*, 2011).

Sawdust mulch has the ability to increase nutrient levels in both foliage and soil (Arthur and Wang, 1999). Photosynthetic and carbohydrate accumulation is accelerated when soil moisture and temperature conditions are favorable. Total soluble solids, pH, vitamin C, and total sugar content appear to rise with increased nutrition intake and their metabolic engagement in important biochemical processes. The application of gibberellic acid in cherry fruits increases the pH level. Kumar *et al.* (2013) found that mulching strawberries with sawdust had the highest pH value. In the human diet, strawberries constitute the most important source of ascorbic acid (Food and Nutrition Board, 1989). During food processing and storage, all nutrients are prone to oxidation loss, but vitamin C is particularly vulnerable. The use of GA₃ aided in the increase of quality parameters such as ascorbic acid and acidity in strawberries (Ouzounidou *et al.*, 2010). Capsicum (Ouzounidou *et al.*, 2010) and sweet cherry (Kappel and Macdonald, 2007) sprayed with GA₃ at the pre-flowering stage resulted in high ascorbic acid content, total soluble solids, and firmness, according to the study. The absence of weeds, better moisture conservation, and efficient nutrient uptake in sawdust mulch may all contribute to enhanced fruit quality. The thick layer of sawdust obstructs water and gas exchange, resulting in an improvement in fruit yield and quality. Control and other mulching treated plants without GA₃ had a much lower quality produce than GA₃ treated plants in terms of quality parameters. Similarly, Kumar *et al.* (2012) observed that GA₃ significantly enhanced TSS and ascorbic acid levels.

11.11. : Effect of Pre-harvest Cypermethrin Spray on Residual Level and Biochemical Attributes of Strawberry Fruit

The chromatogram of the selected insecticides found from the injected extract of strawberry samples at different days after spray are shown in Figure 77 shows the chromatogram of cypermethrin residue observed in strawberry collected immediately after spraying (0 days after spraying, hereafter called DAS). Other several chromatograms were also observed but they are not related to cypermethrin. The GC chart exhibits the main peak of cypermethrin residue at R.T 15.857 min (Figure 77A). The height of cypermethrin residue peak found in strawberry declined with days after spraying. Figure 77B shows the chromatogram peak of cypermethrin at 1 DAS. Peak was observed at the same retention time, 15.887 but height is lower than 0 DAS chromatogram peak. Similarly, lower height of cypermethrin chromatogram peak was observed at 3 DAS at same retention time (Figure 77C). Figure 15D shows the chromatogram peak of cypermethrin residue observed in strawberry samples collected at 5 DAS. The height of this peak was lower than that of 3 and 1 DAS samples. Similarly, reduced peak height was observed when samples were collected at 7 and 10 DAS (Figure 77E & 15F). However, chromatogram peak of cypermethrin residue was not observed in strawberry sample when collected at 12 DAS (Figure 78). This result indicates that measurable amount of cypermethrin residues does not exist in strawberry after 10 DAS.

Residue of cypermethrin in strawberry

Residues of cypermethrin in fruits of strawberry during a period of 12 days are shown in figure 90. Results revealed that the initial deposits of cypermethrin on fruits of strawberry were 0.874 mg/kg. A moderate degradation of the tested insecticide residues was noticed, one day after application with values of 0.552 mg/kg. The time elapsed after application resulted in more degradation of residues. The initial deposits were gradually decreased during the experimental period. It could be noticed that 0.043 mg/kg of cypermeyhrin was detected on strawberry fruits 10 days after application. This indicated that only 10 days were long enough to reduce the residues below the maximum residue limits (0.1 mg/kg) on strawberry according to EU Pesticides database - European Commission. Therefore, strawberry fruits could be marketed with apparent safely for human consumption. The PHI of cypermethrin was determined at 10 DAS for strawberry. Farmers in Bangladesh have no idea about pesticide residue levels in food, as well as MRL levels and effect of pesticides. People may consume pesticide-contaminated vegetables and fruits, which might result in serious health concerns (Chowdhury *et al.*, 2012). Hossen (2008) found that cypermethrin remains in tomato samples up to 5 days after harvest, which is similar to the current study's findings.

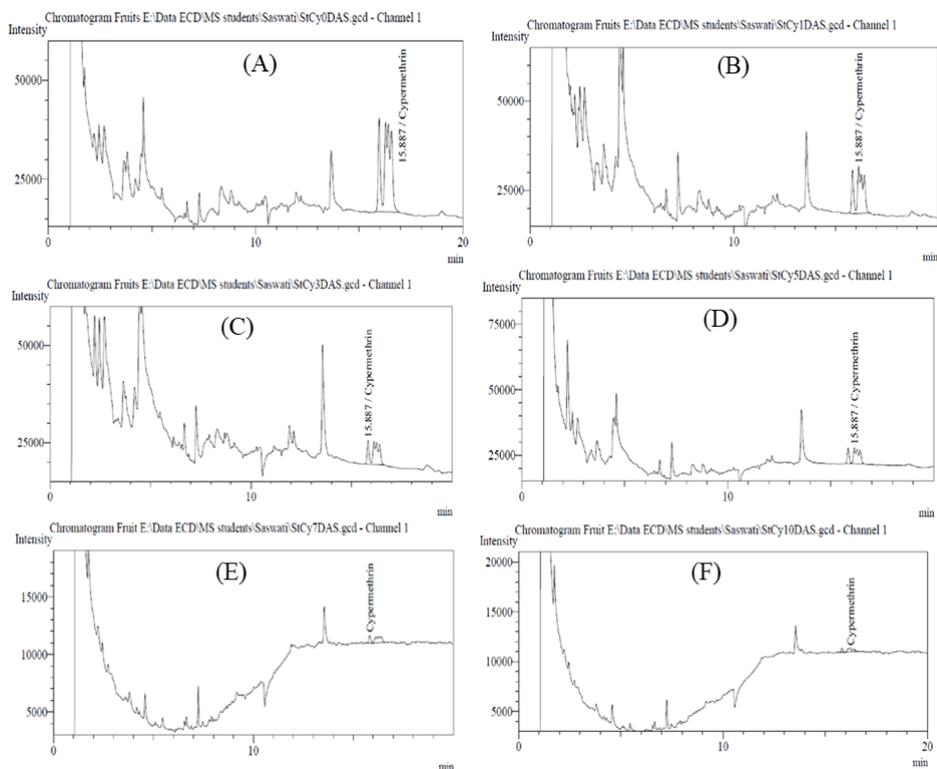


Figure 77: Chromatogram of cypermethrin obtained from strawberry extract at 0 (A), 1(B), 3(C), 5 (D), 7 (E) and 10 (F) DAS

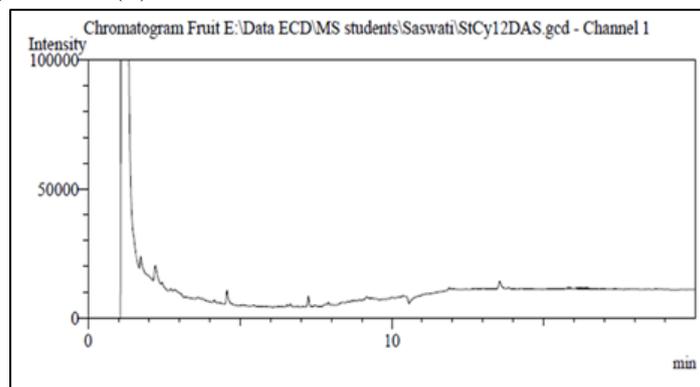


Figure 78: Chromatogram of cypermethrin obtained from strawberry extract at 12 DAS

Trend of residue degradation

The trend of degradation of detected residue of cypermethrin in the sample over time is shown in Figure 79. From the figure it is observed that the cypermethrin residue was degraded gradually, however, the level of detected residues and the degradation rate were not same at different DAS. The level of detected residues at 0 DAS was 0.874 mg/kg. The residues were detected up to 10 DAS. According to the World Health Organization, developing countries account for 20% of global pesticide use (PAN G, 2012). Agriculture is the most pesticide-consuming sector in many South Asian countries, and in the case of India, Pakistan, and Bangladesh, this is due to the fact that around 14% of world agricultural area is used for agricultural activities (Atapattu and Kodituwakku, 2009). To ensure consumer safety, many developing countries have established Maximum Residue Limits (MRLs) based on Acceptable Daily Intake (ADI) and Potential Daily Intake (PDI) that should not be exceeded for a food item to be consumed safely (Rahman 2007). Cypermethrin residues in yard-long bean were found to be above the MRLs up to 5 DAS (Prodhan *et al.*, 2009). It is

assumed that the use of toxic pesticides on vegetables and fruits has increased the risk of consumer in toxication as well as disease transmission (Fatema, 2013). Pesticide residues contaminate approximately 50-70% of fresh fruits and vegetables (Karanth, 2002).

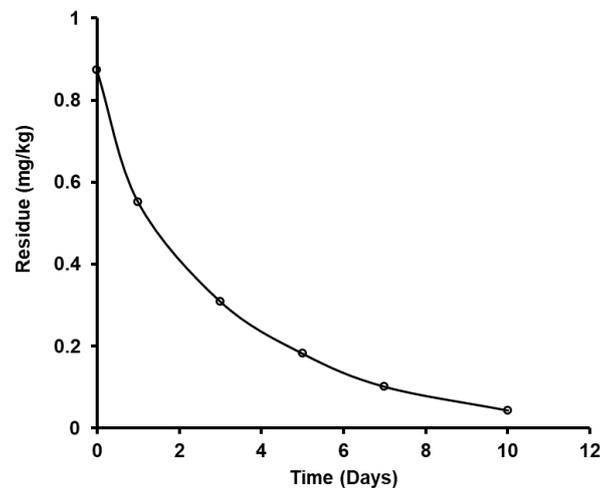


Figure 79: The trend of degradation of detected residue of cypermethrin in strawberry over time.

Biochemical parameters

Total soluble solids (TSS)

TSS content in fruits of strawberry during a period of 12 days was shown in figure 80A. Results revealed that the initial TSS on fruits of strawberry was 5.7 °Brix. A moderate degradation of the TSS was noticed one day after application with values of 5.4 °Brix. The lower TSS content was found in fruits 0-7 DAS of cypermethrin and the TSS value started to increase at 10 DAS (Figure 80A). The decreased TSS and ascorbic acid content of fruit decreased the quality in fruits (Lata *et al.*, 2018).

Titrateable acidity (%)

The trend of increased of titrateable acidity in the sample over time is shown in Figure 80B. From the figure it is observed that titrateable acidity was increased gradually reached the peak on 7 DAS of cypermethrin and the value started to decline after 7 DAS. A moderate increased of the titrateable acidity was noticed one day after application with values of 0.32%. However, the increasing levels were not same at different DAS. The increasing level of titrateable acidity was higher at 7 DAS (0.63%). Relatively high acid content is required for good strawberry flavor (Kader, 1990).

Ascorbic acid content

Ascorbic acid content in fruits of strawberry during a period of 12 days was shown in figure 80C. Results revealed that the initial ascorbic acid content in fruits of strawberry was 44.16 mg/100g. A moderate degradation of the ascorbic acid was noticed, one day after application with values of 42mg/100g. The time elapsed after application resulted in more degradation of ascorbic acid content. The initial amount was gradually decreased up to 7 DAS. Pesticide residues significantly decreased the levels of ascorbic acid in pepper fruits (Shalaby, 2017).

Phenolic content

From the data represented in figure 80D, it was found that phenolic content in fruits were increased gradually 1-7 DAS of cypermethrin. The increasing levels were not same at different DAS. A moderate increased of phenolic content was noticed one day after

application with values of 510 mg/100g. The increasing level of phenolic content was higher at 7 DAS (1034 mg/100g). Phenols are secondary metabolites found in plants and within the framework of plant physiology serving to defend stresses, e.g., pathogen attacks (Slatnar *et al.*, 2016). The increased content of phenols in pesticide treated fruits indicates more infection of fruits (Borum, 2017).

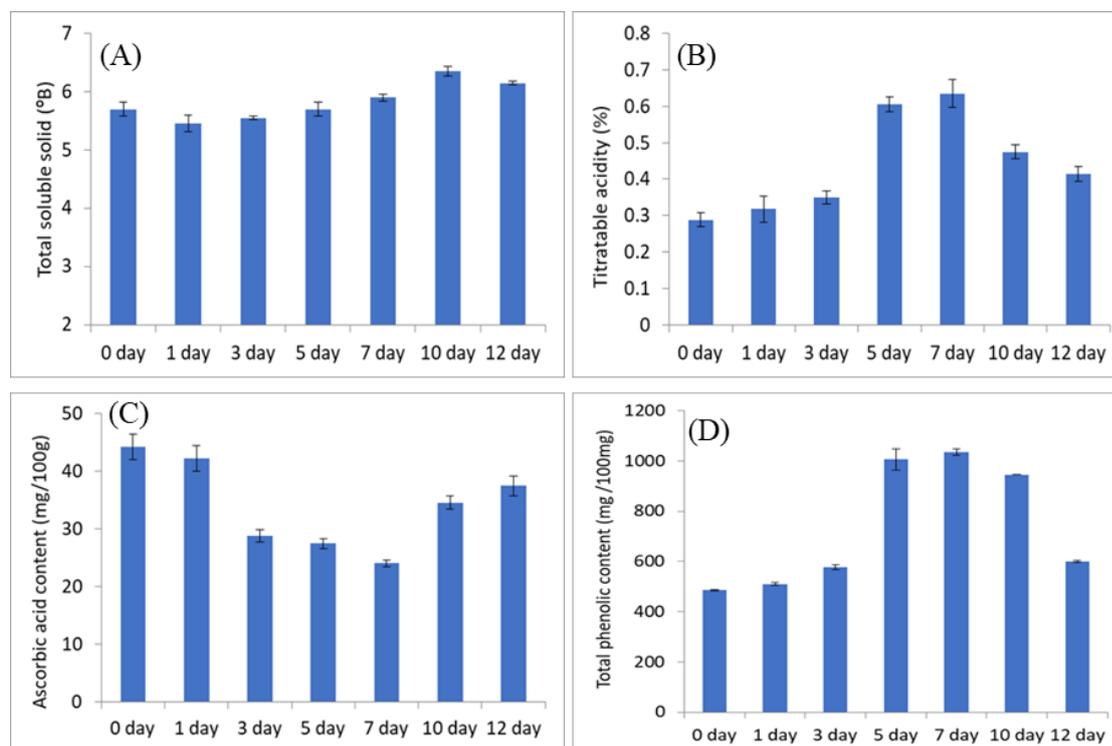


Figure 80: Average content of total soluble solids (A), titratable acidity (B), ascorbic acid (C) and phenolic content (D) of strawberry at different days after pesticide spraying. Standard error bar are shown on each column.

11.12. Effect of Maleic Hydrazide and Potassium Foliar Spray on Sex Expression, Yield and Quality Enhancement of Muskmelon

Vine length

The results revealed that the application of maleic hydrazide significantly effective in reducing the vine length (Table 33). In plants sprayed with maleic hydrazide, the lowest vine length (167.66 cm) was reported, preceded by maleic hydrazide with potassium treated plants (177.56). The highest vine length (221.66 cm) was, however, recorded in control plants followed by plants treated with potassium (210.33). The decrease in the length of the primary branches may have been due to a suppression of the plant's apical growth. Maleic hydrazide acts as a growth retardant and inhibits the biosynthesis of gibberellins that elongates the shoot length (Malik *et al.*, 2017).

Number of branch per plant

The results revealed that the application of maleic hydrazide significantly effective in increasing the number of branch per plant. In plants sprayed with maleic hydrazide, the maximum number of branches (13) was recorded followed by maleic hydrazide with potassium treated plants (12). The minimum number of branches (7.67) was recorded in untreated plants (control) (Table 33). Maleic hydrazide triggers an increase in the number of branches due to the fact that the growth retardant reduces the basipetal flow of auxins and

induces lateral vegetative buds to increase the production of more branches (Goren *et al.*, 2004). The result indicated that Maleic hydrazide is a growth retardant, therefore it causes decrement of the plant height, and ultimately it increases number of branches in muskmelon.

Table 33: Effect of maleic hydrazide and potassium on vine length, number of branch and number of leaves per plant of muskmelon.

Treatments	Vine length (cm)	No. of leaves/plant	No. of branch/plant
Control	221.00a	49.66c	7.66c
Maleic hydrazide	210.33a	52.00bc	9.33b
Potassium	167.67b	55.33ab	13.00a
Maleic hydrazide + Potassium	177.67b	56.66a	12.00a
LSD _{0.05}	2.77	3.81	1.37
CV %	10.75	3.57	6.54

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Number of leaves per plant

The statistical analysis showed that treatment combination (maleic hydrazide + potassium) gave maximum number of leaves (56.67) whereas the minimum number of leaves was found in control (49.67) (Table 33). It is evident from the findings that leaf number was significantly increased with the spraying with maleic hydrazide that might be due to slowing down of cell division and reduction in cell expansion. Maleic hydrazide suppresses the apical dominance and increases leaf number (Jadhav *et al.*, 2015).

Days to flowering

Based on the statistical analysis, days required for first male and female flower for control were significantly different from maleic hydrazide, potassium and (maleic hydrazide + Potassium) treatment. In this research, maleic hydrazide was sprayed from the third leaf stage, required approximately 11 days to first male flower open where it was approximately 14 days for control (Table 34). Plants sprayed with maleic hydrazide required 14 days to first female flower where it was approximately 18 days for control (Table 34). Maleic hydrazide significantly shortened the number of days to first female flower compared with control. It might be due to maleic hydrazide has inhibitory role on certain growth promoters such as auxin and gibberellins as a result plant experienced a sort of stress and hence caused early flowering (Navale *et al.*, 2010).



Plate 12: Growth, flowering and Fruit development of the muskmelon plant

Number of male and female flowers

The maximum number of male flower (37) was recorded in control and the minimum number of male flower (28) was recorded in Maleic hydrazide treatment (Table 34). Maleic hydrazide

either alone or combination with potassium showed a significant effect on female flowering compared to other treatments. The maximum number of female flower (15) was recorded in maleic hydrazide treatment, where minimum number of female flower was recorded in control (10) (Table 34). It indicates that maleic hydrazide reduces catabolic activities going inside the plants which reduces transpiration and other activities and thereby increased the number of female flowers and reducing the number of male flowers. As far as the internal balance of hormones is concerned, there is more production of auxin in the male flower which contributes to anther development, and in the case of female flower, there is more production of ethylene, which induces further degeneration (Yamasaki *et al.*, 2003).

Number of fruits per plant

The results revealed that the application of maleic hydrazide significantly effective in increasing the number of fruit per plant. The maximum number of fruits (7) was recorded in plants sprayed with maleic hydrazide with potassium followed by plants treated with maleic hydrazide (6.33). The minimum number of fruits (3) was recorded in untreated plants (control) (Table 34). Application of maleic hydrazide, either alone or in combination with potassium, influenced fruit yield. The use of growth retardant such as maleic hydrazide increased the level of endogenous ethylene that triggered metabolic processes and affected the C: N ratio in plants, stimulating flowering, fruit setting, sex ratio and thus yield. The increased fruit yield was obtained as a result of more female flower and better vegetative growth (Dostogir *et al.*, 2006). Hence, muskmelon yield was highly influenced by the use of plant growth regulators.

Table 34: Effect of maleic hydrazide and potassium on days to male flower, days to female flower, no. of male flower, no. of female flower, number of fruit/plant and average fruit weight and Fruit yield/plant of muskmelon.

Treatments	Days to 1 st male flower	Days to 1 st female flower	No. of male flower/plant	No. of female flower/plant	No. of fruits/plant	Average Fruit weight (kg)	Fruit yield/plant (kg)
Control	13.66a	17.66a	37.00a	10.66b	3.00b	0.89b	2.61 d
Maleic Hydrazide	13.66a	16.66ab	28.66b	11.33b	4.33b	1.30a	5.64c
Potassium	12.66a	16.00ab	35.33a	15.00a	6.33a	1.18a	7.50b
Maleic hydrazide+ Potassium	10.00b	14.33b	34.66a	14.33a	7.00a	1.29a	9.03a
LSD _{0.05}	2.07	3.19	4.06	0.94	1.85	0.14	0.83
CV %	8.33	9.89	6.00	3.67	17.96	6.27	6.72

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Average fruit weight

Single fruit weight contributes towards overall yield in muskmelon. Foliar application of potassium and (maleic hydrazide + potassium) significantly increased single fruit weight (1.3 kg) as compared to control (0.89), while there was no significant difference between treatments with potassium and (maleic hydrazide + potassium) (Table 34). This rise could be interpreted as requiring a high amount of K and other nutrients to conduct the biological operations as an improvement in photosynthesis due to couples with chlorophyll synthesis

during the flowering and fruit setting stages. An adequate quantity of K plays a major role in crop growth and development by activating abundant enzymes during photosynthesis that regulate cell osmo-regulation and the stomatal movement (Coskun *et al.*, 2014).

Fruit yield/plant (kg)

The maximum fruit yield (9 kg/plant) was recorded in plants which were sprayed with (maleic hydrazide + potassium) followed by plants treated with maleic hydrazide (7.5 kg/plant). The minimum amount of soluble solids (2.6 kg/plant) was recorded in untreated musk melon fruits (control) (Table 34).

Total soluble solid (°Brix)

The result revealed that the application of potassium significantly increased total soluble solid in fruits compared to control (Table 35). The maximum amount of soluble solids (7.5°Brix) was recorded in fruits which were sprayed with (maleic hydrazide + potassium) followed by plants treated with potassium (7 °Brix). The minimum amount of soluble solids (6 °Brix) was recorded in untreated musk melon fruits (control). The increase in total soluble solids may be caused due to better formation and translocation of carbohydrates, starch hydrolysis and early maturation of fruits (Meena *et al.*, 2017).

pH

The lower pH (5.6) was found in fruit treated with potassium and the higher pH (5.8) in untreated fruit (control) followed by plants treated with maleic hydrazide (5.7) (Table 35). However, no significant differences were observed in the pH values of muskmelon fruits grown with the application of maleic hydrazide, (maleic hydrazide + potassium) and untreated fruits. Determining fruit acidity at complete maturation, when acidity decreases, is possibly the explanation for the low values. High fruit quality is associated with low pH (Davies and Hobson, 1981).

Titrateable acidity

The fruits produced without foliar spray to be less acidic than the fruits produced with foliar application of potassium and maleic hydrazide. The higher titrateable acidity was found in plants treated with maleic hydrazide and (maleic hydrazide + potassium); approximately 0.22% in both plants, and the lowest titrateable acidity was found in untreated fruits (0.13%) followed by plants treated with potassium (0.15%) (Table 35). Loss of organic acids from ripe fruit tends to be largely due to respiration (Halinska and Frenkel, 1991). During maturation in muskmelon, as in other fruits, the decrease in acidic content is followed by an increase in sugar content (Akbudak, 2010).

Ascorbic acid

The highest amount of ascorbic acid was found in potassium treated fruits (20.16 mg/100 g) followed by the lowest ascorbic acid in fruits sprayed with maleic hydrazide (13.08 mg/ 100 g) (Table 35). Foliar K applications during fruit production and ripening enhance marketable fruit quality by increasing the levels of ascorbic acid and K. An improvement of fruit quality due to appropriate K nutrition might be due to improved photosynthates assimilation, their translocation from leaves to fruit and increased enzyme activation (Kanai *et al.*, 2007).

Beta-carotene

β-carotene content is an important commercial attribute of melon. In our results, beta-carotene content was highest (3.54 mg/100g) in the plants spray with maleic hydrazide followed by (maleic hydrazide + potassium) (3.14 mg/100g) and, whereas beta-carotene

content was lowest in untreated muskmelon fruit (2.46 mg/100g) (Table 35). Beta-carotene, derived from chloroplasts (Gross 1991), plays an important role as antioxidants in humans when consumed in diets. Highly-colored muskmelon fruits are desirable for their better appearance and higher nutritive value (Lester, 2006).

Table 35: Effect of maleic hydrazide and potassium on total soluble solid, pH, Titratable acidity, ascorbic acid, β -carotene and reducing sugar of muskmelon

Treatments	TSS (°Brix)	pH	Ascorbic acid (mg/100g)	TA (%)	Reducing sugar (mg/g)	β -carotene (mg/100g)
Control	6.50b	5.75a	19.20a	0.12b	5.69c	2.46c
Maleic Hydrazide	7.00ab	5.63a	20.16a	0.15b	9.36a	2.70c
Potassium	6.50b	5.70a	13.08b	0.22a	4.99d	3.13b
Maleic hydrazide+ Potassium	7.50a	5.66a	18.24a	0.22a	7.37b	3.54a
LSD _{0.05}	0.86	2.21	2.55	0.06	0.47	0.25
CV %	6.30	2.31	7.23	10.65	3.49	4.32

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Reducing sugar

The highest sugar content was found in potassium sprayed plants (9.36 mg g⁻¹FW), followed by (maleic hydrazide + potassium) (7.37 mg g⁻¹FW), while the lowest sugar content was found in maleic hydrazide spray plants (4.99 mg g⁻¹FW) (Table 35). It is well established that potassium plays a key role in the metabolism and photosynthesis of carbohydrate and (Marschner, 1995) and as a consequence an optimal supply of potassium conclude a better amount of sugar in sink organs. Potassium is the most abundant cation present in the phloem sap (almost 80% of the total cations) as a result of sugar charging and transport mechanisms through sink organs via the phloem (Cakmak, 2005).

11.13. : Effect of Plant Growth Regulators and Pruning Levels on Sex expression, Yield and Quality in Watermelon

Number of branch plant⁻¹

Pruning of the branches showed the highest number of branches in water melon and was significantly different from non-pruning. The highest number of branches plant⁻¹ (8.33) was observed under pruning activity of water meon whereas the lower number of branches plant⁻¹ (7.166) was found under non-pruning condition (Figure 81A). Dhillon *et al.* (2017) argued that since watermelon has naturally many branches, pruning is advised to keep adequate number of branches, leaves and fruits to enable them to share efficiently the plant resources. In agreement with findings of the current study, Alia *et al.* (2016) also reported a significant effect on yield of cucumber and bitter gourd through pruning by removal of lateral shoots. The number of branches plant⁻¹ significantly varies under the application of different plant growth regulators in water melon. Maleic hydrazide showed highest number of branches plant⁻¹ (8.16) whereas, the lowest number of branches plant⁻¹ (7.33) was recorded under control condition. Alia and Mehrajc (2016) observed that MH stimulates the process of cell division and expansion in epidermal and parenchyma cells has been well documented. Such

activities in the meristematic tissue of leaf primordial in MH treated plants might be higher and perhaps a greater number of branch with broader leaf lamina and petiole of longer length.

SPAD Value

Significant difference was found for SPAD value (chlorophyll content) as influenced by both pruning and non-pruning activity of the branches of water melon. The SPAD value (47.28) was recorded maximum at pruning activity of the branches of water melon whereas, the SPAD value (45.21) was found minimum under non-pruning activity of the branches of water melon (Figure 81B). These results may be attributed to the effect of pruning on vegetative characteristics of plants and shows that vegetative growth has direct relation with leaf area, dry matter and stem diameter; however, pruning limits vegetative growth and allows more light penetration and increases photosynthesis efficiency and so improve vegetative growth and chlorophyll content of plants. (Hesami *et al*, 2012). Plant growth regulators also showed significant variation for SPAD value content in the leaves of water melon. The highest SPAD value (47.41) was observed from the maleic hydrazide treatment followed by GA₃ treatment (46.75) while, the minimum SPAD value (44.75) was found in the control condition. MH boosts the process of photosynthesis which needs more light absorption thus higher chlorophyll content. MH acts to accumulate nutrition elements from plant parts to positions which MH accumulated. Some of these nutrition elements became parts of new chlorophyll molecule (Abbas, 2011).

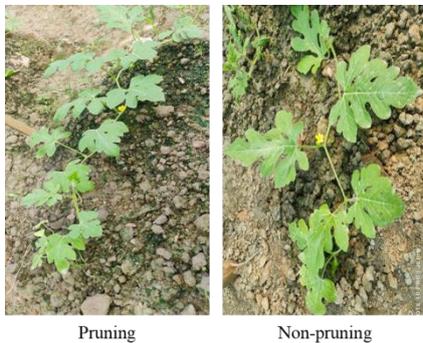


Plate 13: Showing watermelon plants with and without pruning



Plate 14: Showing watermelon plants using different plant growth regulators

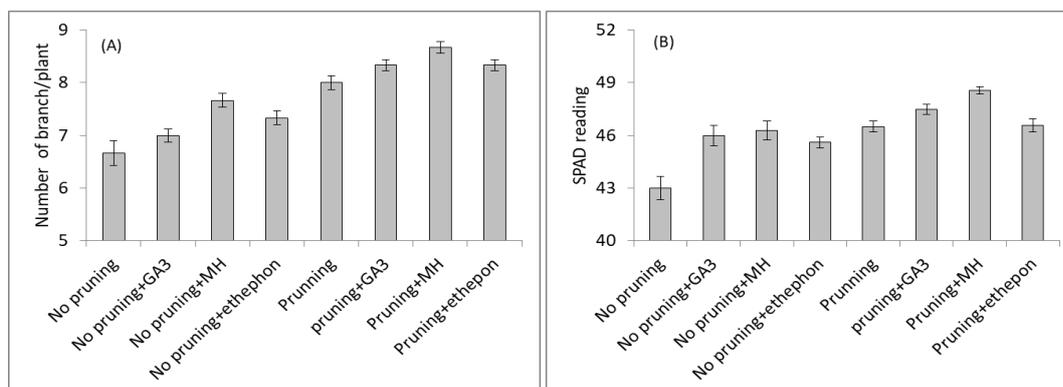


Figure 81: Effect of different growth regulators and pruning on number of branch (A) per plant and SPAD reading of watermelon. Standard error bars are shown on each column.

Days to flowering

There was a significant difference between pruned and non-pruned plants in days to flowering. All plants sprayed with growth regulators required a minimum number of days to flower compared to the non-growth regulators sprayed plants. Based on the statistical analysis, days required for first male and female flower for both pruning and non-pruning treatment were significantly different from growth regulators treatment. The minimum (37) days were required to first male flower in non-pruned plants treated with GA₃. The plants that needed the most time (51 days) to male flower were those that had no pruning and plant growth regulators (Table 36).

In this research, GA₃ was sprayed from the third leaf stage, required approximately 46 days to first female flower open where it was approximately 59 days for control (no pruning + no growth regulators) (Table 36). Apical bud and leaf removal in okra have demonstrated to enhance okra vegetative growth and its development. Gibberellic acid stimulated and induced early flowering and fruit setting by activating the florigin hormone, which expands buds and thus increases flower count (Khalid, 2016).

Number of flowers/plant

The maximum number of male flower (25) was recorded in non-pruned plants treated with GA₃ and the minimum number of male flower (19) was recorded (Table 36). GA₃ either alone or combination with pruning were showed a significant effect on female flowering compared to other treatments. The maximum number of female flower (10) was recorded in GA₃ treatment with pruning, where minimum number of pistillate flower (5) was recorded in control (Table 36). It indicates that growth regulators reduces catabolic activities going inside the plants which reduces transpiration and other activities and thereby increased the number of female flowers and reducing the number of male flowers. As far as the internal balance of hormones is concerned, there is more production of auxin in the male flower which contributes to anther development, and in the case of female flower, there is more production of ethylene, which induces further degeneration (Yamasaki *et al.*, 2003).

Number of fruits plant⁻¹

It was observed from the results of the present experiment that total number fruits plant⁻¹ significantly differed by pruning and non-pruning activity of the branches of water melon. The total number of fruits plant⁻¹ (2.83) was found maximum under pruning activity where, the total number of fruits (2.33) was minimum under non-pruning activity of the branches of water melon (Table 36). Singh *et al.* (2004), who reported that trees, which have begun to decline in vigor, yield and size of fruit need pruning to help the restore their condition. In

current investigation it can be concluded the pruning of old and undesirable branches stimulated the growth of new shoots to obtain new fruiting wood. So the numbers of fruits were more in pruned trees as compared to un-pruned. Plant growth regulators exposed significant variation regarding the total number of fruits of water melon. The maximum number of total fruits plant⁻¹ (3.41) was recorded from the application of GA₃ followed by maleic hydrazide application (3.00) and the total number of fruits plant⁻¹ (1.66) was minimum under control condition. Ramteke *et al.* (2015) found maximum number of fruits in treatment with GA₃. Higher number of fruits under GA₃ treatment might be due to the fact that gibberellic acid causes the production of large number of flowers with rapid elongation of peduncle, acceleration the development of differentiated inflorescences and leading to full development of flower buds having all reproductive parts functional and accumulate higher starch, carbohydrates and photosynthates which increases the fruit set and number of fruits per plant.

Individual fruit weight (kg)

It is evident from the data presented in the Table that individual fruit weight has been found significantly different from non-pruned plants. Individual fruit weight (2.50) was maximum under pruning and individual fruit weight (2.32) was minimum from non-pruning function of the branches of water melon (Table 36). Maximum weight of fruit was found in pruned plants by Ayala *et al.* (2019). Individual fruit weight statistically differs under the application of plant growth regulators in water melon. Individual fruit weight (2.75 kg) was found maximum from GA₃ treatment whereas, individual fruit weight (2.02 kg) was observed minimum from the control treatment. Asadi *et al.* (2013) stated that gibberellic acid significantly increases the total and marketable yield but decreases the individual fruit weight of strawberry compared control fruits. The probable reason for the decrease in individual fruit weight is due to the production of more number of secondary and tertiary fruits by applying GA₃.

Fruit yield plant⁻¹:

Pruning and plant growth regulators showed significant variation regarding fruit yield plant⁻¹ in water melon. Pruning activity of the branches of water melon gave highest fruit yield plant⁻¹ (7.25 kg) and non-pruning activity of the branches of water melon gave lowest fruit yield plant⁻¹(5.52 kg) (Table 36). Douglas *et al.* (2001) observed that the removal of the lateral shoot had a positive effect on the total yield of Cucumber. They noted that pruning the lateral runner near the base of the plant will result in higher yield. Similar observation was made by Palada *et al.* (2003) who reported that the removal of lateral shoot had a positive effect on total yield of bitter gourd. In case of plant growth regulators, the highest fruit yield plant⁻¹ (9.41 kg) was observed under GA₃ treatment and the lowest fruit yield plant⁻¹ (3.35 kg) was found under control condition.

Table 36: Effect of different growth regulators and pruning on flowering, fruit yield and yield attributes of watermelon.

Treatments	Days to male flower	Days to female flower	Number of male flowers	Number of female flowers	Total number of flowers	Individual fruit weight (g)	Yield (g/plant)
Pruning							
Pruning	47.08a	57.25a	22.83a	8.41a	2.83a	2.50a	7.25a
Non pruning	43.83b	51.50b	22.66a	7.08b	2.33b	2.32b	5.52b

Treatments	Days to male flower	Days to female flower	Number of male flowers	Number of female flowers	Total number of flowers	Individual fruit weight (g)	Yield (g/plant)
CV%	5.18	5.28	4.25	8.74	17.16	6.23	15.84
LSD _{0.05}	2.06	2.51	0.84	0.59	0.38	0.13	0.88
Plant growth regulators							
Control	50.16a	58.16a	21.00c	6.50 b	1.66c	2.02c	3.35d
GA ₃	40.83c	50.16b	24.83a	9.00a	3.41a	2.75a	9.41a
MH	44.50b	52.16b	22.50b	8.33a	3.00a	2.35b	7.10b
Ethephon	46.33b	57.00a	22.66b	7.16b	2.25b	2.52b	5.68c
CV%	5.18	5.28	4.25	8.74	17.16	6.23	15.84
LSD _{0.05}	2.91	3.55	1.19	0.83	0.54	0.18	1.25
Interaction							
Non pruning	51.00c	58.00a	19.33e	5.33d	1.50f	1.95e	2.86f
Non pruning+GA ₃	37.66e	46.00b	25.33a	8.33b	3.16abc	2.63ab	8.31b
Non pruning+MH	41.00de	47.00b	22.33cd	8.00b	2.66bcd	2.28cd	6.10d
Non pruning+Ethephon	45.66bc	55.00a	23.66abc	6.66c	2.00def	2.42bc	4.83de
Pruning	49.33ab	58.33a	22.66bcd	7.66bc	1.83ef	2.10de	3.85ef
Pruning+GA ₃	44.00cd	54.33a	24.33ab	9.66a	3.66a	2.86a	10.51a
Pruning+MH	48.00abc	57.33a	22.66bcd	8.66ab	3.33ab	2.43bc	8.10bc
Pruning+Ethephon	47.00abc	59.00a	21.66d	7.66bc	2.50cde	2.63ab	6.53cd
LSD _{0.05}	4.12	4.02	1.69	1.18	0.77	0.26	1.77
CV%	5.18	5.28	4.25	8.74	17.16	6.23	15.84

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Quality Parameters

TSS

Pruning significantly increased the TSS content of water melon. The maximum TSS content (9.03°Brix) was found in pruning treatment while the minimum was recorded from non pruning (8.08 °Brix). In melons, pruning the main stem promotes a rapid growth of lateral stems. A subsequent increase in the photosynthetic area of the plant allows for the production of larger fruits with high soluble solids content (Pereira *et al.*, 2017). Plant growth regulator had no significant variation regarding TSS of watermelon. However, maximum TSS content was found in ethephon (9.80) and minimum from GA₃ (7.78). Palei *et al.* (2016) recorded higher TSS of watermelon fruits with the application ethephon as compared to untreated plants. This might be due to the treatment effect on physiological accumulation of sugar and change in metabolism which eventually resulted in more retention of TSS and total sugars.

pH

Variations in pH of watermelon under pruned and unpruned plants were observed. The pH values under pruning and non-pruning showed significant variation (Table 37). The highest

(5.27) pH value was recorded in pruning and lowest value was recorded in non-pruning (4.27). pH value is the measure of acidity, less the value more the sourness of the fruit. This result was consistent with previous studies on mango (Asrey *et al.*, 2013), which demonstrated that the fruits produced by pruned plants presented a higher organic acid content than those from unpruned plants. Increase the pH value (5.46) was observed as fruit treated with ethephon. The lowest value was found in control (4.66). There was no significant variation regarding pH of water melon by plant growth regulators.

Titrateable acidity

The maximum titrateable acidity (0.31%) was recorded in fruits from unpruned plants and minimum was recorded in pruned (0.22%) plants (Table 37). The effect of pruning on titrateable acidity of watermelon fruit pulp had significant variation. This difference in organic acid content occurs due to changes in the source-sink relationships induced by this cultivation practice. According to Pereira *et al.* (2003), pruning the main stem breaks the apical dominance of melon, inducing it to invest in the production of new lateral stems. In pruned plants, some of the assimilates that would form organic acids in fruits were possibly redirected to the formation of lateral stems, explaining their lower content relative to fruits from unpruned plants. Plant growth regulators had no significant variation towards titrateable acidity of watermelon fruit pulp. However, Maximum titrateable acidity (0.33%) was recorded in control and minimum (0.15%) in plant sprayed with ethephon. Ethephon might enhance the conversion of organic acids to sugars since present findings revealed that sugar content was increased and acidity was decreased following ethephon application (Sabuz *et al.*, 2019).

Ascorbic acid content (mg/100g)

The maximum ascorbic acid content (11.04 mg/100g) was recorded in unpruned plants and minimum was recorded in pruned (8.25 mg/100g) plants (Table 37). The effect of pruning on ascorbic acid content of watermelon fruit pulp had significant variation. These results suggest that the fruits of pruned plants had a slower metabolism than the controls and the use of organic acids as carbon skeleton in fruit respiration (Chitarra and Chitarra, 2005). Maximum ascorbic acid (12.18 mg/100g) was recorded in control and minimum (7.04 mg/100g) in plant sprayed with ethephon. There was no significant variation on ascorbic acid content of water melon.

Reducing sugar (%)

It was observed from the results of the present experiment that reducing sugar significantly differed by pruning. Highest reducing sugar (5.42%) was recorded in pruned plants and lowest was recorded in unpruned plants (5.15%) (Table 37). It was seen that pruned plants had higher leaf to fruit ratio as compared to control which might be the reason to increase reducing sugar due to more metabolites synthesis (Bhanu *et al.*, 2009). Plant growth regulators had significant effect on reducing sugar of watermelon. The maximum was found in plants sprayed with ethephon (5.96%) and minimum (4.53%) was recorded in control. Probably ethephon enhanced the rate of accumulation of reducing sugar in watermelon in fruits. The finding is corroborated with the result of Kumar and Singh (1993) who observed that higher percentage of sugar in ethephon (750 ppm and 500 ppm) treated mango fruits over control treatment.

Non reducing sugar

It was observed from the results of the present experiment that non reducing sugar significantly differed by pruning. Highest non reducing sugar (5.61%) was recorded in pruned plants and lowest was recorded in unpruned plants (4.20%) (Table 37). This is might be due

to pruning had a stronger effect on the distribution of photoassimilates, which improved some of the internal quality parameters of the harvested fruit (Presman *et al.*, 2020). Plant growth regulators had significant effect on non-reducing sugar of watermelon. The maximum was found in plants sprayed with ethephon (6.55%) and minimum (3.67%) was recorded in control. The reason for the increase in non-reducing sugars could be attributed to the water loss and hydrolysis of starch and other polysaccharides to soluble form of sugar were more in ethephon treated fruits than control (Dhall and Singh, 2013).

Total suagr

Pruning had a significant effect on a total sugar of watermelon. The data revealed that total sugar (10.53%) was found highest in pruned treatment while lowest was found from unpruned plants (9.36%) (Table 37). In melons, pruning the main stem promotes the rapid growth of lateral stems. A subsequent increase in the photosynthetic area of the plant allows for the production of larger fruits with high soluble-solids content and subsequently increased the total sugar of fruits. This finding is confirmation with Pereira *et al.* (2017). It is, therefore, possible that in the case of watermelon, pruning had a stronger effect on the distribution of photoassimilates, which improved some of the internal quality parameters of the harvested fruit. Ethephon significantly increased the total sugar content (12.51%) of watermelon while lowest (8.01%) was recorded in plants were not sprayed with any plant growth regulators. The study of Lal and Das (2017) showed that the application of ethephon significantly increased the total sugar level in fruit juice of strawberry and grape. The significant increase in sugar contents might be due to accumulation of carbohydrates watermelon fruits as a result of increased absorption of ethephon.

Total phenol

Total phenol content was higher (11.03 mg/g) in pruned water melons and lower content (9.36 mg/Figureg) was recorded in unpruned plants. Pruning had a significant effect on total phenol content (Table 37). Phenolics are secondary plant metabolites known for their role in plant defense mechanisms against stress (Lavola *et al.*, 2000). It is important to note that higher recovery of total phenolics was recorded under pruned conditions. It is presumed that pruning imparted shock/stress to the plants and consequently elevated the synthesis of phenolics (Asrey *et al.*, 2013). Plant growth regulators had significant effect on total phenol content of watermelon. The maximum was found in plants sprayed with ethephon (12.51 mg/g) and minimum (8.79 mg/g) was recorded in GA application. Enhanced phenolic compound with the application of ethephon is due to binding of ethylene to receptor which forms an activated complex leading to a wide variety of physiological responses including antioxidant activity (Yang, 1990).

Anthocyanin content

The results revealed that anthocyanin content significantly affected by pruning and non-pruning of watermelon. Pruned treatment had maximum anthocyanin content (29.93 mg/100g) while minimum was recorded in non-pruned (25.12 mg/100g) plants (Table 37). The literature, there is evidence that main stem pruning influence melon (Long *et al.*, 2004) anthocyanin content. Plant growth regulators had no significant variation towards anthocyanin content of watermelon. However, Maximum (30.79 mg/100g) was recorded in GA₃ spayed plants and minimum (21.67 mg/100g) in control. The increase in the anthocyanin content by GA₃ may be attributed to the higher synthesis of some metabolic intermediary substances which promoted the greater synthesis of the precursor of anthocyanin content (Dhall and Singh, 2013).

Table 37: Effect of different growth regulators and pruning on quality attributes of water melon fruit

Treatments	pH	TSS (°Brix)	TA (%)	Ascorbic acid (mg/100g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Phenol (mg/g)	Anthocyanin (mg/100g)
Pruning									
No pruning	4.72b	8.08b	0.31a	11.04a	5.15b	4.20b	9.36b	9.36b	25.12b
Pruning	5.27a	9.03a	0.22b	8.25b	5.42a	5.61a	10.53a	11.03a	29.93a
CV%	0.75	1.33	5.19	7.08	2.57	3.42	1.39	1.35	1.86
LSD _{0.05}	0.032	0.098	0.012	0.5909	0.117	0.1451	0.119	0.119	0.2093
Plant growth regulators									
Control	4.66c	7.81c	0.33a	12.18a	4.53d	3.67d	8.01d	9.01c	21.67c
GA3	4.94b	7.78c	0.32a	9.76b	5.12c	4.48c	8.79c	8.79d	30.79a
MH	4.91b	8.80b	0.25b	9.60b	5.54b	4.93b	10.46	10.46b	28.85b
Ethephon	5.46a	9.80a	0.15c	7.04c	5.96a	6.55a	12.51a	12.51a	28.79b
CV%	0.75	1.33	5.19	7.08	2.57	3.42	1.39	1.35	1.86
LSD _{0.05}	0.045	0.139	0.016	0.8357	0.1662	0.2052	0.168	0.1687	0.6276
Combination									
No pruning	4.20f	6.97f	0.42a	14.08a	4.06f	2.65g	7.24h	7.24g	16.94f
No pruning+ GA3	4.82d	7.67e	0.34b	11.52b	5.66b	3.17f	8.31g	8.31f	28.38d
No pruning MH	4.55e	8.03d	0.28d	10.24c	5.25c	4.67e	9.91d	9.91d	28.26d
No pruning+ ethephon	5.30b	9.63b	0.19f	8.32d	5.66b	6.31b	11.97b	11.97b	26.89e
Pruning	5.11c	8.67c	0.23e	10.28c	4.99d	4.68e	8.79f	10.79c	26.40e
pruning+ GA3	5.05c	7.90d	0.31c	8.00d	4.59e	5.79c	9.27e	9.27e	33.21a
Pruning MH	5.27b	9.57b	0.21ef	8.96d	5.63b	5.19d	11.01c	11.02c	29.44c
Pruning+ ethephon	5.62a	9.97a	0.12g	5.76e	6.25a	6.80a	13.05a	13.05a	30.69b
LSD _{0.05}	0.064	0.196	0.023	1.818	0.2351	0.2902	0.238	0.2386	0.8875
CV%	0.75	1.33	5.19	7.08	2.57	3.42	1.39	1.35	1.86

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

11.14. : Effect of Different Sheds on Growth, Yield and Quality of Papaya

Environmental conditions

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. Different shed houses and open field conditions influenced the air temperature. Data on the temperatures for each treatment was measured at 12 pm daily during the experimental period. The average monthly temperature varies from approximately 23.09 to 36.40°C, as shown in Table 38. Temperatures above 30°C inhibit photosynthesis and flower fertilization, resulting in decreased yields. During the experimental period, the relative humidity data for each treatment was measured at 12 pm daily. From February to October, the average monthly relative humidity ranged between 61.90 and 86.13% during the day (Table 38). Relative humidity was always higher in the net house during the growing season,

while the relative humidity was approximately similar in both the poly shed and the open field conditions. Relative humidity was higher under the net house even though the temperature was low in the net house. The lowest percentage of relative humidity and higher temperatures were measured under the UV poly shed. In the present study under net house, there was a reduction in temperature in the summer months to the tune of 3-6°C compared to control.

Table 38. Monthly average air temperature (°c) and relative humidity (%) at 12 hrs in different shed house and open field during February to October 2020

Month	Shed houses							
	Open field		UV Poly shed		Net Poly shed		Net house	
	Temp (°c)	RH (%)	Temp (°c)	RH (%)	Temp. (°c)	RH (%)	Temp. (°c)	RH (%)
February	26.48	66.17	26.21	63.93	24.96	67.72	23.09	69.01
March	31.41	62.51	32.05	61.90	30.85	62.19	27.55	68.19
April	33.8	75.70	34.52	66.07	33.84	70.27	28.61	72.87
May	32.58	82.45	34.29	76.53	33.04	83.63	29.62	84.53
June	32.33	83.23	33.30	72.60	31.61	79.20	29.78	81.53
July	33.04	78.10	36.40	70.39	35.11	77.89	32.29	76.82
August	32.13	86.13	35.76	76.67	34.51	82.97	31.61	84.97
September	32.63	82.07	34.01	76.03	31.87	81.43	30.34	83.93
October	31.90	81.94	33.27	81.26	30.94	83.35	29.27	85.13

Fruit set is reduced, and early leaf drop is caused by a lack of humidity. Relative humidity was higher under the net house even though the temperature was low (Gaurav *et al.*, 2015). Red mite growth is aided by low relative humidity and high temperatures

Table 39. Plants turn in different growth stages during the growing periods

Month	Plant growth stage
February	Vegetative stage
March	Vegetative stage
April	Flowering stage
May	Flowering stage/Fruit setting
June	Fruit setting/ Fruit development
July	Fruit development
August	Fruit development/ Harvesting
September	Harvesting
October	Harvesting

Growth parameters

Plant height (cm)

The results for the papaya under three protected structures (UV poly house, net poly house and net house) studied showed that plant height was increased significantly during the growing periods. Plant height was the highest under net house, from flowering (157.2cm) to the harvesting stage (306 cm). The lowest plant height was observed in the case of control, from flowering (124cm) to harvesting (151.4cm) (Table 40). The plant height of papaya was highest in the net house. This may be due to enhanced photosynthesis and respiration due to the favourable microclimatic conditions in the net house. High temperatures reduced shoot dry mass, relative growth rate, and net assimilation rate significantly in maize, pearl millet, and sugarcane (Wahid, 2007).

Leaf number

During the flowering, fruiting, and harvesting stages, the leaf number varied in different shed houses and open field conditions (Table 40). The result showed that the number of leaves of papaya decreased in all growing conditions during the harvesting stage, whereas the number increased in the fruiting stage in all growing conditions. The highest number of leaves was observed in the net house (30) at the time of fruiting and the lowest was found in the control condition (23). There is a significant increase in the number of green leaves and average maximum number of total leaves of mango grown under net house in comparison to open field conditions (Medany *et al.*, 2009). This was due to the crop's favorable environmental conditions like adequate relative humidity, lower maximum temperature, lower light irradiance, and lower evapotranspiration that usually prevailed under net house.

Stem diameter

There was no significant difference in stem diameter between poly and UV poly shed during the fruiting and harvesting stages (Table 40). In the harvesting stage, the maximum stem diameter of papaya was observed in the poly shed (39.4cm), followed by the UV poly shed (38.2cm) during the harvesting stage, and the lowest was found in open field conditions (21.8cm). This could be attributed to increased bud growth, which increased nutrient absorption and translocation from the soil, both of which play a role in a variety of plant metabolic activities under poly and UV polymer conditions (Singh, 2001).

Table 40: Average plant height, stem diameter and number of leaves/plant aof papaya grown under different sheds and open field condition

Treatment	Flowering			Fruiting			Harvesting		
	Plant Height (cm)	Leaf No.	Plant diameter (cm)	Plant height (cm)	Leaf No.	Plant diameter (cm)	Plant height (cm)	Leaf No.	Plant diameter (cm)
Open Field	124.00 c	23.33 c	21.66c	135.00 d	23.33c	24.33b	151.33d	20.33ab	29.00d
UV Poly shed	149.00 b	29.66 a	28.33ab	227.00 b	29.66a	31.66a	266.67c	14.00c	38.00b
Poly shed	143.33 b	25.66 b	25.66b	211.67 c	25.66b	30.66a	287.33b	21.33a	39.33a
Net House	161.67 a	30.33 a	28.66a	135.00 d	30.33a	32.00a	306.6 a	19.6b	35.33c
LSD _{0.05}	4.24	2.42	2.88	2.56	1.45	1.37	3.47	1.48	0.88
CV %	12.24	4.68	5.53	10.472	2.67	2.32	7.5	3.96	1.25

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Chlorophyll content

In this study, there were significant differences among different growing environments in leaf chlorophyll content (Figure 82). The highest chlorophyll content was found in plants during the flowering stage in all growing environments. However, the plants in the net house showed the highest chlorophyll content (54.48) and the lowest chlorophyll content was found in open field condition (47.50) at flowering stage. In our study, leaf chlorophyll content was found to be significantly lower in open field conditions and other shed houses than in net houses. The increased temperature is likely to play a key role in limiting plant growth by lowering photosynthetic activity and rising respiration rates (Darnell and Hancock, 1996).

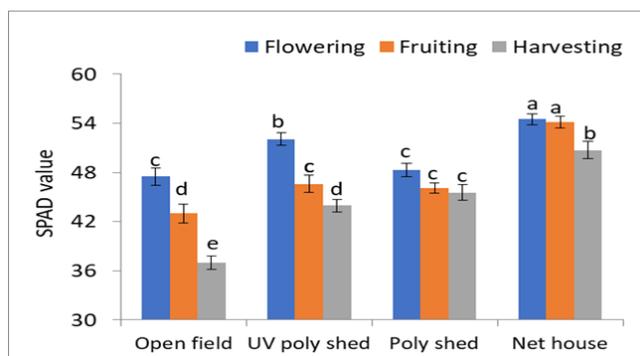


Figure 82: Average leaf chlorophyll content (SPAD reading) of papaya grown under different sheds and open field condition. Standard error bars are shown on each column

Yield Parameters

Days to flower initiation and number of fruits/plant

Different growing conditions (Table 41) significantly influenced the days to flowering. It was found that the maximum number of days to flowering (67) was recorded in open field conditions, whereas the minimum number of days to flowering was recorded (58) for the plants grown under net house. The number of fruits/plants was significant among the shed houses (Table 41 & Plate 15). The net house plants had the maximum fruit (71), while the UV poly shed had the fewest (37). In this experiment, higher temperatures might have reduced flower formation and fruit yield of the plants grown in poly and UV poly sheds.. Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set (Fraga *et al.*, 2019).



Plate 15: Papaya fruits grown under different shed houses

Table 41: Average days to flower initiation, number of fruits/plant, individual fruit weight and fruit yield (kg) of papaya grown under different sheds and open field condition.

Treatments	Days to flower initiation	No. of fruits/plant	Individual fruit weight (g)	Fruit yield/ plant (kg)	BCR
Open Field	66.66a	39.66b	633.33b	25.10b	2.6b
UV Poly shed	62.33b	34.33d	396.33d	13.57d	1.6c
Poly shed	61.00b	36.33c	466.67c	16.96c	1.9c
Net House	58.00c	68.33a	824.00a	56.28a	5.1a
LSD _{0.05}	2.03	1.52	1.95	1.58	0.6
CV %	2.45	1.71	3.79	2.83	3.1

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

Individual fruit weight (g) and fruit yield (kg)

Different growing environments showed significant variation in individual fruit weight (Table 41). The maximum fruit weight (824g) was recorded in plants grown under net houses and the minimum weight was recorded in UV poly sheds (396 g). A similar trend was found for the production of fruit yields. The maximum fruit yield was found in the net house (56 kg/plant) whereas the minimum fruit yield was observed in the UV poly shed (14 kg/plant) (Table 41). Weight and yield could be affected by changes in environmental conditions beneath protective netting. The unfavorable environmental conditions 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 (Table 41). The unfavorable environmental conditions prevented the development of proper fruit size, resulting in a decrease in fruit weight. The favorable environmental conditions in protective nets were the result of greater net photosynthesis, which resulted in faster fruit growth throughout the season (Bastias *et al.*, 2011). This enhancement of the light spectrum may result in an increase in assimilated carbon, which will support fruit growth and yield. The benefit cost ratio of strawberry production in open field, UV poly shed, poly shed and net house was estimated as 2.4, 1.6, 1.9 and 5.1 respectively (Table 41).

Quality Parameters

Total soluble solid

The total soluble solids content of the fruit responded significantly differently to the different shed houses (Table 42). The total soluble solids were maximum in the fruits obtained from the plants grown under net house conditions (13 °Brix), whereas a minimum was recorded from the plants cultivated in the UV poly shed (9.33 °Brix). Similar results were revealed by Cheema *et al.* (2013) that tomato cultivars had maximum TSS content under the net house. This might be due to the congenial micro-climatic conditions maintained in net house which influenced the production of more photosynthates that might result in sweeter fruits with maximum total soluble solids. Pérez de Camacaro *et al.* (2017) reported that greater accumulation of TSS in fruit has been observed in shading conditions due to reduced sugar degradation. Yanagi *et al.* (1995) stated that the titratable acidity also increases with shading.

Titratable acidity and Juice pH

It was found that the fruits produced in the net house were less acidic than the fruits produced in other growing environments. The higher titratable acidity was found in poly shed (0.31%), followed by the open condition (0.21%), and the lowest titratable acidity was found in the fruits grown in net house conditions (0.18%) (Table 42). In the present investigation, a decrease in percent titratable acidity was found during ripening, which is similar to the findings of Selvaraj *et al.* (1982). The results of the study revealed that the minimum titratable acidity in the juice of papaya obtained from net house might be due to the high sugar content present in the fruit and the more edible portion of the fruit. High fruit quality is associated with low pH (Davies and Hobson 1981). The pH values of papaya fruits cultivated in poly shed and UV poly shed showed no significant variations. The lower pH was found in UV poly shed (5.15) followed by poly shed (5.17) and the higher pH was found in fruits grown in net house (5.34) followed by open field condition (2.25) (Figure 31C). However, determining fruit acidity at complete maturation, when acidity decreases, is possibly the explanation for the low values.

Ascorbic acid

The highest ascorbic acid was found in the net house (60.13 mg/100 g), followed by open field conditions (54.19/100 g) and the lowest ascorbic acid was found in the fruits grown in the UV poly shed (41.95 mg/100 g) (Table 42). Koley *et al.* (2013) investigated quality

parameters of tomato under protected conditions and found significantly higher vitamin C in the fruit produced under protected structures. In this study, the fruits in UV poly shed and poly shed showed lower quality due to the maximum temperature during the fruit production stage, resulting in lower ascorbic acid content in harvested fruits. Temperature has a significant influence on vitamin C, with low average temperatures during fruit maturation and ripening contributing to increased enzymatic activity and thus increasing vitamin C and other bioactive compounds in the fruit (Mditshwa *et al.*, 2019).

Total phenolic content

The total phenolic content was significantly variable depending on the shading circumstances. The total phenolic content in the plants grown under the poly shed was the highest (2.56 mg/g FW) followed by the net house (2.55 mg/g FW), whereas the total phenolic content in papaya fruits in the UV poly shed was the lowest (2.44 mg/g FW) followed by the open field (2.33 mg/g FW) (Table 42). The phenolic compounds directly contributed to the antioxidant action. Koley *et al.* (2013) investigated quality parameters of tomato under protected and open cultivation and found significantly higher antioxidant activity in the fruit produced under protected structures at full ripe stage. Polyphenols in papaya have antioxidant properties because they defend cells from free radical damage and also prevent low density lipoproteins from oxidizing (Rana and Bhushan, 2016).

Reducing sugar

There were significant differences between different growing environments in reducing sugar content (Figure 32C). The highest reducing sugar content in the plants grown in net houses was seen (9.24 mg/g FW), while the lowest sugar content in UV poly sheds (8.77 mg/g FW), was observed (Table 42). Fruits grown under a tunnel usually have more reduced sugar in them (Voca *et al.*, 2009). The high sugar content of papaya grown under net house conditions may be due to adequate light intensity and higher photosynthetic plant activity in this crop environment (Beckmann *et al.*, 2006).

Table 42: Average content of total soluble solid, titratable acidity, pH, ascorbic acid, total phenol, reducing sugar and β -carotene of papaya fruits grown under different sheds and open field condition.

Treatment	TSS (°Brix)	TA (%)	pH	Ascorbic acid (mg/100g)	Total Phenol (mg/g)	Reducing Sugar (mg/g)	β - carotene (mg/100g)
Open Field	12.33ab	0.21b	5.24b	54.19b	8.77b	8.92b	0.24b
UV Poly shed	9.00c	0.19b	5.15c	41.95d	9.20a	8.77c	0.16d
Net Poly shed	11.77b	0.31a	5.16bc	50.14c	9.19a	9.20a	0.19c
Net House	13.00a	0.18b	5.34a	60.13a	0.00c	9.19a	0.32a
LSD _{0.05}	1.03	0.031	0.08	1.85	0.72	0.065	0.029
CV %	4.48	6.84	0.79	1.80	2.71	0.36	6.23

Different letters mean significant differences between the treatments according to Duncan's multiple range test ($p < 0.05$).

β -carotene

There was a significant response in the β -carotene content of the fruit to the different shed houses (Table 42). The fruits obtained from the net house had the highest β -carotene content

(0.33 mg/100g), while the fruits obtained from the UV poly house had the lowest β -carotene content (0.16 mg/100g). According to Gomez *et al.* (2001), papaya grown in a net house had higher beta-carotene content than papaya grown in the field. In our study, fruits grown in poly and UV poly sheds had the highest temperatures compared to other growing environments. Papaya exposed to direct sunshine in the field generally develops a poor color, owing to the low beta carotene content of fruit subjected to high temperatures. The findings show that a cooler microclimate created by a shed net generates a favorable environment in the fruit for chlorophyll breakdown and carotene accumulation.

Color measurement

Remarkable variation was noted in the fruit color of papaya, influenced by the effects of different shed houses (Figure 83A-33D & Plate 16). The higher L^* value indicates the lighter color, which was found in the fruits grown in the UV poly shed (56.52) and the lower L^* value found in both the poly shed and net house (approximately 48). The redness value a^* was highest in the treatment of the net house (48.28), whereas the lowest a^* value was found in the treatment of the open field (24.94). The higher b^* value indicates yellow color and was found in the treatment of open fields (44.03) and the lower value was found in the treatment of poly sheds (36.73). The higher Chroma value was found in the treatment of net houses (52.89) and the lower value was found in the treatment of open fields (49.55). Several factors influence fruit color development, including canopy temperature and light intensity (Mditshwa *et al.*, 2019). Pomegranate fruit grown in the open field has poor color development compared to trees grown under shed nets (Meena *et al.*, 2016).

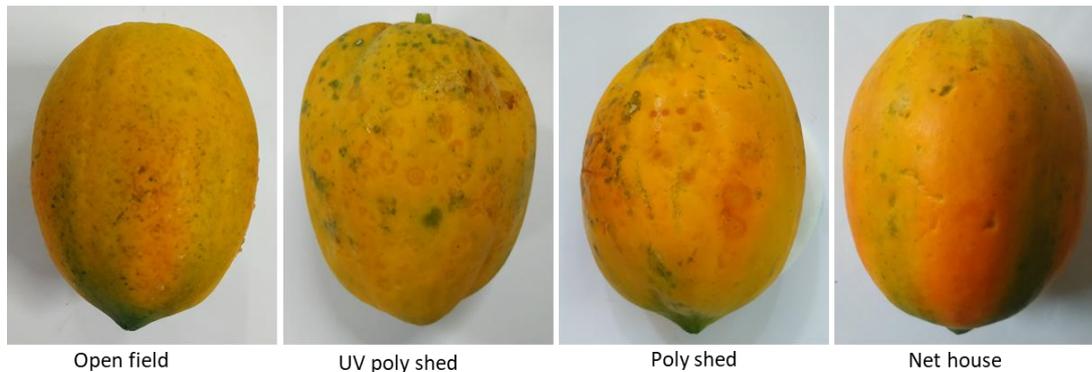


Plate 16: Skin color of papaya fruits grown under different shed houses

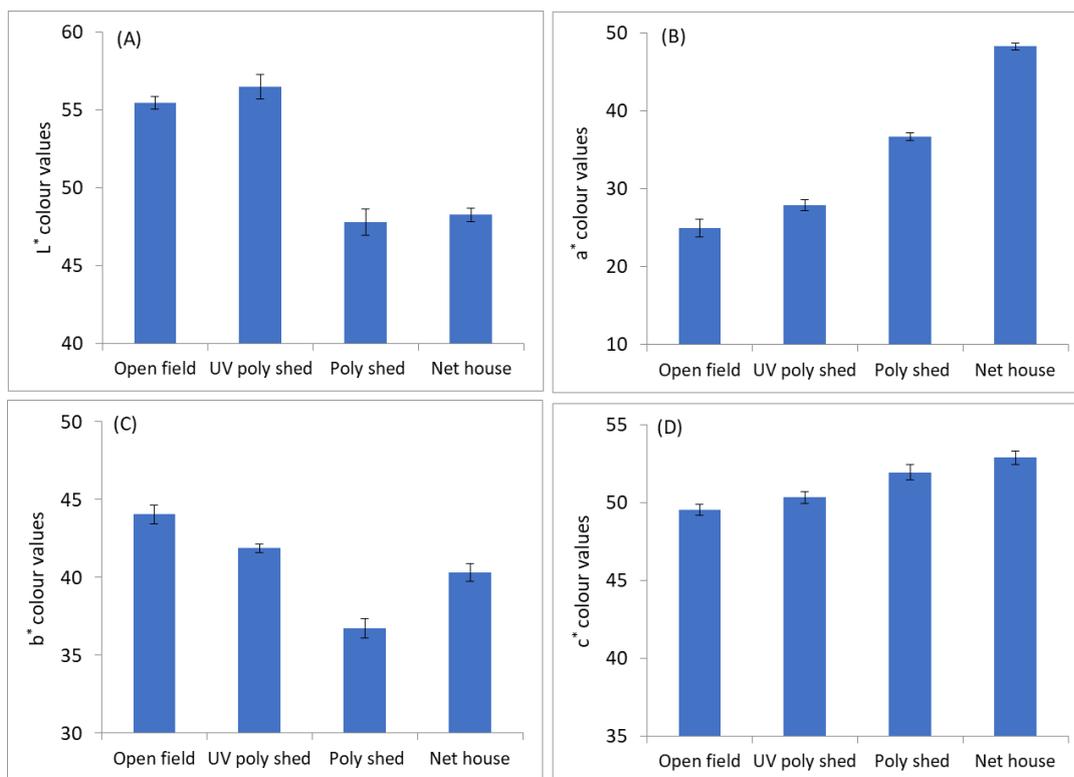


Figure 83: Average color values of L* (A), a* (B), b* (C), and C* (D) of papaya fruits at edible stage grown under different sheds and open field condition. Standard error bars are shown on each column.

11.15. : Effect of Maturity Stage of Papaya on Physiological and Biochemical Parameters under protective cultivation

Weight of fully ripened papaya (g)

Fruit weight varies with the different maturity stages both in net house and open field condition. The fruit weight was increased with the advancement of the maturity in open field and net house. The results revealed that the weight of the fruits were highest in net house grown papaya than open field (Figure 84A). Although the fruits were harvested at different maturity stages, the fruits weight were recorded in fully ripen stage of papaya. Maturity index and growing condition both had the significant effect regarding weight of the fruits. In net house, the highest weight (990g) was measured in harvesting of papaya at stage 4 (90% skin color) whereas the lowest weight was found in stage 1. The heavier weight of single fruit in the fully ripen stage was mainly due to the high moisture content that enhanced turgidity and thereby fresh weight. This support the review report (Fawole and Opara, 2013) on pomegranate fruits where weight increased with progress in maturity stages. The heavier weight of the fruit due to advancement of maturity indicated that this stage contain the highest fraction of edible flesh component which was another aspect of quality.

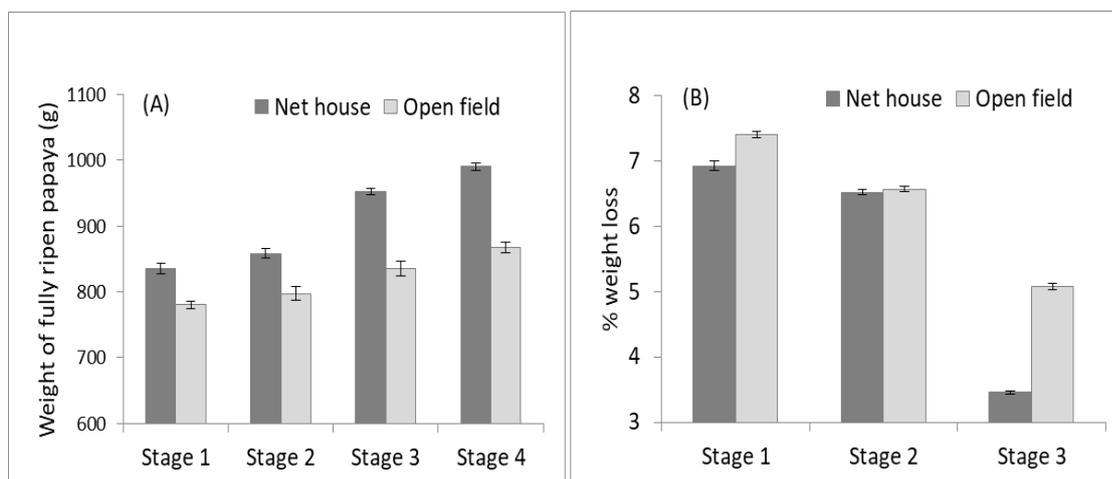


Figure 84: Average weight (A) and weight loss (B) of papaya fruits at edible stage harvested from net house and open field at four maturity stages. Mean \pm Standard error (S.E.) (n = 15).

Weight loss (%)

Physiological loss in weight of papaya fruits were influenced by the different maturity stages. The cumulative weight loss decreased progressively from stage 1 to stage 3 by the harvesting days. The weight loss of the fruits at stage 1 and stage 3 had significant variation in net house and open field condition. The maximum weight loss (7.41%) occurred in harvesting at stage 1 in open field condition compared to 6.93% in net house grown fruits. The minimum weight loss (3.42%) occurred in harvesting of papaya at stage 3 in net house (Figure 84B). The increase in weight loss over the storage period has been attributed to the loss of moisture (transpiration) through the stomata cells of the fruit. Transpiration is partially dependent on temperature and humidity. Yaman and Bayoundurh (2002) stated that the moisture loss mechanism in fresh fruits is as a result of differences in the water vapour pressure within the fruits and their storage environment which causes vapour phase diffusion. The loss of weight of papaya was high at stage 1 because of the high transpiration rate that happened at room temperature which is non-renewable loss of water due to fruit is no more attached to the plant (Chen and Paul, 1989). In this study, stage 1 was harvested earlier than stage 2, 3 and 4. This might be the reason of increased weight loss of papaya harvested at stage 1.

Color

The effect of initial fruit maturity on L index value (0= black and 100= white). Net house grown papaya fruits tended to be lighter in color than open field grown papayas. The change in the peel color was observed from the 25% skin coloration of papaya to the fully ripened stage (90% skin coloration). L* value has no significant difference between net house and open field grown papaya when the skin coloration was just started (25% only one yellow stripe). But L* value had significance influence on the papaya peel color from 50% skin color (stage 2) to 90% (stage 4) skin color grown in net house and open field condition (Figure 85A). The data revealed that L* value was increased up to fully ripening of papaya. The highest L value (58.01) was recorded in net house grown papayas during 90% skin coloration. The redness value a* was highest (29.08) in net house grown papayas.

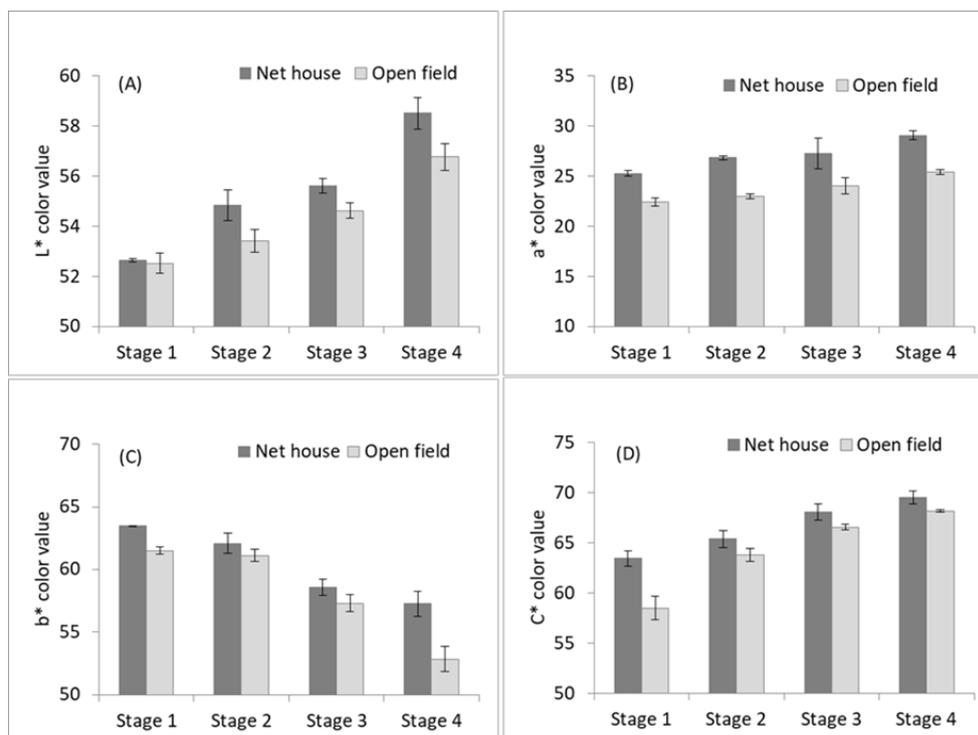


Figure 85: Average color values of L* (A), a* (B), b* (C) and C* (D) of papaya fruits at edible stage harvested from net house and open field at four maturity stages. Mean \pm Standard error (S.E.) (n = 15). Stage 1: 25% skin color, stage 2: 50% skin color, Stage 3: 75% skin color and Stage 4: 90% skin color.

a* value was gradually increased from 25% skin color to 90% skin color of papaya. The increase in the a-value over the storage period was an indication of ripening of the papaya and the reduction of greenness. The highest a value was measured in fully ripened stage (90% skin color). The yellow index b* was decreased gradually from 25% skin color to 90% skin color. The highest (63.46) b value was measured when papaya peel color was 25% in net house grown papayas (Figure 85B).. The decrease in the b value from 25% to 90% peel color was characterized by the departure from yellow scale to red and then eventual darkening of the peels (Adi *et al.*, 2019). Net house grown papaya had the highest Chroma value, indicating brighter yellow peel color than open field grown papayas.

The highest c* value was recorded when the peel color (68.78) was 90% and lowest Chroma value was recorded in open field grown papayas in 25% peel color (58.48) (Figure 85D). Therefore, the bright yellow color peel was found in fully ripened papaya. The color of fruits change with change in stage of maturity and this change in color is also positively associated with composition of secondary metabolites that affect nutritional value and flavor acceptance of the fruits (Borges *et al.*, 2011). The total color difference of the papaya peels increased as ripening progressed. This indicates the change from the green color of the matured unripe papaya (25% skin color) as ripening progressed (Adi *et al.*, 2019). The peel color change over the maturity stages of papaya during ripening, there was degradation of chlorophyll pigments revealing the carotenoids which are already at their peak in the fruit at maturity.



Plate 17: Skin color of papaya fruits at edible stage harvested from net house and open field at four maturity stages. Mean \pm Standard error (S.E.) (n = 15). Stage 1: 25% skin color, stage 2: 50% skin color, Stage 3: 75% skin color and Stage 4: 90% skin color.

Total soluble solids

Total soluble solids content in fruits was significantly higher (13.42°Brix) in net house grown papaya which made the fruits sweeter and acceptable and lowest was found in open field grown papaya (11.92 °Brix) (Table 43). Similar results are also observed by Cheema *et al* (2013) in tomato. This might be due to the congenial micro-climatic conditions maintained in net house which influenced the production of more photosynthesis that might result in sweeter fruits with maximum total soluble solids. Maturity indices had no significant variation regarding TSS content of papaya. However, the maximum TSS content was recorded in stage 2 (13.71 °Brix) although it had no significant variation with stage 2, 3 and 4. The minimum TSS was found fruit harvested in stage 1 (11.83 °Brix). Total soluble solids tended to increase as the harvesting date progressed. Similarly, Dick *et al.* (2009) reported that mangos collected at 100 days after flowering developed better sugar content and other organoleptic characteristics than earlier harvested fruits. Lebrun *et al.* (2008) indicated that later harvest maturities resulted in sweeter fruits. Jha *et al.* (2007) measured TSS by a

handheld refractometer and computed, with a HunterLab colorimeter, that fruits predicted to be mature could ripe with high-satisfied.

pH

Variations in pH of papaya under growing condition were observed (Table 43). The pH values under both growing condition showed significant variation. The highest (5.36) pH value was recorded in net house and lowest value was recorded in open field (5.12). pH value is the measure of acidity, less the value more the sourness of the fruit. The environmental effect on fruit acidity is complex and some studies favour the hypothesis that organic acids are produced in the fruit itself from stored carbohydrates (Sakiyama and Stevens, 1976). Increase the pH value (5.32) was observed as harvesting season of papaya progressed (Table 43). The lowest value was found in stage 1 (5.24). The pH has been correlated to maturity index in papaya (Hakkim *et al.*, 2012) and strawberry (ElMasry *et al.*, 2007). The high pH at stage 4 probably was a result of an increase in the organic acid contents in the fruits (Arvanitoyannis and Mavromatis, 2009).

Titrateable acidity

The maximum titrateable acidity was recorded in open field condition (0.21%) and minimum was recorded for net house (0.16%) (Table 43). The effect of growing condition on titrateable acidity of papaya fruit pulp had significant variation. Results of the study revealed that minimum titrateable acidity in the juice of papaya obtained from net house might be due to the high sugars present in fruit and more edible portion of the fruit. Results of these findings are confirmed by Manu *et al.* (2015) in papaya cv. Red Lady Papaya. Maturity indices had a significant variation towards titrateable acidity of papaya fruit pulp. However, Maximum titrateable acidity was recorded fruit harvested in stage 2 (0.24) and lowered by the progression time of harvesting of papaya (stage 4). In the present study, the acidity in papayas was reduced during ripening, mainly fruit harvested at maturity stage 4. Adi *et al.*, (2019) reported that the maleic acid content decreases during papaya ripening. However, Seymour *et al.* (2000) concluded that the titrateable acidity increases with fruit ripening until approximately 75% of yellow skin.

Ascorbic acid content (mg/100g)

The maximum ascorbic acid (52.61 mg/100g) was recorded in net house grown papayas and minimum was recorded in open field grown papayas (52.51 mg/100g) (Table 43). The effect of growing condition on ascorbic acid content of papaya had no significant variation. Ascorbic acid content was significantly affected by the maturity stages of papaya. The maximum ascorbic acid content was recorded in fruit harvested at stage 3 (57.16 mg/100g) and minimum was found in stage 1 (45.51 mg/100g). At maturity stage 3 vitamin c was highest before decreasing at stage 4 (55.38 mg/100g). This result could be explained by the rate of vitamin C which increases naturally during maturation and decreases during the ripening of papaya (Bron and Jacomino, 2006). This might be the reason behind the lower vitamin c content found in papayas which picked at full ripened stage (stage 4) than stage 3 (75% skin color).

Total phenol (mg/g)

Total phenol content was higher (0.46 mg/g) in net house grown papayas and lower content (0.39 mg/g) was recorded in open field grown papayas (Table 43). Growing condition had a significant effect on total phenol content. Phenol content had no significant variation in harvesting of papaya at different maturity stages. However, the maximum was found in the stage 2 (0.48 mg/g).

Reducing sugar (%)

It was observed from the results of the present experiment that reducing sugar significantly differed by growing condition of papaya. Highest reducing sugar (3.54%) was recorded in net house and lowest was recorded in open field grown papayas (3.34%) (Table 43). High reducing sugar content in papaya produced under net house may be due to the sufficient light intensity and greater photosynthetic plant activity in this crop environment (Beckmann *et al.*, 2006). Maturity indices exposed no significant variation regarding the reducing sugar content of papaya. However, the highest reducing sugar content was found in harvesting at stage 4 (3.72%). According to Selvaraj *et al.* (1982), reducing sugar increases up to five times when papayas attached to the tree, when skin color begins to yellow and it is reasonable to assume that fruit harvested at maturity stage 1 and stage 2 did not have sufficient time to accumulate sugar before harvest.

Table 43: Average content of biochemical parameters of papaya fruits obtained from net house and open field at four maturity stages. Mean \pm Standard error (S.E.) (n = 15). Stage 1: 25% skin color, stage 2: 50% skin color, Stage 3: 75% skin color and Stage 4: 90% skin color

Treatments	TSS ($^{\circ}$ Brix)	pH	TA (%)	Ascorbic acid content (mg/100g)	β -carotene (mg/100g)	Reducing sugar (%)	Phenol (mg/g)
Growing condition							
Net house (G ₁)	13.42 a	5.36 a	0.16 b	52.61 a	0.29 a	3.54 a	0.46 a
Open field (G ₂)	11.92 b	5.12 b	0.21 a	52.51 a	0.23 b	3.34 b	0.39 b
CV%	3.95	0.86	3.16	2.33	2.14	2.85	3.53
LSD _{0.05}	0.4327	0.0394	0.0210	1.0596	0.0159	0.0847	0.0129
Maturity indices							
Stage 1 (M ₁)	11.83 b	5.24b	0.13 d	45.51 d	0.23 b	3.11 c	0.38 c
Stage 2 (M ₂)	13.17a	5.25 b	0.24 a	52.17 c	0.24 b	3.45 b	0.48 a
Stage 3 (M ₃)	12.83 a	5.29 ab	0.20 b	57.16 a	0.28 a	3.47 b	0.45 b
Stage 4 (M ₄)	12.83 a	5.32 a	0.16 c	55.38 b	0.29 a	3.72 a	0.38 c
CV%	3.95	0.86	3.16	2.33	2.14	2.85	3.53
LSD _{0.05}	0.6120	0.0558	0.0296	1.4985	0.0225	0.1197	0.0183
Combination							
G ₁ M ₁	10.67 e	5.33b	0.12 c	41.37 e	0.24 bc	3.14 c	0.38 de
G ₁ M ₂	13.67 a	5.34 b	0.22 ab	55.41 bc	0.27 b	3.51 b	0.56 a
G ₁ M ₃	13.00 abc	5.34 b	0.19 b	60.13 a	0.33 a	3.52 b	0.50 b
G ₁ M ₄	13.33 ab	5.44a	0.11 c	53.51 c	0.30 a	3.98 a	0.41 c
G ₂ M ₁	12.00 d	5.15 d	0.14 c	49.65 d	0.22 cd	3.08c	0.37 e
G ₂ M ₂	12.67 bcd	5.16 d	0.26 a	48.93 d	0.21 d	3.38 b	0.41 c
G ₂ M ₃	13.67 a	5.25 c	0.22 ab	54.19 c	0.25 bc	3.41 b	0.40 cd
G ₂ M ₄	12.33 cd	5.20 cd	0.21 b	57.26 b	0.25 b	3.47 b	0.36 e
CV%	3.95	0.86	3.16	2.33	2.14	2.85	3.53
LSD _{0.05}	0.8654	0.788	0.0419	2.1192	0.0318	0.1693	0.0258

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p < 0.05).

β-carotene content (mg/100g)

The results revealed that beta carotene content significantly differed by growing condition of papaya. Highest beta carotene (0.29 mg/100g) was recorded in net house and lowest was recorded in open field grown papayas (0.23 mg/100g) (Table 43). Papaya exposed to direct sunlight in the open field often develop a poor color, mainly due to fruit exposed to high temperatures has low beta carotene content (Helyes *et al.*, 2006). As beta carotene biosynthesis is mediated by phyochrome, slight variations in light over mature green fruits stimulates beta carotene accumulation (Alba *et al.*, 2000) which may explain the beta carotene content obtained depending on the which environmental conditions plants were grown. Maturity indices exposed no significant variation regarding the β-carotene content of papaya. However, the highest beta carotene content was found in fruit harvested at stage 4 (0.29 mg/100g). At the onset of carotenoid biosynthesis in green mature fruits of the papaya, biosynthetic enzymes like lycopene cyclases and β-hydroxylases displayed detectable activities (Blas *et al.*, 2010). Low proportions of β-carotene might be explained by their rapid conversion into xanthophylls at the early harvesting of fruit (stage1). During further maturation of papaya lycopene contents increased disproportionally, and β-carotene as well as free and esterified β-cryptoxanthins were simultaneously synthesized (Schweiggert *et al.*, 2011).

11.16. : Effect of Different Growing Environment on Growth Yield and Quality of Banana

Temperature and relative humidity (RH) conditions

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. Different shed houses and open field conditions influenced the temperature. Data on the temperatures for each treatment was measured at 12 pm daily during the experimental period. The average monthly temperature varied approximately 27.28 to 36.80°C, as shown in Table 44. During the experimental period, the relative humidity for each treatment was measured at 12 pm daily. From February to October, the average monthly relative humidity ranges between 64.52 and 80% during the day (Table 44).

Table 44: Monthly average air temperature (°c) and relative humidity (%) at 12 hrs in different shed houses and open field during February to October 2021.

Month	Average monthly air temperature and relative humidity at 12 hrs							
	Open field		UV Poly shed		Poly shed		Net house	
	Temp (°c)	RH (%)	Temp (°c)	RH (%)	Temp. (°c)	RH (%)	Temp. (°c)	RH (%)
February	27.28	68.15	28.24	68.03	26.80	69.65	26.09	70.01
March	32.31	64.52	33.14	65.11	31.25	65.15	30.55	71.19
April	34.5	70.10	36.05	67.25	33.08	70.32	30.61	72.87
May	32.08	80.25	34.19	75.63	31.02	79.42	29.62	75.53
June	32.03	79.00	34.00	70.21	31.56	75.12	30.78	80.53
July	32.84	75.20	36.80	70.41	31.21	74.65	32.29	70.82
August	31.53	71.03	35.06	74.32	30.22	72.78	31.61	72.97
September	32.53	72.09	34.08	72.25	32.27	66.13	31.34	65.93
October	31.70	70.04	33.25	70.42	31.04	68.25	30.27	68.13

Growth parameters

The pseudo stem height and girth were influenced significantly with different growing environments. The highest pseudo stem height (175.67cm) was recorded in net house condition whereas the highest girth size (68.66cm) were recorded in poly net house condition at harvesting stage and the lowest pseudo stem height (151.67 cm) and the pseudo stem girth (51.00 cm) were recorded in open field condition (Table 45). Similarly Panigrahi *et al.* (2010) also conducted an experiment with green house and open field condition on capsicum annum cv. California Wonder. The 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.

Banana grown in different protected condition had shown significant effect on leaf chlorophyll content at harvesting stage. The highest leaf chlorophyll content (57.63 %) was recorded in poly net house condition. Whereas the lowest leaf chlorophyll content (40.46 %) was recorded in open field condition (Table 45). Shed net house modify the light concentration which affect the chlorophyll concentration. The leaves grown under poly net house reduced levels of light and contain more chlorophyll than leaves grown under the open conditions. The reason for the more chlorophyll in the leaves grown under poly net house could be attributed to the purpose of capture of scattered radiation which ultimately is needed for the plant growth by the production of the carbohydrates. Similarly, Gent (2007) reported that there was high total chlorophyll content in the leaves of tomato cultivated under the black and blue coloured shed nets as compared to the tomato plants cultivated in the open conditions. Megharaja (2000) reported that Capsicum fruits grown under greenhouse condition were recorded significantly higher TSS and total chlorophyll content as compared to fruits from open condition.

Table 45: Growth parameters of banana grown under different sheds and open field condition. Mean \pm S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Different sheds	Pseudo stem height (cm)	Pseudostem girth (cm)	Chlorophyll content
Open field	151.67 b	51.00 c	40.46 c
UV poly shed	164.00 ab	65.66 ab	45.73 bc
Poly shed	171.00 a	68.66 a	57.63 a
Net house	175.67 a	60.66 b	51.23 ab
LSD _{0.05}	16.05	6.24	6.90
CV%	5.15	5.39	7.52

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p <0.05).

Yield contributing parameters

The early emergence of inflorescence (170 dayss) was recorded when fruits were grown in UV poly shed condition, preceded by poly net house growing condition (180 days), while banana grown in open field condition took 210 days to take inflorescence emergence (Table 46). Days required to harvesting after fruit setting was significantly influenced by different growing environments. The minimum harvesting time (100 days) was recorded for the poly net house condition, and the maximum harvesting time (120 days) was recorded for the control (open space condition) (Table 46). It was observed that open space condition delayed the harvesting time over the poly net house condition. The highest bunch length (1st hand to

last hand) (85.33 cm) was recorded when the fruits were grown in poly net house condition and the lowest (64.00 cm) was recorded when fruits grown in open field condition.

The maximum number of hands per bunch (9.66) was observed in poly net house condition and the minimum number of hands per bunch (7.33) was found in open space condition. Maximum number of fingers/bunch (140) was recorded in poly net house protected condition and minimum number (93) was recorded in open field condition (Table 46). The number of fruit was significantly higher in poly net house which could be due to the better availability of better environmental conditions especially the higher relative humidity, moderate temperature which might have helped in maintaining the pollen viability and avoided desiccation of pollen on stigmatic surface. The maximum number of fingers hand⁻¹ (14.50) was observed in poly net house condition and the minimum number of fingers hand⁻¹ (12.67) was found in open space condition (Table 46). Plants grown under polyhouse condition over the plants grown in the open field was associated with the production of higher number of fruits (38) with greater length (4.4 cm) and diameter (5.4 cm) and fruit weight (68 g) than those in open field. These results are in agreement with Kang and Sidhu (2005) and Parvej *et al.* (2010).



Plate 18: Banana fruits grown in different growing condition i.e. open field (a), uv poly shed (b), net poly shed (c) and net house (d).

Table 46: Yield contributing parameters of banana grown under different sheds and open field condition. Mean \pm S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Different sheds	Inflorescence initiation (month)	Inflorescence initiation to harvesting (month)	1st hand to last hand length (cm)	No. of hands/bunch	Total no. of fingers/bunch	No. of fingers/hand
Open field	210 a	120 a	64.00 c	7.33 b	93.00 c	12.67 b
UV poly shed	170 c	110 b	78.00 b	9.33 a	125.67 b	13.48 ab
Poly net house	180 b	100 c	85.33 a	9.66 a	140.00 a	14.50 a
Net house	185 b	100 c	68.00 c	8.66 a	122.67 b	14.20 a
LSD _{0.05}	0.374	0.232	4.92	1.087	2.37	1.532
CV%	3.08	3.21	3.54	6.60	5.46	5.94

Mean \pm S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Yield parameters

There were significant differences of finger length among the treatments. The highest finger length (16.17 cm) was recorded when the fruits were grown in poly net house condition and the lowest (14.41 cm) was recorded when fruits grown in net house condition. Maximum breadth of the banana fruit (3.46 cm) was recorded in poly net house growing condition and the minimum fruit breadth (2.89 cm) was recorded in open field condition (Table 47). Different growing environments also positively influenced the diameter and fruit breadth of banana finger and the effect different growing condition was significant. Among the different growing conditions, UV shed condition produced the highest diameter of finger (12.13 cm) followed by the poly net house (12.08 cm) and the lowest diameter (11.52 cm) was recorded for open field condition. The maximum individual fruit weight (125.00 g) was observed in poly net house condition and the minimum average fruit weight (102.18g) was found in open field condition (Table 47). The benefit cost ratio (BCR) of strawberry production in open field, Uv poly shed, poly net house and net house was estimated as 2.1, 2.5, 3.1 and 2.4 respectively (Table 47).

The greater pulp/peel ratio of banana (3.35) was recorded in poly net house condition and the lower pulp/peel ratio (2.21) was recorded in open field condition (Table 47). The greater pulp/peel ratio at higher temperature and at low humidity also confirms that these bananas were at a more advanced stage of ripening because the pulp/peel ratio increased with ripening, because pulp/peel ratio in banana fruit has previously been shown to increase with ripening (Montenegro, 1988). The second reason for the greater pulp/peel ratio at the higher temperature and lower humidity could be due to the greater weight loss. Because the pulp mass of banana fruit increases during ripening due to an increase in water content, it could be due to the movement of water from peel to pulp and to the surrounding air (Lizada *et al.*, 1990).

Table 47: Yield contributing parameters of banana grown under different sheds and open field condition. Mean \pm S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Different shed	Fruit length (cm)	Fruit breadth (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Pulp: peel	Yield/Plant (kg)	BCR
Open field	15.66 b	2.89 d	11.52 b	102.18 d	2.21 c	380.11d	2.1d
UV poly shed	15.50 b	3.24 b	12.13 a	117.50 b	3.18 a	590.65b	2.5c
Poly net house	16.17 a	3.46 a	12.08 a	125.00 a	3.35 a	700a	3.1a
Net house	14.41 c	3.13 c	11.68 b	109.80 c	2.97 b	538.76c	2.4b
LSD _{0.05}	0.404	0.079	0.236	2.22	0.189	2.5	0.05
CV%	1.39	1.33	1.06	6.91	3.44	9.1	1.9

Different letters mean significant differences between the treatments according to Duncan's multiple range test (p < 0.05).

Quality contributing parameters

The data presented in table 1 showed the quality character viz., TSS, TA, p^H, reducing sugar, non-reducing sugars, total sugars in banana which were influenced due to various growing environments. All these parameters had significant difference through various treatments.

The maximum total soluble solids (21.78%) was found in poly net house growing condition and minimum total soluble solids (TSS) (16.77%) was found in UV poly shed condition (Table 48). The decrease in TSS throughout the season has been attributed to the increase in temperature resulting in an increase in the respiration rate and, consequently, decreasing the content of sugars, organic acids and soluble solids of the fruits (Ruan *et al.* 2013).

The maximum TA% (0.57%) was found in net house growing condition followed by UV poly shed condition (0.55%) and minimum titratable acidity (TA) (0.40%) was found in poly net shed condition. The highest pH (5.64) was recorded in poly net house condition and the lowest p^H (4.92) was recorded in UV poly shed condition. Lower pH and higher titratable acidity in uv poly shed due to higher temperature (Table 48). Similar result was found by Goto-Yamamoto *et al.* (2009) who reported that the lower TSS (total soluble solids) and pH of Cabernet-Sauvignon grapes were in high temperature than in the low temperature. The lower acidity of the fruits grown in the protected environment may be a result of the lower photosynthetic activity of the plant (shading in protected environment) in this environment.

The ascorbic acid content of banana was significantly affected by different protected condition. The highest ascorbic acid content of banana (10.24 mg/100 g) was recorded in poly net house condition (Table 48). Whereas the lowest titratable ascorbic acid content (8.96 mg/100 g) of banana was recorded in net house protected 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. The maximum total sugar (25.44%), reducing sugar (15.5%) and non-reducing sugar were recorded in poly net house growing environment, whereas the minimum total sugar (21.17%), and non-reducing sugar (7.87%) were recorded in open space condition (Table 48). Higher sugar content in the fruits produced in poly net house may be due to the greater light intensity and greater photosynthetic plant activity in this crop environment.

Table 48: Quality parameters of banana grown under different sheds and open field condition. Mean ± S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Different shed	TSS (°Brix)	TA%	pH	Vitamin c mg/100g	Total sugar (%)	Reducin g sugar (%)	Non reducing sugar (%)
Open field	20.89 a	0.43 b	5.18 b	9.38 ab	21.17 c	13.30 c	7.87 b
UV poly shed	16.77 c	0.55 a	4.92 c	9.17 b	21.76 c	12.17 d	9.59 a
Poly shed	21.78 a	0.40 b	5.64 a	10.24 a	25.44 a	15.75 a	9.68 a
Net house	18.33 b	0.57 a	5.27 b	8.96 b	23.01 b	14.21 b	8.79 ab
LSD _{0.05}	0.992	0.059	0.181	0.983	0.812	0.853	1.154
CV%	2.71	6.45	1.83	5.54	1.89	3.27	6.82

Mean ± S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

Color measurement

Significant changes in colour values (L*, a*, b*) during ripening for the period of were presented in table 49. It can be observed from the table, that the lightness value (L* value)

and yellowness (b^* value) increased during the ripening. This might be due to the chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments (Seymour, *et al.*, 1993). The highest L^* and a^* value was recorded in fruits of poly net house condition and the lowest value of L^* and b^* value was recorded in fruits in UV poly shed conditions. The lower value of L^* and b^* might be due to the development of brown flecks over the peel, spots were observed by Salvador *et al.* (2007) on ripening the banana. The maximum a^* value (greenness) was recorded in fruits of UV poly shed conditions. The greenness value of banana fruit increased from negative side to positive side. This confirms the de-greening of banana peel. Similar results were reported by Boudhrioua *et al.* (2002).

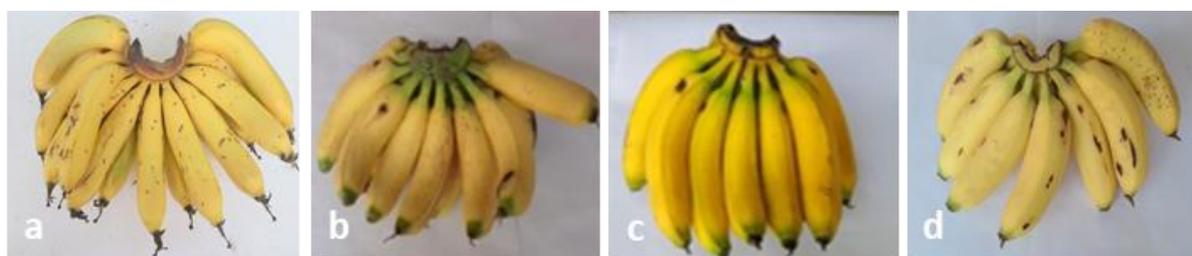


Plate 19: Skin color of banana fruits grown under different shed houses (a: open field, b: UV poly shed, c: poly net house, d: net house)

Table 49: Average color values of banana grown under different sheds and open field condition.

Different shed	Color measurement		
	L^*	a^*	b^*
Open field	68.37 a	7.14 b	47.56 ab
UV poly shed	62.0 b	9.79 a	43.36 c
Poly shed	68.87 a	3.98 c	49.20 a
Net house	62.16 b	3.41 c	45.33 bc
LSD _{0.05}	1.74	0.77	3.351
CV%	3.86	6.74	3.84

Mean \pm S.E. (n = 15). Means with the same letter are not significantly different at P = 0.05 by Duncan's multiple range test.

11.17. Effect of Maturity Stage of Banana on Physiological and Biochemical Parameters Under Protective Cultivation

Days to required color development

Banana fruits harvested from different shed houses at different maturity stages showed differences to develop fully yellow color in first hand and all hands in banana bunch (Table 50). Fruits required the maximum days for yellow color development in all growing conditions at under mature stage whereas the minimum days required at over mature stage. The maximum number of days required for bunches produced in open field condition and the minimum number of days required for bunches cultivated in poly net house to develop yellow peel color. This difference may be due to the fact that fruits harvested at over maturity exhibit rapid change in colour (chlorophyll breakdown) compared to those harvested at under mature stage. It could also be due to higher tannin content in the fruits harvested early. This is in close conformity with findings of Narayana and Mustaffa (2007).



Plate 20: Under mature (a), mature (b) and over mature (c) banana fruits

Table 50: Days to color development of banana fruits at edible stage harvested from different shed houses at three maturity stages.

Treatment	Maturity indices	Days to color development (1 st hand)	Days to color development (Fruits of entire bunch)
Open field	Under mature	12	15
	Mature	9	14
	Over maturity	2	11
UV poly shed	Under mature	8	12
	Mature	5	10
	Over maturity	4	6
poly net house	Under mature	10	16
	Mature	7	13
	Over maturity	3	8

Total soluble solids (TSS): Maturity indices had significant variation regarding TSS content of banana. However, the maximum TSS content was recorded in mature stage (19.44°Brix) and the minimum TSS was found fruit harvested in under mature stage (17.52 °Brix). Total soluble solids tended to increase as the harvesting date progressed. Jha *et al.* (2007) measured TSS by a handheld refractometer and computed, with a Hunter Lab colorimeter, that fruits predicted to be mature could ripe with high satisfied.

Table 51: Quality attributes of banana fruits at edible stage harvested from different shed houses at three maturity stages.

Treatment	TSS (°Brix)	TA (%)	p ^H	Vitamin c (mg/100g)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
Maturity indices							
Under mature	17.52 c	0.54 a	5.06 b	7.46 b	20.58 c	10.31 b	10.27 a
Mature	19.44 a	0.48 b	5.26 a	9.03 a	22.23 a	13.54 a	8.68 b
over maturity	18.29 b	0.49 b	4.94 c	6.54 c	21.69 b	12.97 a	8.72 b
LSD _{0.05}	0.63	0.02	0.09	0.58	0.46	0.60	0.66
CV%	3.47	4.61	1.84	7.69	2.19	5.01	7.25
Different shade							
Open field	19.96 a	0.55 a	5.11 a	8.04 a	21.47 b	12.56 b	8.90 b
UV poly	15.63 b	0.44 c	4.96 b	7.82 a	19.84 c	10.97 c	8.86 b
Poly net house	19.67 a	0.52 b	5.20 a	7.18 b	23.19 a	13.29 a	9.90 a

LSD _{0.05}	0.63	0.02	0.09	0.58	0.46	0.60	0.66
CV%	3.47	4.61	1.84	7.69	2.19	5.01	7.25
Interaction effect							
T1	18.11 b	0.66 a	5.10 bc	7.25 c	20.89 c	10.24 de	10.56 a
T2	20.89 a	0.57 bc	5.18 b	9.38 ab	21.17 c	13.30 b	7.87 d
T3	20.89 a	0.43 de	5.05 bc	7.46 c	22.34 b	14.15 b	8.19 d
T4	15.57 c	0.41 e	4.96 cd	8.53 b	19.35 d	9.74 e	9.61 abc
T5	15.67 c	0.45 d	4.97 cd	7.46 c	20.08 d	11.59 c	8.49 cd
T6	15.66 c	0.45 d	4.97 cd	7.46 c	20.08 d	11.59 c	8.49 cd
T7	18.89 b	0.55 c	5.14 b	6.61 c	21.51 c	10.95 cd	10.55 ab
T8	21.78 a	0.40 e	5.64 a	10.24 a	25.44 a	15.75 a	9.68 ab
T9	18.33 b	0.60 b	4.82 d	4.69 d	22.62 b	13.16 b	9.47 bc
LSD _{0.05}	1.06	0.04	0.160	1.01	0.80	1.05	1.14
CV%	3.47	4.61	1.84	7.69	2.19	5.01	7.25

T₁= open field +under mature, T₂= open space +mature, T₃= open field + over mature, T₄= UV poly shade + under mature, T₅= UV poly shade + mature, T₆= UV poly shade+ over maturity, T₇= poly net house+ under mature, T₈= poly net house + mature, T₉= poly net house + over maturity

Titratable acidity: Maturity indices had a significant variation towards titratable acidity of banana fruit pulp. However, Maximum titratable acidity was recorded fruit harvested under mature stage (0.54%) and minimum was observed in mature stage (0.48%) followed over mature stage (0.49%) (Table 51). In the present study, the acidity in papayas was reduced during ripening, mainly fruit harvested at maturity and over maturity stage. Adi *et al.*, (2019) reported that the maleic acid content decreases during papaya ripening. However, Seymour *et al.* (2000) concluded that the titratable acidity increases with fruit ripening until approximately 75% of yellow skin.

pH: The maximum pH value (5.26) was recorded in banana harvested at mature stage and the minimum was recorded in banana which is harvested at over mature (4.94) stage (Table 51). The pH has been correlated to maturity index in papaya (Hakkim *et al.*, 2012) and strawberry (ElMasry *et al.* 2007). The high pH at banana harvested at mature stage probably was a result of an increase in the organic acid contents in the fruits (Arvanitoyannis and Mavromatis, 2009).

Ascorbic acid content (mg/100g): The maximum ascorbic acid (9.03 mg/100g) was recorded in banana harvested at mature stage and the minimum was recorded in banana which is harvested at over mature (6.54 mg/100g) stage (Table 51). This result could be explained by the rate of vitamin C which increases naturally during maturation and decreases during the ripening of papaya (Bron and Jacomino 2006). This might be the reason behind the lower vitamin c content found in banana which picked at over mature stage (stage 4) compared to mature stage.

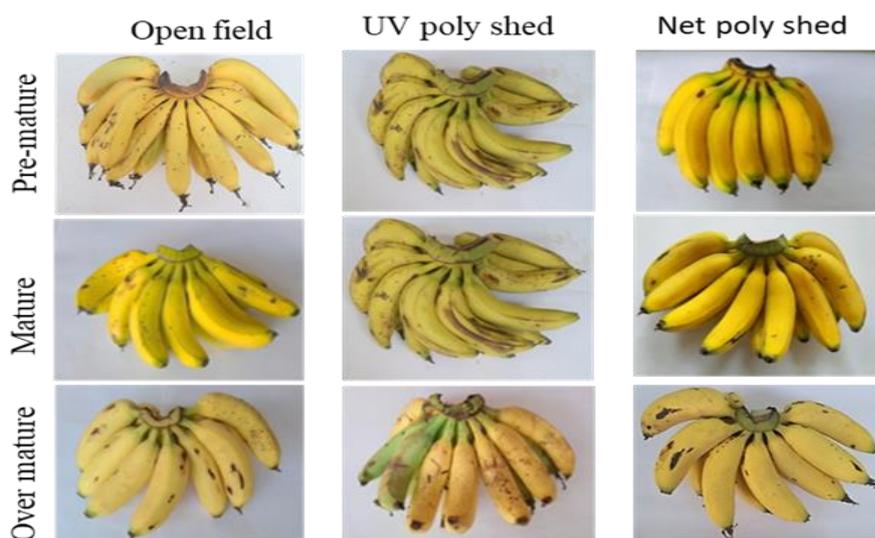


Plate 21: Skin color of banana fruits at edible stage harvested from different shed houses at three maturity stages.

Table 52: Average color values of L*, a* and b* of banana fruits at edible stage harvested from different shed houses at three maturity stages.

Treatment	L*	a*	b*
Maturity indices			
Under mature	65.60 b	9.33 a	45.60 b
Mature	66.43 b	6.97 b	46.71 b
over maturity	70.32 a	7.26 b	50.86 a
LSD _{0.05}	1.40	0.73	1.73
CV%	2.10	9.40	3.65
Different shade			
Open field	70.63 a	7.10 b	48.46 a
UV poly	63.84 c	9.22 a	44.81 b
Poly net house	67.88 b	7.23 b	49.90 a
LSD _{0.05}	1.40	0.73	1.73
CV%	2.10	9.40	3.65
Interaction effect			
T1	72.04 a	6.73 cd	49.45 bc
T2	68.37 c	7.14 cd	47.56 c
T3	71.49 ab	7.43 cd	48.38 bc
T4	60.24 e	11.52 a	40.22 e
T5	62.07 e	9.79 b	43.36 d
T6	69.20 bc	6.36 d	50.86 bc
T7	64.53 d	9.73 b	47.14 c
T8	68.87 c	3.98 e	49.20 bc
T9	70.26 abc	7.99 c	53.36 a
LSD _{0.05}	2.43	1.26	2.99
CV%	2.10	9.40	3.65

T₁= open field +under mature, T₂= open space +mature, T₃= open field + over mature, T₄= UV poly shade + under mature, T₅= UV poly shade + mature, T₆= UV poly shade+ over maturity, T₇= poly net house+ under mature, T₈= poly net house + mature, T₉= poly net house + over maturity

Total sugar: Maturity indices had a significant effect on total sugar content. Total sugar content was higher (22.23%) in fruits harvested at mature stage and the lower content

(20.58%) was recorded in in fruits harvested at over mature stage (Table 51). The results indicated that fruits harvested at mature stage developed better sugar content and other organoleptic characteristics than earlier and later harvested fruits.

Reducing sugar and Non-reducing sugar (%): Maturity indices exposed significant variation regarding the reducing sugar content of banana. It was observed from the results of the present experiment that reducing sugar significantly differed by different maturity indices of banana. Highest reducing sugar (13.54%) was recorded in fruit harvested at mature stage and the lower non-reducing sugar (8.72) was recorded in in fruits harvested at under mature stage (Table 51). However, non-reducing sugar content was higher (10.27%) in fruits harvested at under mature stage and the lower content (8.68%) was recorded in in fruits harvested at mature stage.

Color measurement

Significant changes in colour values (L^* , a^* , b^*) during ripening for the period of were presented in table 52. It can be observed from the table, that the lightness value (L^* value) and yellowness (b^* value) increased during the ripening (Table 52). This might be due to the chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments (Seymour, *et al.*, 1993). The highest L^* and b value was recorded in fruits harvested at over maturity stage i.e. 70.32 and 50.86 respectively and the lower value was recorded in ripen banana harvested at premature stage i.e. 65.60 and 45.60 respectively. The lower value of L^* and b might be due to the development of brown flecks over the peel, spots were observed by Salvador, *et al.*, 2007 on ripening the banana. The maximum a value (greenness) was recorded in ripen fruits harvested at premature stage. The greenness value of banana fruit increased from negative side to positive side. This confirms the de-greening of banana peel. Similar results were reported by Boudhrioua, *et al.*, 2002.

11.18. Effect of Different Planting Materials and Nutrient Management of Banana Fruits

The research work was accomplished for the evaluation of the performance of planting materials of banana against different organic and inorganic fertilizers. Some of the data have been presented in table and others in figure for ease of discussion, comprehension and understanding.

Number of green leaves

The number of fresh leaves was counted during harvesting stage of banana (Table 53). Number of leaves was not found statistically significant by planting materials of banana. However, maximum number of leaves was counted in P_2 (11.66) this could be due to the availability of relatively more stored food material in corm than in tissue culture plantlets. Similar results in respect of number of leaves have been reported earlier (Singh *et al.*, 2000). Minimum number of leaves was counted in P_1 (10.58). The maximum number of leaves (12) was recorded on M_2 (12.00) during harvesting stage and minimum (10.50) was found in M_4 . However, there were no significant differences among the fertilizers. The number of leaves was increased in M_2 due to the presence of plant growth regulating substance in vermicompost and soil biological function improvement (Cristina and Jorge, 2011). Considering combined effects, the total number of leaves (13.00) was counted highest in P_2M_2 and lowest (10.00) in P_1M_1 treatment. P_2M_2 was significantly different from the P_1M_1 , P_1M_4 , P_2M_4 treatments.

Chlorophyll content (SPAD value)

Significant variation was detected between corm and tissue culture plantlets regarding chlorophyll content of leaves. P₂ (47.14) was recorded highest chlorophyll content during harvesting stage and lowest was found in P₁ (45.33) (Table 53). P₂ had the highest SPAD value this could be due to corm propagated bananas captured more sunlight and have maximum reserved food than tissue culture saplings. These findings confirm the results of Uddin *et al.* (2002) and Sharma and Gupta (2003) in gladiolus. Chlorophyll content of banana exposed statistically significant among vermicompost, spent mushroom compost, NPK at harvesting stage. But there was no significant variation between cowdung (M₁; 46.43) and vermicompost (M₂; 48.07). Maximum chlorophyll content was observed in vermicompost treated plants whereas minimum in NPK (M₄; 45.20). Vermicompost is a good source of nitrogen, potassium and phosphorus. N is the chief constituent of chlorophyll, proteins and amino acids, the synthesis of which is accelerated through increased supply of N (Kohli *et al.*, 1980). Vermicompost contains both major and micro nutrients and contributed to the higher level of chlorophyll. Combined effect of planting material and fertilizers showed insignificant variation. Maximum chlorophyll content was found in P₂M₂ (49.15) treatment which was statistically identical with all other treatments.

Pseudo-stem diameter

Stem diameter was measured during harvesting stage of banana. The maximum stem diameter was found in P₂ (64.00) and minimum was found in P₁ (59.87). Corm propagated plants had significantly the highest pseudo-stem diameter (Table 53). This might be due to increased availability of photosynthates due to enhanced growth rate of vegetative plant parts under the treatments of corm. These results are in accordance with those obtained by Sharma and Gupta (2003).

Vermicompost treated plants had the highest pseudo-stem diameter (M₂; 68.16) whereas lowest was found in NPK treated plants (M₄; 56.00). In this research, pseudo-stem diameter was measured during harvesting stage and vermicompost treated plants had the statistically superior pseudostem-diameter among all other treatments. The increase in girth of pseudo-stem by the treatment with vermicompost might be due to the improvement of physical properties of soil, higher nutrients uptake and increased activity of micro-organisms which were manifested in the form of enhanced growth and higher carbohydrates production as explained by Kumar *et al.* (2008) and Hassan *et al.* (2001) in banana. The treatment combination of P₂M₂ (71.00) significantly increased the pseudo-stem diameter of banana and statistically different from all other treatment combinations. The lowest was measured in P₁M₄ (55.00).

Table 53: Effect of different fertilizers and planting materials on plant growth of banana

Treatments	No. of green leaves	Chlorophyll (SPAD value)	Pseudostem diameter (cm)
Planting material			
Tissue culture P ₁)	10.58 a	45.33 b	59.87 b
Corm (P ₂)	11.66 a	47.14 a	64.00 a
LSD _{0.05}	1.089	1.732	1.833
CV%	11.31	4.33	3.42
Fertilizer			
Cowdung (M ₁)	11.00 a	46.43 ab	63.25 b

Vermi compost (M ₂)	12.00 a	48.07 a	68.16 a
Mushroom spawn (M ₃)	11.00 a	45.23 b	60.33 c
NPK (M ₄)	10.50 a	45.20 b	56.00 d
LSD _{0.05}	1.540	1.33	1.42
CV%	2.31	2.449	2.593
Combination			
P ₁ M ₁	10.00 b	46.56 ab	60.00 cd
P ₁ M ₂	11.00 ab	49.15 a	65.33 b
P ₁ M ₃	11.00 ab	46.30 ab	59.16 cd
P ₁ M ₄	10.33 b	46.80 ab	55.00 e
P ₂ M ₁	12.00 ab	46.30 ab	66.50 b
P ₂ M ₂	13.00 a	49.15 a	71.00 a
P ₂ M ₃	11.00 ab	46.30 ab	61.50 c
P ₂ M ₄	10.66 b	46.80 ab	57.00 de
LSD _{0.05}	2.178	1.464	1.667
CV%	11.31	4.33	3.42

P₁M₁ = cow dung+ Tissue culture, P₁M₂ = vermicompost+ Tissue culture, P₁M₃= Spent mushroom compost+ Tissue culture, P₁M₄ = NPK+ Tissue culture, P₂M₁= cow dung+ Corm, P₂M₂= vermicompost +corm, P₂M₃ = Spent mushroom compost+ corm, P₂M₄= NPK + corm

Table 54: Effect of different fertilizers and planting materials on yield contributing parameters of banana

Treatment	Days to inflorescence initiation	Days to maturation	Length of inflorescence (cm)	1 st hand to last hand length (cm)	Total no. of hands	Total no. of fingers	Individual fruit weight (g)
Planting material							
Tissue culture (P ₁)	7.03 b	4.48 b	124.10 b	62.75 b	7.66 b	108.93 b	168.75 a
Corm (P ₂)	7.70 a	5.16 a	136.77 a	72.75 a	8.33 a	121.36 a	139.00 b
LSD _{0.05}	0.201	0.290	5.21	3.637	0.612	4.973	4.873
CV%	3.16	6.95	4.62	5.40	8.84	4.99	3.66
Fertilizer							
Cow dung (M ₁)	7.23 b	4.76 ab	140.50 a	70.25 b	8.00 b	116.50 b	159.33 a
Vermicompost (M ₂)	7.56 a	4.83 ab	143.17 a	80.00 a	9.16 a	134.87 a	164.17 a
mushroom spawn (M ₃)	7.31 ab	4.61 b	116.02 b	59.25 c	7.66 b	107.83 c	134.50 b
NPK (M ₄)	7.36 ab	5.09 a	122.05 b	61.50 d	7.16 b	101.39 c	157.50 a
LSD _{0.05}	0.284	0.410	7.369	4.88	0.865	7.03	6.892
CV%	3.16	6.95	4.62	5.40	8.84	4.99	3.66
Combination							
P ₁ M ₁	6.83d	4.70 c	137.33 bc	65.00 cd	8.00 bc	112.00 cd	176.67 ab
P ₁ M ₂	7.30 bc	4.60 c	132.33 c	71.00 bc	8.33 b	123.07 b	185.3 a

Treatment	Days to inflorescence initiation	Days to maturation	Length of inflorescence (cm)	1 st hand to last hand length (cm)	Total no. of hands	Total no. of fingers	Individual fruit weight (g)
P ₁ M ₃	6.96cd	3.90 d	110.71 f	57.00 e	7.33 bc	101.67 e	138.00 cd
P ₁ M ₄	7.03 cd	4.75 c	116.00 ef	58.00 e	7.00 c	99.00 e	175.00 b
P ₂ M ₁	7.50 ab	4.83 bc	143.67 ab	75.50 b	8.00 bc	121.00 bc	142.00 c
P ₂ M ₂	7.83 a	5.06 abc	154.00 a	89.00 a	10.00 a	146.67 a	143.00 c
P ₂ M ₃	7.80 a	5.33 ab	121.33 de	61.50 de	8.00 bc	114.00 bc	131.00 d
P ₂ M ₄	7.70 ab	5.43 a	128.10 cd	65.00 cd	7.33 bc	103.78 de	140.00 cd
LSD _{0.05}	0.402	0.580	10.42	6.507	1.223	9.946	9.74
CV%	3.16	6.95	4.62	5.40	8.84	4.99	3.66

P₁M₁ = cow dung+ Tissue culture, P₁M₂ = vermicompost+ Tissue culture , P₁M₃ = mushroom span+ Tissue culture , P₁M₄ = NPK+ Tissue culture, P₂M₁ = cow dung+ Corm, P₂M₂ = vermicompost +corm, P₂M₃ = mushroom spawn+ Corm, P₂M₄ = NPK + corm

Days to inflorescence initiation

Significant variation in respect of days (from days after planting of corm and transplantation of tissue culture plantlets) taken for inflorescence initiation (visual observation) was observed between the planting materials of banana. Longest period was required for P₂ (7.70) whereas shortest period for P₁ (7.03) (Table 54). The earlier inflorescence initiation in tissue culture plants might be due to the faster development of the tissue culture plants compared with corm propagated plants reported by (Hwang *et al.*, 1984), would have contributed to the shorter crop cycles reported with Tissue culture plants (Robinson *et al.*, 1993). Days to inflorescence initiation was not significantly affected by different fertilizers. However, inflorescence initiation was earliest in cowdung (M₁; 7.23) treated plants and maximum days required for vermicompost (M₂; 7.56) treated plants. Findings of Dauda (2003) who observed that each increase in cowdung manure rate significantly increased plant growth. Thus requires less days to inflorescence initiation. Considering the combined effect of planting materials and fertilizers, minimum days were required in M₁P₁ treatment and maximum days were required in P₂M₂ treatment.

Days to maturation

The maturity period, measured in number of days, from planting to physiological maturity followed the same pattern as the time of inflorescence initiation. The plants that matured earliest were those that had the shortest number of days to flowering and vice versa. Significant variation in respect of days taken for maturation was observed between the planting materials of banana. Longest period was required for P₂ (5.16) whereas shortest period for P₁ (4.48) (Table 54). Shortest days required for maturation of banana for tissue culture plants due to root system, originating from juvenile rhizome tissue (Preece, 1991), and the large initial leaf area, enabled tissue culture plants to reach full assimilation potential at an earlier stage of development, with a doubling of both mean functional leaf area and total dry-mass production compared with corm propagated plants. Maturation of banana was taken minimum days in spent mushroom compost (M₃; 4.61) treated plants which was statistically same with M₁ and M₂ treatments and maximum days was required in NPK treated plants (M₄; 5.09). The rapid growth of banana on organic fertilizer treated plants resulted in early flowering and maturity. This means adequate fertilization of the soil leads to shorter growing and reproductive cycle culminating in more frequent harvesting (Mintah *et al.*, 2017). The earliness of the plants on manipulated soils to flower, fruit and mature is an indication of

balanced nutrient composition, especially in terms of Nitrogen, Phosphorous and Potassium. The organic treatments were the first to produce mature fruits. The treatment combination of P₁M₃ (3.90) significantly lowest the days to maturation of banana and statistically different from all other treatment combinations. The maximum days required in P₂M₄ (5.43) treatment.

Length of inflorescence (cm)

The maximum inflorescence length was found in P₂ (136.77) treatment whereas minimum length was found in P₁ (124.10) treatment. P₂ was significantly different from P₁ treatment (Table 54). This indicates the rate of growth is more in corm propagated bananas than tissue culture plants. This agrees with the findings of Joab (2004) and Ogero (2012). Vermicompost treated plants had the highest inflorescence length of banana (M₂; 143.17) but M₂ was statistically same with M₁ (140.50) treatment. The minimum length was found in M₃ (116.02) treatment. Vermicompost has high microbial activity due to presence of fungi, bacteria and actinomycetes (Tomati *et al.*, 1988). Microorganisms like bacteria, fungi, yeast, actinomycetes and algae can produce plant growth regulators (PGRs) such as auxins, gibberellins, cytokinins, ethylene and abscisic acid (Frankenberger and Arshad, 1995). Vermicompost affected positively on the length of inflorescence of banana ultimately increased yield. The treatment combination significantly affected the inflorescence length. P₂M₂ (154.00) had the maximum inflorescence length and minimum was found in P₁M₃ (110.71). P₂M₂ was significantly different from each other.

First hand to last hand length (cm)

Corm propagated banana plants gave the highest length from first hand to last hand (P₂; 72.75 cm) comparing with tissue culture plants P₁ (62.75 cm) during the experimentation. P₂ was significantly different from P₁ treatment (Table 54). Tealolia *et al.* (2014) observed that banana bunch yield was strongly correlated with plant girth and its contribution to variation in yield. Plant girth was maximum in corm propagated plants (64.00 cm) which may be the reason for corm propagated plants had maximum length from first hand to last hand, ultimately increased yield. Length from first hand to last hand of banana significantly affected by the fertilizers. The maximum length was found in M₂ (80.00 cm) and minimum was found in M₃ (59.25 cm). Vermicompost is the rich source of humic acids (Arancon *et al.*, 2005) and micro and macronutrients (Fernández-Luqueno *et al.*, 2010). Plant-available form of nitrogen (nitrate) is greater in vermicompost. Increase in N levels, microbial activity on adding vermicompost leads to greater root expansion, which in turn leads to greater uptake of nutrients, water and rate of photosynthesis, ultimately leading to high yield (Taleshi *et al.*, 2011). Vermicompost affected positively on the length from first hand to last hand of banana. Combined effect of planting material and fertilizers also exposed significant variation. The highest length of first hand to last hand was measured in P₂M₂ (89.00 cm) treatment whereas minimum was found in P₁M₃ (57.00 cm).

Total no. of hands

Highest number of hands recorded by the treatment P₂ (8.33) which was significantly higher than P₁ (7.66) (Table 54). This might be due to corm propagated plants are more adaptable to the field conditions because they are photosynthetically active hence produce more bunch and number of hands, while tissue cultured plants are partially photosynthetic and hence are very delicate and do not establish easily under field conditions (Tenkouano *et al.*, 2006). Among the fertilizers, vermicompost treated plants had the highest number of hands (M₂; 9.16). M₂ was significantly different from all other treatments. Lowest number of hands was counted in M₄ (7.16) treatment although it was statistically same with M₁ and M₄ treatments. The increase in hands number in vermicompost treatment may be attributed to increase in level of

readily converted available form of essential micro & macro nutrient in the presence of either dead or live worms and offered growth mechanism in plants, resulting in increased yield parameters. Vermicompost has also beneficial effects on physical and chemical soil structure and water up take, resulting in improving plant growth and productivity. The present findings are supported with the results reported by Shukla *et al.* (2014) in guava, Hussain *et al.* (2015) in banana and Kundu *et al.* (2015) in Ber. The maximum number of hands was found in P₂M₂ (10) whereas minimum hand numbers was counted in P₁M₄ (7.00). P₁M₄ had no significant variation with P₁M₁, P₁M₃, P₂M₁, P₂M₃, P₂M₄ treatments.

Total no. of fingers

Highest number of fingers was recorded in the treatment P₂ (121.36) which was the treatment combination P₂M₂ (10.00) significantly increased the total no of Significantly higher than P₁ (108.93) (Table 54). Undeniably the leaves produce photosynthates which are utilized to develop the reproductive parts as a site of storage for future perpetuation. In banana plant the number of leaves present at the time of shooting decides the bunch size, bunch weight and the finger characteristics (Suryanarayana *et al.*, 2018). The data revealed that corm propagated bananas had the highest number of leaves during shooting hence produce more photosynthates thus, increased finger number. Among the fertilizers, vermicompost treated plants had the highest number of fingers (M₂; 134.87). M₂ was significantly different from all other treatments. Lowest number of fingers was counted in M₄ (101.39) treatment, however it was statistically same with M₃ (107.83) treatments. The effect of vermicompost on number of fingers could be attributed to their role on the availability of elements as constituent of proteins and other compounds, which produce the new tissues through their role as constituents of the nucleic acid DNA and RNA. The treatment combination P₂M₂ (146.67) significantly increased the total no of hands whereas minimum hand numbers was counted in P₁M₄ (99.00).



Plate 22: Banana fruits grown with different fertilizers and planting materials

Individual fruit weight (g)

It was observed from the results of the present experiment that planting material significantly differed by means of the individual fruit weight. Maximum fruit weight of banana was observed in P₁ (168.75 g) (Table 54). Tissue culture plants have several leaves already present at the time of planting. Theoretically therefore, tissue culture plants have more leaf area, resulting in active photosynthetic rate and dry matter accumulation rate, ultimately increased fruit weight of bananas (Robinson *et al.*, 1993). Fertilizers had no significant variation regarding individual fruit weight. However maximum fruit weight was recorded in M₂ (164.17g) and minimum fruit weight value was found in M₃ (134.50g). Vermicompost has rich nutrient content and leading to increase uptake of NPK (Wani *et al.*, 2012) which help the plant to get adequate food and nutrients thus may help to enhance the fruit weight. The treatment combination P₁M₂ (185.3g) significantly increased weight of individual fruit whereas minimum was found in P₂M₃ (131.00 g).

Total soluble solid

Total soluble solid content in fruits was higher (21.73^oBrix) in P₂ which make the fruits sweeter and acceptable. P₂ is significantly different from P₁ (Table 55). Total soluble solid was higher in corm propagated plants due to Translocation and mobilization of assimilates are more in corm thereby making fruits sweeter (Kumar and Gill, 2010). Organic manures had no significant variation regarding TSS content of banana. However, the maximum TSS content was recorded in M₂ (22.09 ^oBrix). The minimum TSS was found in T₄ (19.08 ^oBrix). NPK was significantly different from the organic manures. The increased total soluble solid were due to the addition of different organic manures to the soil and in turn to plants, which might had enhanced the biosynthesis and translocation of carbohydrates into fruits (Athani and Hulamni, 2000). The combination of treatments in respect of TSS content of banana had significant variation. The highest content of TSS was found in P₂M₂ (23.11 ^oBrix) and lowest TSS content was recorded in P₁M₄ (18.00 ^oBrix).

pH

Variations in pH of bananas under different planting materials were observed during quality analysis of banana. The pH values under planting materials showed significant variation. The highest (5.04) pH value was recorded in P₂ and lowest value was recorded in P₁ (4.82) (Table 55). The pH has been correlated to planting material in banana (Lebrum, 2008; Hakkim *et al.*, 2012) and strawberry (ElMasry *et al.*, 2007). The high pH in corm propagated plants probably was a result of an increase in the organic acid contents in the fruits (Arvanitoyannis and Mavromatis, 2009). Among the fertilizers, cowdung treated plants had the highest pH value (M₁; 5.06) followed by M₂ (5.04) and they were statistically same. The lowest value was found in M₄ (4.74). Water-soluble organic carbon was enhanced by the addition of cowdung. Qualities such as the vitamin C, pH, soluble sugar contents in fruit were significantly positively correlated with water-soluble organic carbon, indicating that banana fruit quality could be improved by adding vermicompost and cowdung (Wang *et al.*, 2017).The treatment combination P₂M₁ (5.32) significantly increase the pH values whereas minimum was recorded in P₁M₄ (4.62).

Table 55: Effect of different fertilizers and planting materials on quality parameters of banana

Treatments	TSS (^o Brix)	p ^H	TA (%)	Vitamin C (mg/100g)	Total sugar (%)	Reducing sugar (%)
Planting material						

Treatments	TSS (°Brix)	p ^H	TA (%)	Vitamin C (mg/100g)	Total sugar (%)	Reducing sugar (%)
Tissue culture (P ₁)	20.65 b	4.82 b	0.62 a	11.87 a	22.97 a	13.67 b
Corm (P ₂)	21.73 a	5.04 a	0.52 b	10.24 b	25.10 a	15.12 a
LSD _{0.05}	0.388	0.081	0.043	0.744	0.829	0.289
CV%	2.12	1.90	8.81	7.78	3.99	2.32
Fertilizer						
Cow dung (M ₁)	21.66 a	5.06 a	0.53 b	11.36 b	24.37 b	16.11 a
Vermicompost (M ₂)	22.09 a	5.04 a	0.52 b	8.00 c	26.27 a	14.94 b
Mushroom spawn (M ₃)	21.94 a	4.87 b	0.56 b	10.79 b	22.69 c	13.71 c
NPK (M ₄)	19.08 b	4.74 c	0.68 a	14.08 a	22.82 c	12.81 d
LSD _{0.05}	0.548	0.114	0.062	1.05	1.173	0.409
CV%	2.12	1.90	8.81	7.78	3.99	2.32
Combination						
P ₁ M ₁	20.22 d	4.80 d	0.64 b	12.48 b	23.44 d	14.85 bc
P ₁ M ₂	21.55 c	5.08 b	0.53 cd	8.32 d	25.58 ab	14.84 bc
P ₁ M ₃	22.86 ab	4.77 de	0.58 bcd	11.34 bc	21.62 e	13.10 e
P ₁ M ₄	18.00 e	4.62 e	0.74 a	15.36 a	21.24 e	11.88 f
P ₂ M ₁	22.33 b	5.32 a	0.42 e	10.24 c	25.30 bc	17.38 a
P ₂ M ₂	23.11 a	5.00 bc	0.51 de	7.68 d	26.96 a	15.03 b
P ₂ M ₃	21.33 c	4.98 bc	0.55 cd	10.24 c	23.76 cd	14.32 c
P ₂ M ₄	20.16 d	4.86 cd	0.62 bc	12.80 c	24.39 bcd	13.74 d
LSD _{0.05}	0.77	0.162	0.087	1.489	1.659	0.578
CV%	2.12	1.90	8.81	7.78	3.99	2.32

P₁M₁ = cow dung+ Tissue culture, P₁M₂ = vermicompost+ Tissue culture , P₁M₃ = mushroom spawn+ Tissue culture , P₁M₄ = NPK+ Tissue culture, P₂M₁ = cow dung+ Corm, P₂M₂ = vermicompost +corm, P₂M₃ = mushroom spawn+ Corm, P₂M₄ = NPK + corm

Titratable acidity

The maximum titratable acidity was recorded in P1 (0.62%) and minimum was recorded for P2 (0.52%). The effect of planting materials on titratable acidity of banana fruit pulp had significant variation (Table 55). The reduction in titratable acidity increasing the pH values in corm propagated plants might be due to more accumulation of sugar in fruits. The similar results were reported by Keshavan *et al.* (2006) and Tripathi *et al.* (2014) in banana. Organic manures had no significant variation towards titratable acidity of banana fruit pulp. However, maximum titratable acidity was recorded in NPK treated plants (M4; 0.68%). These results are in agreement with those of Hamman *et al.* (2003) as they found that plants received organic source of nutrients had lower titratable acidity compared with using NPK mineral source alone. The combined effect of P₁M₄ (0.74%) had the highest titratable acidity which is significantly different from all other treatments whereas minimum was recorded in P₂M₂ (0.51).

Ascorbic acid content (mg/100g)

The maximum ascorbic acid was recorded in P₁ (11.87) and minimum was recorded in P2 (10.24). The effect of planting materials on ascorbic acid content of banana fruit pulp had significant variation (Table 55). The decrease in ascorbic acid in corm propagated bananas

may be due to increase in accumulation of more assimilate or total soluble solids in corm propagated bananas compared to tissue culture (Seema *et al.*, 2018). The maximum ascorbic acid content was recorded in NPK treated plants (M₄; 14.08) whereas minimum was recorded in M₂ (8.00). M₄ was statistically superior over M₁, M₂ and M₃ treatments. The improvement in quality characteristics including ascorbic acid content by application of optimum dose of NPK may be explained by the fact that phosphorus enters into the composition of phospholipids and nucleic acids, the latter combines with proteins and result in the formation of nucleoproteins which are important constituents of the nuclei of the cells. Similar results have also been reported by Singh *et al.* (2008) and Shukla *et al.* (2014) in guava. The combined effect of P₁M₄ (15.36) had the highest titratable acidity which is significantly different from all other treatments whereas minimum was recorded in P₂M₂ (7.68).

Total sugar (%)

Total sugar content in fruits was higher (25.10%) in P₂, which make the fruits sweeter and acceptable and lower content was recorded in P₁ (22.97%) (Table 55). However, there was no significant variation between corm and tissue culture plants. Total sugar was significantly found unchanged due to different planting materials (Parmar and Vinod, 2018). Vermicompost significantly increased the total sugar content (M₂; 26.27%). Spent mushroom compost and NPK were statistically same. The minimum total sugar content was recorded in M₄ (22.82%). Higher fruit quality with higher sugar content could be explained due to the better role of the nutrients especially exchangeable potassium available more through vermicompost. The potassium was a major factor in the carbohydrate synthesis, break down and translocation of starch and synthesis of protein and neutralization of physiologically important organic acids (Pandey *et al.*, 2001). The combination of treatment P₂M₂ (26.96%) had the highest content of total sugar followed by P₁M₂ (25.58%) and lowest total sugar content was recorded in P₁M₄ (21.24%).

Reducing sugar (%)

It was observed from the results of the present experiment that planting material significantly differed by means of reducing sugar content. Highest reducing sugar was recorded in P₂ (15.12%) and lowest was recorded in P₁ (13.67%) (Table 55). The differences in reducing sugars and non-reducing sugar content of banana are due to varietal differences and use of different planting materials (Venkata Subbaiah *et al.*, 2013). Fertilizers exposed significant variation regarding the reducing sugar content of banana. The highest reducing sugar content was found in cowdung treated plants (M₁; 16.11%) and lowest was measured in NPK treated plants (M₄; 12.81%). The availability of nitrogen from cowdung might have increased leaf area with higher synthesis of assimilates which is due to enhanced rate of photosynthesis. Such effects have been attributed to increase rate of translocation of photosynthetic products from leaves to developing fruits and thereby increasing reducing sugars in banana. These findings are in agreement with Dey *et al.* (2005). The combined effect of planting materials and fertilizers had the significant effect. The treatment combination P₂M₁ (17.38) had highest reducing sugar content whereas minimum was found in P₁M₄ (11.88%).

Color measurement

Results showed that there was a significant difference among the treatments with organic and inorganic fertilizers (Figure 86). The brightness (L) color was noted from the fruit which had been fertilized with the NPK (64.83) fertilizer. On the other hand, the lowest external lightness was found with organic fertilizer (Cowdung; 50.50) treatment. In a previous study by Crecente-Campo. (2012), similar results were noted where they compared the external color brightness value of the banana fruits and reported low L values for organic and high L*

values for chemical fertilizer. However, in this study, the highest lightness values were obtained while chemical (NPK) fertilizer treatment. The treatment combination had a significant effect in respect of L* values. The highest L* value was found in cow dung+ Tissue culture (69.00) and the lowest L* value was recorded in cow dung+ Corm (48.67). The redness value a* was highest in the treatment of corm (10.83), whereas the lowest a* value was found in the treatment of tissue culture (8.42). The a* value had the significant variation between the planting materials. The highest a* value was found in cowdung (10.50) although it was statistically same with vermicompost and mushroom spawn. The lowest a value was found in NPK (7.67). The treatment combination vermicompost +corm (11.33) had the highest a value and P1M4 had the lowest a value (6.33). vermicompost +corm and NPK+ Tissue culture significantly different from each other. The higher b* value indicates yellow color and was found in tissue culture (45.08) and the lower value was found in the treatment of corm (39.96).

Vermicompost treated plants had the highest b* values (vermicompost; 45.22) followed by cow dung (42.17) and lowest value was found in NPK (41.04). Similar to a* values, the highest b* values were noted from the organic fertilizer treatment. Gulbag and Ilgin (2016) similarly investigated the effects of organic and inorganic nutrients on strawberry cultivars. In that study, researchers found that the highest b* value was obtained from the ‘Elsanta’ cultivar treated with vermicompost, the lowest b* value was obtained from the inorganic treatments. The treatment combination vermicompost+ Tissue culture (50.33) had the highest b* value followed by cow dung+ Tissue culture (46.00) and P2M4 had the lowest b* value (38.33). vermicompost+ Tissue culture and NPK + corm significantly different from each other. There was a significant variation in chroma values of planting materials. The higher Chroma value was found in tissue culture (46.25) and the lower value was found in the treatment of corm (40.25). Vermicompost treated plants had the highest chroma values (vermicompost; 45.46) followed by cowdung (43.83) and lowest value was found in NPK (41.98). They had no significant variation in chroma values. There was no significant variation among the treatment combination regarding the chroma value of banana. However, the highest chroma value was observed in vermicompost+ Tissue culture (50.67) and lowest was found in NPK + corm (40.25).

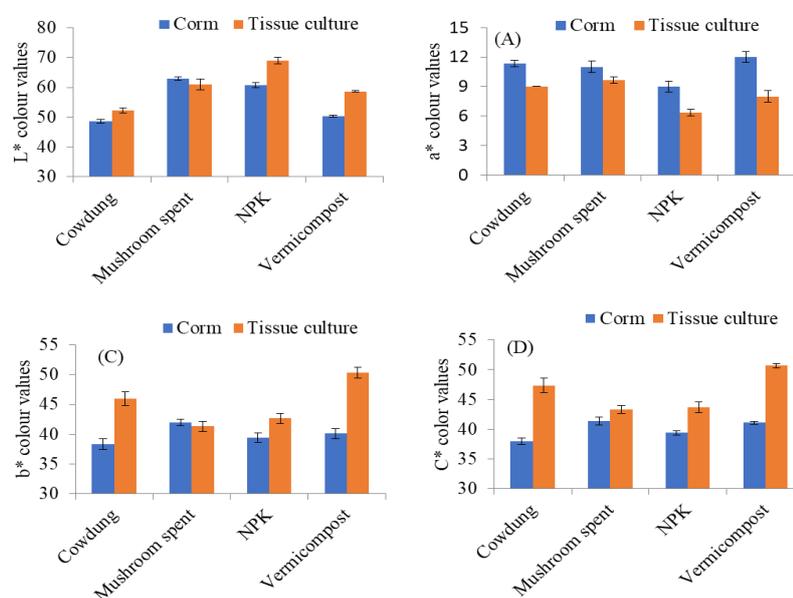


Figure 86: Average color values of L* (A), a* (B), b* (C) and C* (D) of banana fruits at edible stage grown with different fertilizers and planting materials. Mean \pm Standard error (S.E.). P₁M₁ = cow dung+ Tissue culture, P₁M₂ = vermicompost+ Tissue culture , P₁M₃ = mushroom spawn+ Tissue culture , P₁M₄ = NPK+ Tissue culture, P₂M₁ = cow dung+ Corm, P₂M₂ = vermicompost +corm, P₂M₃ = mushroom spawn+ Corm, P₂M₄ = NPK + corm

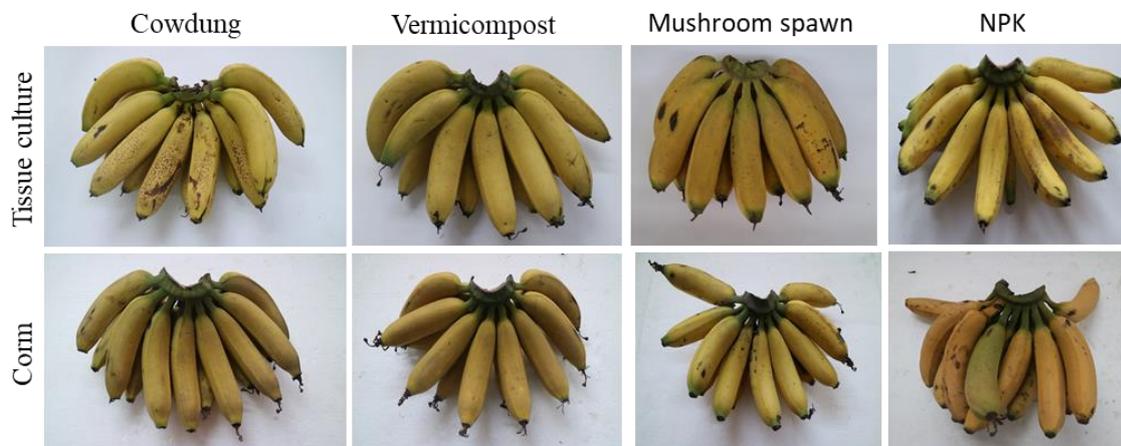


Plate 23: Skin color of banana fruits at edible stage as influenced by planting materials and manures

11.19 : Yield and Quality of Dragon Fruits as Influenced by Different Protective Cultivation Approaches

Yield condriduting Parameters

Different growing conditions (Table 56) significantly influenced the days to flowering. It was found that the maximum number of months for flowering (30) was recorded in UV poly shed conditions, whereas the minimum number of months for flowering was recorded (27) for the plants grown under net poly shed house. The number of fruits/three plants/pole was significant among the shed houses (Table 56). The net poly shed house had the most fruits (11), while the UV poly shed had the fewest (3). In this experiment, higher temperatures might have reduced flower formation and fruit yield of the plants grown in poly and UV poly sheds. Likewise, Gaurav *et al.* (2015) showed that high temperatures (above 32 °C) have a negative impact on fruit set in dragon fruit, decreasing yield. Plants cultivated in favorable conditions may have a higher rate of photosynthesis, which may explain their increased growth and fruit set.

Table 56: Comparison of flower initiation and fruit characteristics at harvest

Different growing condition	Flower initiation (MAP)	No. of fruits/three plants/pole	Fruit length (cm)	Fruit breadth (cm)	Individual fruit weight (g)	Yield(g/ Three plant)	BCR
Open field	28.00 ab	4.00 bc	8.26 b	6.36 b	216.00 c	856.3c	1.4c
UV poly shed	30.00 a	3.00 c	6.63 c	4.90 c	111.40 d	326.2d	0.7c
Net poly shed	27.00 b	11.00 a	9.60 a	7.23 a	288.67 a	3180.3a	5.9b
Net House	28.00 ab	5.00 b	9.20 a	5.50 c	252.33 b	1259.7b	2.6a
LSD _{0.05}	2.49	1.88	0.562	0.78	12.69	2.25	1.1
CV%	4.68	7.39	3.54	6.91	4.57	8.96	3.8

MAP= Months after planting; BCR= Benefit cost ratio

Different growing environments showed significant variation in fruit length, breadth and individual fruit weight (Table 2). The maximum fruit length (9.60 cm) and breadth (7.23 cm) were recorded in plants grown under net poly shed and the minimum fruit length (6.63 cm) and breadth (4.90 cm) were recorded in UV poly shed. The individual fruit weight was found maximum in the net poly shed (288.67 g/plant) whereas the individual fruit weight was observed minimum in the UV poly shed (111.40 g/fruit) (Table 56). Fruit yield was found maximum in the net poly shed (3180.3 g/three plant) whereas the fruit yield was observed minimum in the UV poly shed (326.2 g/three plant) (Table 56). Fruit length, breadth and individual fruit weight could be affected by changes in environmental conditions beneath protective netting. 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 56). In the present result, favourable environmental conditions, such as optimum temperature and humidity, were recorded in net poly house (Table 56), which resulted in faster fruit growth throughout the season. Fruit weight and yield were found to be linearly related to the percentage of favorable environmental conditions (Temperature, humidity and light) received by trees (Bastias *et al.*, 2011). Higher temperatures are likely to play an important role in limiting growth and fruit development by reducing photosynthetic activity and increasing the rate of respiration (Silva *et al.*, 2019). The benefit cost ratio of strawberry production in open field, UV poly shed, net poly shed and net house was estimated as 1.3, 1.0, 2.9 and 1.5 respectively (Table 23).

Quality Parameters

High fruit quality is associated with low juice pH. The juice pH values of dragon fruits cultivated in UV poly shed and net house showed no significant variations. The lower juice pH was found in the UV poly shed (4.89), preceded by net house (4.92), and the higher juice pH was found in fruits grown in net poly shed house (5.2) (Table 57). However, determining fruit acidity at complete maturation, when acidity decreases, is a possible explanation for the low values. The increase in wild plum fruit juice pH with increasing storage temperature was attributed to the increased level of fruit ripening. According to the authors, pH reduction may be due to the accumulation of organic acids, and pH increase to the consumption of organic acids during fruit ripening, as they are used as a substrate in respiration or converted into sugars (Emongor and Ramagonono, 2019).

The total soluble solids content of the fruit responded significantly differently to the different shed houses (Table 57). The total soluble solids were maximum in the fruits obtained from the plants grown under net poly shed house (15.6 °Brix), whereas a minimum was recorded from the plants cultivated in the net house (10.6 °Brix). The increase in the content of soluble solids is a good indicator of maturation and taste of fruits (Lima *et al.* 2014). The increase in TSS content at proper maturation under net poly shed house is possibly due to starch degradation and quick metabolic transformation in soluble compounds, mainly sugars due to the congenial micro-climatic conditions (Patel *et al.*, 2014). We found that the fruits produced in the net house are less acidic than the fruits produced in other growing environments. The higher titratable acidity (0.44%) was found in net house followed by the UV poly shed condition (0.40%), and the lowest titratable acidity was found in the fruits grown in net poly shed conditions (0.34%) (Table 57). In the present investigation, a decrease in percent titratable acidity was found during ripening, which is similar to the findings of (Yanagi *et al.*, 1995). The results of the study revealed that the minimum titratable acidity in the juice of dragon obtained from net house might be due to the high sugar content present in the fruit

and the more edible portion of the fruit. (Selvaraj *et al.*, 1982) stated that the titratable acidity also increases with shading.

Table 57: Average content of pH, total soluble solid, titratable acidity, ascorbic acid, anthocyanin content, reducing sugar, non-reducing sugar and total sugar of dragon fruits grown under different sheds and open field condition.

Treatments	pH	TSS (°Brix)	TA (%)	Ascorbic acid (mg/100g)	Anthocyanin (mg/100g)
Open Field	5.02 b	12.33 c	0.36 ab	78.14 b	36.097 c
UV Poly shed	4.89 c	14.00 b	0.40 ab	84.86 a	39.63 b
Net Poly shed	5.20 c	15.66 a	0.34 b	78.59 b	42.12 a
Net House	4.92 c	10.66 d	0.44 a	84.35 a	33.69 d
LSD _{0.05}	0.05	1.59	0.10	1.90	1.43
CV %	0.60	6.07	8.14	3.40	1.90

The highest ascorbic acid content was found in the UV poly shed house (84.86 mg/100 g), followed by net house conditions (84.35 mg/100 g), and the lowest ascorbic acid was found in the fruits grown in the open field (78.14 mg/100 g) (Table 57). (Koley *et al.*, 2013) investigated quality parameters of tomato under protected conditions and found significantly higher vitamin C in the fruit produced under protected structures. In our study, the fruits grown in the UV poly shed and poly shed showed lower quantity of vitamin C content. An adequate supply of hexose sugars in photosynthetic activity might explain the higher availability of ascorbic acid under UV poly shed house, while enzymatic oxidation of the L-ascorbic acid to dehydro-ascorbic acid during the metabolic process explains the reduction in ascorbic acid content (Neeraj and Bhatia, 2002). Moreover, growing conditions, agro-climatic conditions, orchard management, maturation stage, and post-harvest handling may also strongly influence vitamin C content in fruits (Lee and Kader, 2000). Reduction in vitamin C content of other fruits were also reported by various workers in peach (Guizani *et al.*, 2019) and banana, mango, papaya (Siriamornpun and Kaewseejan 2017).

The highest anthocyanin content was found in the net poly shed house (42 mg/100 g) and the lowest ascorbic acid was found in the fruits grown in the open field (33.50 mg/100 g) (Table 57). Soluble sugars were the anthocyanin donor substrates and acted as signaling molecules in the anthocyanin system (Zheng *et al.*, 2009). Additionally, organic acids contribute to the stability of anthocyanins and the positive correlation between organic acids and anthocyanins was reported (Hara *et al.*, 2003). Soluble sugars and organic acids also play an important role in the formation of fruit anthocyanin (Ubi *et al.*, 2006). Hence, the contents of 12 sugars and sugar alcohols, and 9 organic acids at different pitaya fruit developmental stages were demonstrated, and their correlation with betalain formation was assessed.

Reducing, non-reducing and total sugar Content

The reducing sugar content was significantly variable depending on the shading conditions. The reducing sugar content in the plants grown under the UV poly shed was the highest (8.6%) whereas the reducing sugar content in dragon fruits in the net house was the lowest (6.8 %) (Table 57). Voca *et al.* (2009) revealed that strawberry fruits grown under a tunnel had higher levels of reducing sugar than open field produced fruits. The increase in reducing sugar could be attributed to enhanced PAR absorption (Funke *et al.*, 2005) and improved light utilization in the apple orchard which could result in more export of leaf carbohydrate (Johnson and Lakso, 1986). There were significant differences between different growing

environments in non-reducing sugar contents (Figure 3B). The highest non-reducing sugar content was seen in the plants grown in net poly shed house (11%), while the lowest non-reducing sugar content was observed in the net house (6.95%) (Table 57).

There was a significant response in the total sugar content of the fruits to the different shed houses (Table 57). The fruits obtained from the net poly shed house had the highest total sugar content (19.33%), while the fruits obtained from the net house house had the lowest total sugar content (13.66%). This rapid increase in sugar content under net poly shed house is believed to occur due to hydrolysis of starch into simple sugars and also the conversion of acids into sugar. The increase in total sugar content during fruit maturity is also depending on sucrose accumulation (Burger and Schaffer, 2007). The increased TSS might have also caused an increase of total sugar.

Color Measurement

Distinct variation was noted in the fruit color of dragon fruit as influenced by the different shed houses (Table 57 & plate 24 A-D). The higher L* value indicates the lighter color which was found in the fruits grown in the net poly shed (16) and the lower L* value found in the open field (11.5) followed by the net house (12). The redness value a* was highest in the treatment of the net poly house (21), whereas the lowest a* value was found in the treatment of the net house (14). The higher Chroma (c*) value was found in the treatment of net houses (22.45) and the lower value was found in the treatment of open fields (15) followed by the net house (15.70). The numerous seeds embedded in the pulp may partially contribute to appearing a darker color (lower L*) of pulp. There was a clear decrease in b* values with fruit development, which is in agreement with previous studies (Ortiz and Takahashi, 2015) that concluded that this decrease is related to the degradation of peel pigments, such as chlorophyll and carotenoids, throughout maturation.

Table 58: Average content of reducing sugar, non-reducing sugar, total soluble solid, titratable acidity, ascorbic acid, anthocyanin content, reducing sugar, non-reducing sugar and total sugar of dragon fruits grown under different sheds and open field condition.

Treatment	Reducing sugar (%)	Non reducing sugar (%)	Total Sugar (%)	Anthocyanin (mg/100g)	L*	a*	c*
Open Field	7.33 b	7.33 b	14.66 bc	33.50 d	11.53 c	15.65 c	15.00 d
UV Poly shed	8.60 a	8.00 ab	16.33 b	39.63 b	14.95 b	18.40 b	20.35 b
Net Poly shed	8.33 a	11.00 a	19.33 a	42.12 a	16.40 a	21.05 a	21.95 a
Net House	6.80 b	6.95 b	13.66 c	36.097 c	11.85 c	14.80 d	15.60 c
LSD _{0.05}	0.94	3.21	1.85	1.43	0.61	0.64	0.50
CV %	6.12	9.29	5.80	1.90	2.24	1.85	1.40

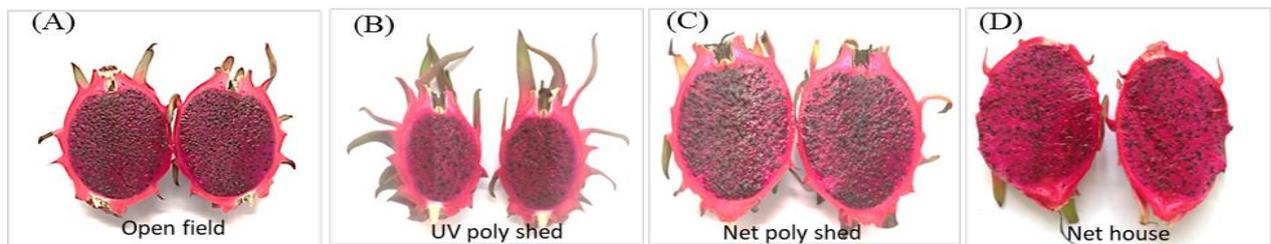


Plate 24: Pulp and peel color of dragon fruits grown under different shed houses (**A:** Open field; **B:** UV poly shed; **C:** net poly shed; **D:** Net house).

Several factors influence fruit color development, including canopy temperature and light intensity (Mditshwa *et al.*, 2019). Compared to open-field dragon fruit, those cultivated in net poly shed had better pulp and peel color. The red pulp color is mainly because of the presence of betamin pigments, which are rich sources of antioxidants with radical scavenging ability (Reddy and Gowda, 2014). Pomegranate fruit grown in the open field has poor color development compared to trees grown under net poly sheds (Meena *et al.*, 2016).

12. Research Highlights

BARI Component

12.1. Effect of Different Net House on Quality Seedling Raising of High Value Vegetables

Background

Vegetables are an important source of food and nutrition. But in Bangladesh vegetable production is much less than the requirement if balanced diet is provided to every individual. The present production of 4.3 million tones is to be raised to 13 million tones (Anonymous, 2020). There are different ways and means to achieve this target, e.g., bringing additional area under vegetable crops, using hybrid seeds, use of improved agro-techniques. Another potential approach is perfection and promotion of protected cultivation of vegetables (Sanwal *et al.*, 2004). During rainy summer season, the temperature and solar radiations are adverse for growing off-season vegetables – tomato, sweet pepper, eggplant, cauliflower, broccoli, lettuce, cucumber, squash, netted melon, water melon. Hence, during extreme conditions of weather these high value vegetables can be well cultivated under protected cultivation structures year-round. Research results have shown that by adopting protected cultivation, productivity of high value vegetable crops can be increased by 3 to 5 times as compared to open environment. Green house, polyhouse, shade net house and low tunnels are the different types of protected cultivation structures commonly adopted by the farmers of developed country.

Quality seedling production is a sector having recently started growing in Bangladesh. Cultivation from seedlings has many advantageous opportunities, such as earlier harvest, utilization of time, economization of land, energy, and seeds, healthy and homogenous production, and warning process for earliness. In order to benefit from these advantages, producers have tended to production not from seeds, but from seedlings, thus increasing their demands for the seedlings of various vegetables. Cultivation from seedlings is much more important in congenial production. Use of vigorous seedlings provides solutions to the worrisome problems of the producers. In order to cultivate healthy seedlings, growing condition is as important as the ecological conditions. Various plant growing condition and dose studies are emphasized in the conducted researches. Efforts should be escalated for establishing, and expanding growing condition, in compliance with the regulations on the production of quality vegetable seedlings, as being an important criterion. It is intended with this study to examine the quality features of the seedlings of the tomatoes and peppers, being produced in different growing condition so as to be utilized in protected production to develop quality vegetable seedlings.

Shadenet house is a framed structure made of materials such as GI pipes, angle iron, wood or bamboo. It is covered with plastics net which are made of 100% Polyethylene thread with specialized UV treatment having different shade percentages. It provides partially controlled atmosphere and environment by reducing light intensity and effective heat during day time to crops grown under it. Hence round the year seasonal and off-season cultivation is possible. Net house nets are used in tropical and subtropical countries for vegetable production (Castellano *et al.*, 2008; Ilic *et al.*, 2012; Kittas *et al.*, 2012). Net house also reduces water requirements and increases irrigation water use efficiency in vegetable crops (Möller and Assouline, 2007). Poly house is a framed structure having 200 micron (800 gauges) UV stabilized transparent or translucent low density polyethylene which creates greenhouse effect

making microclimate favorable for plant growth and development. Structure is large enough to permit a person to work inside. Poly film layer placed beneath shade net (around 1m below shadenet) which increases the temperature during winter & reduces during the summer season. This structure also aims at protect crop from devastating rains. Net house concept of protected house is a concept for protecting the insect. In well framed structure made up of GI pipes covered with 60 mesh nets

To date, there is not much work available on protected cultivation of quality vegetables seedling production in Bangladesh condition. There is an urgent need to assess the quality vegetables seedling production and suitability for different vegetables under protected cultivation structures to meet the growing demand of the vegetables. Thus, the investigation was aimed to determine the efficacy of protected cultivation compared to open field on temperature and water requirement of vegetables during winter season. Since the selected crops viz., tomato, eggplant, sweet pepper , and broccoli are high value vegetables in Bangladesh that is why these vegetables are selected for these types of protected house to get quality seedlings. In this investigation an attempt is made to estimate the best protected cultivation structures for growing quality vegetables seedling production in Bangladesh condition.

Objectives

1. To find out the effect of different net house on seedlings growth
2. To identify the suitable net for growing healthy insect and disease free seedlings

Methodology

Experimental site

The experiment was designed at the research field of the Olericulture Division, HRC, BARI, Gazipur during November to December, 2019. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28 (Annon, 1995). The farm was situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental time.

Treatments and raising of plant materials

Four vegetables varieties viz., tomato- BARI Tomato-15 (V1), eggplant- BARI Hybrid Begun-4 (V2), sweet pepper- BARI Mistimorich-1 (V3), broccoli- BARI Broccoli-1 (V4) and 4 net house treatments [i) UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)] were included in this study. Total 16 treatment combinations were laid out in factorial design with three replications. Four types of vegetables were sown on polypot (12 cm × 10 cm) with fungicide treated seed on 15 November 2019 under four type of net house treatments. The polypots were filled up with fine sandy-loam soil and organic manure with 50:50 ratio. Different cultural operations such as irrigation, weeding, mulching etc. were done as and when needed.

Air temperatures and relative humidity of the experimental area

Average monthly maximal and minimal air temperatures during the season in different structures are shown in Fig 87, while Fig 88 shows that the average relative humidity.

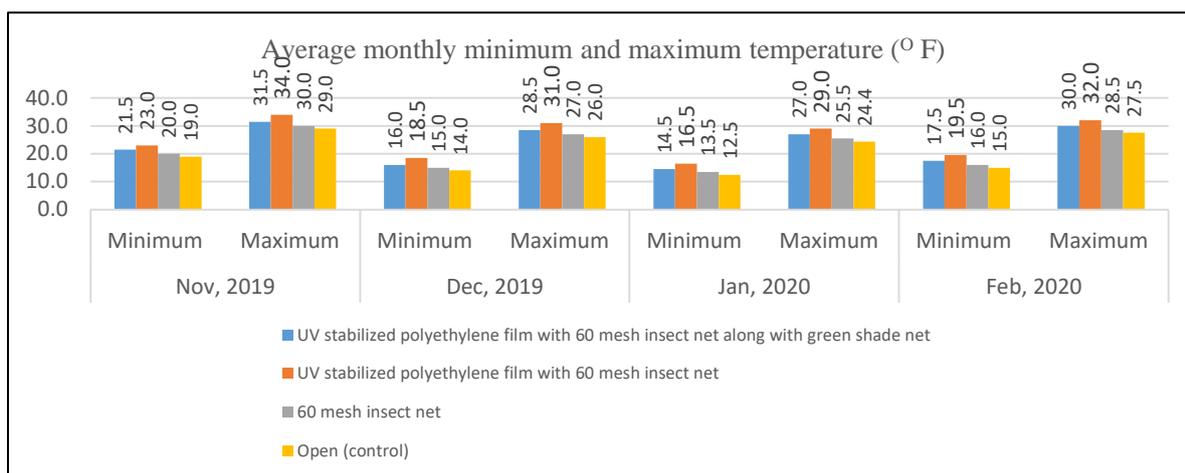


Fig 87. Average monthly minimum and maximum temperature recorded in different protected cultivation structures for winter season.

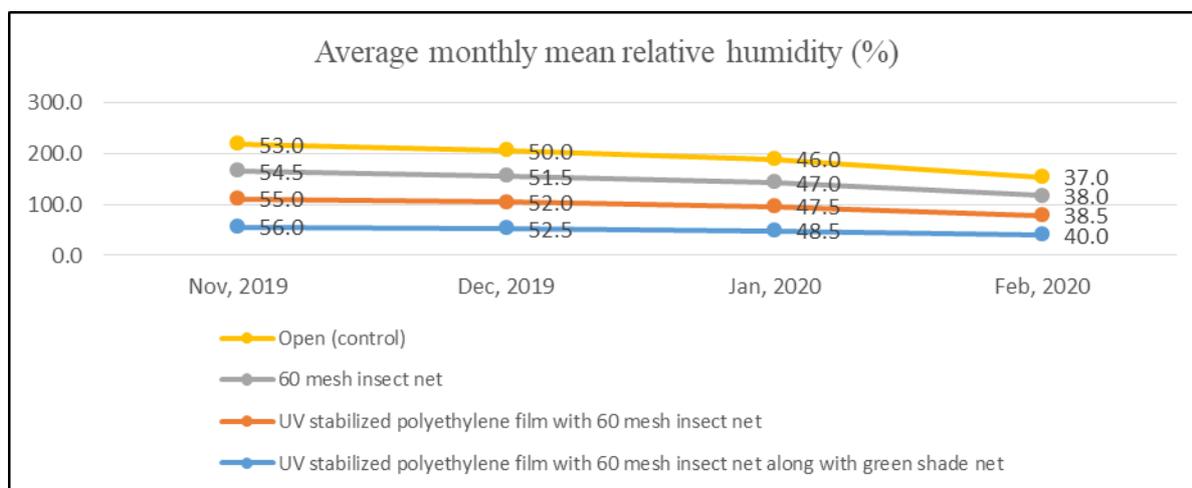


Fig 88. Average monthly relative humidity (%) recorded in different protected cultivation structures for winter season.

Data recorded

Data were collected on seed germination (%), seedling mortality (%), seedling height (at 15DAS, 20 DAS, 25 DAS, 30 DAS), no. of leaves at (at 15 DAS , 20 DAS , 25 DAS , 30 DAS), insect infestation (%) (at 15 DAS , 20 DAS , 25 DAS , 30 DAS), from 5 randomly selected seedling from each of replication.

Statistical analysis

The recorded data for different characters were analyzed statistically using MSTAT-C program to find out the variation among the different genotypes by F-test. Treatment means were compared using Duncan's Multiple Range Test (DMRT) and standard error and coefficient of variation (CV %) were also estimated for each character.

Key findings

Eggplant (V2) resulted the maximum seed germination (93.58%) with lowest mortality (5.58 %), in case of net house treatment, UV stabilized polyethylene film with 60 mesh insect net

along with green shade net (T1) exhibited the maximum seed germination (94.83%) with lower mortality (3.33 %). In case of combined effect, maximum seed germination (93.58%) and lowest mortality (2.08 %) was observed in V2T1.

Key words: Net house, quality seedling raising, high value vegetables

12.2 Effect of Different Mulch Paper on Growth and Yield of Different High Value Vegetables in Bangladesh

Background

Vegetable production is one of the emerging businesses in Bangladesh both in on season and offseason. But the yield of the vegetables is low as compared to the other countries in Bangladesh. Although many efforts had laid out for its improvement the desired level of the expectation cannot be met till now. The present vegetable production is 4.37 million tons from 0.45 million hectares of land (Anonymous, 2020). In Bangladesh, the agriculture sector contributes to about 12.68% of the GDP (Plecher, 2020) and 60% of the working population are directly or indirectly involved in agriculture (Owuor, 2019). The income is quite far better than any other crops i.e. 2-4 times more cash than other crops. Efforts have been made to increase the production per unit area. Vegetables have much importance as economic, nutritional, medicinal, and industrial and also have employment opportunities. It needs 1.5 times more labor than other crops. In order to judicious water use efficiency by the plant and to improve the quality of produce, the use of mulch has become an important cultural practice for the commercial production of vegetable crops. A favorable soil-water-plant relation is maintained by using of mulch over the soil surface. The microclimate condition surrounding the plant and soil is significantly affected by mulch i.e. the physical soil structure, the moisture, the erosion, the thermodynamic environment, the incidence of pests and diseases, crop growth and yield.

Organic mulches are being used traditionally by the farmers. Organic mulches add nutrients to the soil as they decompose, improving its tilth and moisture-holding capacity (Lamont, 2005). The most commonly used organic mulches in Bangladesh are rice straw, wheat straw, a dried maize plant, sugarcane leaves, grass clippings, etc. The use of plastic mulch has brought a considerable change in vegetable production in many countries. In temperate countries the year-round production of vegetables has been possible with the use of plastic mulches. The growing period of crops with a tropical origin have also been extended (Lamont, 2005). The plastic mulch may be transparent, black, red, yellow or others depending on the purpose of the mulch (Rudich *et al.*, 1978). Mulches also help in reducing the fertilizer losses. Since plastic mulch techniques generally include drip irrigation, nutrient loss is kept to a minimum. Nutrients can be injected into the drip system and accurately delivered to the root zone. Mulch also helps reduce the disease incidence. Using mulch increased microbial activity and biomass to the soil and reduced the infestation of diseases of plants in crops such as tomatoes (Abbasi *et al.*, 2002).

Plastic mulch is considered useful for weed control, temperature control, reduced salinity which reduces water loss from the soil due to increased water resistance. Advantages of plastic mulching are weed control, temperature moderation, salinity reduction, which increases the popularity of using plastic mulching in vegetable cultivation (Kumar *et al.*, 2019). In agricultural practices, it is also reported that mulching showed a good impact on good crop growth and yield (Ashworth and Harrison, 1983). It is also reported that grafted

eggplant plastic mulch also gives a higher yield (Rajasekar *et al.*, 2017). To produce quality vegetables and also for earliness with better yield use of plastic mulch is a good option (Raina *et al.*, 1999; Bharadwaj, 2013). Mulching with crop residue like organic mulching is reported to be one of the best options for more yield in crop production likes groundnut and cassava (Chakraborty *et al.*, 2008; Ghosh *et al.*, 2006). Common organic mulches are leaf stubble, maize stalk, paddy straw, husk and water hyacinth, etc. To improve soil properties and add organic matter to the soil organic mulches are used in agriculture on large scale (Memon *et al.*, 2017).

Objectives

To select the suitable mulch paper for quality high-value vegetable production.

Methodology

Experimental site

The experiment site was the farm of Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during November 2019 to March 2020. The field was at 23.9920° N Latitude and 90.4125° E Longitudes, while the elevation was 8.2 m from sea level and situated under the agro-ecological zone (AEZ) 28 (Anonymous, 1995). The site was situated in the sub-tropical climatic zone with scanty rainfall during the time. The average maximum and minimum temperature were 28.3⁰C and 18.4⁰C and the average relative humidity varied from 54.20 to 74.60 %. The soil was sandy clay loam having a pH around 6.0.

Treatments and plant materials

Three types of much paper viz., Silver over black (M1), Black (M2), No much- Control (M3) and 4 types of vegetables viz., tomato (BARI Tomato-15), eggplant (BARI Hybrid Begun-4), sweet pepper (BARI Mistimorich-1) and broccoli (BARI Broccoli-1) were planted under UV stabilized polyethylene film net house. The Experiment was laid out with three replications.

Land preparation and fertilization

The unit plot size was 3.0 x 1.00 m in a RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distance was maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. One third of the organic fertilizer and half of TSP and full of gypsum, zinc and borax were applied during final land preparation. Rest of organic fertilizer and TSP and 1/3 of MoP were applied as basal in pit. After land preparation, the land was covered with mulch paper. Then the proper sized seedlings were transplanted with proper distance. One third of urea and MoP were applied in liquid form after 20 days of transplanting in the hole where the plant is standing. Rest of urea and MoP was applied in equal two installments at flowering and fruiting condition.

Intercultural operation and plant protection

The required agronomic operations viz., irrigation, weeding, mulching, use of stick, crop protection measures and other intercultural operations were done as and when necessary following standard procedure.

Data recorded

Different types of yield and yield contributing data of 4 types of vegetables viz., tomato, eggplant, sweet pepper and broccoli were collected from 5 randomly selected plant from each of replication.

For tomato the traits were- plant height (cm), days to first flowering, days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg), yield (t/ha) and TSS (%).

For eggplant the traits were- plant height (cm), days to first flowering, days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg) and yield (t/ha).

For sweet pepper the traits were- days to first harvest, fruit length (cm), fruit breadth (cm), number of fruits/ plants, average fruit weight (g), yield/ plant (kg) and yield (t/ha).

For broccoli the traits were- days to 50% curd initiation, days to curd harvest, curd length (cm), curd breadth (cm), whole plant weight (kg), only curd wt. (g), marketable curd wt. (g), marketable curd yield (t/ha).

Statistical analysis

The recorded data for different characters were analyzed statistically using MSTAT-C program to find out the variation among the different genotypes by F-test. Treatment means were compared using Tukey's test and standard error and coefficient of variation (CV %) were also estimated for each character.

Key findings

Mulching produced higher fruit yield per plant and fruit yield per hectare than for the control, indicating that the mulch had a positive effect in generating increased fruit yield. Silver over black plastic mulch produced the highest fruit yield viz., 98.05 t/ha (tomato), 54.11 t/ha (eggplant), 34.33 t/ha (sweet pepper), 26.09 t/ha (broccoli) followed by black and no mulches, while the control plot produced the lowest fruit yield due to open condition.

Key words: Mulch paper, high value vegetables, growth and yield

12.3 Effect of Different Type of Nethouse on The Incidence of Insect and Diseases of High Value Vegetables

Background

Protected cultivation is a total concept of modifying the natural environment for optimum plant growth). It comprises the manipulation of environmental factors to some extent to control the crop's growth. It provides a partially controlled atmosphere and environment by reducing light intensity and effective heat during the daytime for crops grown under it. Hence, round the year, seasonal and off-season cultivation is possible. Protective nethouses are used in tropical and subtropical countries for effective vegetable production (Ilic *et al.*, 2012). Vegetable production has undergone many changes in the way it is being grown in different protective nethouses, since different limiting factors, including climatic conditions, availability of water and nutrients, and quality and quantity of light, must be taken into account to provide appropriate conditions for the optimal growth and development of the crop (Sotelo-Cardona *et al.*, 2021). As summarized by Arsovski *et al.* (2012), light affects many developmental and physiological processes, including germination [Bentsink *et al.*, 2008], flowering [Alvarez-Buylla *et al.*, 2010], and direction of growth [Pedmale *et al.*, 2010].

In Israel (which receives 50 mol/m² per day of daily light integral in the summer), the recommended shading was 30% to 60% to achieve satisfactory biomass accumulation (Raveh *et al.*, 1998) and flowering (Khaimov and Mizrahi, 2006). Since the cladodes (shoots) are sensitive to high temperature and strong sunlight in summer, they are prone to sunburn (Chang *et al.*, 2016), (Chu *et al.*, 2015), (Hsu, 2004), (Zee *et al.*, 2004), which may reduce yield (Chen and Lin, 2016). Thus, the use of shade screens in net house can help minimize sunburn (Mupambi *et al.*, 2018) and maximize fruit yield and quality during the natural reproductive period. A preliminary study reported by (Lai, 2017) showed that the use of 32 mesh net house in Taichung, Taiwan, significantly reduced radiation and sooty mold without affecting fruit quality of *H. undatus*. However, the maximum and average air temperatures inside the net house in summer were greater than those in open field, and such environmental conditions are not favorable for the flowering of *H. undatus*. Lower mesh specifications, such as 16 mesh or 24 mesh, may be helpful to combat the heat accumulation problem and provide proper light intensity.

The protective nethouse promotes physiological responses in plant and fruit development by manipulating the spectra of radiation reaching the crops, including leaf area index, chlorophyll and carotenoid contents, tissue structure, fruit ripening, physiological disorders, nutritional quality, and so on (Ilić and Fallik, 2017). High temperatures and high solar radiation, on the other hand, may reduce lycopene and β -carotene levels during tomato production, causing fruit damage, sunscald, and an increase in unmarketable fruit yield (Díaz-Pérez, 2014). In Bangladesh, medium-sized farmers have begun flower and vegetable cultivation under various types of modular protected structures, depending on their investment capacity and market availability in their area. To date, there is not much work available on protected cultivation of quality vegetable production in Bangladesh. There is an urgent need to assess the quality of vegetable production and suitability for different vegetables under protected cultivation structures to meet the growing demand for vegetables.

Objectives

1. To know the incidence of different insect and diseases under different protective nets
2. To produce quality and safe vegetables
3. To ensure good price for the producers and consumers

Methodology

Experimental site

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) from Sep 2021 to Mar 2022. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and was characterized by scanty rainfall during the experimental period.

Air temperatures and relative humidity of the experimental area.

The average temperature and relative humidity for different growing conditions (NH1, NH2, NH3, NH4) during April 2021 to March 2022 were viz., 29.8 °C and 76.3 %; 32.2°C and 72.1%; 27.8°C and 78.2%; and 31.0°C and 76.5%, respectively (Fig 114). The soil of the experimental field was sandy clay loam in texture, having a pH range of around 6.0.

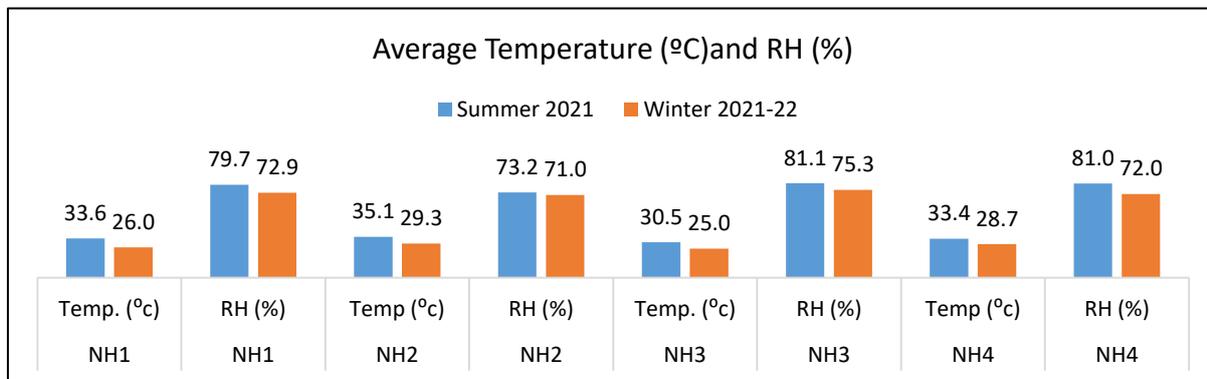


Fig 89. Air temperatures and relative humidity of different growing conditions

Treatments and plant materials

Six vegetables [i] tomato, ii] eggplant, iii] sweet pepper, iv] broccoli, v] cucumber, and vi] okra, as well as four nethouse treatments [i] UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (NH1); ii] UV stabilized transparent polyethylene film with 60 mesh insect net (NH2); iii] 60 mesh insect net (NH3); and iv] Open condition (NH4) were included in this study. A total of 24 treatment combinations were laid out in a factorial design with three replications.

Land preparation and fertilization

The unit plot size was 3.0 x 1.00 m in a RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distances were maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. During final land preparation, one-third of the organic manure, half of the P, and full of S, Zn, and B, was applied. Organic manure and P and 1/3 of K were applied as basal in the pit. After land preparation, the proper sized seedlings were transplanted at the proper distance. One third of N and K were applied after 20 days of transplanting. The remaining N and K were applied in two equal installments during flowering and fruiting.

Intercultural operation and plant protection

Irrigation, weeding, crop management and other intercultural operations were done following standard practice and done as and when needed. No plant protection was taken during the study time to get proper pest infestation data.

Data collection and statistical analysis:

Different types of growth and pest infestation data were collected from five randomly selected plants from each of the replications. The recorded data for various characters were statistically analyzed, with analysis of variance (ANOVA) and mean separation performed using R 3.6.3 statistical software.

Monitoring of Insect Pests

The presence of white fly, aphid, leaf miners, mites, and ESFB (eggplant shoot and fruit borer) was also monitored on a weekly basis during the morning hours on the different treatments. In the case of white fly and aphid, eight randomly selected leaves per block were collected in order to record the combined number of eggs, nymphs, puparium, and adult exuviae. For leaf miners, mites and ESFB, visual damage was recorded on five randomly selected plants using a 0–5 scale [18], with level 0 = plants not affected; level 1: number of branches with damage symptom/total branches = 10%; level 2: number of branches with

damage symptom/total branches = 20%; level 3: number of branches with damage symptom/total branches = 30%; level 4: number of branches with damage symptom/total branches = 40%; and level 5: number of branches with damage symptom/total branches = 50%.

Key findings

Under open field and NH1 conditions, a significant amount of white fly, aphid, leaf miners, mites, and ESFB infestation was observed, whereas NH2 and NH3 conditions had a lower infestation. The use of NH2, i.e. UV stabilized transparent polyethylene film with a 60 mesh insect net, continues to be a good strategy to allow a better utilization of the sunlight due to the manipulation of the light spectrum, which in turn promotes desired physiological plant responses. The use of stabilized transparent polyethylene film with a 60 mesh insect nethouse provided a negative effect on the presence of different types of notorious insects on vegetables. So, this type of protected nethouse will provide a new dimension to producing safe and quality vegetables in Bangladesh.

Key words: Protective nethouse, incidence of insect and diseases, high value vegetables.

12.4. Effect of Different Net House on Growth and Quality of High Value Vegetables

Background

Protected cultivation is the total concept of modifying the natural environment for optimum plant growth. It comprises the manipulation of environmental factors to some extent to control the crop's growth. In the present scenario of liberalized economic policy and encouraging export promotion from governments, there are ample opportunities for net house technology to make a significant contribution to the sustainability of crop production, especially short-duration vegetable crops. It provides a partially controlled atmosphere and the environment by reducing light intensity and effective heat during the daytime for crops grown under it. Hence, round the year, seasonal and off-season cultivation are possible. Shading nets are used in tropical and subtropical countries for vegetable production (Kittas *et al.*, 2012).

Vegetable production has undergone many changes in the way it is being grown in different protective net houses, since different limiting factors, including climatic conditions, availability of water and nutrients, and quality and quantity of light, must be taken into account to provide appropriate conditions for the optimal growth and development of the crop (Sotelo-Cardona *et al.*, 2021). Given the condition of sessile organisms, plants have a complex system for the perception of light that allows them to adjust and optimize their performance and metabolism based on the particular prevalent conditions. Light affects many developmental and physiological processes, including germination (Bentsink *et al.*, 2008), flowering (Alvarez-Buylla *et al.*, 2010), and direction of growth (Pedmale *et al.*, 2010). Likewise, two distinct functions of light have been described: photosynthesis and photomorphogenesis. In the case of photosynthesis, pigments such as chlorophyll a and b and carotenoids are responsible for the use of visible light or photosynthetically active radiation, absorbing light in two regions of the spectrum, blue (B: 400–500 nm) and red (R: 600–700 nm). In the case of photomorphogenesis, or the processes related to morphological and physiological changes, at least four major classes of photoreceptors are used: the phytochromes in red/far-red wavelengths (Wang, 2004), the cryptochromes responding in blue and UVA (Yu *et al.*, 2010; Chaves *et al.*, 2011), the phototropin responding in blue (phototropism), and UVB photoreceptors [Rizzini *et al.*, 2011]. In terms of the practical

application of these results, a wide variety of techniques have been used to create specific spectral modifications under protected cultivation structures (i.e., greenhouses, plastic net-houses, and tunnels), which provide protection and colored-differentiated solar radiation that may promote physiological responses that are controlled by light in order to improve commercial production of different vegetable crops (Shahak *et al.*, 2004, Kotilainen *et al.*, 2018).

Protected shade nets allow better utilization of sunlight due to the manipulation of the spectra of radiation reaching the crops, thus promoting physiological responses in plant and fruit development, including leaf area index, chlorophyll and carotenoid content, tissue structure, fruit ripening, physiological disorders, nutritional quality, etc. (Ilic and Fallik, 2017). Furthermore, previous studies have shown that red and pearl color net house structures improved tomato fruit quality (Ilic *et al.*, 2015) and carotenoid content (Selahle *et al.*, 2014). High temperatures and high solar radiation, on the other hand, may reduce lycopene and -carotene levels during tomato production, causing fruit damage, sunscald, and an increase in unmarketable fruit yield (Daz-Pérez, 2014.).

In order to get more information about the effect of protective net houses on vegetable production for specific climatic conditions in Bangladesh, the objective of this study is to assess the effect of low-cost protective net houses on plant morphometric parameters and growth, productivity, and nutritional yield, as well as to evaluate the incidence of pests, which are the common insect pests under four different light conditions: (1) UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net, (2) UV stabilized transparent polyethylene film with 60 mesh insect net, (3) 60 mesh insect net, and (iv) open field conditions. To date, there has not been much work available on the protected cultivation of quality vegetable production in Bangladesh. There is an urgent need to assess the quality of vegetable production and suitability for different vegetables under protected cultivation structures to meet the growing demand for vegetables. Thus, the purpose of the study was to compare the efficacy of protected cultivation to open fields in terms of temperature and water requirements of vegetables during the winter and summer seasons. Since the selected crops, viz., tomato, eggplant, sweet pepper, cucumber, and netted melon, are high-value vegetables in Bangladesh, that is why these vegetables are selected for these types of protected houses to get a quality yield. In this investigation, an attempt is made to estimate the best protected net house for growing quality vegetable production in Bangladesh.

Objectives

To select the suitable net house for quality production of tomatoes, eggplants, sweet peppers, cucumbers, and netted melon in Bangladesh conditions.

Methodology

Experimental site

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) from Mar 2021 to Feb 2022. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and was characterized by scanty rainfall during the experimental period. The soil of the experimental field was sandy clay loam in texture, having a pH range of around 6.0.

Air temperatures and relative humidity of the experimental area

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. The net house and open field conditions influenced the air temperature. Data for the temperatures for each treatment was measured at 12 pm daily during the experimental period. During the experimental period, the relative humidity data for each treatment was measured at 12 pm daily. The average monthly relative humidity varies between 71.66 to 79.33 % and 72.77 to 76.66%, while the average monthly temperature varies between 30.12^oc to 34.73^oc and 24.49^oc to 28.72^oc, respectively, during the summer and winter seasons in the day time (Table 59).

Table 59. Monthly average air temperature (^oc) and relative humidity (%) at 12 hrs in different shed house and open field during March to Sep 2021 and Oct 2021 to Feb 2022

Month	Air temperature (^o c) and relative humidity (%) at 12 hrs in different net house and open field							
	Nethouse 1		Nethouse 2		Nethouse 3		Open field	
	Temp. (^o c)	RH (%)	Temp (^o c)	RH (%)	Temp. (^o c)	RH (%)	Temp (^o c)	RH (%)
Summer 2021								
March, 2021	31.15	62.69	32.45	62.1	27.7	68.54	32.01	62.21
April, 2021	34.14	70.77	34.92	66.27	28.76	73.22	34.4	75.4
May, 2021	33.34	84.13	34.69	76.73	29.77	84.88	33.18	82.15
June, 2021	31.91	79.7	33.7	72.8	29.93	81.88	32.93	82.93
July, 2021	35.41	78.39	36.8	70.59	32.44	77.17	33.64	77.8
August, 2021	34.81	83.47	36.16	76.87	31.76	85.32	32.73	85.83
September, 2021	32.17	81.93	34.41	76.23	30.49	84.28	33.23	81.77
Average	33.28	77.30	34.73	71.66	30.12	79.33	33.16	78.30
Winter 2021-22								
October, 2021	31.24	83.85	33.67	81.46	29.42	85.48	32.5	81.64
November, 2021	27.17	71.03	30.43	68.27	27.02	73.54	29.93	70.68
December, 2021	21.75	73.1	26.33	71.15	21.6	74.36	25.63	72.45
January, 2022	21.33	74.83	25.81	72.73	21.18	76.56	25.25	74.3
February, 2022	23.39	71.67	27.36	70.23	23.24	73.36	27.08	70.42
Average	24.98	74.90	28.72	72.77	24.49	76.66	28.08	73.90

Treatments and plant materials

Five types of vegetables, viz., tomato, eggplant, sweet pepper, cucumber, and netted melon, were cultivated in 4 net house treatments [i) UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized transparent polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3); and iv) open field (control) (T4)] were included in this study. A total of 20 treatment combinations were laid out in factorial design.

Land preparation and fertilization

The unit plot size was 3.0 x 1.00 m in an RCBD (Randomized Complete Block Design) with three replications. Row to row and plant to plant distances were maintained with standard practice. The land was fertilized with organic fertilizer-N-P-K-S-Zn-B @ 10,000-170-50-125-18-4.3-1.70 kg/ha, respectively. During the final land preparation, one-third of the organic fertilizer, half of the P, and all of the S, Zn, and B were applied. The rest of the organic fertilizer and P and 1/3 of K were applied as basal in the pit. After land preparation, the properly sized seedlings were transplanted at a proper distance. Two rows of plants were grown per bed, and the spacing between plants was followed according to standard distance. One-third of N and K were applied after 20 days of transplanting. The remaining N and K were applied in two equal installments during flowering and fruiting.

Intercultural operation and plant protection

Irrigation, weeding, crop protection measures and other intercultural operations were done following standard practice and done as and when needed.

Data collection and statistical analysis

Different types of growth, yield, and yield contributing parameters of five types of vegetables, viz., tomato, eggplant, sweet pepper, cucumber, and netted melon, were collected from five randomly selected plants from each replication. The recorded data for various characters were statistically analyzed, with ANOVA and mean separation performed using R 3.6.3 statistical software.

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

Key findings

Fruit weight and fruit yield were influenced by changes in environmental conditions beneath the protective net house system. If the protected net house conditions are prepared with UV stabilized transparent polyethylene film with 60 mesh insect net, the tomato, eggplant, sweet pepper, cucumber, and netted melon (95.04, 41.60, 31.27, 28.8, and 25.87 t/ha, respectively) produced higher yields with good horticultural traits. The average BCR of these vegetables were 3.13, 1.85, 6.88, 3.69, and 12.55, respectively. The product will be safe and of good quality due to the absence of pesticide use. Considering yield and yield contributing traits, pest infestation and BCR, four types of vegetables performed best, viz., tomato, sweet pepper, cucumber, and netted melon. They can be selected under the net house condition, which will be prepared with UV stabilized transparent polyethylene film with 60 mesh insect net to ensure year-round production in Bangladesh.

Key words: Protective net house, High value vegetables, Growth and Quality

12.5. Effect of Maturity Indices on Growth and Quality of High Value Vegetables

Background

In order to acquire high-quality produce and productivity during the off-season, vegetables must be grown in protected environments such as green houses or poly net homes (Aherne *et al.*, 2010). Poly net buildings have the potential to be used economically to grow high-value temperature sensitive veggies all year. Because of their better productivity and economic feasibility, poly nethouses are commonly used for the cultivation of high-value vegetables. Due to the manipulation of the spectra of radiation reaching the crops, protected poly net houses allow for better utilization of sunlight, promoting physiological responses in plant and fruit development, such as leaf area index, chlorophyll and carotenoid content, tissue structure, fruit ripening, physiological disorders, nutritional quality, and so on (Ilic and Fallik, 2017). Protected, naturally ventilated high-tunnel cultures are ideal for growing high-value crops in the off-season (Sugani and Varma, 2014). Plastic tunnels, both high and low, have long been a useful tool for crop diversification and season extension, allowing growers to create a microclimate more conducive to warm-season crops (Lamont, 1996; Wells and Nugent, 1980). Because plants are planted more consistently, big gaps between plants and rows are minimized, and light interception is optimized, higher fruit yield/unit area can be attained in a high-tunnel protected culture than in a field (Rodriguez *et al.*, 2007; Vescera and

Brown, 2016). Poly homes have a yield potential of 1.5 times that of open fields (Patel *et al.*, 2003). When compared to the previous year, total fruit yields (t/ha) increased by 113 to 131 percent.

Identifying the correct stage of maturity and harvesting at the appropriate time are critical pre-harvest criteria for getting the most out of the covered nethouses. Maturity indices are useful for determining when a certain item should be harvested in order to provide some marketing flexibility and ensuring that the consumer receives appropriate eating quality. Maturity is the stage of growth that leads to a consumer's attainment of a specific goal. Physiological maturity: When a plant or a plant part has all of the necessary characteristics to be used. Selvakumar (Selvakumar, 2014). In a physiological sense, maturity refers to a plant portion or the entire plant reaching the last stage of biological activity. Vegetable quality can be retained for a longer amount of time if gathered at the right time (Kalia, 2011). Harvesting of tomatoes, for example, is done at different times depending on the function of the fruit. Vegetables are typically harvested at various stages of maturity for long-distance sales, local markets, fresh consumption, or consumer preferences. For long-distance marketing, the tomatoes are collected at a ripe green to turning stage. Pink to light-red tomatoes are picked for the local market.

Determination of maturity indices: Maturity can be judged by various means, like: 1. Computational methods [a) Calendar date, b) Days after anthesis /pollination]; 2. Physical methods [a) Increase in size, b) Color development, c) Softening of tissues, d) Seediness, e) Development net like structure, f) Yellowing and drying of foliage or top, g) Flowering and bolting]; 3. Chemical methods [a) Increase in sugar content, b) Increase in fiber content, c) Increase in sugar : acid ratio]; 4. Physiological methods [a) Respiration rate, b) Ethylene evolution rate]. Thus, farmers ought to schedule the harvesting at optimum maturity periods to ensure quality and obtain a good market price, followed by correct handling and packing of fruit (Rajkumar *et al.*, 2012). Despite this, most farmers, especially those operating on a small scale, face challenges, among which are the choice of the right varieties, ineffective transport to distant markets, and high perishability of products, exacerbated by harvesting at improper maturity stages due to farmers' limited knowledge of maturity indicators (Kato, 2011; Muzaale, 2015). Non-temperature controlled plastic tunnel nethouses can be used due to their low cost and simplicity as they use natural ventilation to reduce temperature (Maboko *et al.*, 2012; Perdignes *et al.*, 2005). Natural ventilation, however, may not sufficiently reduce the heat load (Perdignes *et al.*, 2005).

Determining the best maturity stage is a challenging practice due to the high variability found in crop. Based on technologies available nowadays, the more relevant maturity indices are coloration, sugars and acids content (evaluated as the ratio between both, TSS:acid ratio) and juice content (as percentage). Maturity indices also depend on the destination markets and the growing regions, therefore, there are no universal or absolute values, and the different producer countries may apply variable maturity standards. The distance to the market and consequently, transportation time is one of the more important parameters to consider when taking harvest decisions (Lado *et al.*, 2014).

There is a scarcity of data on the maturation indicators of many high-value vegetables for qualitative qualities in protected habitats. Because the selected crops, such as tomato, broccoli, sweet pepper, cucumber, and netted melon, are high-value vegetables in Bangladesh, they were chosen for poly net homes to ensure a high-quality production. The

goal of this study is to calculate the maturity indices for quality vegetable production in Bangladesh.

Objectives

To determine the maturity indices for quality tomato, broccoli, sweet pepper, cucumber, and netted melon production in Bangladesh.

Methodology

Experimental site

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during Mar 2021 to Feb 2022. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental period. The soil of the experimental field was sandy clay loam in texture having a pH range of around 6.0.

Air temperatures and relative humidity of the experimental area

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. The protected nethouse condition influenced the air temperature and RH. Data for the temperatures and RH were measured at 12 pm daily during the experimental period. The average minimum and maximum temperatures varied between 25.8°C to 36.8°C, while relative humidity varied between 62.1% to 81.5 % in day time (Fig 89).

Plant materials

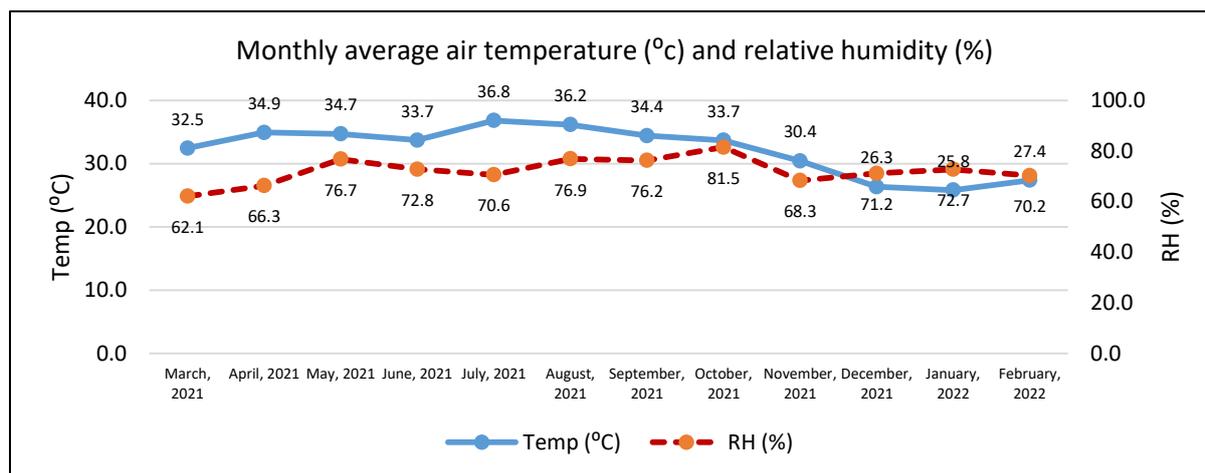


Fig 90. Monthly average air temperature (°C) and relative humidity (%) at 12 hrs during March 2021 to Feb 2022

Five types of vegetables, viz., tomato, broccoli, sweet pepper, cucumber, and netted melon, were cultivated in UV stabilized transparent polyethylene film with a 60 mesh insect nethouse. Different intervals of harvest were followed for different vegetables for this study. Fruit and quality related traits were visually observed and categorized. Fruits were selected randomly from tagged plants and picked to measure fruit length, diameter, average weight, TSS, and pH. Fruits were harvested on different days after flower opening.

Flower tagging and fruit harvest

Flowers were tagged at anthesis to determine the stage of fruit development, and 10 randomly selected fruits from 10 plants were harvested at specific day intervals according to the vegetable to determine their growth and maturity. At each harvesting date, 10 fruits were used to determine physicochemical properties like fruit length, diameter, weight, TSS, and pH.

Measurement of fruit weight, length, diameter

Fruit weight was determined using a digital electronic balance (Mettler PJ400, Switzerland) after transporting the harvested fruit in a closed plastic bag to the laboratory. Fruit length and diameter were measured with a digital vernier caliper.

Measurements of total soluble solids (TSS) and pH

The total soluble solids and pH of the juice were determined by using a hand-held Kruss refractometer (Model HR 900, SN 1200793, brix range 0–90% at 20° C, Germany) and a glass electrode pH meter (Delta 320, Mettler, Shanghai), respectively.

Evaluation of sensory attributes

Sensory evaluation, based on general visual appeal, colour, crispiness, flavor, and taste, was conducted. The scores were: 7 = like extremely; 6 = like very much; 5 = like moderately; 4 = neither like nor dislike; 3 = dislike moderately; 2 = dislike very much and 1 = dislike extremely. Fruit scored above 4 was considered acceptable. Sensory evaluation was performed by a panel of judges consisting of 5 scientific personnel, including both male and female members. Different preferences, as indicated by scores, were evaluated by statistical methods.

Statistical analysis

Using the R 3.6.3 statistical software, the data was subjected to analysis of variance (ANOVA). The results showing significant differences were then subjected to mean separation using Tukey's Studentized Range (HSD) Test at $P \leq 0.05$.

Key findings

Tomatoes were found to be an appropriate size (6.5 cm length and 6.2 cm diameter), weight (84 g), TSS (4.5 percent), pH (4.3), 'turning red' and 'tasty' at the week 5 stage, while broccoli was found to be an appropriate size (12.0 cm length and 13.0 cm diameter), weight (360 g), 'green' color at the day 12 stage in our study. At the week 6 stage, nettled melon was found to be of appropriate size (15.2 cm length and 14.5 cm diameter), weight (800 g), TSS (10.8 percent), pH (6.3), 'net fully developed' on the skin of the fruit, and 'much tasty,' while cucumber was found to be of appropriate size (8.8-10.8 cm length and 2.2-2.9 cm diameter), weight (61-88 g), TSS (3.8-4.1 percent), pH (6.3), 'less powdery with less spine' on fruit skin and 'tasty' at day 10-12 stage. Sweet peppers that were found to be of appropriate size (9.2-9.5 cm length and 6.0-6.2 cm diameter), weight (131-142 g), TSS (4.5-4.8 percent), pH (5.6-5.65), 'Shiny green' fruit color, and 'Pleasant flavored taste' at the week 5-6 stage lost their attractiveness and shininess, and became slimy in texture within a short time. As a result, determining our study's optimal maturity will help both the consumer and the grower.

Key words: Maturity indices, TSS, pH, Taste, High value vegetables, Growth and Quality.

12.6. Study of Different Nutritional Facts of Vegetables Under Different Type of Protected Growing Condition

Background

Protected culture is a technique in which the micro-environment surrounding the plant body is controlled partially or completely according to the plant's needs during its growth cycle to maximize production and save resources. This technology is also useful for protecting plants from birds, insects, etc., and conserving soil moisture simultaneously (Ummyah *et al.*, 2017). Additionally, protected cultivation reduces damage by wind, hail and excess solar radiation. Water use is decreased since evapotranspiration is reduced by 25% compared to open fields. Protected cultivation technology can, however, serve as a solution to these constraints. Some studies revealed that protected structures resulted in outstanding achievements in terms of vegetable production. Higher biomass production of coriander is possible under naturally ventilated poly houses (Issac, 2015). The growing of sweet pepper (Ghosal and Das, 2012) and tomatoes (Cheema *et al.*, 2004) in the off season under net house conditions gives a good yield as the incidence of pest and disease is low as compared to open field conditions. When papaya is planted in protected structures, fruit productivity and quality have also been reported to increase (Galán and Pastor, 2007). The most feasible means of attaining the objectives of protected agriculture is to modify the natural environment using solid engineering concepts to produce optimum plant growth and production with increased input usage efficiency.

Light, wind, temperature, relative humidity, and biotic variables like mycorrhizal fungi all have a substantial impact on productivity and physiology. Temperature is a factor that affects the chemical composition of the plants (Lee and Kader, 2000). It interferes with the formation of sugars due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates, and the increase in the transpiration rate (Palonen *et al.*, 2017). Temperatures below 20°C have a negative effect, causing carpelloidly, sex changes, reduced pollen viability, and low sugar content (Nakasone and Paul, 1998). So, use of protected nethouse has a positive impact on the plant growth and development.

Besides temperature, light is another very crucial factor for the productivity of vegetables. Maximum vegetables are a light-demanding plant, and prolonged periods of low light intensity can result in significant changes in leaf anatomy and morphology (Buisson and Lee, 1993). The chlorophyll content of leaves and light interception by plants in poly net houses also increased as the growth temperature increased. Increased environmental growth temperatures reduced fruit quality, such as soluble solids. Sugar-acid ratio, titratable acids, and pH varied among the cultivars, indicating that these qualities may be heritable traits as they were less influenced by the environment. Kumakura and Shishido (1995) observed that the fruit weight in the glasshouse dropped as the mean temperature increased. Excessively warm or cold temperatures can negatively affect the plants or its fruit. Nevertheless, in subtropical climates, cold temperatures during the winter season have an impact on fruit set as well as fruit growth and production. As a result, protected cultivation offers a significant advantage in terms of preventing cold damage and ensuring a steady supply of fruits to market throughout the seasons.

Protected agriculture has expanded to help improve agricultural productivity. To date, there is little research available on vegetables cultivation under protected nethouse conditions. To meet the increasing demand for quality vegetables, there is an urgent need to assess the

cultivation and suitability of vegetables production and quality measurement within different net houses.

Objectives

To determine the efficacy of various net house cultivations compared to open field in terms of nutritional quality of different vegetables.

Methodology

Experimental site

The evaluation site was the research farm of Olericulture Division, Bangladesh Agricultural Research Institute (BARI) during Mar 2021 to Feb 2022. The field was at 23.9920° N Latitude and 90.4125° E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental time. The soil of the experimental field was sandy clay loam in texture having a pH range around 6.0.

Air temperatures and relative humidity of the experimental area

Under protected conditions temperature can be monitored and managed, and better plant growth could be expected. Different net 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. During the experimental period the relative humidity data for each treatment was measured at 12 pm daily. The average monthly relative humidity varies between 71.66 to 79.33 % and 72.77 to 76.66 %, while average monthly temperature varies between 30.12°C to 34.73°C and 24.49°C to 28.72°C, respectively during summer and winter season in day time (Table 60).

Table 60. Monthly average air temperature (°C) and relative humidity (%) at 12 hrs in different shed house and open field during March to Sep 2021 and Oct 2021 to Feb 2022

Month	Air temperature (°C) and relative humidity (%) at 12 hrs in different net house and open field							
	Nethouse 1		Nethouse 2		Nethouse 3		Open field	
	Temp. (°C)	RH (%)	Temp (°C)	RH (%)	Temp. (°C)	RH (%)	Temp (°C)	RH (%)
Summer 2021								
March, 2021	31.15	62.69	32.45	62.1	27.7	68.54	32.01	62.21
April, 2021	34.14	70.77	34.92	66.27	28.76	73.22	34.4	75.4
May, 2021	33.34	84.13	34.69	76.73	29.77	84.88	33.18	82.15
June, 2021	31.91	79.7	33.7	72.8	29.93	81.88	32.93	82.93
July, 2021	35.41	78.39	36.8	70.59	32.44	77.17	33.64	77.8
August, 2021	34.81	83.47	36.16	76.87	31.76	85.32	32.73	85.83
September, 2021	32.17	81.93	34.41	76.23	30.49	84.28	33.23	81.77
Average	33.28	77.30	34.73	71.66	30.12	79.33	33.16	78.30
Winter 2021-22								
October, 2021	31.24	83.85	33.67	81.46	29.42	85.48	32.5	81.64
November, 2021	27.17	71.03	30.43	68.27	27.02	73.54	29.93	70.68
December, 2021	21.75	73.1	26.33	71.15	21.6	74.36	25.63	72.45
January, 2022	21.33	74.83	25.81	72.73	21.18	76.56	25.25	74.3
February, 2022	23.39	71.67	27.36	70.23	23.24	73.36	27.08	70.42
Average	24.98	74.90	28.72	72.77	24.49	76.66	28.08	73.90

Nethouse 1= UV stabilized transparent polyethylene film with 60 mesh insect net along with green shade net (Poly green shed house)

Nethouse 2= UV stabilized transparent polyethylene film with 60 mesh insect net (UV poly shed house)

Nethouse 3= 60 mesh insect net (Net house)

Nethouse 4=Open field

Plant materials

Six types of vegetables viz., tomato, eggplant, sweet pepper, broccoli, cucumber and netted melon were cultivated in 4 net house treatments [i) UV stabilized transparent polyethylene

film with 60 mesh insect net along with green shade net (T1); ii) UV stabilized transparent polyethylene film with 60 mesh insect net (T2); iii) 60 mesh insect net (T3) and iv) Open field (control) (T4)] were included in this study. Total 20 treatment combinations were laid out in factorial design. Fruits were selected randomly from tagged plants and picked for measuring the nutritional facts.

Sample preparation

Vegetables were harvested at commercial mature stage from the experimental farm of Olericulture Division, Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI) during 2021–22 (23.9920° N Latitude and 90.4125° E Longitude), washed, sorted by color and size, and divided into two groups. The first group was used fresh for proximate and mineral analysis, whereas the second was freeze-dried and stored at -80 °C for further ascorbic acid evaluations.

Proximate composition

Moisture, ash, protein (N x 6.25), crude fibre, fat and carbohydrates (by difference) contents were determined according to AOAC methods (AOAC, 2002).

Analyses of macro and micro elements

The mass spectrometry method was used in mineral analyses. Minerals were made soluble through closed system microwave wet etching and concentrations were determined by using ICP-OES. AOAC (2002) was used to determine the sodium, potassium, calcium, magnesium, iron, and zinc contents of the bean genotypes.

Vitamin evaluations

The water-soluble vitamins of retinol, thiamine, riboflavin, niacin, pyridoxine, folate and L-dehydroascorbic acid contents were determined in this study. Vitamin C content was determined as L-dehydroascorbic acid. Sample vitamin C contents were determined by measuring the area of peak obtained from the HPLC UV detector following the sample extraction with metaphosphoric acid (Bognar, 1998). Following an enzymatic incubation, B vitamins were determined in the HPLC HL detector (Gauch *et al.*, 1992). Vitamin A was determined by measuring the area of peak received from the reverse-phase analytical HPLC UV detector following direct extraction and placing the extract into the proper dissolvent (Genestar and Grases, 1995).

Statistical analysis

In this study, mean values of the different biological assays were analyzed via one way Analysis of Variance (ANOVA). Significant differences among mean values were calculated at $p < 0.05$ by using the least significant difference test (Steel *et al.*, 1997).

Key findings

Lower temperatures have a negative effect, causing carpelloidly, sex changes, reduced pollen viability, and low sugar content. So, use of protected nethouse has a positive impact on the plant growth and development. Consumption of foods with rich nutritional values has various preventive impacts on diabetes, heart diseases and various cancer type. Protein contents of investigated growing conditions varied between 0.58 – 2.70g and dietary fiber contents between 0.44-3.50 g, while the range of sodium, calcium, magnesium content were obtained 2.6-20.3mg in cucumber under poly green shed house, 7.8 mg (cucumber in poly green shed house) - 47.0 mg (broccoli in UV poly shed house), 12.5 mg (sweet pepper in poly green shed

house) - 23.0 mg (tomato in poly green shed house, respectively). In maximum vegetables, the vitamins content was higher in UV poly shed house compare to other conditions.

Key words: Nutritional facts, Vegetables, Protected growing condition, Protein, Vitamins and Minerals.

12. 7. Upscaling of Protective Nethouse Technology at Farmers' Field

Background

Naturally ventilated high-tunnel, protected culture is suitable for offseason cultivation of high value crops (Sugani and Varma, 2014). High, and low, plastic tunnels have been an important tool for crop diversification and season extension, enabling growers to create a microclimate better suited to warm-season crops (Lamont, 1996; Wells and Nugent, 1980). Since highly valued vegetables have much economic importance, growers are not in a position to produce good quality vegetables with high productivity due to various biotic (pests and diseases), abiotic (rainfall, temperature, relative humidity and light intensity) and crop factors (flower and fruit drop). Hence, to obtain good quality produce and production during the off season, there is a need to cultivate vegetables under protected conditions such as green houses or poly nethouses (Aherne *et al.*, 2010). Cultivation of high-value vegetables is widely grown in poly-nethouses due to higher productivity and economic feasibility. Greater fruit yield/unit area may be achieved in high-tunnel protected culture than in a field because plants are arranged more uniformly, large gaps between plants and rows are avoided, and light interception is optimized (Rodriguez *et al.*, 2007; Vescera and Brown, 2016). The yield potential of poly houses is about 1.5 times more than the open field (Patel *et al.*, 2003). Total fruit yields (t/ha) were increased by 113 to 131 percent when compared to the open field (Ilić *et al.*, 2011).

In consideration of the above circumstances, BARI has developed a model with a naturally ventilated high-tunnel protected nethouse to cultivate year-round production of high-value vegetables, which is prepared by using UV stabilized polyfilm on top and upper side of the vertical portion. The rest of the vertical portion was built with 60 mesh insect net to protect insects and provide ventilation. Since this nethouse provided a significant production of high-value vegetables year round, the technology needs to be evaluated at a farmers' field at a minimum of two locations.

Objectives

To cultivate year-round production of high value vegetables at two farmers' fields, Narshingdi and Cumilla.

Methodoly

Experimental site

The evaluation sites were the farmers' fields of Shibpur, Narshingdi (24.050° N Latitude and 90.718° E) and Chowara Bazar, Cumilla (23.408° N Latitude and 91.244° E). The evaluation was conducted from Oct 2021 to Sep 2022. The fields were owned by Mr. Delwar and Mr. Anowar Hossain, respectively. The areas were situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental period. The soil of the experimental field was sandy clay loam in texture, having a pH range of around 6.0.

Plant materials and cultural practices

Five types of vegetables, viz., tomato, sweet pepper, cucumber, netted melon, and okra, were cultivated in the UV poly nethouse. On the first week of October, seeds of all vegetables were sown on polypot, and 30 day old seedlings of tomato and sweet pepper were transplanted on bed, while 20 day old seedlings of cucumber and netted melon were transplanted on bed with the required distance under the poly nethouse. The okra seeds were sown directly on the bed on the 1st week of October (Table 61).

Table 61. The planting distances, plot size, seedling age and sowing date of different vegetables

Vegetables	Planting distances	Plot size	Seedling age	Sowing date
Tomato	60x50 cm	4x1m	30 days old seedling	1 st week of October 2021
Sweet pepper	60x50 cm	4x1m	30 days old seedling	1 st week of October 2021
Cucumber	80x60 cm	4x1.2m	20 days old seedling	1 st week of October 2021
Netted melon	100x60 cm	4x1.2m	20 days old seedling	1 st week of October 2021
Okra	60x40 cm	4x1m	Direct seed sow	1 st week of October 2021

UV poly nethouse size: 5x7.5m

Key Findings

Cultivation under UV Poly nethouse was found to be more successful in Cumilla than in Narshingdi, possibly due to differences in grower management. Cumilla farmers produced far more tomatoes, sweet peppers, cucumbers, netted melon, and okra than Narshingdi farmers. As a result of UV poly nethouse technology, high-value thermos-sensitive vegetables may be successfully cultivated commercially year-round to provide a safe and high-quality product, while greater fruit yield per unit area will be achieved in a protected nethouse compared to an open field. Farmers are overjoyed to be producing safe and high-quality vegetables under UV poly net houses because production was higher, pesticides were used less frequently, and the price was higher compared to neighboring farmers.

Key words: Upscaling, Protective nethouse, BCR, Farmers' field

SAU Component

12.8. Effect of Different Growing Environments on Growth, yield and quality Attributes of Strawberry

Background

Strawberry is one of the world's most tasty and fragrantly sweet aromatic fruits. It is a small, creeping, perennial, stoloniferous herb that belongs to the Roseaceae family. It is a significant fruit and has a major natural source of bioactive compounds (Ariza *et al.*, 2016). The fruit has a high content of manganese, potassium, iodine, magnesium, copper, iron, and phosphorus. In addition to these nutrient compounds, strawberries contain a number of non-nutrient elements, such as polyphenolic phytochemicals (Giampieri *et al.*, 2012). Due to its charming red colour and high nutritional value, strawberry has a unique place among all the berry fruits (Sharma *et al.*, 2013). It is a thermo and photo sensitive crop (Sharma, 2002). Being a winter fruit crop, it has to face a lot of natural adversities like poor soil moisture, temperature fluctuation and so on specially during flowering and fruiting (Sharma *et al.*, 2013).

Because of its high variability, climate is the most influential factor in agricultural production, so that the environment in which the crops are grown can be modified through a protected environment (Iizumi and Ramankutty, 2015). It is necessary to evaluate the conditions in which the plants are developed and take into account that environmental variables affect the quality of the fruit (Martínez *et al.*, 2017). is the principal environmental factor influencing cymes, flowers, and fruit production. Mireku (2012) indicated that increased growth temperatures led to a small leaf area, while the length of the leaf increased. Kumakura and Shishido (1995) observed that the fruit weight in the glasshouse dropped as the mean temperature increased.

Several studies have been made about strawberry responses to various temperature regimes. Zang *et al.* (1997) found that strawberry cells at 30°C grew gradually and usually did not proliferate in suspension cultures. When modifying the environmental conditions, it is necessary to know its effect on the postharvest quality of the fruits. The behaviour of the temperature inside the high tunnel is of great importance, because it intervenes in the “metabolic activity, the absorption of water and nutrients, the gas exchange, the production and expenditure of carbohydrates and growth regulators” (Argandar, 2010). Temperature is a factor that affects the chemical composition of the fruits (Lee and Kader, 2000). It interferes in the formation of sugars, due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates and the increase in the transpiration rate (Palonen *et al.*, 2017). To meet the increasing demand of fruit crops, there is an urgent need to assess the cultivation and suitability of strawberry production and quality measurement within different shade houses.

Objectives

The experiment was thus aimed at determining the efficacy of various shade houses cultivation compared to open field on strawberry quality and yield.

Methodology

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

Key findings

The results revealed that shading conditions significantly influenced growth, yield and quality of the strawberry. Fruits grown under shade houses contained higher quality than fruits grown in field conditions. Among the shade houses fruits grown under UV poly shade had substantially more total soluble solid, titratable acidity, ascorbic acid and lower pH. Fruits

grown under poly shade had more reducing sugar and total phenol. However, yield and yield contributing parameters of the strawberry were higher in net house. Based on the results, we suggest that growing strawberry under net house was the most suitable growing conditions for yield and yield contributing parameters while strawberry produced in a UV poly shed and poly shed presented better quality fruits.

Key words: Strawberry, Shade house, Growth, Yield, Quality

12.9. : Impact of Different Shed Houses and Growing Media on Growth, Yield and Quality of Strawberry

Background

Strawberry (*Fragaria ananassa*) belongs to the Rosaceae family. Strawberry is a moderate, short-day herbaceous perennial plant that can be grown successfully at optimum temperatures of 22 ° C to 25 ° C during the day and 7 ° C to 13 ° C at night (De and Bhattacharjee, 2012). The climate is the most important factor in agricultural production because of its high variability, so that the atmosphere in which the crops are grown can be changed by a protected environment (Iizumi and Ramankutty, 2015). The conditions in which plants are produced must be measured and it must be taken into consideration that environmental factors influence the quality of the fruit (Martínez *et al.*, 2017). Some of the environmental effects that have an important impact are temperature, relative humidity. Temperature is the principal environmental factor influencing cymes, flowers, and fruit production. The microclimate in the shed house was more conducive to the fruit crop's growth and yield attributes. The enhanced rate of photosynthate transfer from the vegetative component (source) to the reproductive organs (sink) may have boosted fruit size and weight, resulting in greater tomato fruit yield (Kuscu *et al.*, 2014).

Plant growth is influenced by the growing medium used. Peat moss, rock wool, coir, perlite, or certain other mixtures are the most increasing media for strawberries. Growing media serves not only as a growing place, but also as a source of plant growth nutrients. The soil is commonly used as a basic medium, as it is the cheapest and simplest to obtain. Vermicompost provides sufficient levels of oxygen to roots, adequate storage of water, and nutrient for the plants. Farmyard manure (FYM) is having good water holding capacity as well as sufficient porosity.

These growing substrates consist of either a single component or mixtures which support plants by providing water, air, and nutrients. However, different growing media vary greatly in composition, particle size, pH, aeration, and ability to hold water and nutrients (Oagile *et al.*, 2016). Limited work has been reported on strawberry cultivation regarding the application of growing media under different shades.

Objectives

The study aimed to assess the response of different growing media and shade houses on plant growth, yield, and quality attributes of strawberries.

Methodology

The experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during 2019-2020, under natural lighting conditions. The present investigation was carried out in three different Shades i.e. net house, Plastic shade house, and open field condition (control), and different growing media were used in different

ratio i.e. Soil: Cowdung (1:1), Soil: Vermicompost (1:1), and Soil: Cocopeat (1:1). The experiment was laid out in a completely randomized design with six replications in plastic pots. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on growth, yield, and physicochemical parameters. Temperature and relative humidity were recorded during the growing period of November 2019 and March 2020.

Key findings

Strawberry plants responded better to the cocopeat-based growing medium than to the other growing media used (cowdung and vermicompost) across all growing shade features, while net house proved superior for reproductive growth and quality traits. The number of flowers, fruit, individual fruit weight, and fruit output of strawberry plants did not improve significantly when using vermicompost-based growing media. Based on findings obtained from the study cocopeat growing media and net house shade may be advised to obtain better quality and yield for strawberry.

Key words: Strawberry, Growing media, Net house, Yield, Quality

12.10. : Effect of Various Mulch Materials and GA₃ on Strawberry Growth, Yield, and Quality Under Net House

Background

In the Rosaceae family, strawberry (*Fragaria × ananassa* Duch.) is one of the world's most delicious fruits. It is a great source of vitamins and minerals, and it has a delicious flavor and aroma. Strawberries contain vitamins A (60 UI/100g edible portion) and C (30-120mg/100g edible portion), as well as 5% total sugar, 0.90 - 1.85% acids, fibre, pectin (0.55%), and water (90%) (Sharma, 2002). Temperature increases in the growing environment reduced fruit quality, such as soluble solids, in the berries and other fruits. It is better to cultivate strawberries under a shed house to protect them from adverse weather conditions.

Adding mulch to the soil enhances growth by improving nutrient availability in the soil, conserving water and decreasing moisture conservation while encouraging plant development and changing soil temperature (Keramat *et al.*, 2011). Mulching had a significant impact on the microclimate around the plants by modifying the radiation budget and increasing vegetative growth. As the day progresses, mulch protects the soil from heat buildup and improves thermal conditions in the early morning. Organic mulches not only improve soil structure, but they also slow down the release of nutrients and keep the soil temperature stable (Shirgure *et al.*, 2003). Synthetic mulch and organic mulch have distinct ways of improving water efficiency. Soil temperature prevents organic mulch from evaporating as quickly as plastic mulch, which is impervious and therefore does not evaporate as quickly. Vishal *et al.* (2016) found that exogenously applied growth regulators had a positive effect on strawberry vegetative growth, flowering, yield, and physico-chemical quality attributes. It has been proven that applying GA₃ to the foliage of numerous horticultural crops has increased their yield and quality. A limited amount of information has been published on strawberry production in terms of the best mulch materials to use in a protected environment with GA₃.

Objectives

The present investigation was conducted to study the effect of different mulching materials and GA₃ on strawberry growth, yield, and quality.

Methodology

Under natural lighting, the experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh in November 2020 to March 2021. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an average elevation of 4 meters (13.12 ft.). GA₃ (0 and 200 ppm) was employed in the present study with different mulch materials (no mulch, sawdust, white and black polythene). A randomized complete block design with four replications was used for the experiment. Strawberries of the cv. Festival were planted in raised beds at 60 cm x 30 cm spacing under a netting house. The average temperature was 23±2°C in daytime and 13±2°C at night, with a relative humidity of 65 to 80%. During the experiment, all essential cultural practices and plant protection measures were followed across all the plots. Growth, yield and physicochemical parameters were measured on randomly selected plants in each replication.

Key findings

In strawberry, the use of organic mulch (sawdust) gave better yield and quality compared to the use of synthetic mulch (black and white polythene). GA₃ treated plants performed better than non-GA₃ sprayed plants. The findings of the current study suggest that the combined application of sawdust mulching and GA₃ can be used successfully in strawberry production, and it may be a better option for increasing strawberry growth, yield, and quality.

Key words: Strawberry, Mulch materials, GA₃, Fruit yield, Quality

12.11. : Effect of Pre-harvest Cypermethrin Spray on Residual Level and Biochemical Attributes of Strawberry Fruit

Background

Strawberry (*Fragaria × ananassa* Duchesne) is a tasty and nutritious fruit which is popular for its attractive colour, aroma and sweetness. Strawberry juice extracts be full of high levels of antioxidant which works against superoxide radicals, hydrogen peroxide, hydroxyl radicals, and singlet oxygen free radicals. In spite of being a prospective crop, high rate of insect pests' infestation is responsible to its low yield and poor quality. Due to plant pests and diseases 20 to 40 percent of the crop yields are reduced globally (FAO, 2012). Farmers face significant yield loss of strawberries every year due to severe attack of various insect pests in our country. In order to manage this limitation, producers apply several pesticides (Wang *et al.*, 2017). Pesticides play a key role to control the insect pests and diseases and hence protect and promote production (Prodhan *et al.*, 2015).

These negative impacts of pesticides are increasing day by day in order to increase the uses of pesticides. Besides, now a day's food safety is a major concern to the consumers. But the percentage of food containing pesticide residues has increased in the last 10 years (PAN Europe, 2014). In order to ensure the supply of safe food, pesticides should be used following Good Agricultural Practices (GAP). Monitoring of pesticide residues is the essential tool to ensure GAP. To monitor pesticide residues nationally in the commercial produce, reliable multi-residue analytical methods are required. As a safety measure for the consumers, many developed countries have set Maximum Residue Limit (MRL) based on the Acceptable Daily

Intake (ADI) and Potential Daily Intake (PDI) that should not be exceeded for a food item to be considered safe for consumption. In Bangladesh, since harvesting and selling of fruits are done without perplexing for the pre-harvest interval, pesticide residue levels in such strawberry would undoubtedly be above Maximum Residue Limit.

As crop production and pesticides are closely related and their left over residue might or might not persist in the environment that should be carefully examined and monitored. The detection and monitoring of pesticide residue particularly in vegetable and fruits is being done in regular fashion in many countries. Currently in Bangladesh, organophosphates (OP), carbamates and pyrethroids are mostly used while organochlorine (OC) insecticides have been banned because of their toxicity, persistence and bioaccumulation in the environment.

Objectives

- To quantify the level of cypermethrin residues in strawberry at different days after spray.
- To determine the effects of pre-harvest foliar spray of cypermethrin on biochemical attributes of strawberry

Methodology

A supervised field trial was conducted in the experimental field of Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka. All the activities like seeding, transplanting and all other cultural operations were undertaken and performed by the field staffs of Horticulture Department of SAU. The synthetic pyrethroid pesticide, cypermethrin (ripcord 10EC) was selected for this experiment. When the fruits were at marketable size, ripcord 10EC was sprayed in the field by knapsac sprayer. The application rate was 1.5 mL/L of water. The pesticides were tank-mixed and applied to the plants following GAP. Samples of strawberry were collected at 0, 1, 3, 5, 7, 10 and 12 days after pesticide application from the experimental field of Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka. The samples were collected in clean transparent air tight polyethylene bag and each bag was properly labeled with sample number and the date of collection. Samples were collected in individual polyethylene bag to avoid cross contamination. All the collected samples were carried to the Pesticide Analytical Laboratory, Entomology Division of Bangladesh Agricultural Research Institute (BARI), Gazipur.

Key findings

The level of residue of cypermethrin was 0.874 mg/kg at 0 DAS and gradually the level of residues were decreased and at 7 DAS (0.101 mg/kg), it was above the EU-MRLs (0.10 mg/kg) and at 10 DAS (0.043 mg/kg), it went to below EU-MRLs (0.10 mg/kg) in strawberry and at 12 DAS, no residue of cypermethrin was detected in the analyzed strawberry sample. Strawberry juice had considerably lower concentrations of total phenols and titratable acidity at 0, 1, and 3 DAS, and a higher concentration of ascorbic acid at 0 and 1 DAS, which indicates less infection. Pesticides on strawberries reduced pest infection and preserved fruit quality, but residues higher than the maximum residue limit of up to 7 DAS were found.

Key words: Strawberry, Cypermethrin, Pest infection, Fruit quality

12.12. : Effect of Maleic Hydrazide and Potassium Foliar Spray on Sex Expression, Yield and Quality Enhancement of Muskmelon

Background

Muskmelon (*Cucumis melo* L.) belonging to the cucurbitaceous family is a valuable cash crop grown throughout the world. It is popular for its taste and flavor. It is a rich source of phyto-nutrients (Lester, 2008). Muskmelon has sex expression like monoecious, dioecious, and hermaphrodite, and flowers which are staminate, pistillate, and bisexual (perfect) can be induced by various forms of sex modification (Miao *et al.*, 2011).

Kooner *et al.* (2000) reported that ethrel and MH affect growth and sex expression in bottle gourd. Sex expression can also be regulated by changing the environment and the use of different growth regulators. Plant growth regulators play multidimensional and multilateral function in growth and development of plants even in limited amounts, by stimulating various systems in the plant. Exogenous use of plant growth regulators can alter the sex ratio and sequence if provided at a two- or four-leaf stage, which is the crucial stage at which either sex can be suppressed or promoted (Hossain *et al.*, 2006). It is possible to increase the yield by using plant growth regulators as plant growth regulators can alter the sex ratio from male to female flower.

Potassium is a major nutrient for increasing the productivity of vegetable crops and its content in vegetables has positive relationship with quality (Bidari and Hebsur, 2011). Previous research has shown that potassium deficiency can be mitigated by supplementary foliar application of potassium during fruit production and maturation (Lester *et al.*, 2005). Muskmelon's consumer preference is primarily determined by its superiority, i.e., content of sugar, flavor/aroma, texture, and most recently by its rich sources of bioactive compounds with health benefits. Among the macronutrients, potassium deficiency has been widely reported in muskmelon during reproductive stage of muskmelon. Soil potassium is rarely adequate during reproductive stage to help crucial processes such as sugar transport from leaves to fruit, enzyme activation, protein synthesis that ultimately decide the quality and yield of the fruit. Foliar application of glycine amino acid complexed potassium (K) sprayed weekly during fruit growth and ripening significantly improved fruit firmness, ascorbic acid, free sugar and beta-carotenes concentrations (Lester *et al.*, 2005). The authors found no research related to both the improvement of female flower production that leads to higher yield of muskmelon and betterment of the fruit quality.

Objectives

To understand the effect of maleic hydrazide on the formation of female flower and to determine whether the foliar application of glycine complex potassium during the fruit development and maturation can mitigate potassium deficiency, thereby improve muskmelon fruit quality.

Methodology

The experiment was carried out in a net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh under natural lighting conditions, with different day/night temperatures. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The seed of F1 hybrid muskmelon (crystal) was obtained from Siddique Bazar, Dhaka, Bangladesh. The seeds were sown in Poly (vinyl) chloride (PVC) tanks (1.2×0.6×0.6 m) using soil mixture with slow releasing mixed fertilizers. At 20th days after sowing (DAS),

healthy uniform seedlings were transplanted to the net house under raised bed at 90 cm × 90 cm spacing. The average minimum and maximum temperatures were 18.5 and 30.4°C respectively, and the average relative humidity was 60% during the experimental period February-May 2020. All essential cultural practices and plant protection measures were followed uniformly for all the plots throughout the experiment.

Key findings

Findings of the research showed that maleic hydrazide played an important role in the control of vegetative characteristics, sexual expression, number of fruit per plant and β -carotene content in harvested fruits. On the other hand, foliar application of potassium improved the fruit size, total soluble solids, ascorbic acid and reducing sugar, and decreased total acidity in fruits. Based on the results, it may be suggested that growing muskmelon was suitable for sex expression and higher fruit yield by spraying maleic hydrazide while foliar potassium spray presented better quality fruits. Therefore, plant sprays of maleic hydrazide with potassium solution had significantly superior effects on growth, sexual expression, and yield and quality characteristics of muskmelon.

Key words: Muskmelon, Maleic hydrazide, Potassium, Sex expression, Quality

12.13. : Effect of Plant Growth Regulators and Pruning Levels on Sex Expression, Yield and Quality in Watermelon

Background

Watermelon (*Citrullus lanatus*) is an important fruit crop among the various cucurbits for its sweet juicy fruits for quenching the thirst especially during summer season. Watermelon production has taken a very important place in world agriculture. The production capacity is about 29.7 million tons from 1.8 million ha (Erdem and Yuksel, 2003). Watermelon not only a nutritional valuable food but also is considered a rich source of the phytochemical lycopene which is considered as anti-cancer in particular prostate cancer in men (Chen *et al.*, 2001). It also contains high potassium and low sodium.

Growth regulators have tremendous effects on sex expression and flowering in cucurbits crop leading to either suppression of male flowers or an increase in the number of female flowers without imposing any deleterious effect on the environment and human health. Plant growth regulators are also used to control the vegetative growth of cucumber plants. Plant growth regulators have a key role in various physiological and biochemical process in plant system. Moreover, pruning has a significant effect for decreasing the sex ratio in cucurbits (Arora and Malik, 1989). Growth regulators can alter the sex ratio and sequence if applied at the two- or four-leaf stage, which is the critical stage at which the suppression or promotion of either sex is possible (Hossain *et al.*, 2006). Flowering in cucurbits is very important phase of development because fruiting and yield depends on this process. A week after male flower initiation takes place the female flowers appear with the small cucumber fruits at the base. Plant growth regulators (PGRs) are organic compounds, other than nutrients that modify plant physiological processes.

Objectives

To investigate the effects of pruning on the flowering, sex expression and fruiting and to study the effects of growth regulators on the flowering, sex expression and fruiting

Methodology

The experiment was carried out in a net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh under natural lighting condition. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and it has an average elevation of 4 meters (13.12 ft.). The seeds of water melon variety (Red star) were obtained from Siddique Bazar, Dhaka, Bangladesh. The seeds were sown in Poly vinyl chloride (PVC) tanks (1.2×0.6×0.6 m) using soil mixture with slow releasing mixed fertilizers. At 20th days after sowing (DAS), healthy uniform seedlings were transplanted to the net house under raised bed at 90 cm × 90 cm spacing. The average minimum and maximum temperatures were 21±2°C and 31±2°C respectively, and the average relative humidity was 65% during the experimental period February-May 2021. All essential cultural practices and plant protection measures were followed uniformly for all the plots throughout the experiment. The treatment comprised of two pruning and three growth regulators treatments. The experiment was conducted in randomized complete block design (RCBD) with three replications of each treatment. The plants were pruned at fourth week after planting. Secateurs were used to prune the main branch of the plant. Three growth regulators namely, GA₃ (150 ppm), ethephon (100 ppm) and maleic hydrazide (MZ) (200 ppm) were used. Two sprays of plant growth regulators were done at 2nd and 4th true leaf stages during morning hours till the both sides of leaves completely wet. The plants were pruned at fourth week after planting. Secateurs were used to prune the main branch of the plant. Total six treatments were tried including control.

Key findings

Plant pruned and sprayed with growth regulator had a positive effect on the growth and yield of watermelon. There is a need to prune watermelon as it enhances its production. Based on the results, it may be suggested that growing watermelon was suitable for sex expression and higher fruit yield by spraying GA₃. Therefore, plant pruned and sprayed with GA₃ had significantly superior effects on growth, sexual expression, and yield and quality characteristics of watermelon.

Key words: Watermelon, Growth regulators, Pruning, Yield, Fruit quality

12.14. : Effect of Different Sheds on Growth, Yield and Quality of Papaya

Background

Papaya (*Carica papaya* L.), which belongs to the family Caricaceae, is grown all over the world. The fruits are highly valued as table fruits when ripe and as vegetables in their unripened condition. Papaya is a significant source of calcium as well as vitamins A and C. Thiamin, riboflavin, iron, potassium, magnesium, and sodium are also present in small amounts.

Light, wind, temperature, relative humidity, and biotic variables like mycorrhizal fungi all have a substantial impact on papaya productivity and physiology. Temperature is a factor that affects the chemical composition of the fruits. It interferes with the formation of sugars due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates, and the increase in the transpiration rate (Palonen *et al.*, 2017). Throughout the year, the optimum temperature for papaya is 25–30 °C (Almeida *et al.*, 2003). Temperatures below 20°C have a negative effect, causing carpelloid, sex changes, reduced pollen viability, and low sugar content in papaya (Nakasone and Paul, 1998).

Kumakura and Shishido (1995) observed that the fruit weight in the glasshouse dropped as the mean temperature increased. Excessively warm or cold temperatures can negatively affect the tree or its fruit. Nevertheless, in subtropical climates, cold temperatures during the winter season have an impact on fruit set as well as fruit growth and production. As a result, protected cultivation offers a significant advantage in terms of preventing cold damage and ensuring a steady supply of fruits to market throughout the seasons. Protected culture is a technique in which the micro-environment surrounding the plant body is controlled partially or completely according to the plant's needs during its growth cycle to maximize production and save resources. This technology is also useful for protecting plants from birds, insects, etc., and conserving soil moisture simultaneously (Ummiyah *et al.*, 2017). Additionally, protected cultivation reduces damage by wind, hail and excess solar radiation. Water use is decreased since evapotranspiration is reduced by 25% compared to open fields. The most feasible means of attaining the objectives of protected agriculture is to modify the natural environment using solid engineering concepts to produce optimum plant growth and production with increased input usage efficiency.

Objectives

The experiment was aimed at determining the efficacy of various shed house cultivations compared to open field in terms of papaya fruit quality and yield.

Methodology

During February to October 2020, the experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an average elevation of 4 meters (13.12 ft.) according to the National Mapping Organization of Bangladesh. The papaya cv. Red Lily was planted at 1.2 m × 1.2 m spacing under four environments, i.e. open field condition (control), net house naturally ventilated polyhouse (entire roof and half the portion of four sides covered with poly sheet, the remaining half covered with 25% shed net) and Fan pad UV polyhouse (fully covered with UV film sheet). The experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on fruit production, yield, and physio-chemical parameters. Temperature and relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions in which the plants were grown.

Key findings

The results revealed that shading conditions significantly influenced the growth, yield, and quality of the papaya. Fruits grown under net house had substantially more total soluble solids, ascorbic acid, reducing sugar, total phenol, and beta-carotene. Furthermore, in the net house, the fruit peel color, yield, and yield contributing parameters of the papaya were higher. According to the findings of this research, papaya can be grown successfully in a net house with improved plant growth, fruit weight, color, yield, and quality.

Key words: Papaya growth, Protective cultivation, Phytochemical accumulation, Yield

12.15. : Effect of Maturity Stage of Papaya on Physiological and Biochemical Parameters Under Protective Cultivation

Background

Papaya (*Carica papaya* L.) belonging to the family Caricaceae, is an evergreen herbaceous commercial fruit plant of tropical and subtropical region (Srinu *et al.*, 2017). Papaya is consumed as fresh, as a vegetable or used for processed products such as drinks, jams, jellies, ice cream, pies and as dried and crystallized fruits world-wide (Jaime *et al.*, 2007). In Bangladesh, papaya occupied 1595 ha of land and total production was about 134647 tones with an average yield of 34.15 tones per acre (BBS, 2018). Reports claim that about 30-50% of the harvested papaya never reaches the consumers mainly because of postharvest spoilage (Mondal and Bose, 2007). If that amount of fruit were equally distributed among the total people of Bangladesh, the per capita availability of fruit is far below the recommended level (100g/capital).

In Bangladesh a considerable amount of papaya is being spoiled due to prevailing high temperature and humidity. Its edible and marketing quality deteriorates rapidly, once it is fully ripe. Harvesting at proper maturity stage is a very important determinant for storage life and final fruit quality. If fruits are harvested at improper maturity, it can lead to uneven ripening and over ripe fruits. Fruit ripening in papaya *Carica papaya* cultivars varies widely in terms of softening, skin color changes and shelf life (Thumdee *et al.*, 2007). Yellow color in the fruit skin has been used as a harvest index criterion to assure adequate ripening and maximum shelf life. Maturity standards based on physical and chemical parameters must be enforced to assure that only high quality fruits are harvested (Lebrun *et al.*, 2008).

Objectives

To determine the effects of protected cultivation and maturity stages on physiological and biochemical changes of papaya fruit related with overall quality

Methodology

Papaya fruit (cv. Red Lady) were harvested in September, 2021 grown in net house and open field condition from Horticulture Farm, Sher-e-Bangla Agricultural University at maturity stage 1, 2, 3 and 4. Fruits were then transported at the Postharvest Laboratory of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The maturity stages were visually defined according to the skin color as: 25% skin color (stage 1), stage 2-50% skin color (stage 2), 75% skin color (stage 3) and 90% skin color (stage 4). The experiment was laid out in a completely randomized design (CRD) with 3 replications of 5 fruits per replication. Fruits were kept in room temperature ($23 \pm 2^{\circ}\text{C}$) until fruit skin color reach at stage 4 and inspected daily for visual change in color. Measurement of color, TSS, pH, vitamin C, reducing sugar, titratable acidity, β -carotene were performed when all the fruits reached at stage 4 (fully ripen).

Key findings

Papaya harvested from net house showed significantly higher accumulation of total soluble solids, total phenol, reducing sugar and β -carotene compared to open field harvested papaya. In terms of peel color, papaya grown in the net house had the better peel color than that grown in the open field. There was no significant difference in maturity stage 3 and 4 in respect of most of the quality parameters i.e. total soluble solid, pH and β -carotene. The ascorbic acid content was significantly higher in stage 3 compared to other maturity stages. In terms of peel color, papaya harvested at maturity stage 4 exhibited the greatest a*, b*, and c*

values, which were statistically equivalent to papaya collected at maturity stage 3. Fruit harvested at maturity stages 1 and 2 had lower quality but could still be consumed. Thus, the study found that papaya collected at maturation stages 3 and 4 from net houses performed better in terms of quality traits.

Key words: Protective cultivation, Papaya, Maturity stages, Fruit quality

12.16. : Effect of Different Growing Environment on Growth Yield and Quality of Banana

Background

Food production through agricultural activities is crucial for our existence, but productivity might be increased with a better understanding of how changes in temperature, rainfall, and relative humidity (RH) affect agricultural output. Geographical location, productivity, and production period of various crops are determined by growth development and crop quality under a certain set of climate characteristics.

According to survey data of banana growers, one of the most significant elements determining the growth and productivity of bananas is the environment (Altaee, 2020). Because of its high unpredictability, the climate is the most essential component in agricultural production, as the atmosphere in which crops are grown can be changed by a protected environment. The conditions under which plants are grown must be measured, and environmental elements that influence fruit quality must be considered. Temperature and relative humidity are two environmental factors that have a significant impact. Temperature has a significant impact on banana development and growth. Banana growth and development are adversely affected by extreme, higher, and lower temperatures. A study by Robinson and Saco (2010) found that the ideal temperature for banana growth and development is around 27 °C. High temperature stress alters plant physiological and biochemical responses, lowering crop quality and yield. Additionally, the growth of bunches is halted at temperatures higher than 38 °C or lower than 9 °C (Ravi and Vaganan, 2016).

By encouraging the crops to grow before and after their natural growing season and extending their overall lifespan, higher than normal temperatures, controlled humidity, or increased artificially induced light levels under protection can increase yields and improve quality (Rabbi *et al.*, 2019). Protected cultivation practices can be defined as a cropping technique wherein the micro-climate surrounding the plant body is controlled partially or fully as per the requirement of the crop species grown during their period of growth. The most practical way to fulfill the aims of protected agriculture is to adapt the natural environment using strong engineering concepts to enhance optimum plant growth and production with increased input usage efficiency.

Objectives

The experiment attempted to determine the efficacy of various shed house cultivation methods against open field methods on banana quality and yield.

Methodology

Plant materials and growing conditions

This experiment was performed at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from February to October 2021. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude), and has an average elevation of 4 meters

(13.12 ft.) according to the National Mapping Organization of Bangladesh. The banana cv. BARI khola 1 was planted at 1.2 m × 1.2 m spacing under four protected cultivation system, those are open field condition (control), net house (60 mesh), poly shed house (naturally ventilated polyhouse; 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 polyhouse; fully covered with UV film sheet). The experiment was laid out with 4 numbers of treatments with 4 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the plots. In each replication, five plants were randomly selected for observations on fruit production, yield, and physio-chemical parameters. Three fruits from each plant and each treatment were harvested for various biochemical analyses. Temperature and relative humidity were recorded during the growing period in all environments, to monitor the actual environmental conditions in which the plants were grown.

Key findings

Present results revealed that protective cultural environment was best suited and beneficial for the growth, yield and quality of banana. Fruits grown under poly net house had substantially more total soluble solids, ascorbic acid, sugar content and total phenol. Furthermore, in the poly net house, the fruit peel color, yield, and yield contributing parameters of the banana were higher. From the present investigation it is concluded that banana can be grown successfully in a poly net house with improved plant growth, fruit weight, color, yield, and quality.

Key words: Shed houses, Banana growth, Fruit quality, Yield

12.17. : Effect of Maturity Stage of Banana on Physiological and Biochemical Parameters Under Protective Cultivation

Background

Banana is one of the most popular fruit crop in the entire world. Banana is also a staple food owing to its rich and easily digestible carbohydrates with a calorific value of 67-137/100 g fruit. It contains nearly all the essential nutrients including minerals and vitamins and has several medicinal properties. It is rich in dietary fibres and helpful for easy bowel movement (Narayan, 2015).

Fruit maturation is an imperative postharvest criterion for banana. The stage of maturation at which the fruit is harvested greatly influences the green-life or storage longevity and eating quality. Every fruit attains its full characteristics e.g. flavour, taste and colour during storage if it is picked at optimum time. Fruits, harvested at an advanced stage of maturity and is not suitable for fruits intended for long distance transportation due to their shorter storage life (Kader, 1994). Green-life or storage longevity and eating quality of banana was greatly influenced by the stage of maturation at which the fruit is harvested.

Depending on season and cultivar, bananas become matured at 90- 120 days after appearing of first flower (Knowledge Master, 2003). Banana bunches are harvested, when the fruits are fully developed, that is, 75% matured, the angles are becoming less prominent and the fruits on the upper hands are changing to light green; and the remnants of flower (styles) are easily rubbed off the tips. Generally, this stage reached 75 to 80 days after the opening of the first hand. Maturity of the banana bunches indicates the quality of fruit during ripening and overall marketability. Most of the post-harvest losses could be managed by harvesting the fruit at proper maturity stage (Chegeh *et al.*, 1995). Early harvest of banana may lack flavour

and may not ripe properly, while harvesting it late may over ripe the fruit and cause splitting (Patil and Rawale, 2012). Optimum maturity stage of banana is important for attaining good quality fruits and optimum storage life of fruits.

Objectives

The study was undertaken to determine the optimum maturity stages of BARI Kola 1 on the basis of different physico-chemical properties

Methodology

Banana fruit (cv. BARI Khola 1) were harvested in October, 2021 grown in open field, uv poly shed and net poly shed condition from Horticulture Farm, Sher-e-Bangla Agricultural University at under mature (the angles are becoming less prominent), mature (disappeared angularity) and over mature stage (the skin colour changes from green to yellow). Fruits were then transported at the Postharvest Laboratory of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in a completely randomized design (CRD) with 3 replications of 5 fruits per replication. Fruits were kept in room temperature ($25 \pm 2^{\circ}\text{C}$) until fruit skin color reach to yellow and inspected daily for visual change in color.

Key findings

Banana fruits can be harvested after reaching full maturation, and before reaching the ripening stage. Banana harvested from poly net house showed significantly higher accumulation of total soluble solid, ascorbic acid, reducing, and total sugar and peel color development compared to open field and UV poly shed harvested papaya during all maturity stages.

Key words: Protective cultivation, Maturity stage, Banana, Postharvest life

12.18. : Effect of Different Planting Materials and Nutrient Management of Banana Fruits

Background

Banana is one of the important fruit crops in Bangladesh belong to the family Musaceae. In Bangladesh, it is one of the top listed fruit crops, which is available throughout the year and consumption rate is higher than any other fruits. It contains carbohydrate, crude fibre, protein, fat, ash, phosphorous, calcium, iron, β carotene, riboflavin, niacin and ascorbic acid (Khader *et al.*, 1996). Besides these, it is rich in K, relatively lower amount of Na and Fe. Bangladesh produces nearly 1.00 million tons of bananas annually (Hossain, 2014). Banana is cultivated almost everywhere in Bangladesh round the year In 2010-2011, the total production of banana in Bangladesh was 800840 metric tons and the cultivated area was about 52847 ha (BBS, 2012).

The type and quality of planting material is an important aspect in the establishment of any banana plantation. Poor planting material limits long term vigour and generally restricts the effectiveness of management practices (Eckstein and Robinson, 1995). Since, conventional methods of propagation of banana are unable to supply large quantities of genetically superior individuals required by cultivar development programs, new methods are required to meet the demands. The use of tissue culture in conjunction with classical breeding methods can accelerate cultivar development programs of this potent species (Singh *et al.*, 2013). Moreover, tissue culture technology enables the rapid production of a large quantity of

disease free true-to-type plants from a single parent plant showing good genetic potential. Banana is a heavy feeder of nutrients and requires large quantities for its growth and development (Hazarika and Ansari, 2010). Organic and inorganic sources of nutrients have an advantage of consistent and slow release of nutrients, by maintaining ideal C: N ratio, improvement of water holding capacity and microbial biomass of soil profile (Yadav *et al.*, 2010). It is also improves soil structure by increasing organic matter, water capacity, microbial activity, and soil temperature, and by decreasing soil compaction (Uzun, 2004).

Objectives

- Evaluation of the performance of corm and tissue culture plantlets regarding growth, yield and quality of banana
- A comparative study between organic and inorganic sources of nutrient on the growth, yield and quality of banana

Methodology

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka 1207 during the period from March 2020 to April 2021. The location of the experimental site is situated in 23⁰74' N latitude and 90⁰35' E longitude with an elevation of 8 meter from sea level (Anon, 1989) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28). The corm and tissue culture plantlet of variety BARI kola-1 was collected from Bangladesh Agricultural Research Institute (BARI), Joydepur, Gajipur. The experiment comprised of two factors. Two different planting materials (tissue culture plantlets and corm) and organic and inorganic fertilizers (cowdung, vermicompost, spent mushroom compost and NPK). Fertilizers were collected from Jannat Nursery, Agargaon, Dhaka except Spent mushroom compost. Spent mushroom compost was collected from National Mushroom Development and Extension center, Savar, Dhaka.

Key findings

Regarding above results, it can be concluded that corm stood for highest number of leaves, chlorophyll content, pseudostem diameter, number of hands, number of fingers. Minimum days were required for tissue culture plants for maturation of banana and also inflorescence initiation was earlier in tissue culture bananas. The yield parameters such as length of inflorescence, total number of fingers were found highest in corm except (individual fruit weight). The quality parameters showed best results in corm propagated bananas. Between the organic and inorganic sources of nutrients vermicompost showed best results regarding the growth, yield and quality of banana. Besides the combination, corm treated with vermicompost performed as the best combination. Looking upon the circumstances, it can easily articulated that corm showed best results and vermicompost was the excellent organic sources nutrients for growth, yield and quality of banana.

Key words: Planting Materials, Nutrients, Banana, Growth, Yield

12.19. :Yield and quality of Dragon Fruits as Influenced by Different Protective Cultivation Approaches

Background

Dragon fruit (*Hylocereus* sp. and *Selenicereus* sp.), also known as pitahaya or pitaya, is a member of the Cactaceae family, is considered as non-climacteric and native to the tropical

forest regions of Southern Mexico, Central America, and Northern South America. Among its different species, *Hylocereus polyrhizus* (red dragon fruit or red pitaya) is highly nutritious and contains numerous health-promoting phytochemicals (i.e., carotenoids, flavonoids, polyphenols, minerals, glucose, fructose, dietary fiber and vitamin C), which are known to play important roles that signify strong antioxidant potential in the fruit (Leong *et al.*, 2018). The climate is the most important factor in agricultural production because of its high variability, so that the atmosphere in which the crops are grown can be changed by a protected environment (Iizumi, 2015). Dragon fruit plant has wide adaptability and grown well in slightly heavy texture soils. Plants are commonly propagated by stem cuttings. Flower buds are emerging after 15-18 months of planting and required 28-30 days for blooming. Temperature is a factor that affects the chemical composition of the fruits. It interferes in the formation of sugars, due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates and the increase in the transpiration rate (Palonen *et al.*, 2017). Fruit growth and development occur during July-September and coincide with relatively higher temperatures, ranging from mean minimum of 30°C to mean maximum of 40°C with about 10°C diurnal temperature variation. Although dragon fruit is a heat loving crop, it can be damaged by long periods of intense sun and heat, resulting in sun scald.

Protected agriculture has grown in popularity as a means of increasing agricultural productivity and lowering costs. In Bangladesh, very little study has been conducted on dragon fruit cultivation in a low-tech protected setting. 'Pitaya' root cuttings under different shading levels and partial shading (between 23 and 42%) increase the cladodes percentage (Lone *et al.*, 2018). The production 'Pitaya' is sensitive to light intensity, as a 50% reduction in the direct incidence of the sun allows the highest growth of plants (Souza *et al.*, 2016). To fulfill the growing demand for fruit crops, it is critical to analyze the cultivation, suitability, and quality measurement of dragon fruit under protected condition.

Objectives

In terms of dragon fruit yield and biochemical attributes, this experiment aimed to introduce a protected farming approach compared to open field.

Methodology

This experiment was carried out at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the summer of 2019. Dhaka is located at 23°42'37" N (Latitude), 90°24'26" E (Longitude) and has an average elevation of 4 m (13.12 ft.) according to the National Mapping Organization of Bangladesh. One-year-old red-fleshed dragon fruits cv. 'Da Hong' pitaya plants were planted on a single-pole system (three plants per pole) at 3 × 2.5 m spacing under four protected cultivation systems, namely open field condition (control), net house (60 mesh), net poly house (entire roof covered with poly sheet and full portion of four sides covered with net), and UV poly shed house (Fan pad UV poly house; fully covered with UV film sheet). The experiment was laid out with 4 treatments with 3 replications. During the experiment, all essential cultural practices and plant protection measures were followed uniformly for all the replications. Fruits from each plant and each treatment were harvested for various biochemical analyses. Temperature and relative humidity were recorded during the growing period in all environments to monitor the actual environmental conditions in which the plants were grown.

Key findings

Our results revealed that shading conditions significantly influenced the growth, yield, and quality of dragon. Fruits grown under a net poly house had substantially more total soluble solids, juice pH, anthocyanin, non-reducing sugar and total sugar. Furthermore, in the net poly shed house, the fruit peel color, number of fruits, individual fruit weight and yield contributing parameters of the dragon fruits were higher. Finally, it can be concluded that the findings of this research provide very basic information that could be used to increase the quality and nutrient contents of dragon fruits in tropical and subtropical regions including Bangladesh.

Key words: Dragon fruit, Shed houses, Peel color, Fruit weight

B. Implementation Status

1. Procurement (component wise):

BARI Component

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
Book Self			1	20898	
Laser printer			1	24000	
Color printer			1	24500	
Monitor			1	15500	
			Sub-total	84898	
(b) Lab & field equipment					
Mini Powertillar.			1	25000	
Water Pump			1	24500	
Spray Machine			4	24000	
			Sub-total	73500	

SAU Component

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
i) Office equipment					
Computer Table	1	247500	1	7800	RFQ
Computer Chair	1		1	4400	
Executive Table	1		1	19800	
Executive Chair	1		1	14800	
File Cabinet	4		4	25000	
Visitor Chair	1		1	23400	
Book Shelf	1		1	20700	
Desktop Computer	1		1	75000	
UPS (Offline)	1		1	4500	
Laser Printer	1		1	19000	
Digital Camera	1		1	26000	
Scanner	1		1	4700	
				Sub-total	
ii) Lab and field equipment					
UV Spectrophotomer		1235000	1	473900	RFQ
Refrigerator			1	84550	
Digital Balance			1	19400	
Air Cooler			1	119500	
Reverse Osmosis Water Filter			1	34350	
Digital PH Meter			1	49,800	
Chlorophyll Meter			1	204950	
Water Bath			1	119750	
Digital refractometer			1	74900	
Luminometer			1	49920	
UV Spectrophotomer			1	473900	
				Subtotal	

2. Establishment/renovation facilities:

N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized:

BARI Component

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop	45	5	50	01 day	
(c) Others (if any)					

SAU Component

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					
(c) Others (if any)					

C. Financial and Physical Progress (combined & component wise)

Combined

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	2261245	2059316	2237505	-178189	162.87	
b. Field research/lab expenses and supplies	8888877	7435485	8851767	-1416282	202.62	
c. Operating expenses	637858	477479	490864	-13385	105.71	
d. Vehicle hire and fuel, oil & maintenance	960000	654274	385843	268431	58.47	
e. Training/workshop/seminar etc.	468000	217227	127900	89327	58.88	
f. Publications and printing	484000	339475	84216	255259	16.88	
g. Miscellaneous	266350	199724	84322	115402	1.09	
h. Capital expenses	3013620	2532631	1649518	883113	35.47	
Total	16979950	13915611	13911935	3675.9		

BARI Component**Fig in Tk**

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	628360	426431	604620	-178189	141.79	
b. Field research/lab expenses and supplies	4519250	3065858	4482140	-1416282	146.20	
c. Operating expenses	501000	340034	353419	-13385	103.94	
d. Vehicle hire and fuel, oil & maintenance	950000	644274	375843	268431	58.34	
e. Training/workshop/seminar etc.	320000	217227	127900	89327	58.88	
f. Publications and printing	450000	305475	50216	255259	16.44	
g. Miscellaneous	170000	115402	0	115402	0.00	
h. Capital expenses	1537500	1056511	173398	883113	16.41	
Total	9076110	6171211	6167536	3676		

SAU Component**Fig in Tk**

Item of Expenditure	Total Approved Budget	Fund Received	Actual Expenditure	Balance Unspent	Physically Progress %	Remarks
a. Contractual Staff Salary	1632885	1632885	1632885	0	21.08	
b. Field Research / Lab expenses and supplies	4369627	4369627	4369627	0	56.42	
c. Operating Expenses	136858	137445	137445	0	1.77	
d. Vehicle Hire and Fuel, Oil & Maintenance	10000	10000	10000	0	0.13	
e. Training/ Workshop/ Seminar etc.	148000	0	0	0	0.00	
f. Publications and printing	34000	34000	34000	0	0.44	
g. Miscellaneous	96350	84322	84322	0	1.09	
h. Capital Expenses	1476120	1476120	1476120	0	19.06	
Total	7903840	7744399	7744399	0	100	

D. Achievement of Sub-project by Objectives (Tangible form): Technology generated/ developed

BARI Component

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
To develop protective culture technology for high value vegetables	Effect of different net house on quality seedling raising of high value vegetables	Eggplant (V2) resulted the maximum seed germination (93.58%) with lowest mortality (5.58 %), in case of net house treatment, UV stabilized polyethylene film with 60 mesh insect net along with green shade net (T1) exhibited the maximum seed germination (94.83%) with lower mortality (3.33 %). In case of combined effect, maximum seed germination (93.58%) and lowest mortality (2.08 %) was observed in V2T1.	The production of high-quality seedlings of various high-value vegetables will be produced by UV-stabilized polyethylene film 60-mesh insect nets and green shade nets.
	Effect of different mulch paper on growth and yield of different high value vegetables in Bangladesh	Mulching produced higher fruit yield per plant and fruit yield per hectare than for the control, indicating that the mulch had a positive effect in generating increased fruit yield. Silver over black plastic mulch produced the highest fruit yield viz., 98.05 t/ha (tomato), 54.11 t/ha (eggplant), 34.33 t/ha (sweet pepper), 26.09 t/ha (broccoli) followed by black and no mulches, while the control plot produced the lowest fruit yield due to open condition.	Higher production of different high value vegetables will be obtained using silver over black plastic mulch
	Effect of different type of nethouse on the incidence of insect and diseases of high value vegetables	Under open field and NH1 conditions, a significant amount of white fly, aphid, leaf miners, mites, and ESFB infestation was observed, whereas NH2 and NH3 conditions had a lower infestation. The use of NH2, i.e. UV stabilized transparent polyethylene film with a 60 mesh insect net, continues to be a good strategy to allow a better utilization of the sunlight due to the	The use of stabilized transparent polyethylene film with a 60 mesh insect nethouse will provide less infestation of different types of notorious insects of high value vegetables

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
		manipulation of the light spectrum, which in turn promotes desired physiological plant responses. The use of stabilized transparent polyethylene film with a 60 mesh insect nethouse provided a negative effect on the presence of different types of notorious insects on vegetables.	
To produce safe and quality vegetables for both local and export market	Effect of different net house on growth and quality of high value vegetables	Under UV stabilized polyethylene film with 60 mesh insect net, the tomato, eggplant, sweet pepper, cucumber, and netted melon (95.04, 41.60, 31.27, 28.8, and 25.87 t/ha, respectively) produced higher yields with good horticultural traits. The average BCR of these vegetables were 3.13, 1.85, 6.88, 3.69, and 12.55, respectively. The product were safe and of good quality due to the absence of pesticide use. Considering yield and yield contributing traits, pest infestation and BCR, four types of vegetables performed best, viz., tomato, sweet pepper, cucumber, and netted melon under UV polyethylene film with 60 mesh insect net which will ensure year-round production in Bangladesh.	The UV-stabilized transparent polyethylene film and 60 mesh insect net used to construct the protected net house will result in higher yields of tomato, eggplant, sweet pepper, cucumber and netted melon as well as higher BCR.
	Effect of maturity indices on growth and quality of high value vegetables	Tomatoes were found to be an appropriate size (6.5 cm length and 6.2 cm diameter), weight (84 g), TSS (4.5 percent), pH (4.3), 'turning red' and 'tasty' at the week 5 stage, while broccoli was found to be an appropriate size (12.0 cm length and 13.0 cm diameter), weight (360 g), 'green' color at the day 12 stage in our study. At the week 6 stage, nettled melon was found to be of appropriate size	The high-value vegetables are picked at the proper maturity stages, the quality parameters are found in an appropriate condition.

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
		<p>(15.2 cm length and 14.5 cm diameter), weight (800 g), TSS (10.8 percent), pH (6.3), 'net fully developed' on the skin of the fruit, and 'much tasty,' while cucumber was found to be of appropriate size (8.8-10.8 cm length and 2.2-2.9 cm diameter), weight (61-88 g), TSS (3.8-4.1 percent), pH (6.3), 'less powdery with less spine' on fruit skin and 'tasty' at day 10-12 stage. Sweet peppers that were found to be of appropriate size (9.2-9.5 cm length and 6.0-6.2 cm diameter), weight (131-142 g), TSS (4.5-4.8 percent), pH (5.6-5.65), 'Shiny green' fruit color, and 'Pleasant flavored taste' at the week 5-6 stage lost their attractiveness and shininess, and became slimy in texture within a short time.</p>	
	Study of different nutritional facts of vegetables under different type of protected growing condition	Protein contents of investigated growing conditions varied between 0.58 – 2.70g and dietary fiber contents between 0.44-3.50 g, while the range of sodium, calcium, magnesium content were obtained 2.6-20.3mg in cucumber under poly green shed house, 7.8 mg (cucumber in poly green shed house) - 47.0 mg (broccoli in UV poly shed house), 12.5 mg (sweet pepper in poly green shed house) - 23.0 mg (tomato in poly green shed house, respectively. In maximum vegetables, the vitamins content was higher in UV poly shed house compare to other conditions.	Protein, dietary fiber, sodium, calcium, magnesium and vitamins content will be higher when the high value vegetables are cultivated under UV polyethylene film with 60 mesh insect net nethouse.
	Upscaling of protective nethouse technology at farmers' field	Cumilla farmers produced more tomatoes, sweet peppers, cucumbers, netted melon, and okra than Narshingdi farmers. As a result of UV polyethylene film	High-value vegetables will be successfully commercially cultivated year-

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
		<p>nethouse technology, high-value thermos-sensitive vegetables may be successfully cultivated commercially year-round to provide a safe and high-quality product, while greater fruit yield per unit area will be achieved in a protected nethouse compared to an open field.</p> <p>Farmers are overjoyed to be producing safe and high-quality vegetables under UV poly net houses because production was higher, pesticides were used less frequently, and the price was higher compared to neighboring farmers.</p>	<p>round under UV polyethylene film nethouse to provide a safe and high-quality product for local and export market.</p>

SAU Component

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
To develop protective culture technology for high value fruits	Effect of different growing environments on growth, yield and quality attributes of strawberry	The most suitable growing conditions for yield and yield parameters of strawberries are net house, whereas UV poly shed and poly house conditions are favourable for the production of better quality fruit.	Shading conditions significantly influenced growth, yield and quality of the strawberry.
	Impact of Different Shed Houses and Growing Media on Growth, Yield and Quality of Strawberry	Strawberry plants responded better to the cocopeat-based growing medium than to the other growing media used (cowdung and vermicompost) across all growing	Cocopeat growing media and net house shade may be advised to obtain better quality and yield for strawberry.

		shade features, while net house proved superior for reproductive growth and quality traits.	
	Effect of various mulch materials and GA ₃ on strawberry growth, yield, and quality under net house	Use of organic mulch (sawdust) gave better yield and quality of strawberry compared to the use of synthetic mulch (black and white polythene) and control (no mulch).	The combined application of sawdust mulching and GA ₃ can be used successfully in strawberry production
	Effect of pre-harvest cypermethrin spray on residual level and biochemical attributes of strawberry fruit	Pesticide (Cypermethrin) residues become below the Maximum Residue Limit (MRL) at 10 days after spraying (DAS) and no pesticide residues were detected at 12 DAS.	Time period is determined to avoid the residual effect of pesticide.
	Effect of Plant Growth Regulators and Pruning Levels on Sex expression, Yield and Quality in Watermelon	There is a need to prune watermelon as it enhances its production. Growing watermelon by spraying GA ₃ was suitable for sex expression and higher fruit yield	Plant pruned and sprayed with GA ₃ had significantly superior effects on and yield and quality of watermelon fruit.
	Effect of different sheds on growth, yield and quality of papaya	Fruit peel color, yield, and yield contributing parameters of the papaya were higher in net house compared to other growing conditions	Papaya can be grown successfully in a net house with improved fruit color, yield and quality.
	Effect of Maturity Stage of Papaya on Physiological and Biochemical Parameters under protective cultivation	Papaya collected at maturation stages 3 and 4 from net houses performed better in terms of quality traits.	The optimal maturation stage for papaya harvesting has been identified.
	Effect of different growing environment on growth yield and quality of banana	Poly net house growing environment was found best in respect of growth, yield and fruit quality parameter of Banana	The poly net house growing environment was the most suitable for quality banana

			production.
	Effect of Different Planting Materials and Nutrient Management of Banana Fruits	Tissue culture bananas had earlier inflorescence initiation and matured faster. However, Crom propagated bananas performed best in terms of yield and quality.	Corm propagated plants and vermicompost nutrients can be used to improve banana growth, yield, and quality.
	Effect of Maturity Stage of banana on Physiological and Biochemical Parameters under protective cultivation	Fruits harvested at an advanced maturity stage are not suitable for long distance transportation due to their shorter storage life. Fruits harvested before optimum maturity was not ripen adequately and develop lower color value.	Fruits grown in poly net house and harvested at mature stage performed better in terms of quality traits.
	Yield and quality of Dragon fruits as influenced by different protective cultivation approaches	Shading conditions significantly influenced the growth, yield, and quality of dragon.	This research provides very basic information that could be used to increase the quality and nutrient contents of dragon fruits.

E: Information/Knowledge generated / Policy generated

BARI Component

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To develop protective culture technology for high value vegetables	Effect of different net house on quality seedling raising of high value vegetables	The production of high-quality seedlings of various high-value vegetables will be produced by UV-stabilized polyethylene film 60-mesh insect nets and green shade nets.	High-quality seedlings of various high-value vegetables will be available to the farmers.
	Effect of different mulch paper on growth and yield	Higher production of different high value vegetables will be obtained using silver over black	Production of vegetables will be higher using plastic

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
	of different high value vegetables in Bangladesh	plastic mulch.	mulch.
	Effect of different type of nethouse on the incidence of insect and diseases of high value vegetables	The use of stabilized transparent polyethylene film with a 60 mesh insect nethouse will provide less infestation of different types of notorious insects of high value vegetables.	Insecticide free vegetables will be produced under nethouse made of polyethylene film with a 60 mesh insect net.
To produce safe and quality vegetables for both local and export market	Effect of different net house on growth and quality of high value vegetables	The UV-stabilized transparent polyethylene film and 60 mesh insect net used to construct the protected net house will result in higher yields of tomato, eggplant, sweet pepper, cucumber and netted melon as well as higher BCR.	Profitable vegetable production will be higher under nethouse made of polyethylene film with a 60 mesh insect net.
	Effect of maturity indices on growth and quality of high value vegetables	The high-value vegetables are picked at the proper maturity stages, the quality parameters are found in an appropriate condition.	
	Study of different nutritional facts of vegetables under different type of protected growing condition	Protein, dietary fiber, sodium, calcium, magnesium and vitamins content will be higher when the high value vegetables are cultivated under UV polyethylene film with 60 mesh insect net nethouse.	Nutrient dense vegetable will be produced under nethouse made of polyethylene film with a 60 mesh insect net.
	Upscaling of protective nethouse technology at farmers' field	High-value vegetables will be successfully commercially cultivated year-round under UV polyethylene film nethouse to provide a safe and high-quality product for local and export market.	Safe and high-quality vegetable will be produced under nethouse for local and export market.

SAU Component

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To develop protective culture technology for high value fruits	To know the response of growing environments on growth, yield and quality attributes of strawberry	The most suitable growing conditions for yield and yield parameters of strawberries are net house.	Shading has positive effect on yield and quality attributes of the strawberry.
	Impact of different shed houses and growing media on growth, yield and quality of strawberry	Cocopeat-based growing medium showed better performance compared to other growing media (cowdung and vermicompost) across all growing conditions for yield and quality traits of strawberry.	A better possibility for strawberry production may be cocopeat growing medium and net house conditions.
	To find out the effect of mulch materials and GA ₃ on strawberry yield, and quality under protected condition	Sawdust mulch gave better yield and quality of strawberry compared to the use of synthetic mulch and control (no mulch).	Mulching with sawdust and spraying with GA ₃ may increase strawberry production in plants.
	To find out the effect of plant growth regulators and pruning levels on sex expression, yield and quality in Watermelon	Pruned plants sprayed with plant growth regulators (GA ₃ , maleic hydrazide and Ethephone) provide high yield and quality fruits	Pruned plants sprayed with GA ₃ might be provide high yield and quality fruits
To produce safe and quality vegetables for both local and export market	To find out effect of different sheds on growth, yield and quality of papaya	When compared to other growth circumstances, the papaya fruit peel color, yield, and yield contributing parameters were all greater in net house.	Growing in a net house can increase yield while also providing safe and quality fruit.
	To know the effect of pre-harvest cypermethrin spray	Pesticide application on strawberries	Delaying fruit harvesting for 7

	on residual level and biochemical attributes of strawberry fruit	reduced insect infection and protected fruit quality; however residues remained above the maximum residue limit (MRL) up to 7 days after spraying.	days following insecticide spraying reduces residual levels below the MRL and can get safe food.
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F. Materials Development/Publication made under the Sub-project

BARI Component

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/ leaflet/ flyer etc.	01		Year round and quality high value vegetables production under protective poly net house
Journal publication	4	3	<p>Quamruzzaman AKM, Islam, F. and Mallick, S.R. 2021. Effect of Different Shade House on Quality Seedling Raising of High Value Vegetables. American Journal of Plant Sciences, 12, 7-17. https://doi.org/10.4236/ajps.2021.121002</p> <p>Quamruzzaman AKM, Islam, F. and Mallick, S.R. 2021. Mulch Effect on Growth and Yield of Vine Vegetables. European Journal of Agriculture and Food Sciences. 3 (1): 143-147.</p> <p>Islam Ferdouse, AKM Quamruzzaman and Sharmila Rani Mallick. 2021. Effect of Different Mulch Paper on Growth and Yield of Different High Value Vegetables in Bangladesh. Agricultural Sciences, 12, 237-246. https://doi.org/10.4236/as.2021.123015</p> <p>Quamruzzaman, A.K.M., Islam, F., Akter, L. and Mallick, S.R. (2022) Effect of Maturity Indices on Growth and Quality of High Value Vegetables. American Journal of Plant Sciences, 13, 1042-1062. https://doi.org/10.4236/ajps.2022.137069</p> <p>Quamruzzaman, A.K.M., Islam, F., Akter, L., Hossain, M.S. and Mallick, S.R. (2022)</p>

			Effect of Different Nethouses on the Incidence of Insect on Vegetable Crops. <i>Advances in Entomology</i> , 10, 223-232. https://doi.org/10.4236/ae.2022.103016
Video clip/TV program	01		
News Paper/Popular Article	0		
Other publications, if any	0		

SAU Component

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/ leaflet/ flyer etc.	0		
Journal publication	4	2	<ol style="list-style-type: none"> Islam N, Zaman S, Shaon A R & Choudhury S (2021) Effect of different growing environments on growth, yield and quality attributes of strawberry. <i>Journal of Applied Horticulture</i> 23(2):178-183. Choudhury S, Islam N, Mustaki S, Uddain J, Azad MOK, Choi KY & Naznin MT (2022) Evaluation of the Different Low-Tech Protective Cultivation Approaches to Improve Yield and Phytochemical Accumulation of Papaya (<i>Carica papaya</i> L.) in Bangladesh. <i>Horticulturae</i> 8(3): 210
Video clip/TV program	0		
News Paper/Popular Article	0		
Other publications, if any	0		

G. Description of generated Technology/Knowledge/Policy

i. Technology Factsheet (title of the technology, introduction, description, suitable location/ecosystem, benefits, name and contact address of author)

BARI Component

Title : Year round safe and quality vegetable production using protective nethouse

Introduction :

Year round vegetable production is one way to increase vegetable production in Bangladesh. And it will be achievable if the protected nethouse can consistently produce high-quality, valuable, secure crops. To lessen the adverse environment, vegetables can be cultivated in protected nethouses. Vegetable production will rise in quantity and quality. All year long, high-quality, safe vegetables can be grown without the need of additional pesticides. If farmers can grow non-seasonal vegetables three to four times a year, they will make more money.

Vegetables cultivated in a protected nethouse have a high initial cost of production, but after two growing seasons, producers will see a return because the fixed asset expenditures are no longer necessary.

Description :

The protective net house structure, crop and variety selection, production technology, and market pricing are the primary factors that affect how profitable protective farming is. A protective nethouse needs to be built first. It will last for 4-5 years if UV-resistant polysheet is used on the nethouse. In order to prevent insects from entering, the four sides of the nethouse should be covered with pest control or pest exclusion nets (60 mesh net). To protect the vegetables from too much sunshine, keep a green shade net up. As a contemporary irrigation system, drip irrigation is advised.

Construction of the nethouse

- The nethouse is covered with transparent polysheet that is UV-resistant.
- Use of green shade nets to provide partial shade to crops inside the nethouse if required.
- Use of a pest control net or pest exclusion net (60 mesh net) on four sides of the nethouse.
- Using drip irrigation techniques
- Making use of different kinds of organic manure (vermincompost, trichocompost).

Crop selection

High-value vegetables must be chosen to grow in the protective nethouse because it is fairly technologically complex and expensive, and they must do so such that the nethouse's building costs are recovered within the first two growing seasons. As a result, high-value vegetables should be chosen to target both domestic and international markets.

- Tomato
- Cucumber
- Sweet pepper
- Nettle melon

Suitable Location/Ecosystem:

Country wide

Benefits :

- Production of quality and safe vegetables throughout the year.
- Controlling adverse environments [high or low temperature, high rainfall, high sun] to increase vegetable production
- The use of water, fertilizers, and manual labor is limited in vegetable production.
- Minimize pesticide and fungicide applications.
- Exports of vegetables will be promoted.

SAU Component

Research Title: Safe and quality fruit production under protective condition

Introduction

Protected cultivation systems are used as a powerful tool to produce crops all over the world. Protected cultivation ensures: soil moisture conservation, efficient use of energy, primarily solar, higher yield, year-round cultivation, better quality, off-season production, self-employment for educated rural youth in the farm sector, least pesticide residues, controlled pollination, easier plant protection, and weed free cultivation. Global factors as well as in area are increasing the demand of high quality and absolute safety agricultural products. The level of microbial contamination and chemical residues, antibiotics, heavy metals in agricultural products has now become serious problems that affect human health and the environment. Good Agricultural Practices are rules that established to ensure a safe and clean production environment. Very little research has been done in Bangladesh on low-tech protected fruit farming. To meet the growing demand for fruit crops, it is critical to examine the cultivation, suitability, and quality measurement of various fruits under protected conditions, such as strawberry, melon, papaya, banana, and dragon fruit.

Description

Crops are protected from unfavorable outdoor climate conditions and pests, and the indoor climate can be modified to create an environment that is optimal for crop growth and production in terms of both quality and quantity. Manipulation of environmental factors depends on the specific properties of the materials used on the roofs and sides of structures, as well as on the structure height, shape, and position. Fruits are planted under four protected cultivation system, those are 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). The fruit yield inside the shed house was more than in the open field condition.

Suitable Location/Ecosystem:

Country wide

Benefits

Protective structures increase crop yield and quality by altering environmental factors, such as light, temperature, air humidity, wind, and/or pest pressure. Protected agriculture is becoming increasingly popular as a means of increasing agricultural productivity while lowering costs. Protected cultivation is in a way precise, progressive and parallel agriculture

encompassing virtually all facets of agriculture and rather under additional scrutiny of technical relevance to situations and grower and market economics. Food must not contain pathogens as biological agent (bacteria, fungi, viruses and parasites) and chemical (pesticide residues, heavy metals, and nitrate concentration); besides, the products must be safe from field to consumers. By adopting protected cultivation technology, the growers can look forward to a better and additional remuneration for high quality produce.

ii. Effectiveness in policy support (if applicable): NA

H. Technology/Knowledge generation/Policy Support (as applied)

- i. Immediate impact on generated technology (commodity & non-commodity):**
Farmers can increase the production of safe and quality fruits in a low-tech protected farming approach compared to open field.
- ii. Generation of new knowledge that help in developing more technology in future:**
Protected cultivation systems will provide safe and quality fruit by using environmentally friendly agricultural inputs.
- iii. Technology transferred that help increased agricultural productivity and farmers' income**
- iv. Policy support**

I. Information regarding Desk and Field Monitoring

- i. Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.]
- ii. Field Monitoring (date & no. of visit, name and addresses of team visit and output)

BARI Component

date	No. of visit	Name and addresses of team visit	Output
03.6.2020	1	Dr. M. Nazirul Islam DG, BARI	1. Visited the different nethouses for high value vegetables. Expressed satisfaction.
29.6.2020	1	Dr. Shaikh Mohammad Bokhtiar Executive Chairman, BARC	1. Visited the different protected nethouses for high value vegetables. Expressed satisfaction and suggested for more crops under this study

18.01.2021	1	<ol style="list-style-type: none"> 1. Dr. Md. Harunur Rashid, Director, PIU-BARC, NATP-2 2. Mohammad Assaduzzaman, Manager (Financial Management) 3. Mohammad Shahidul Islam, Procurement specialist 4. Dr. Mohammad Abdullah Al Faroque, assistant Manager (Administrator) 	<ol style="list-style-type: none"> 1. Need special emphasis to complete the rest of task using alternate plan overcoming the losses due to COVID-19 pandemic situation 2. Should preserve the bills and finance related documents properly. 3. In case of procurement goods should complete in time 4. Using the checklist of Indicative Fraud & Corruption for RFQ method
10.2.2022	1	<ol style="list-style-type: none"> 1. Dr. M. Sirajul Islam, Environmental and social safeguard specialist, PIU-BARC, NATP-2 2. Munshi Mamunur Rahman, Documentation Associate, PIU-BARC, NATP-2 3. AKM Rakib Ullah, Resource Management Associate, PIU-BARC, NATP-2 	<ol style="list-style-type: none"> 5. Proper labelling should be done with permanent ink. 6. PIU-BARC, NATP-2 should be well written in experimental signboard

SAU Component

date	No. of visit	Name and addresses of team visit	Output
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18.01.2021	1	<ol style="list-style-type: none"> 1. Dr. Md. Harunur Rashid, Director, PIU-BARC, NATP-2 2. Mohammad Assaduzzaman, Manager (Financial Management) 3. Mohammad Shahidul Islam, Procurement specialist 4. Dr. Mohammad Abdullah Al Faroque, assistant Manager (Administrator) 	<ol style="list-style-type: none"> 1. Need special emphasis to complete the rest of task using alternate plan overcoming the losses due to COVID-19 pandemic situation 2. Should preserve the bills and finance related documents properly. 3. In case of procurement goods should complete in time 4. Using the checklist of Indicative Fraud & Corruption for RFQ method
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iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities

J. Sub-project Auditing (covers all types of audit performed)

BARI Component

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial Audit by NATP-2, BARC	No issues	3936727	30.06.2020	1 st audit
Financial Audit by M I Chowdhury & Co	No issues	3936727	30.06.2020	2 nd audit
Financial Audit by FAPAD	No issues	2512283	30.06.2021	3 rd audit
Financial Audit by M I Chowdhury & Co	No issues	2512283	30.06.2021	4 th audit

SAU Component

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial Audit by NATP-2, BARC	No issues	3936727	30.06.2020	1 st audit
Financial Audit by M I Chowdhury & Co	No issues	3936727	30.06.2020	2 nd audit
Financial Audit by FAPAD	No issues	2512283	30.06.2021	3 rd audit
Financial Audit by M I Chowdhury & Co	No issues	2512283	30.06.2021	4 th audit

K. Lessons Learned:

- i) The performance of shed houses varied depending on the type of fruit
- ii) Optimum growing conditions identified for fruit production
- iii) Enhancing safe and quality fruit production in protected condition

L. Challenges (if any): There have some challenges in execution and adoption of the technologies.

1. This method will not be suitable for marginal farmers due to the initial high cost involvement.
2. Requires some modern knowledge of agriculture, particularly protected cultivation
3. A strong storm that is prepared for semi-permanent construction could demolish the net house.
4. Transperant polyfim cleaning is required after a period.
5. Local animals can destroy border insect nets.

M. Suggestions for Future Planning (if any): N/A

The protective culture technology of fruit and vegetable crops will allow farms to be more profitable, efficient, safe, and environmentally friendly.

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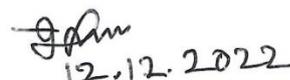
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ড. কে.রদৌলী ইসলাম
কো-অর্ডিনেটর
ডেপার্টমেন্ট অফ প্রোটেক্টেড কালচার টেকনোলজি অ্যান্ড
সেক্স এক কোম্পানি ডেভেলপমেন্ট এন্ড ফুট হোমসিকলিং
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সিএনও, সর্বমুখ্য বিভাগ এইচআরএসি, বিএআরআই, গাজীপুর



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Different type of net houses for vegetable production



Net house



Poly house



UV Poly house



Open field



UV poly shed



Poly shed



Net house

