

**SUSTAINABLE PRODUCTION OF SWEET PEPPER (*Capsicum annuum* L.) USING  
POLYHOUSE FOR LOW TEMPERATURE MANAGEMENT**

**A Thesis**

**By**

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**Student ID No. 1601376**

**MASTER OF SCIENCE  
IN  
CROP PHYSIOLOGY AND ECOLOGY**



**DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY  
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,  
DINAJPUR-5200, BANGLADESH**

**DECEMBER 2023**

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**DEDICATED  
TO  
MY BELOVED PARENTS**

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## ABSTRACT

A research work was conducted during November 2022 to May 2023 to manage low temperature effect for sustainable production of sweet pepper (*Capsicum annuum* L.) using polyhouse. Two growing conditions (Polyhouse and open field) and four genotypes were evaluated based on their morpho-physiological, biochemical characteristics and yield attributes at research field and laboratory of the Department of Crop Physiology and Ecology, HSTU, Dinajpur. The experiment was laid out in a Split Plot Design with three replications. Main plot treatment comprised of two growing conditions mentioned above and subplot treatment included four varieties of sweet pepper such as green, orange, red and yellow varieties. Polyhouse condition played a significant role on regulation of temperature and relative humidity (%) which ultimately control the production of sweet pepper. Different growth parameters, physiological, biochemical and yield attributes such as plant height, leaf number, SPAD value, vitamin C, total carotenoid, fruit length, fruit diameter, single fruit weight, no. of fruit per plant, fruit weight per plant, fruit yield per plot and fruit yield ( $\text{tha}^{-1}$ ) were measured during the experiment period. Result revealed that the poly house condition always showed better performance in production of sweet pepper than that of open field condition. All the varieties performed equally in terms of fruit yield. Red variety contained the maximum vitamin C (74.1mg/100ml) but the yellow variety contained the highest total carotenoid (30.48  $\mu\text{g}$ ). Poly house growing condition significantly influenced the yield and yield traits. Red variety in polyhouse field condition produced the highest yield (12.33  $\text{tha}^{-1}$ ) but the best market quality of fruit (fruit length 105.95 mm and diameter 100.53 mm) was produced by green variety in poly house field condition which was statistically similar with red variety. Therefore, polyhouse field condition could be used for sweet pepper production at farmer's level as a low-cost sustainable technique.

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## CHAPTER I

### INTRODUCTION

Sweet pepper or Bell pepper (*Capsicum annuum* L.) is one of the most important vegetable crops grown extensively throughout the world especially in the temperate countries. Bell pepper commonly known in the Bangladesh as capsicum or sweet pepper to separate it from hot peppers. The crop is very sensitive to environmental factors (Bhutiya *et al.* 2018 and Sarada *et al.* 2015). Owing to its sensitivity, its yield is affected significantly. Capsicum is the most important summer crop of temperate regions but now a days efforts are being made to grow sweet pepper in Bangladesh (Paul 2009). Some advanced farmers grow capsicum sporadically to meet the demand of the periphery of Dhaka city (Saha and Salam 2004). Its production in Bangladesh is largely affected due to high infestation of mite and low night temperature (Anon 2008). The optimum temperature requirement for sweet pepper growth ranged from 16-25 °C. High night temperature is more detrimental to fruit set than day temperature (Thuy and Kenji 2015). Again, night temperature below 16 °C and day temperature above 32 °C also causes fruit dropping (Thuy and Kenji 2015). In Bangladesh, from December to January during vegetative and fruiting stage of the crop, night temperature is gradually decreased below 10 °C or less. In that situation vegetative and reproductive stage of capsicum plants become ceased or stunted, fruit and flower drops may occur. So, for proper growth and yield of capsicum at low temperature under netted poly tunnel or poly house may be effective because it protected the plants from pest infestation and from cold injury since night temperature inside poly covers raises higher than outside. It is 6-10 months crop under protected conditions. One can take the production advisable to do the greenhouse farming. With the development of facility protected cultivation, acreage of capsicum is increasing under greenhouse to pursue the maximum economic profits. However, its cultivation is confined to warm and semi-arid countries where water is often a limiting factor

for production. The crop grown under open conditions will not fulfill the export standards, so the search for new avenues has led to development of Hi-Tech precision horticultural systems. Recently, few entrepreneurs have started its cultivation under protected conditions like greenhouse; shade house etc. to get higher productivity and quality adopting the hybrids supplied by the private companies.

Now a days apart from green color, other varieties like red, yellow, light green are also available. However, there is a need to assess the performance of capsicum hybrids under different growing conditions to advise small and marginal farmers of the regions to get higher unit returns. The main purpose of protected (polyhouse) cultivation is to create a favorable environment for the sustained growth of crop so as to realize its maximum potential even in adverse climatic conditions. It has very high entrepreneurial value and profit maximization leading to local employment, social empowerment and respectability of the growers. The greenhouse covering materials play a very important role in defining the microclimate based on their transmissivity, also impacting different energy balance components such as sensible, latent heat flows and transpirations and photosynthetic processes. The choice of the greenhouses cover material is essential for optimizing crop production. The scientific information regarding interaction between environment and capsicum fruit yield and quality is still lacking.

Climate changes, including low and high temperatures, strong wind, drought, flooding, and heavy rainfall can severely influence crop yield and productivity. Particularly, reports demonstrated the impact of the night low temperature (NLT) with different temperature regimes during the period of entire growth and development (Cruz-Huerta *et al.* 2011). The NLT remarkably affected seed germination, seedling growth, leaf morphology, stem diameter (SD), and plant height (PH) during the vegetative stages of tomato, cucumber, and pepper plants (Cruz-Huerta *et al.* 2011), causing poor growth and development. The temperature stress

also affected the reproductive index, including the agronomical traits of the number of flowers (NFL), the number of fruits (NFR), fruit set (FS), and fruit yield (FY) during reproductive stages of pepper plants. Since the flower development was highly associated with NFR, FS, and FY in response to LT, many studies focused on the development of the floral organs. For example, the plants grown in temperatures below 15<sup>0</sup>C resulted in abnormal flower shapes, reduced pollen activity and quality parthenocarpic fruits, a decrease in the number of seeds in the fruit (NSF) Moreover, in comparison with those grown in normal and low temperatures, flower development was shown in the malformation of unexpanded petals, stunted stamens containing a few of pollen, and a reduced pollen germination activity in androecium (Shaked *et al.* 2004). Flower development was also impaired by the swollen ovary and shorter styles in the gynoecium, resulting in the poor quality of fruit development; small, flat, and irregular shaped fruits (Bhutiya *et al.* 2018 and Sarada *et al.* 2015).

In Bangladesh sweet pepper is a high valued, limited grown horticultural crops. But its production is highly hampered due to low night temperature during December to January, the coldest months, in the country. During flowering and fruiting setting minimum temperature should be 15<sup>0</sup>C. For lengthy fruit production in Bangladesh condition, October is the best time for transplanting of sweet pepper which helps to proper vegetative growth of the plants. After two months, December to January, flowering and fruit occur. During this period low temperature especially at night goes below 15<sup>0</sup>C which is very harmful for flower production and fruit setting. By increasing temperature, it could be mitigated. Green house is the best option to produce quality fruit by regulating temperature. But it is very expensive for the farmers of Bangladesh especially marginal and medium scale farmers. So, A low-cost technology is required such as poly house shade. A poly house shade may regulate the temperature as well as keep the moisture for better production of sweet pepper. Besides these,

it also helps prevent from different calamities (sudden rainfall, insect infestation and hailstones etc).

Sweet pepper has been grown in Bangladesh for nearly two decades, but not on a large scale. Initial cultivation was confined to the area around Dhaka, the capital city. Cultivation has expanded, however, due to its popularity in urban areas. Bell pepper – commonly known in the country as capsicum, or sweet pepper, to separate it from hot peppers – has several advantages for consumers: it can be consumed fresh or cooked; it's rich in vitamin A and C, phenolic compounds and fibers; it's low in calories; it contains a trace amount of omega-3 and omega-6 fatty acids. Research on bell pepper production in Bangladesh has been limited. To start closing that gap, we have to conduct experiments on it.

The increasing global demand for food and other agricultural products calls for urgent measures to increase unit crop production in terms of land and water. Concerning this problem protected cultivation is scientific intervention through which production can be multiplied many times per unit land and per unit water.

A low-cost sustainable technology (polyhouse) will help to boost up the sweet pepper production. It will increase the food security as well as health status of the lower income group of the country. It can also open the window of earning foreign currency by exporting. The income generation by cultivation of sweet pepper may increase the economic status of the farmer. It has very high entrepreneurial value and profit maximization leading to local employment, social empowerment and respectability of the growers.

Objective: This research work was designed with the following objectives-

- To evaluate and compare the effects of open field and polyhouse conditions on growth, physiological parameters and yield of sweet pepper.
- To find out suitable sweet pepper genotypes.

## CHAPTER II

### REVIEW OF LITERATURE

Use of polythene sheet made house (polyhouse) can lead to sustainable maintenance of air temperature and humidity and increase productivity of sweet pepper. Maintaining and manipulation of air temperature and humidity cause high growth and yield of sweet pepper. Optimum air temperature and humidity enhance sustainable crop production. However, available information regarding use of polyhouse in sweet pepper is meagre. Therefore, an attempt was made in this section to collect and study the research work carried out by prominent scientists in Bangladesh and abroad regarding the influence of polyhouse on growth and yield of sweet pepper to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion. The research works and their findings have been briefly reviewed in this chapter under the following write up.

Thuy and Kenji (2015) reported that chili peppers grow best and are likely to reach the maximum yield at temperature ranging from 21°C to 33°C. In the plastic house, the temperature increases to 42°C in the summer. The fruit set and fruit growth were affected correlative with the high temperature condition. In this study, Shishito peppers were grown in plastic house in two periods (in the early stage of April and the end stage of May) in 2012. The difference in temperature between two periods of planting was about 4°C. During temperature changed in the summer, the fruit weight and the number of seeds per fruit of both “Shishi-homare” and 105c-10 varieties were reduced about 0.5 and 2.8 times in the 2nd planting compared with the 1st planting.

Saha *et al.* (2010) conducted a study to investigate the influence of 29/23°C and 24/18°C stress on 12 sweet pepper genotypes on growth, development, reproductive behavior and yield potentialities and to verify the results of the phytotron study. Plant height was found higher at

29/23°C compared to 24/18°C. High temperature reduced percent fruit set as well as size of fruits. Leaf proline content of the sensitive genotypes decreased under the high temperature conditions and the heat tolerant lines produced higher amount of proline indicating the role of proline in expressing the heat tolerant capability of sweet pepper genotypes concerned.

Srikanth *et al.* (2019) reviewed that increasing temperature influenced greenhouse crop production, particularly in sub-tropical regions. So, there is a need to adjust the sowing time according to changing temperatures. Selecting cultivars which are more tolerant are adaptable to changing environmental conditions. So, polyhouses are best solution to avoid losses due to unfavorable climatic conditions like high temperature, heavy rains, strong winds and hailstones etc.

Rajametov *et al.* (2021) conducted a research to assess the agronomical traits of 39 pepper accessions belonging to the chili and bell fruit varieties which were cultivated under two different night temperature set-points: at 15 °C for a suboptimal temperature (CT) and at 10°C for a low temperature (LT). The plant height (PH) of most pepper accessions in a LT were significantly decreased compared to those in a CT. The Stem diameter and the length of main axis varied depending on the genotypes under LT. Moreover, the number of flowers, total number of fruits, fruit yield, fruit fresh weight, fruit length, fruit diameter, and number of seeds in a fruit remarkably declined in a LT compared to in a CT.

Rosmaina *et al.* (2021) carried out a study to observe the impact of temperature, exposure of duration, and the interaction between temperature and exposure duration at the germination phase and seedling growth of chili pepper. Temperature consisted of five-level of temperature i.e. 35°C, 37°C, 39°C, and 41°C. Temperature exposure duration consisted of four hours, eight hours, and twelve hours. The rise in the temperature and duration of exposure decreases shoot

length 35.15%, root length (23.23%), number of roots (29.82%), fresh weight of seedling (40%), number of leaves (30%), chlorophyll content.

Shukla *et al.* (2019) carried out a study to determine the effect of different micro climate on the physiological parameter and yield of capsicum at plasticulture farm. There are four small structures (1, 2, 3 and 4) of 64 m<sup>2</sup> (16 m×4 m) area each with varying cladding material i.e., 75% shade net, 40 mesh insect net, 200-micron LDPE UV stabilized sheet air vent on side and top provided with 75 % shade net, and 200-micron LDPE UV stabilized sheet and air vent on side and top provided with insect net, respectively. It was observed that maximum plant height (174.7 cm), leaves per plant (64) and first harvesting (57.3 DAT) was found in structure-1. Early flower initiation (29 DAT) was found in Structure-2. Maximum number of flowers per plant (23.7), cumulative number of flowers per plant (18.20), highest individual fruit weight (94.4 g), highest fruit yield (1720 g/plant) were found in structure-4. Based on the results, structure-4 was found best in respect of yield, physiological yield, physiological parameters, maximum net income (Rs. 13813/- per structure i.e. Rs. 215.83/m<sup>2</sup> area) and B:C ratio (1.87).

Halim and Islam (2013) evaluated sweet pepper cultivation under different protective structures in two consecutive seasons at the experimental field. A variety, California Wonder, was included in the study with four protective structures (low height poly tunnel, poly tunnel with side open, poly tunnel with side closed and poly house) including control (open field). The highest individual fruit weight (65.2g) was recorded from the plants grown under poly house condition while it was the lowest from open field grown plant (3.34 g). The maximum fruit yield per plant (334.0g) was recorded from poly house, which was 160.4% higher than that of plants grown under open field condition. The second highest yield was recorded from the plants of poly tunnel (212.5) indicating bright scope for sweet pepper cultivation under protective structures.

Islam *et al.* (2020) conducted an experiment to evaluate growth and yield of sweet pepper varieties under net protected condition. Considering the effect of varieties, the highest value for all the parameters viz. fruit length (10.01 cm), fruit diameter (5.90 cm), number of fruits/plant (13.61), fruit weight per plant (0.77 kg), fruit yield (21.31 t/ha) were found in California Wonder followed by BARI Mistimorich-1 and Yolo Wonder. Again, considering the effect of net protection system, maximum values for parameters viz. early flowering, fruit length (10.58 cm), fruit diameter (6.29 cm), number of fruits/ plant (16.14), fruit yield/plant (0.94 kg) and per hectare (26.86 t/ha) were recorded under fine net protection system. The earliest flowering (60.67 days), the highest number fruits per plant (19.18) and the maximum fruit yield (35.71 t/ha) were observed in BARIMistimorich-1grown under fine net system followed by California Wonder grown under coarse net protected system. Benefit cost ratio (BCR) for fine net (5.28) and coarse net (6.75) protected system were much higher than that of open field (1.64) condition indicating bright future for sweet pepper cultivation under net protected system.

Basavaraja *et al.* (2003) reported that the higher yield obtained from the polyhouse was due to the favourable weather conditions, i.e., air temperature, relative humidity and light intensity present in the growing structure, which influenced good vegetative and reproductive growth.

Sood and Kaul (2006) reported the number of fruits per plant in bell pepper, which had also direct effect on fruit yield, ranged from 20.33 to 52.00 fruits per plant. All the fifteen hybrids exhibited more fruits than the standard check Anupam, but only one hybrid California Wonder X Kandaghat Selection with 24.66 fruits was significantly superior to better parent.

Singh K *et al.* (2013) studied the impact of low plastic tunnel on the performance of bell pepper, an experiment was conducted from 2004-05 to 2006-07 at vegetable experimental area, Punjab Agricultural University, Ludhiana. The treatments consisted of transplanting of bell pepper

during November under low plastic perforated tunnel, low plastic non perforated tunnel, without protection and February transplanting in open field. The results clearly indicated that early yield (68.7q/ha), total yield (278.2 q/ha), fruit number per plant (18.9), plant height (49.44 cm), fruit girth (33.17 cm) and harvesting span (93 days) were significantly more in low plastic non perforated tunnel as compared to un protected and February transplanted crops. However average fruit weight was at par in all the treatments.

Singh *et al.* (2007) reported fruit yield of 6.5 kg/m<sup>2</sup> with average fruit weight of 54g, in California Wonder transplanted in March under naturally ventilated polyhouse whereas it was negligible when grown under open field conditions.

Singh AK *et al.* (2011) found that Protected technology enhanced crop duration, (270 days) in polyhouse, (180 days) in poly tunnel, (150 days) in poly-mulching as compare to (117 days) in open field condition. highest number of fruit weight (2.91 kg/plant) and yield (17.48 kg/m<sup>2</sup>) were achieved in polyhouse, followed by poly-tunnel (1.89 kg/plant, 11.34 kg m<sup>2</sup>), poly-mulching (1.57 kg/plant, 9.43 kg/m<sup>2</sup>) and open field condition (0.98 kg/plant, 5.90 kg/m<sup>2</sup>), respectively. Different protected technologies exhibited greater net return (253.84 /m<sup>2</sup> in polyhouse 132.08 /m<sup>2</sup> in poly-tunnel, 88.56 /m<sup>2</sup> in polymulching, 37.37/m<sup>2</sup> in open) and B:C ratio (1.0: 4.72) in polyhouse, (1.0: 3.68) in poly-tunnel, (1.0: 3.03) in poly-mulching was achieved while it was lowest in open field condition (1.0:2.12). Minimum bacterial wilt (3.40%) and blossom end-rot of fruit (4.32%) was observed under polyhouse condition, while it was maximum in open field condition (68.7 and 17.10%) respectively. It is concluded that protected features considerably enhance production of sweet pepper as compared to open fields, particularly during rainy and off-season in Uttarakhand

Kurubetta and Patil (2009) studied the performance of capsicum hybrids, i.e., Orobelle, Bomby and Indra under naturally ventilated polyhouse (NVPH), naturally ventilated shadow hall. The

quantitative parameters like earliest flower initiation (33.00 days), first fruit harvesting (86.00 days) and highest fruit set (49.81%) and the quality parameters like fruit weight (160.00 g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) were significantly maximum under naturally ventilated polyhouse than naturally ventilated shadow hall. Among the hybrids, Bomby recorded higher fruit weight (158.50 g), fruit volume (310.00 cc) while Indra recorded higher rind thickness (0.87 cm) and shelf life (8.60 days).

Kanwar and Sharma (2010) evaluated performance of capsicum hybrids and recommended hybrid Bharat, BSS-519 and Spinx which performed best under greenhouse conditions in the cold arid region of Ladakh. There were no significant differences observed for the plant characters like plant height, number of fruits per plant and days to first harvest, however hybrid Bharat was earliest for marketable yield and had longest fruit span.

Kanwar (2011) studied that production of tomato is limited by harsh climate and a short growing season in the trans-Himalayan Ladakh region of India. The performance of five tomato genotypes was compared under polyhouse and open field conditions. The study revealed that the performance of all tested tomato genotypes is far superior in the polyhouse, as compared to open field conditions, for all the considered characters. 'Shivalik' performed best with respect to yield characters followed by 'Pusa Rohini' under polyhouse conditions. However, in the open field, 'Pusa Rohini' showed the highest values, followed by 'Shivalik'. Cultivation of tomato under the polyhouse produced 136.12% more yield per ha and 188.93% more fruits per plant compared to open field cultivation. Therefore, tomato cultivation under protected conditions is advised for Ladakh growing conditions, employing specific polyhouse-responsive varieties.

Lee *et al.* (2017) found that horticultural crop production and changes in physiological aspects during the growing season may be affected by climate change factors (CC), which include

increased temperature and the associated doubling or tripling of atmospheric CO<sub>2</sub> concentrations. However, the potential effects are complex and many parameters might impact on the observed effects. To evaluate the effects of CC, the growth, yield, fruit characteristics, photosynthetic traits, and morphological characteristics of hot peppers were investigated. The hot peppers were grown under two CC scenarios, with the Representative Concentration Pathway (RCP) of 4.5 (Temp.; +3.4°C, CO<sub>2</sub> conc.; 540 µmol/mol, Precipitation +17.3%) and RCP 8.5 (Temp.; +6.0°C and CO<sub>2</sub> conc.; 940 µmol/mol, Precipitation +20.3%), respectively, using extreme weather simulators. This was compared with existing weather conditions occurring in Jeonju, South Korea in terms of air temperature, relative humidity, radiation, and precipitation. Overall, the plant height showed the highest under moderate CC conditions (RCP 4.5) among all the treatments tested. The number of leaves in the RCP 8.5 condition showed 7,739/plants, which was 2.2 times higher than that of the control. In addition, fruit shape was shortened and percentage dry matter was also the highest. The yield of hot pepper in the CC RCP 4.5 and 8.5 conditions were decreased by 21.5% and 89.2% when compared with that of the control, respectively. The days to harvest in the condition of CC scenarios were shortened from 5 to 13 compared with that of control, predominantly due to the increased air temperature. The results indicated that the severe RCP CC scenarios made reduction in the yields and negative affection on the fruit qualities. Overall, hot pepper was tolerant of mild CC scenarios of temperature×CO<sub>2</sub> but was significantly affected by more extreme CC interacting parameter concentrations (or similar)

Singh AK *et al.* (2005) conducted a study during (January-April) 2001-2003 (3 seasons) under protected and unprotected (open) conditions at New Delhi on 'Poinsett' cucumber (*Cucumis sativus* L.), 'Pusa Alankar' summer squash (*Cucurbita pepo* L.) hybrid and 'Varsa Improved' okra [*Abelmoschus esculentus* (L.) Moench.] to study effect of protected and unprotected condition on biotic stress, yield and economics of spring summer vegetables. The incidence of

biotic stress (insect-pests), plant mortality and use of chemical insecticide were found minimum under protected condition. The marketable fruit yield (kg/plant), gross income, net income (Rs/plant), cost:benefit ratio and money saving were higher under protected condition. Vegetable cultivation under protected condition was thus observed to be ideal technique to avoid biotic, abiotic stress and enhanced yield.

Shil S *et al.* (2015) investigated in instructional farm of KVK, West Tripura with an objective to find the actual result under climatic condition of Tripura, during 2014. The investigation revealed that highest no. of fruits/plant (38) along with maximum fruit diameter (5.7 cm), individual fruit weight (58.8 g), crop duration (195 days), yield (8.55kg/m<sup>2</sup>) and BC 3.5 and lowest pest and disease percentage was recorded in Capsicum grown under polyhouse conditions in comparison with the open field condition. It can be concluded that protected condition considerably enhances production of capsicum as compared to open fields.

Singh *et al.* (2011) concluded that protected conditions enhanced production of sweet pepper as compared to open fields, particularly during rainy and off-season. They recorded maximum crop duration (270 days) in sweet pepper under polyhouse conditions, (180 days) in poly tunnel, (150 days) along with poly-mulching as compare to (117 days) in open field condition along with maximum fruit diameter (6.91 cm), maximum number of fruits per plant (47), highest individual fruit weight of fruits, fruit weight, early fruit yield, marketable fruit yield, and total fruit yield were obtained in the polyhouse when the crop was planted on 30 October along with black polythene mulch. Therefore, they concluded that the polyhouse cultivation and black plastic mulch, when combined with appropriate planting date, early and total yields of capsicum was improved characters in capsicum. The interaction effect between growing environment and nutrients supply and uptake was found to be significant, indicating a favourable influence of these two parameters on growth and fruit yield of the sweet pepper crop.

Murthy *et al.* (2009) have confirmed the significance of protected cultivation of capsicum due to its economic viability, high yield, better fruit quality, superior fruit appearance and ensured availability of capsicum throughout the year. They have further endorsed the promotion of this technology should be regulated by government and non-government institutions.

Singh and Sirohi (2006) had emphasized over the use of low cost protected structures like low plastic tunnels or walk-in-tunnels or shade net houses for offseason nursery production, small scale production of vegetables to fetch high price, virus free and insect free development of nursery in rainy season and good quality production of sweet pepper during rainy and post-rainy season. Tunnel farming is one of the modified techniques of plastic-culture of modern farming. Tunnel farming was started first in 1948; it is a cheapest form of greenhouse. Later on, more operational and economical forms of tunnel farming were introduced. The Plastic tunnels had diverse mechanism as tunnels are not heated-up artificially and are operative under minimum environment control as compared to greenhouses. Tunnels are more cost-effective than the greenhouses.

Takte *et al.* (2003) have used plastic films and shade nets in order to protect high value crops against various stresses like extreme atmosphere and insect-pests. Further, they added that ventilation played an important role in crop production under controlled conditions.

Medany *et al.* (2009) concluded that black net greenhouse gave significantly the highest early crop yield, while white net greenhouse significantly contributes to the highest plant height, number of leaves per plant, leaf area index and total fruit yield as compared to the other greenhouses.

Ilic *et al.* (2011) have reported 113 – 131% of yield of bell pepper grown under pearl, red, blue or black coloured shade nets with shading of 40% or 50% in comparison to open cultivation.

Ombodi *et al.* (2015) had reported 23–39% of decrease in incoming radiation and 32–46% reduction in PAR under shade nets of white, green, yellow or red colour. However, yellow and green shade nets decreased yield while white shade nets in green house was reported best under unfavourable conditions

Gungor and Yildirim (2013) used growing mixture as peat:perlite:sand (1:1:1 v:v:v) in polythene bags to study their effect on different qualitative and quantitative characters of capsicum grown under greenhouse conditions. A significant improvement in fruit size and weight was reported when mixture was used as media while Vitamin C, Total Soluble Solids (TSS), fruit count and yield was highest when peat was used as media.

Yosepha *et al.* (2007) observed that all sweet pepper cultivars showed more productivity under photo-selective shading, as there was an increase in number of fruits per plant by 30 to 40 per cent compared to the use of common black net. Different coloured nets were used for photo-selective shading and it was found that the red net had some productivity advantage over the pale and yellow nets. The risk of disease infestation by small insects like aphids, thrips and the incidence of insect borne viral diseases were recorded significantly lower under yellow net as compared to all other nets.

Kaur *et al.* (2010) studied that thrips and mites were serious pests on sweet pepper. The root-knot nematode population was not recorded at the time of transplanting in most net houses, but gradually increased over the growing season in capsicum. They also revealed that the farmers applied prophylactic insecticide sprays to manage sucking insect-pests in net house.

Anwar *et al.* (2013) conducted a survey to determine the occurrence of plant parasitic nematodes on vegetable crops, i.e., cucumber, tomato, chili and bell peppers grown in plastic tunnels. The presence of nine species of plant-parasitic nematodes viz., *Aphelenchus avenae*, *Helicotylenchus dihystera*, *Hoplolaimus columbus*, *Meloidogyne javanica*, *M. incognita*,

*Pratylenchus penetrans*, *Radopholus similis*, *Tylenchorhynchus claytoni* and *Xiphinema* sp. were recorded. Un-uniform foliage growth, stunted growth, chlorotic leaves and wilted plants in patches were observed under the tunnels where the vegetables were grown. The infestation of nematodes in tunnel grown vegetables needed significant control measures to tackle nematode infestation by the use of integrated pest management strategies.

Singh *et al.* (2004) concluded that protected cultivation of capsicum under net house created favourable atmosphere for consistent plant growth, early and prolonged production. Further, this practice is suitable for small land holdings or fragmented land holdings to provide high profit. Among 7 hybrids of capsicum tested under controlled condition, Bharat was reported with high fruit yield, uniform fruit size, quality fruit due to management of insect pest by nonchemical technique under protected structures.

Sreedhara *et al.* (2013) performed protected cultivation of capsicum and has reported high cost of establishment, fruit yield [5.50 tons/unit (0.25 acre)], total returns (Rs. 1,54,734/- per unit), net returns (Rs. 1,15,279/- per unit) and B:C ratio (3.92).

Galinato and Miles (2013) had reported 5-times more cost invested for lettuce cultivation under high tunnel and 8 times for tomato cultivation when compared with open cultivation while yield was 3 and 4 times higher under tunnel grown lettuce and tomato respectively. This was further confirmed that cultivation of lettuce under open condition was 43 % more profitable and tunnel-based cultivation of tomato was 3 times profitable.

Kumar *et al.* (2016) conducted economic studies on capsicum cultivation under polyhouse and open field conditions and concluded that due to higher yield (145%) of capsicum under polyhouse conditions than the open field conditions, the net returns/acre of the crop was 208 percent higher than the open field conditions. A split-plot experiment is a blocked experiment, where the blocks themselves serve as experimental units for a subset of the factors. Thus, there

are two levels of experimental units. The block is referred to as main plot, while the experimental unit within blocks are called split plot, split unit, or subplot. Split-plot designs were originally developed by Fisher (1925) for use in agricultural experiments. The cost of running a set of treatments in split plot order is generally less than the cost of the same experiment when under completely randomized design. Split-plot experiments are not just less expensive to run than completely randomized experiments and are statistically more efficient.

Kanwar *et al.* (2014) Under cold arid Ladakh condition, production of bell pepper is limited by climate and short growing season and people depend upon outside supply for consumption. Keeping this in view, seven promising hybrids popular in other parts of country were tried in six different protected structures. Design of the experiment was split plot. Results revealed that Mud wall greenhouse recorded highest yield per ha and number of fruits but par with Chinese and LEHO greenhouses. Bell pepper hybrid US-181 was highest yielder. Mud wall greenhouse in combination with hybrid Bharath recorded statistically highest yield per ha. Mud wall greenhouse and LEHO greenhouse may be recommended for small and marginal farmers while Chinese being costly for commercial bell pepper production to bring more economic prosperity.

Lee *et al.* (2018) found horticultural crop production and changes in physiological aspects during the growing season may be affected by climate change factors (CC), which include increased temperature and the associated doubling or tripling of atmospheric CO<sub>2</sub> concentrations. However, the potential effects are complex and many parameters might impact on the observed effects. To evaluate the effects of CC, the growth, yield, fruit characteristics, photosynthetic traits, and morphological characteristics of hot peppers were investigated. The hot peppers were grown under two CC scenarios, with the Representative Concentration Pathway (RCP) of 4.5 (Temp.; +3.4°C, CO<sub>2</sub> conc.; 540 µmol/mol, Precipitation +17.3%) and RCP 8.5 (Temp.; +6.0°C and CO<sub>2</sub> conc.; 940 µmol/mol, Precipitation +20.3%), respectively, using extreme weather simulators. This was compared with existing weather conditions

occurring in Jeonju, South Korea in terms of air temperature, relative humidity, radiation, and precipitation. Overall, the plant height showed the highest under moderate CC conditions (RCP 4.5) among all the treatments tested. The number of leaves in the RCP 8.5 condition showed 7,739/plants, which was 2.2 times higher than that of the control. In addition, fruit shape was shortened and percentage dry matter was also the highest. The yield of hot pepper in the CC RCP 4.5 and 8.5 conditions were decreased by 21.5% and 89.2% when compared with that of the control, respectively. The days to harvest in the condition of CC scenarios were shortened from 5 to 13 compared with that of control, predominantly due to the increased air temperature. The results indicated that the severe RCP CC scenarios made reduction in the yields and negative affection on the fruit qualities. Overall, hot pepper was tolerant of mild CC scenarios of temperature  $\times$  CO<sub>2</sub> but was significantly affected by more extreme CC interacting parameter concentrations (or similar)

Singh R and Asrey (2005) found that the production of tomato and sweet pepper under medium-cost greenhouse during 2000-01 was 93.2 and 76.4 t/ha, respectively. The crops grown in the greenhouse were of excellent quality compared to the outside environment, where the crop could not survive due to prevailing low temperature.

## CHAPTER III

### MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

**3.1 Location and duration:** The experiment was conducted at the research field and laboratory of Department of Crop Physiology and Ecology, HSTU, Dinajpur during the period of July 2022 to June 2023.

**3.2 Experimental site and soil:** The experimental site is located at 25°39' N latitude and 88°41' E longitude with an elevation of 37.58 m above the sea level and under the Agro-ecological zone Old Himalayan Piedmont Plain (AEZ-1). The soil type of the experimental field is non-calcareous dark gray floodplain with sandy loam texture (pH 5.1 and organic matter around 1.06 %). The experimental site belongs to the subtropical climate characterized by heavy rainfall during the month of last April to October and scanty rainfall in December.

#### **3.3 Experimental design, layout and treatment**

The experiment was laid out in a Split Plot Design with three replications. The unit plot size was (1.25×1.6) m<sup>2</sup> having plot to plot and block to block distance of 0.50 m and 1 m, respectively. Three genotypes were randomly assigned to two growing conditions (Polyhouse and open filed) for eco-physiological evaluation. Two growing conditions were maintained such as open field and polyhouse as treatment.

**3.4 Collection of Sweet pepper genotypes:** Seedlings of 4 genotypes were collected from Sobuj Nursery, Bogura.

**3.5 Land preparation:** One plough followed by two or three harrowing was done to get fine tilth. Proper moisture was maintained in the soil at the time of transplanting of seedlings. The supply of moisture and good drainage were equally ensured at the time of land preparation.

**3.6 Transplanting of seedling:** Seedlings of sweet pepper genotypes were transplanted on 30 November 2022 following 25cm×40cm spacing. Seedlings were treated with Gold Hope 75 WP @2g/L fungicide before transplanting.

**3.7 Fertilizer application:** Compost, urea, TSP, MoP, gypsum and Zn were applied to the plots as Krishi Projukti hatboi, BARI (2011) at the rate of 10000, 250, 330, 250, 110 and 5 Kg $ha^{-1}$ , respectively. Irrigation, weeding and other intercultural operations was done when and as necessary. Necessary measures were taken to protect the crop from various insect and diseases during the entire growing period of the crop.

### **3.8 Polyhouse**

A structure was made by bamboo of 15m long and 5 m wide to shade the plots. Polythene sheet of 0.2mm is used to cover the bamboo structure fully from all side and was hanging to the ground. Polyhouse helps to protect plants from very low temperature of January and to conserve and manipulate the polyhouse relative humidity.

### **3.9 Intercultural operation and plant protection**

Weeding was done by hand using traditional simple tools like khurpi, kachi etc at the interval of every 30 days. Stacking was done at 60 DAT to support the growing plants from falling on ground against strong wind or heavy rain.

### **3.10 Irrigation**

Irrigation is very crucial for this crop as it is a vegetable crop. Irrigation was done by Jhahhri, a local nursery tool for irrigation at root establishment stage soon after the transplanting. Then flood irrigation with less depth was done as the field demand. And from the summer irrigation was done frequently as field demand it's about 7 days interval. Then in April irrigation was done 3 to 5 days interval.

**3.11 Fruit harvesting:** Fruits of sweet pepper were harvested from March to April when reached full size of edible maturity depending on the germplasm and became firm but before turning colour (Yellow, Orange or Red) as per Berke *et al.* (1999).

**3.12 Data collection:** Data were collected on following observations-

#### **3.12.1 Temperature and relative humidity (RH)**

Temperature was measured four times in a day at 12:00 am, 6:00 am, 12:00 pm and 6:00 pm by digital hygrometer daily from January to April of the experiment period. And relative humidity was measured from January to mid of March.

**3.12.2 Plant height (cm):** The plant height was taken at 30, 55, 70, 85, 100, 120 DAT from base to the top of the main raceme with scale for five tagged plants and their average was worked out.

**3.12.3 Number of leaf:** Number of leaf was counted every 15 days interval from the tagged plants.

**3.12.4 SPAD value of leaf:** SPAD value of the fully expanded youngest leaf of the selected plants was estimated with the help of a SPAD meter at different stages.

**3.12.5 Vitamin analysis:** Ascorbic acid and total carotenoid were measured as per standard chemical analysis methods.

### **3.12.6 Fruit length and diameter**

After harvesting fruit length and diameter were measured through digital electronic slide calipers individually and noted down.

### **3.12.7 Single fruit weight(g)**

Fruits were collected from randomly selected plants of a plot then measured by digital weighing scale and converted into average.

**3.12.8 Number of fruit plant<sup>-1</sup>:** The number of fruits was counted separately on five randomly selected plants and then converted into the number of fruit plant<sup>-1</sup>.

### **3.12.9 Fruit yield plant<sup>-1</sup>(g)**

Fruits were collected from the tagged plants then averaged to get fruit yield plant<sup>-1</sup>.

### **3.12.10 Fruit yield plot<sup>-1</sup>**

Total number of fruits was taken from each plot and measured by weighing scale.

**3.12.11 Fruit yield (tha<sup>-1</sup>):** The weight of fruit obtained from whole area of each plot was recorded on an electrical balance. Finally, the fruit yield per m<sup>2</sup> was converted into fruit yield ha<sup>-1</sup> by multiplying with the appropriate conversion factor. Individual fruit weight (g), fruit length (mm), fruit diameter (mm) was also measured.

**3.13 Data analysis technique:** All investigated data were subjected to analysis of variance (ANOVA) using Statistix 10 program. The treatment means were compared using Tukey's test at the 5% level of significance.

## CHAPTER IV

### RESULTS AND DISCUSSION

The results of the present investigation on the effect of polyhouse field condition than open field condition for the sustainable sweet pepper cultivation are presented in several tables and paragraphs and adequate discussions are done in this chapter.

#### **4.1 Temperature and Relative Humidity (RH)**

**4.1.1 Temperature:** On the eve of this research period winter season was starting and the temperature was falling down from December to February and at the end of February it was increasing. The coldest temperature was observed in January and April was the hottest month during this research program (Figure 1). Temperature was measured daily 4 times (6am, 12pm, 6pm and 12am). Whole cultivation period, temperature inside polyhouse was higher than that of open field conditions. But during March to April noon temperature inside the polyhouse was lower than that of open field condition.

**4.1.2 Relative humidity (RH):** Relative humidity is a major factor in plant growth development. Here relative humidity was also measured both in polyhouse and open field condition (Figure 2). RH was measured four times a day during cultivation. It was found that RH (%) always higher inside polyhouse condition than that of open field condition.

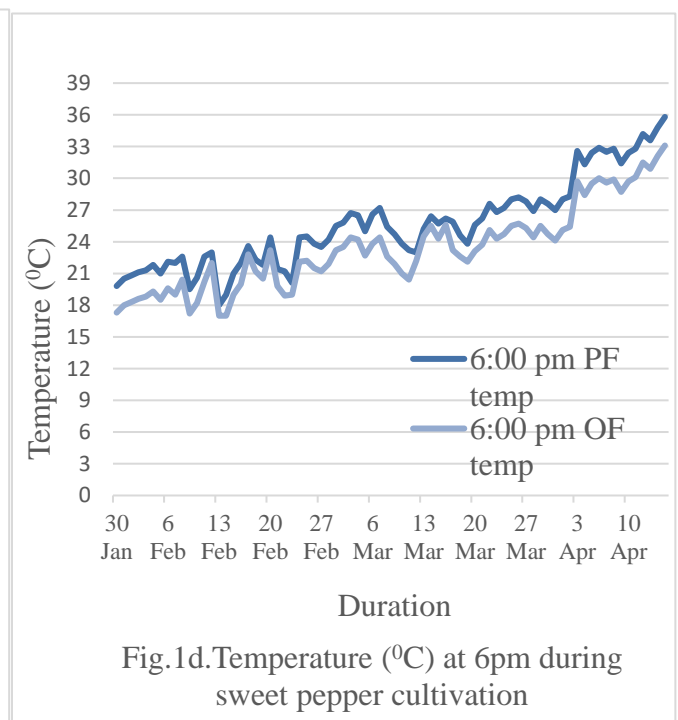
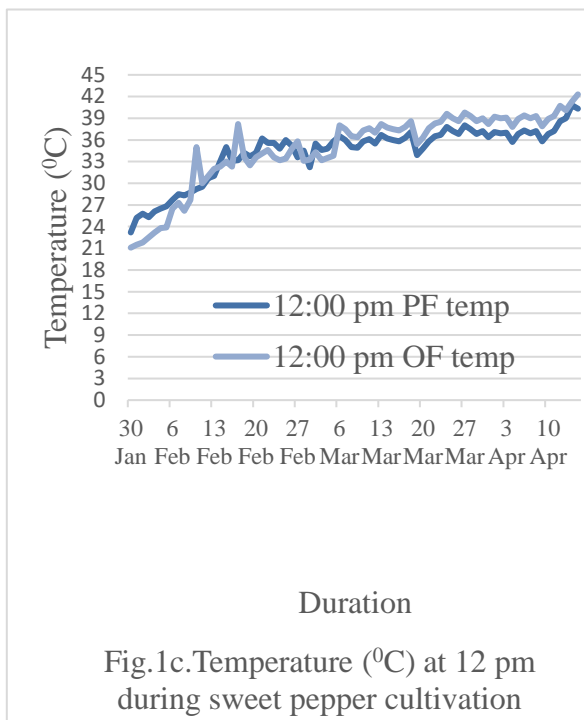
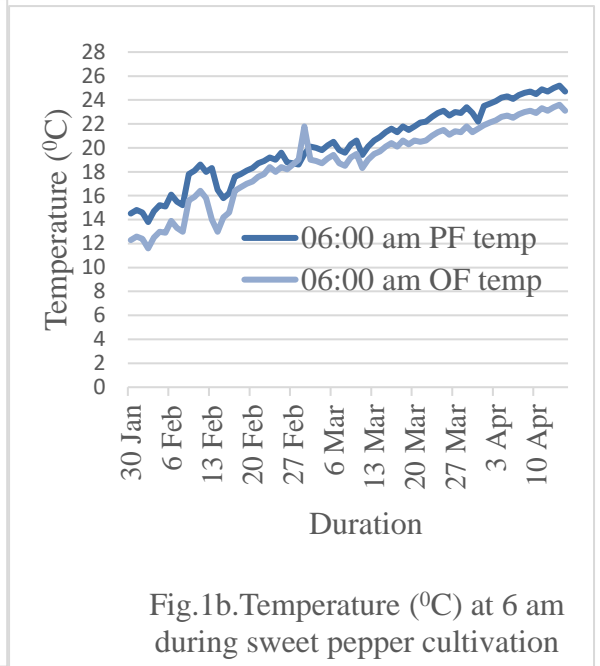
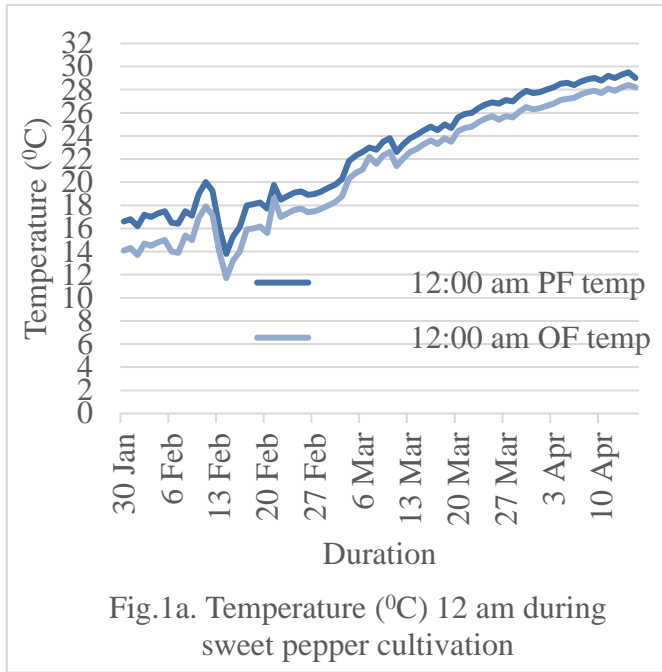


Figure 1: Temperature during cultivation of sweet pepper  
 PF= Polyhouse field condition, OF=Open field condition

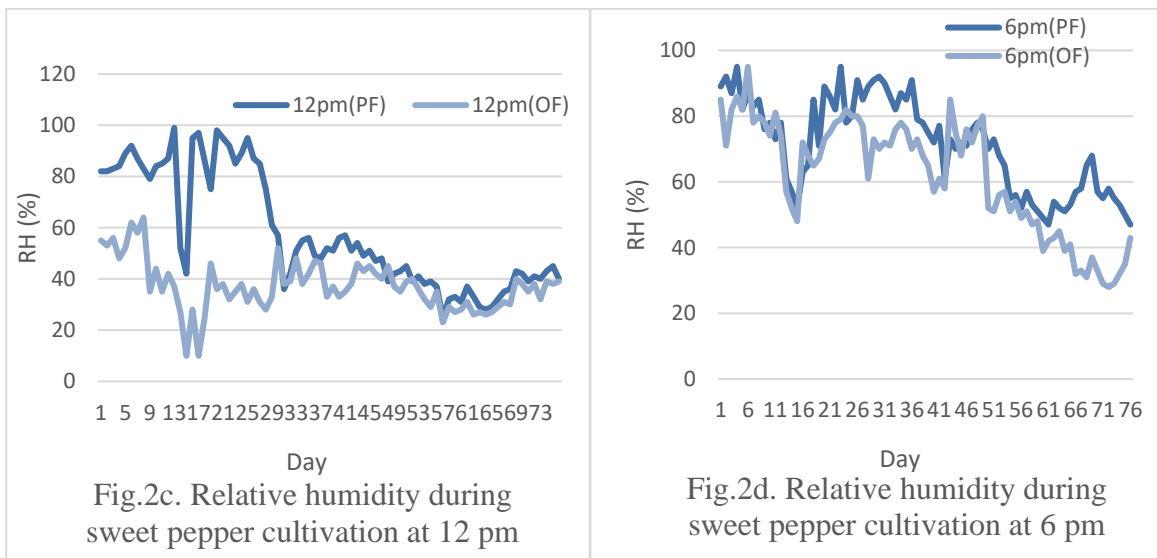
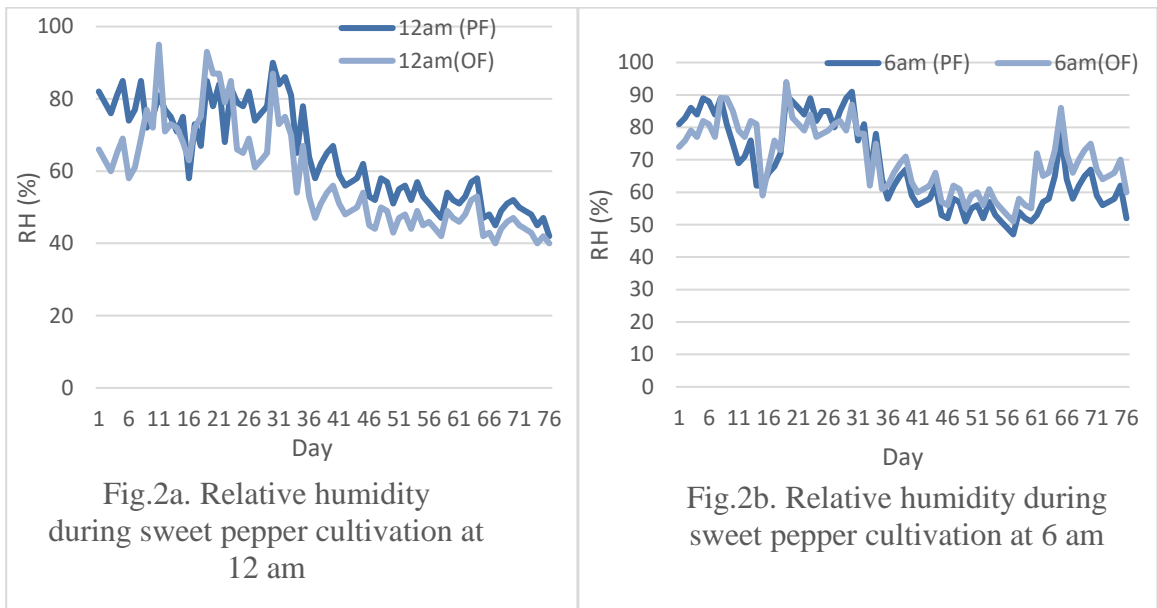


Figure 2: Relative humidity (%) during sweet pepper cultivation

PF= Polyhouse field condition, OF=Open field condition

## 4.2 Plant height

Plant height of sweet pepper at final harvest was significantly influenced by the growing condition (table 1). The highest plant height was recorded in polyhouse field condition (74.66 cm) while the lowest plant height was observed in open field condition (64.08 cm).

Variety had significant effect on plant height at final harvest (table 1). The maximum plant height was found in orange variety (72.62 cm) followed by red variety and the lowest height was observed in green variety (64.94 cm).

Plant height at final harvest was significantly varied by the interaction of growing condition and variety (table 1). The longest plant was found in polyhouse field condition with orange variety (76.27 cm) followed by red variety with polyhouse field condition and the shortest plant was recorded in open field condition with yellow variety (61.96 cm).

Low temperature decreases photosynthesis and consequently reduces plant height. Shorter plant was observed in open field due to very low temperature (10-12)<sup>0</sup>C during early growth stage. Rajametov et al. (2021) and Rosmaina et al. (2021) observed the similar results.

It was mentioned that during the experiment at January midnight temperature inside the polyhouse field was around 17<sup>0</sup>C and 12-14 <sup>0</sup>C in open field conditions and at noon temperature was around 25-26<sup>0</sup>C in poly house field and 21-22<sup>0</sup>C in open field condition. In all the variety of sweet pepper plant height increases in polyhouse field condition rather than open field condition. This may be due to higher temperature inside the polyhouse condition during winter season which helps to more photosynthesis and thus increase plant height. Similar result was stated by Rajametov *et al.* (2021).

Table 1: Effects of growing condition and variety on different plant growth parameters of sweet pepper					
Treatment	Growth and physiological parameters				
GROWING CONDITION (GC)	Plant height (cm)	Number of leaf	SPAD at 30 DAT	SPAD at 60 DAT	SPAD at 120 DAT
Polyhouse field (PF)	74.626 a	140.5 a	72.917 a	75.017 a	77.71 a
Open field (OF)	64.083 b	123.93 b	66.488 a	68.588 a	71.28 a
Level of significance	*	*	NS	NS	NS
Critical Difference(CD)	6.288	11.03	7.88	7.885	7.885
CV(%)	5.16	4.75	6.44	6.25	6.03
VARIETY C					
Green	64.943 c	129.38 b	69.21 a	71.31 a	74.01 a
Orange	72.62 a	135.88 a	70.388 a	72.488 a	75.188 a
Red	71.843 a	134.48 a	70.628 a	72.728 a	75.428 a
Yellow	68.012 b	129.14 b	68.583 a	70.683 a	73.383 a
Level of significance	*	*	NS	NS	NS
CD(LSD)	2.158	3.077	5.86	5.86	5.86
INTERACTIONS between GC×V					
PF × green	72.32 b	138.92 ab	64.453 b	66.553 b	69.253 b
PF × orange	76.273 a	142.34 a	65.277 b	67.377 b	70.077 b
PF × red	75.853 a	141.72 a	67.723 ab	69.823 ab	72.523 ab
PF × yellow	74.057ab	139.04 ab	68.5 ab	70.6 ab	73.3 ab
OF × green	57.567 d	119.83 d	73.967 ab	76.067 ab	78.767 ab
OF × orange	68.967 b	129.43 bc	75.5 a	77.6 a	80.3 a
OF × red	67.833 b	127.23 c	73.533 ab	75.633 ab	78.333 ab
OF × yellow	61.967 c	119.23 d	68.667 ab	70.767 ab	73.467 ab
Level of significance	*	*	*	*	*
Critical Difference(CD)	3.052	4.352	8.288	8.288	8.288
CV(%)	2.47	1.85	6.68	6.49	6.25
In a column within the treatment, means having similar letter did not differ significantly at 5% level of probability by tukey's test. *Significant at 5% probability. <sup>NS</sup> Nonsignificant at 5% level of probability.					

### **4.3 Number of leaf plant<sup>-1</sup>**

Number of leaf of sweet pepper at final harvest was significantly influenced by the growing condition (table 1). The highest number of leaf plant<sup>-1</sup> was recorded in polyhouse field condition (140.5) while the lowest number of leaf plant<sup>-1</sup> was observed in open field condition (123.93).

Variety had significant effect on number of leaf plant<sup>-1</sup> at final harvest (table 1). The maximum number of leaf plant<sup>-1</sup> was found in orange variety (135.88) followed by red variety and the minimum number of leaf plant<sup>-1</sup> was observed in yellow variety (129.14).

Number of leaf plant<sup>-1</sup> at final harvest was significantly varied by the interaction of growing condition and variety (table 1). The highest number of leaf plant<sup>-1</sup> was found in polyhouse field condition with orange variety (142.34) followed by red variety with polyhouse field condition and the minimum number of leaf plant<sup>-1</sup> was recorded in open field condition with yellow variety (119.23).

In all the variety of sweet pepper number of leaf increased in polyhouse field condition rather than open field condition. This may be due to increased temperature inside the polyhouse condition during winter which helps to more photosynthesis and ultimately increase leaf number. Similar result was found by Islam *et al.* (2020) and Rosmaina *et al.* (2021) in Sweet pepper.

### **4.4 SPAD value of leaf**

SPAD value of leaf at different days after transplanting (DAT) did not differ significantly due to growing condition and variety individually (table 1).

Combined effect of growing condition and variety had significant impact on SPAD values of leaf at different DATs (table 1). The maximum SPAD value was recorded in orange variety with open field condition (80.3). Similar result was observed by the other varieties with open field condition but the lowest value was observed by green variety with polyhouse field condition (69.25).

SPAD value of capsicum leaf increases in open field condition rather than polyhouse field condition. This may be due to sunlight which help in augment leaf greenness. Similar result was found by Islam *et al.* (2020) and Rosmaina *et al.* (2021).

#### **4.5 Days to 50% flowering, 50% fruiting and fruit shedding percentage**

There were significant variations observed in flowering, fruiting and fruit shedding percentage in sweet pepper. Days to require 50% flowering, 50% fruiting and fruit shedding percentage of sweet pepper was significantly affected by growing condition (table 2). The maximum days required to 50% flowering and fruiting of sweet pepper were found in open field condition (97.35 and 119.45 days, respectively) and whereas the maximum days required for poly house field condition were 90.35 and 110.82 days, respectively. Therefore, the polyhouse condition required less days for 50% flowering and fruiting. Fruit shedding was also higher in open field condition than polyhouse field condition. This might higher in open field condition due to higher temperature than polyhouse condition. Temperature above 32<sup>0</sup>C causes shedding of flower, fruit. Similar results were also found by Saha *et al.* (2010) and Rajametov *et al.* (2021).

Table 2: Effects of growing condition and variety on physiological and biochemical traits of sweet pepper

Treatment	Yield contributing parameters				
GROWING CONDITION (GC)	Days to 50% flowering	Days to 50% fruiting	Fruit shedding percent	Vitamin- C (mg/100g fruit weight)	Total carotenoid
Polyhouse field (PF)	96.35b	116.82b	72.66a	61.61a	24.52a
Open field (OF)	97.35a	119.45a	76.06a	61.26a	24.22a
Level of significance	*	*	*	NS	NS
CD	0.90	0.82	1.53	0.85	0.62
CV(%)	3.03	3.03	3.03	3.84	3.61
VARIETY (V)					
Green	93.67d	113.8d	70.883c	48.43c	22.22b
Orange	97.08b	116.63c	72.733b	52.36b	20.83b
Red	95.97c	118.32b	73.4b	74.1a	23.96b
Yellow	100.7a	123.8a	76.433a	70.85a	30.48a
Level of significance	*	*	*	*	*
CD(LSD)	1.03	0.90	1.69	4.21	5.34
INTERACTIONS between GC×V					
PF × green	93.09e	112.17f	70.088c	48.60cd	22.35b
PF × orange	94.25de	115.43e	71.679c	52.51c	20.99bc
PF × red	97.12c	115.73de	72.254bc	74.35a	24.08b
PF × yellow	97.05c	117.53cd	73.213abc	70.98b	30.66a
OF × green	95.62cd	117.77c	71.754bc	48.26cd	22.09bc
OF × orange	96.31 c	118.87c	75.046ab	52.21c	20.67c
OF × red	99.59b	121.63b	76.554a	73.85a	23.84b
OF × yellow	101.81a	125.97a	76.313a	70.72b	30.30a
Level of significance	*	*	*	*	*
CD	1.7	1.5	2.9	3.25	3.05
CV(%)	4.98	4.9	4.98	4.75	4.82
In a column within the treatment, means having similar letter did not differ significantly at 5% level of probability by tukey's test. *Significant at 5% probability. <sup>NS</sup> Nonsignificant at 5% level of probability					

#### **4.6 Vitamin analysis**

##### **Vitamin C (Ascorbic acid)**

There was significant variation observed of vitamin C due to varietal effect (table 2). Highest vitamin C content was recorded in red variety (74.1 mg/100ml) followed by variety yellow and the lowest vitamin C was found in green variety (48.43 mg/100 ml).

##### **Total carotenoid**

Total carotenoid was significantly differed due to varietal differences (table 2). Maximum total carotenoid content was recorded in yellow variety ( $30.48 \mu\text{g}^{-1}$ ) followed by variety red and the lowest vitamin c was observed in orange variety ( $20.83 \mu\text{g}^{-1}$ ).

#### **4.7 Fruit length (mm)**

Fruit length of sweet pepper was significantly influenced by growing condition (table 3). The maximum fruit length was found in polyhouse field condition (92.28 mm) and the minimum fruit length was recorded in open field condition (68.65 mm).

Variety had significant effect on fruit length in bell pepper (table 3). The highest fruit length was observed in green variety (94.81 mm). But the lowest fruit length was found in yellow variety (74.412 mm). Similar trend was observed in orange and red variety

Fruit length was significantly differed due to the interaction between growing condition and variety (table 3). The maximum fruit length was found in polyhouse condition with green variety (105.95 mm) followed by others variety with polyhouse condition except orange variety. But the lowest fruit length was recorded in open field condition with yellow variety (60.47 mm). Similar trend was observed by the other varieties with open field condition.

#### **4.8 Fruit diameter (mm)**

Fruit diameter of sweet pepper was significantly affected by growing condition (table 3). The maximum fruit diameter was found in polyhouse field condition (89.43 mm) and the minimum fruit diameter was recorded in open field condition (68.92 mm).

There was no significant varietal effect on fruit diameter of bell pepper (table 3). The highest fruit diameter was observed in green variety (85.7 mm). But the lowest fruit diameter found in orange variety (75.022 mm).

Fruit diameter was significantly differed due to the interaction between growing condition and variety (table 3). The maximum fruit diameter was found in polyhouse condition with green variety (100.53 mm) followed by others variety with polyhouse condition. But the lowest fruit diameter was recorded in open field condition with red variety (64.46 mm). Similar result was observed by the other varieties with open field condition.

#### **4.9 Single fruit weight (g)**

Single fruit weight (SFW) of sweet pepper was significantly influenced by growing condition (table 3). The maximum SFW was found in polyhouse field condition (88g) and the minimum SFW was recorded in open field condition (59.83g).

Variety had significant effect on SFW in bell pepper (table 3). The highest (SFW) was observed in green variety (77.78g). Similar trend was observed in orange and green variety but the lowest (SFW) found in yellow variety (70.27g).

Single fruit weight was significantly differed due to the interaction between growing condition and variety (table 3). The maximum (SFW) was found in polyhouse condition with green

variety (91.47 g) followed by others variety with polyhouse condition. But the lowest (SFW) was recorded in open field condition with yellow variety (53 g). Almost similar trend was observed by the other varieties with open field condition. The weight and size of the fruit decreases due to higher temperature during fruit develop stage. Open field condition showed higher temperature and ultimately produce smaller fruit. Similar resul was found by Rajametov et al. (2021) and Rosmaina et al. (2021)

#### **4.10 Number of fruit plant<sup>-1</sup>(nfp<sup>-1</sup>)**

Number of fruit plant<sup>-1</sup> differed significantly due to growing condition and variety individually (table 3). Maximum number of fruit plant<sup>-1</sup> was found in polyhouse condition (6.56) whereas minimum number of fruit plant<sup>-1</sup> was recorded in open field condition (4.45). The highest number of fruit plant<sup>-1</sup> was observed in green variety (6.29) and the lowest number of fruit plant<sup>-1</sup> was noticed in yellow variety (4.58).

Combined effect of growing condition and variety also affected significantly number of fruit plant<sup>-1</sup> of sweet pepper (table 3). The maximum number of fruit plant<sup>-1</sup> was observed in green, red and yellow varieties with polyhouse condition but lowest result was also noticed in yellow variety (3.83) with open field condition.

#### **4.11 Fruit yield plant<sup>-1</sup>(g)**

Fruit yield plant<sup>-1</sup> of sweet pepper was significantly influenced by growing condition (table 3). The maximum yield plant<sup>-1</sup> was found in polyhouse field condition (332.66 g) and the minimum yield plant<sup>-1</sup> was recorded in open field condition (233.92 g).

Variety had not significant effect on yield plant<sup>-1</sup> in bell pepper (table 3). The highest yield plant<sup>-1</sup> was observed in yellow variety (288.22 g). Similar trend was observed in other varieties.

Fruit yield  $\text{plant}^{-1}$  was significantly differed due to the interaction between growing condition and variety (table 3). The maximum yield  $\text{plant}^{-1}$  was found in polyhouse condition with yellow variety (349.11 g). Similar results were also observed by others variety with polyhouse condition. But the lowest yield  $\text{plant}^{-1}$  was recorded in open field condition with yellow variety (277.33 g). Almost similar trend was observed by the other varieties with open field condition.

#### **4.12 Fruit yield $\text{plot}^{-1}$ (g)**

Fruit yield  $\text{plot}^{-1}$  of sweet pepper was significantly influenced by growing condition (table 3). The maximum yield  $\text{plot}^{-1}$  was found in polyhouse field condition (2593.8 g) and the minimum yield  $\text{plot}^{-1}$  was recorded in open field condition (1458.5 g).

Variety had not significant effect on yield  $\text{plot}^{-1}$  of bell pepper (table 3). The highest yield  $\text{plot}^{-1}$  was observed in red variety (2087.70 g). Similar trend was observed in other varieties but the lowest yield  $\text{plot}^{-1}$  found in yellow variety (1880.70 g).

Fruit yield  $\text{plot}^{-1}$  was significantly differed due to the interaction between growing condition and variety (table 3). The maximum yield  $\text{plot}^{-1}$  was found in polyhouse condition with red variety (2775.10 g). Similar results were produced by others variety with polyhouse condition. But the lowest yield  $\text{plot}^{-1}$  was recorded in open field condition with yellow variety (1126 g). Almost similar trend was observed by the other varieties with open field condition.

#### **4.13 Fruit yield ( $\text{tha}^{-1}$ )**

Fruit yield of sweet pepper was significantly influenced by growing condition (table 3). The maximum yield was found in polyhouse field condition (11.527  $\text{tha}^{-1}$ ) and the minimum yield was recorded in open field condition (6.483  $\text{tha}^{-1}$ ).

Variety had not significant effect on yield of bell pepper (table 3). The higher yield was observed in red variety (9.27 tha<sup>-1</sup>). Similar trend was observed in orange and green variety but the lowest yield found in yellow variety (8.36 tha<sup>-1</sup>).

Fruit yield was significantly varied due to the interaction between growing condition and variety (table 3). The maximum yield was found in polyhouse condition with red variety (12.33 tha<sup>-1</sup>). The lowest yield was recorded in open field condition with yellow variety (5.07 tha<sup>-1</sup>)

Fruit yield of all varieties tested in this study was increased in polyhouse field condition rather than open field condition. It was mentioned that during March to April (fruiting period) midnight temperature was around 23<sup>0</sup>C-29<sup>0</sup>C inside the polyhouse field and 21<sup>0</sup>C-26<sup>0</sup>C in open field condition, and at noon temperature was around 34<sup>0</sup>C-38<sup>0</sup>C in poly house field and 35<sup>0</sup>C-38<sup>0</sup>C in open field condition. It is widely known that temperature between 25-35<sup>0</sup>C occur more photosynthesis. This may be due to increase temperature (within maximum photosynthesis rate) inside the polyhouse condition during winter season which helps to more photosynthesis and thus fruit yield. Thuy and Kenji (2015) also recorded the similar trend yield (Saha *et al.* 2010). Halim and Islam (2013) found the higher yield in bell pepper on polyhouse condition than open field condition.

Table 3: Effects of growing condition and variety on different yield parameters of sweet pepper

Treatment	Yield and yield contributing traits						
GROWING CONDITION (GC)	Fruit Length (mm)	Fruit diameter (mm)	Single fruit weight (g)	Number of fruit plant <sup>-1</sup>	Fruit yield plant <sup>-1</sup> (g)	Fruit yield plot <sup>-1</sup> (g)	Fruit yield (tha <sup>-1</sup> )
Polyhouse field (PF)	92.28 a	89.43 a	88 a	6.56a	332.33 a	2593.8 a	11.527 a
Open field (OF)	68.65 b	68.92 b	59.83 b	4.45 b	233.92 b	1458.5 b	6.483 b
Level of significance	*	*	*	*	*	*	*
CD	4.6788	11.48	8.79	0.154	75.165	875.51	3.889
CV	3.31	8.24	6.78	1.56	15.11	24.6	24.59
VARIETY (V)							
Green	94.81 a	85.7	77.78 a	6.29a	278.67 a	2067.80 a	9.19 a
Orange	74.417 b	75.022	73.83 ab	5.26b	286.33 a	2068.90 a	9.19 a
Red	76.578b	80.678	73.66 ab	5.89 ab	279.28 a	2087.00 a	9.27 a
Yellow	76.055b	75.305	70.27 b	4.58 c	288.22 a	1880.70 a	8.36 a
Level of significance	*	NS	*	*	NS	NS	NS
CD	10.052	12.413	5.198	0.75	60.744	331.09	1.47
INTERACTIONS between GC×V							
PF × green	105.95 a	100.53 a	91.447 a	7.42a	311.67 a-d	2471.3ab	10.983 ab
PF × orange	80.93 bc	75.71 b	85.667 a	6.19ab	340.33 ab	2493.2ab	11.08 ab
PF × red	90.59 ab	96.9 a	87.333 a	7.28a	328.22 abc	2775.1a	12.333 a
PF × yellow	91.64 ab	84.58 ab	87.557 a	5.33bc	349.11 a	2635.4a	11.713 a
OF × green	83.67 bc	70.87 bc	64.333 b	5.16bc	245.67 bcd	1664.3bc	7.397 bc
OF × orange	67.9 cd	74.33 bc	62 b	4.3cd	232.33 cd	1644.7bc	7.313 bc
OF × red	62.57 d	64.46 c	60 bc	4.5cd	230.33 cd	1399cd	6.217 cd
OF × yellow	60.47 d	66.03 c	53 c	3.83d	227.33 d	1126d	5.007 d
Level of significance	*	*	*	*	*	*	*
CD	17.327	21.397	7.35	1.30	85.906	468.23	2.082
CV	7.29	9.14	5.59	7.99	17.06	12.99	13

In a column within the treatment, means having similar letter did not differ significantly at 5% level of probability by tukey's test. \*Significant at 5% level of probability. <sup>NS</sup>Nonsignificant at 5% level of probability.

## CHAPTER V

### SUMMARY AND CONCLUSION

A field experiment was conducted at the Crop Physiology and Ecology Research Field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during November, 2022 to May, 2023 to compare the effects of open field and polyhouse conditions on growth, physiological parameters and yield of sweet pepper. The experiment was laid out in a Split Plot Design with three replications. The unit plot size was (1.25×1.6) m<sup>2</sup> having plot to plot and block to block distance of 0.50m and 1m, respectively. Four genotypes were randomly assigned to two growing conditions (Polyhouse and open field) for eco-physiological evaluation. Data were collected on plant height (cm), number of leaf plant<sup>-1</sup>, days to 50% flowering, days to 50% fruit setting, fruit diameter (mm), fruit length (mm), single fruit weight(g), fruit plant<sup>-1</sup>, yield plant<sup>-1</sup> (kg), yield plot<sup>-1</sup> (kg), and yield (t ha<sup>-1</sup>).

The highest plant height was recorded in polyhouse field condition (74.66 cm) while the lowest plant height was observed in open field condition (64.08 cm). Variety had significant effect on plant height at final harvest. Maximum plant height was found in orange variety (72.62 cm) followed by red variety and the lowest height was observed in green variety (64.94 cm).

The highest number of leaves was recorded in polyhouse field condition (140.5) while the lowest number of leaves was observed in open field condition (123.93). Variety had significant effect on number of leaves at final harvest. Maximum number of leaf was found in orange variety (135.88) followed by red variety and the minimum number of leaf was observed in yellow variety (129.14).

Combined effect of growing condition and variety had significant impact on SPAD values of leaf at different DATs. The maximum SPAD value was recorded in orange variety with open field condition (80.3). Similar result was observed by the other varieties with open field

condition but the lowest value was observed by green variety with polyhouse field condition (69.25). SPAD value of capsicum leaf increases in open field condition rather than polyhouse field condition.

There was significant variation observed of vitamin C due to varietal effect. Highest vitamin C content was recorded in red variety (74.1 mg/100ml) followed by variety yellow and the lowest vitamin C was found in green variety (48.43 mg/100 ml).

Total carotenoid was significantly differed due to varietal differences. Maximum total carotenoid content was recorded in yellow variety ( $30.48 \mu\text{g}^{-1}$ ) followed by variety red and the lowest vitamin c was observed in orange variety ( $20.83 \mu\text{g}^{-1}$ ).

Fruit length and diameter were significantly differed due to the interaction between growing condition and variety. The maximum fruit length was found in polyhouse condition with green variety (105.95 mm) followed by others variety with polyhouse condition except orange variety. But the lowest fruit length was recorded in open field condition with yellow variety (60.47 mm). The maximum fruit diameter was found in polyhouse condition with green variety (100.53 mm). But the lowest fruit diameter was recorded in open field condition with red variety (64.46 mm).

Single fruit weight (sfw) of sweet pepper was significantly influenced by growing condition. The maximum sfw was found in polyhouse field condition (88 g) and the minimum sfw was recorded in open field condition (59.83 g).

Single fruit weight was significantly differed due to the interaction between growing condition and variety. The maximum sfw was found in polyhouse condition with green variety (91.47 g). But the lowest sfw was recorded in open field condition with yellow variety (53 g).

Number of fruit plant<sup>-1</sup> (nfp<sup>-1</sup>) differed significantly due to growing condition and variety individually. Maximum nfp<sup>-1</sup> was found in polyhouse condition whereas minimum nfp<sup>-1</sup> was recorded in open field condition. The highest nfp<sup>-1</sup> was observed in green variety and the lowest nfp<sup>-1</sup> was noticed in yellow variety.

Variety had not significant effect on yield plant<sup>-1</sup> in bell pepper. The highest yield plant<sup>-1</sup> was observed in yellow variety (288.22 g).

Fruit yield plant<sup>-1</sup> was significantly differed due to the interaction between growing condition and variety (table 3). The maximum yield plant<sup>-1</sup> was found in polyhouse condition with yellow variety (349.11 g). But the lowest yield plant<sup>-1</sup> was recorded in open field condition with yellow variety (277.33 g).

Fruit yield plot<sup>-1</sup> of sweet pepper was significantly influenced by growing condition. The maximum yield plot<sup>-1</sup> was found in polyhouse field condition (2593.8 g) and the minimum yield plot<sup>-1</sup> was recorded in open field condition (1458.5 g).

Variety had not significant effect on yield plot<sup>-1</sup> of bell pepper. The highest yield plot<sup>-1</sup> was observed in red variety (2087.70 g). The lowest yield plot<sup>-1</sup> found in yellow variety (1880.70g).

Fruit yield plot<sup>-1</sup> was significantly differed due to the interaction between growing condition and variety. The maximum yield plot<sup>-1</sup> was found in polyhouse condition with red variety (2775.10 g). But the lowest yield plot<sup>-1</sup> was recorded in open field condition with yellow variety (1126 g).

Fruit yield of sweet pepper was significantly influenced by growing condition. The maximum yield was found in polyhouse field condition (11.527 tha<sup>-1</sup>) and the minimum yield was recorded in open field condition (6.483 tha<sup>-1</sup>).

Variety had not significant effect on yield of bell pepper. The highest yield was observed in red variety (9.27 tha<sup>-1</sup>).

Fruit yield was significantly varied due to the interaction between growing condition and variety. The maximum yield was found in polyhouse condition with red variety (12.33 tha<sup>-1</sup>). But the lowest yield was recorded in open field condition with yellow variety (5.00007 tha<sup>-1</sup>).

From the above result it may be concluded that

- Yield of sweet pepper increased almost double owing to polyhouse field condition rather than open field condition.
- All the varieties showed almost similar performance in terms of yield in poly house field condition but considering market quality (fruit length and diameter) green variety showed the better performance.
- Therefore, it could be said that low cost poly house technique could be used for better yield of sweet pepper at farmers' level.

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## APPENDICES

### Appendix I: Characteristics of soil of the experimental site

Soil Analysis Report	
General characters	Description
Location	Crop Physiology and Ecology, HSTU, Dinajpur
AEZ	Old Himalayan Piedmont Plain (AEZ-1)
General soil type	Non-Calcareous Brown Floodplain Soil
Parent material	Piedmont alluvium
Soil series	Ranishankail
Drainage	Moderately well drained
Flood level	Above flood level
Topography	High land
Chemical characteristics	Value
pH	5.08
OC (%)	1.32
OM (%)	2.27
TN (%)	0.011
P ( $\mu\text{g}^{-1}$ )	11.60
K ( $\mu\text{g}^{-1}$ )	0.30
Mg ( $\mu\text{g}^{-1}$ )	1.87
S ( $\mu\text{g}^{-1}$ )	6.86
Zn ( $\mu\text{g}^{-1}$ )	1.04
B ( $\mu\text{g}^{-1}$ )	0.08
EC ( $\text{dSm}^{-1}$ )	0.20
Salinity ( $\text{dSm}^{-1}$ )	0.39

Appendix II: Analysis of variance of data on plant height, leaf plant<sup>-1</sup> and SPAD value at different DAT, days to 50% flowering and days to 50% fruiting influenced by different treatments

Sources of variation	Degrees of freedom	Mean square						
		Plant height	Leaf plant <sup>-1</sup>	SPAD value			Days to 50% flowering	Days to 50% fruiting
				30 DAT	60 DAT	120 DAT		
REP	2	4.247	30.2	49.835	49.835	49.835	17.7829	34.091
GC	1	666.866	1647.56	247.941	247.941	247.941	51.5815	106.345
Error REP×GC	2	12.815	39.43	20.152	20.152	20.152	2	13.781
VAR	3	76.239	72.23	5.645	5.645	5.645	1.3882	3.168
GC×VAR	3	18.48	17.3	31.755	31.755	31.755	0.3575	0.294
Error REP×GC×VAR	12	2.943	5.99	21.706	21.706	21.706	17.7829	34.091
Total	23							

NS indicates non-significant  
 \* means significant at 5% level of probability  
 Rep means replications  
 GC means growing condition  
 Var means variety

Appendix III: Analysis of variance of data on fruit shedding Percentage (%), Single fruit weight, no. of fruit plant-1, yield plant-1, yield plot-1, yield at different DAT influenced by different treatments

Sources of variation	Degrees of freedom	Mean square					
		Fruit shedding Percentage %	Single fruit weight	No. of fruit plant <sup>-1</sup>	Yield plant <sup>-1</sup>	Yield plot <sup>-1</sup>	Yield
REP	2	45.3538	46.69	1.67903	3132.5	123336	2.443
GC	1	31.9471	4760.45	1.04584	58114.1	7732994	152.662
Error	2	3.92	25.09	1.34986	1831.1	248428	4.903
REP×GC	3	3.2526	58.19	0.27664	141.9	56851	1.12
VAR	3	1.0193	31.44	0.90386	844.3	193978	3.835
GC×VAR	12	45.3538	17.07	0.45247	2331.8	69275	1.371
Total	23						

NS indicates non-significant

\* means significant at 5% level of probability

Rep means replications

GC means growing condition

Var means variety