GROWTH AND YIELD OF HYDROPONIC SWEET PEPPER AS INFLUENCED BY ORGANIC SUBSTRATES

MD. ZAHIDUL ISLAM

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

MD. ZAHIDUL ISLAM

Reg. No. 11-04652

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Approved by:

Prof. Dr. Md. Jahedur Rahman
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Prof. Dr. Md. Nazrul Islam
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Co- Supervisor

Prof. Dr. Mohammad Humayun Kabir

Chairman
Examination Committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Ref. No. *Date :*

CERTIFICATE

This is to certify that thesis entitled, ***"GROWTH AND YIELD OF HYDROPONIC SWEET PEPPER AS INFLUENCED BY ORGANIC SUBSTRATES "*** *submitted to the,* ***Department of Horticulture****, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN HORTICULTURE****, embodies the result of a piece of bona fide research work carried out by* ***MD. ZAHIDUL ISLAM****, Registration:* ***11-04652*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information received during the course of this investigation has been duly acknowledged.

Dated: JUNE, 2017

Dhaka, Bangladesh

Prof. Dr. Md. Jahedur Rahman

Department of Horticulture

Sher-e-Bangla Agricultural University

Dhaka-1207

Supervisor

DEDICATED

TO MY

BELOVED PARENTS

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ABSTRACT

Rice husk, coconut coir and sawdust are considered as good growing substrate components, but high water holding capacity causes poor air-water relationship, thus affecting oxygen diffusion to the roots. Incorporation of coarser materials into these substrate components could improve aeration status. Therefore, an experiment was conducted in the semi-green house at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207 to assess the physicochemical properties of growing substrate mixtures and their effects on growth and yield of soilless sweet pepper. Four types of growing substrate mixtures, viz. M_1= coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2= rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3= sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4= ash (60%) + khoa (30%) + vermicompost (10%); and a variety of sweet pepper, 'Red star' were used in this experiment. The experiment was conducted in a completely randomized design with three replications. Physicochemical properties of growing substrate mixtures and growth, yield and physiological parameters of sweet pepper were measured in this experiment. The highest pH (7.74) was found in M_4 which was not suitable for sweet pepper production while suitable pH (6.10) was found in M_2. Water holding capacity, air filled porosity and dry weights of substrate mixtures were higher in M_2 and lower in M_3. The highest plant height (78.3 cm), number of fruit per plant (11.50), individual fruit weight (131.99 g), fruit yield (1517.89 g/plant), fruit length (7.74 cm), fruit diameter (5.70 cm), fruit volume (95.26 cc) and ascorbic acid content (149.5 mg/100 g FW) were found in M_2 but statistically similar results were found in case of growth and yield in M_1 while the lowest in M_4. In case of physiological traits viz. leaf area, leaf mass ratio, net assimilation rate and relative growth rate were found highest in M_2 while the lowest in M_4. Therefore, M_2 growing formulation can be used for sweet pepper cultivation in solid hydroponic system in Bangladesh.

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LIST OF ABBREVIATED TERMS

DAT	=	Days after transplanting
SAU	=	Sher-e-Bangla Agricultural University
EC	=	Electrical Conductivity
ANOVA	=	Analysis of Variance
LA	=	Leaf Area
LAR	=	Leaf Area Ratio
LMR	=	Leaf Mass Ratio
RWR	=	Root Weight Ratio
RGR	=	Relative Growth Rate
NAR	=	Net Assimilation Ratio
LDR	=	Leaf Dry Weight
RDR	=	Root Dry Weight
df	=	Degrees of freedom
AFP	=	Air-filled porosity
BCSIR	=	Bangladesh Council of scientific and Industrial Research

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an economically important crop belonging to the family solanaceae which has high demand both in local and export market. Sweet peppers are green at the immature stage and turn red, gold, purple, orange as they ripen. Because sugar content increases as they ripen, colored peppers tend to be sweeter than green peppers. The most notable feature of peppers is flavor, which can be sweet, mild or strongly pungent. Sweet peppers are rich sources of antioxidants and vitamin C. The level of carotene, like lycopene, is nine times higher in red peppers. Red peppers have twice the vitamin C content than green peppers. Red bell peppers are a great source of vitamin B6 and folate. Both these vitamins and minerals can help prevent anemia. Red bell peppers are high in vitamin A, which helps to support healthy eyesight, especially night vision. (University of the District of Columbia, Center for Nutrition, Diet and Health, 2013.)

Growing sweet pepper in the field involves extensive labor and a high cost of agrochemicals to assure good yield and quality. Cultivation of plant without soil gives more production in less time, allows to growing plant more densely with balanced supply of air water and nutrient where the products are more resistant to diseases and natural or biological control can be easily employed to it. Moreover, soil born pests and diseases can be easily eliminated easily through the soil less cultivation. Troublesome weeds can be avoided by this cultivation (Munoz *et al.* 2010). Soilless growing is becoming an attractive option because of the unpredictable problems of soil due to fluctuating temperatures, moisture holding capacity, obtainability of nutrients, salinity, root aeration, undesirable microbial activities and nematode, disease and pest to overcome these problems with soilless. Since the growth medium relates to every cultural practice in the soilless production stage, selection or formulation of medium is extremely important.

Hydroponics culture technique is popular all over the world and has huge probabilities in our country. It is highly productive, conservative of water and land, and protective of the environment. Hydroponics has proved to be an excellent alternative crop production system (Savvas, 2003). This technology assure high yields and high quality product even in saline or acidic soils, or non-arable soils with poor structure, which represent a major proportion of cultivable land throughout the world. A further advantage of hydroponics is the precise control of plant nutrition. Also, the preparation of the soil is avoided in hydroponics, thereby increasing the potential length of cultivation time, which is an effective means of increasing the total yield in greenhouses. The reason, imposing a switch over to hydroponics is increasingly associated with environmental policies as well. A hydroponic system enables a considerable reduction of fertilizer application and a drastic restriction or even a complete elimination of nutrient leaching from greenhouses to the environment (Avidan, 2000).

Hydroponics is a suitable system of growing crops in which space, fertilizer and labor are efficiently used. In soilless culture, growing media are inert substrates in which plants are grown. It covers different organic (viz., peat, compost, tree bark, coconut husk, sawdust, etc.) and inorganic materials (clay, perlite, vermiculite, rock wool, volcanic tuff, etc.). While these substrates can be used alone, but mixtures of the substrates such as peat and perlite; coir and clay, peat and compost (Grunert *et al.* 2008) are more suitable for crop culture in soilless system. A good substrate should have adequate mechanical properties, high porosity, ability to distribute consistent oxygen and water for activity, low soluble salts content with a pH between 5.0 to 6.5 and should be sterile and chemically inert. Soil less substrate originated from organic materials which would improve the product quality with health substance (Donnan, 1998). Growing media have some functions such as providing aeration and water, allowing maximum root growth and physical support to the plants. There are many different materials that have been used for vegetable production. However, local available materials were used throughout the world (Schmilewski, 2009). Rice hull is an agricultural by-product which is poorly utilized. More than 100 million tons of rice hull is generated annually in the world (Okafor and Okonkwo, 2009).The collection and disposal of rice hull is becoming more difficult and expensive and is, therefore, left unused as waste or simply burned in the fields, thereby creating significant environmental problems (Mansaray and Ghaly, 1997). It has useful properties as a growing media such as low in weight, inert with respect to adsorption and desorption of nutrients and also has good drainage, aeration and low rate of decomposition (Saparamadu, 2008).

Physical and chemical properties of the growing substrates are important factors for used as growing media. Regarding the physical properties of the substrates, a high content of easily available water in combination with an adequate air supply are considered as the most important characteristics of growing media used in soilless culture. Nevertheless, the pH and EC are two important characteristic of growing media that have been effect on crop growth and nutrient availability in root zone. Therefore, proper mixing of different types of individual substrate can improve the physicochemical properties of substrate mixture. On the other hand, use of locally available growing media can help to reduce crop production cost in soilless culture. In Bangladesh, many media are available that can be used in soilless culture of sweet pepper, such as rice husk, saw dust, ash, bamboo chips, coconut coir, etc. Proper drainage and aeration in these growing substrates are the main problems for the plants root zone.

Therefore, it is needed to identify a suitable growing media mixture for sweet pepper soilless culture in Bangladesh.

Considering the above mentioned facts, the present research work was aimed to study with the following objectives:

- To assess the chemical and physical properties of different substrate mixtures,
- To identify the effects of growing substrate mixtures on growth and yield of sweet pepper, and
- To select a suitable growing substrate mixture for sweet pepper in soilless culture in Bangladesh.

Chapter II

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

Very few studies on the growth and yield of sweet pepper in hydroponic system have been carried out in our country. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nowadays, a wide variety of sweet pepper and leafy vegetables can be successfully grown in hydroponic systems. An appropriate growing substrate mixture is necessary to produce a high quality crop.

Some of the research findings related to the growth and yield of hydroponic sweet pepper as influenced by organic substrates so far have been reviewed here.

Samarakoon *et al.* (2006) reported that the EC values for hydroponic systems range from 1.5 to 2.5 ds m^{-1}. Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield.

Jayawardana *et al.* (2014) reported that capsicum plants treated with rice hull leachate showed a significant increase in weight of fruits/plant (51 %), fruit weight (37 %), fruit length (32 %), shoot length (60 %), root length (100 %), no of leaves (55 %) and leaf area (44 %).

Hell *et al.* (2013) reported that the temperature of the nutrient solution influenced the behavior of sweet pepper changing the electrical conductivity (EC). They found that the increased in EC did not reduce sweet pepper productivity when the maximum temperature of the nutrient solution was limited at $26^{o}C$. They also found that cooling of the nutrient solution provided greater accumulation of biomass and higher water content in plants, increasing the productivity of hydroponic sweet pepper in the tropics.

Jayawardana *et al.* (2016) concluded that the simplified hydroponics system consisting Si sources rice hull:sand (3:2 v/v) media was effective in reducing the anthracnose disease caused by *Colletotrichum gloeosporioides* by more than 83 % and enhancing shoot and root length, fruit fresh weight, fruit length and fruit firmness of *Capsicum annuum* L. 'Muria F1' in comparison with non-circulating liquid hydroponic system supplied with either NF or Albert's nutrient solution. Therefore, it could be concluded that simplified hydroponics system with a natural silicon sources, rice hull in the media would be a low-cost and environmental friendly method for growing capsicum to enhance anthracnose disease resistance and also shoot length, root length, fruit length, fruit weight and fruit firmness were also increased significantly .

Schnitzler *et al.* (2004) reported that, low-tech system suitable for long-term cultivation of bell pepper (*Capsicum annuum* L.) using wood fibre as substrate was further simplified. In a two years study, four different types of slow release fertilizers (SRF) in mixed or sole application in different container and closed irrigation systems (10 L plastic pots fitted with drips, troughs with continuous flow, troughs with drips and grow bags with drips) were investigated for 40 weeks in organic substrate. The low-tech systems with SRF were compared with re-circulating liquid feed (LF), PAR regulated irrigation, and EC dependent nutrient replenishment. Plant growth, fruit yield and quality parameters were better in the pot system fitted with drippers than in other container systems. High marketable yield of 12.80 kg m^{-2} was obtained in Mat-4 (mixture of 3 and 6 month types SRF) formulated fertilizer. The trend for other horticultural characters was also positive in Mat-4 combination.

Dyśko *et al.* (2008) studied that in the root zone this element can be found as PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^{-}$ ions; the last two ions are the main forms of P taken by plants. On inert substrates, the largest amount of P available in a nutrient solution is presented when its pH is slightly acidic (pH 5). In alkaline and highly acidic solutions the concentration of P decreases in a significant way.

Urrestarazu (2004) studied that the pH value determines the nutrient availability for plants. Accordingly, its adjustment must be done daily due to the lower buffering capacity of soilless systems.

Tyson *et al.* (2007) in a study to determine the nitrification rate response in a perlite trickling biofilter (root growth medium) exposed to hydroponic nutrient solution, varying NO3- concentrations and two pH levels (6.5 and 8.5), founded that nitrification was significantly impacted by water pH. The increased ammonia oxidation rate (1.75) compared to nitrite oxidation rate (1.3) at pH 8.5 resulted in accumulation of NO^{2-} to levels near those harmful to plants (observed peak of 4.2 mg L^{-1} NO^{2-}). The potential for increased levels of un-ionized ammonia, which reduced plant nutrient uptake from micronutrient precipitation, are additional problems associated with pH 8.5.

Marschner (1995) concluded that an important feature of the nutrient solutions is that they must contain the ions in solution and in chemical forms that can be absorbed by plants, so in hydroponic systems the plant productivity is closely related with to nutrient uptake and the pH regulation.

Bergquist *et al.* (2007) reported that with the exception of carbon (C) and oxygen (O), which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Other elements such as sodium, silicon, vanadium, selenium, cobalt, aluminium and iodine among others, are considered beneficial because some of them can stimulate the growth, or can compensate the toxic effects of other elements, or may replace essential nutrients in a less specific role. The most basic nutrient solutions consider in its composition only nitrogen, phosphorus, potassium, calcium, magnesium and sulphur and they are supplemented with micronutrients. The nutrient composition determines electrical conductivity and osmotic potential of the solution.

Garceäs-Claver *et al.* (2006) produced sweet pepper in stationary culture of hydroponics successfully under tropical greenhouse conditions (38.5^{o}C). A solution concentration of 0.5 g/L of Albert's solution (having an EC of l.4 dS/m) with renewal at 2 weeks intervals could be identified as the best fertigation strategy under hot and humid conditions. Increasing solution concentrations above that level upto 2 dS/m increased the plant uptake of N, P, K and Ca but, without a significant increase in leaf growth and yield.

Dufour and Guéri (2005) reported that when a nutrient solution is applied continuously, plants can uptake ions at very low concentrations. So, it has been reported than a high proportion of the nutrients are not used by plants or their uptake does not impact the production. It was determined that in anthurium, 60% of nutrients are lost in the leachate.

Fanasca *et al.* (2006) reported that Iron, copper, zinc, boron, and manganese, become unavailable at pH higher than 6.5 in nutrient solution of Hydroponic system.

Voogt (2002) studied that in closed systems of hydroponic nutrient solution, the loss of nutrients from the root environment is brought to a minimum.

De Rijck and Schrevens (1999) reported that each nutrient on sweet pepper shows differential responses to changes in pH of the nutrient solution as described below. In the nutrient solution, NH_3 only forms a complex with H^+. For a pH range between 2 and 7, NH_3^+ is completely present as NH_4^+. Increasing the pH above 7 the concentration ofNH_4^+ decreases, while the concentration of NH_3^+ augments.

Epstein (1994) reported that Silicon application in hydroponic systems has been reported beneficial on growth, yield and also disease resistance of some crops.

Saparamadu (2008) reported that Si concentration leached into water by rice hull and sand mixture (1:1 v/v) was increased up to 92 ppm within a period of 17 weeks while K, P and N were not increased more than 6 ppm which shows that rice hull is a cheap natural source of Si.

De Rijck and Schrevens (1998a) studied that the pH is a parameter that measures the acidity or alkalinity of a solution. This value indicates the relationship between the concentration of free ions H^+ and OH^- present in a solution and ranges between 0 and 14. Changing the pH of a nutrient solution affects its composition, elemental speciation and bioavailability. The term “speciation” indicates the distribution of elements among their various chemical and physical forms like: free ions, soluble complexes, chelates, ion pairs, solid and gaseous phases and different oxidation states.

De Rijck and Schrevens (1998b) conveyed that the pH is a parameter that measures the acidity or alkalinity of a solution. This value indicates the relationship between the concentration of free ions H^+ and OH^- present in a solution and ranges between 0 and 14 exchanges the pH of a nutrient solution affects its composition, elemental speciation and bioavailability. The term “speciation” indicates the allocation of elements among their various chemical and physical forms like: free ions, soluble complexes, chelates, ion pairs, solid and gaseous phases and different oxidation states.

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Ghehsareh (2013) reported some physicochemical properties of rice hull media such as porosity (73 %), water holding capacity (88 %), bulk density (0.09 g/cm3), organic matter content (88.52 %), electrical conductivity (2.24 ds/m) and pH (6.2).

Zeiger (1998) studied that an essential elements of nutrient solution for hydroponic sweet pepper have physiological role and its absence prevents the complete plant life cycle.

Marulanda and Izquierdo (1993) reported that the composition of N, P, and K in rice hull is 0.5, 0.08 and 0.4 %, respectively, and the C/N ratio of rice hull is 25:1. The 50% coco-peat + 50% perlite media caused a higher chlorophyll content (64.16 SPAD unit) in leaves and this increase was accompanied with increase of plant growth, which produced highest weight and length aerial shoots by 1262 g and 339.80 cm, respectively in tomato. The high yield and fruit number (4.51 kg plant 1 and 40.2) and superior quality of fruits containing 7.31% dry matter content and 4.74 brix TSS was obtained in this media mixture.

McRijck *et al.* (1998) conducted an experiment on sweet pepper (*Capsicum annuum* L.) under three nutrient solution nitrate contents which represented a range of adequate and inadequate environments. Larger, faster-growing plants should have a larger demand for nitrate and hence larger uptake rates than smaller, environmentally stressed plants. Results showed higher sustained levels of nitrate uptake by larger plants. Neither the severity of stress under which a plant was grown nor the plant sizes were the sole determinants of maximum potential uptake behavior, however. Increased light level was related to an increased ability to transport nitrate on a short-term basis. Increased light level was associated with increased maximum nitrate uptake rates. The effects of environmental light and nitrate levels on nitrate uptake were incorporated into a power relationship where the maximum uptake velocity was determined in relation to the shoot growth rate.

Schreven *et al*. (1997) found that with pH 5, 100% of P is present as $H_2PO_4^-$; this form converts into HPO_4^{2-} at pH 7.3, reaching 100% at pH 10. The pH range that dominates the ion $H_2PO_4^-$ on HPO_4^{2-} is between 5 and 6. Potassium is almost completely present as a free ion in a nutrient solution with pH values from 2 to 9; only small amounts of K^+ can form a soluble complex with SO_4^{2-} or can be bound to Cl^-. Like potassium, calcium and magnesium are available to plants in a wide range of pH; however, the presence of other ions interferes in their availability due to the formation of compounds with different grade of solubility.

Ayers and Westcot (1987) found that as water naturally contains HCO_3^-, this anion turns into CO_3^{2-} when the pH is higher than 8.3 or to H_2CO_3 when it is less than 3.5; the H_2CO_3 is in chemical equilibrium with the carbon dioxide in the atmosphere.

Steiner (1984) found that at a pH above 8.3, Ca^{2+} and Mg^{2+} ions easily precipitate as carbonates (Also, as mentioned above, when the pH of the nutrient solution increases, the HPO_4^{2-} ion predominates, which precipitates with Ca^{2+} when the product of the concentration of these ions is greater than 2.2, expressed in mol m^{-3}.

Hansen (1978) reported that the addition of plant nutrients to hydroponic systems may be performed according to the plant nutrient requirement. Application of nutrients may be performed according to analyses of a specific crop stage that may describe the consumption of the various typical nutrients of the particular crop or by means of analyses of the total plant needs quantitatively adjusted to the rate of growth and the amounts of water supplied.

Steiner (1966) reported that a nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants. Eventually, some organic compounds such as iron chelates may be present.

Ghehsareh (2013) reported some physicochemical properties of rice hull media such as porosity (73 %), water holding capacity (88 %), bulk density (0.09 g/cm3), organic matter content (88.52 %), electrical conductivity (2.24 ds/m) and pH (6.2).

Okafor and Okonkwo (2009) reported that rice husk is an agricultural by-product which is poorly utilized. More than 100 million tons of rice hull is generated annually in the world.

Saparamadu (2008) found that rice husk has useful properties as a growing media such as low in weight, inert with respect to adsorption and desorption of nutrients and also has good drainage, aeration and low rate of decomposition.

Saparamadu (2008) reported that Si concentration leached into water by rice hull and sand mixture (1:1 v/v) was increased up to 92 ppm within a period of 17 weeks while K, P and N were not increased more than 6 ppm which shows that rice hull is a cheap natural source of Si.

Saparamadu *et al.* (2008) reported that simplified hydroponics system which consisted rice hull:river sand (3:2 v/v ratio) medium enhanced growth of bush beans and tomato.

Patel *et al.* (1987) found that the Si content in raw rice husk is 10.3 (wt%).

Michael and Lieth (2008) studied that total pore space for most growing media is 1.5 – 2.8 times higher than the values found for common soils (about 35 per cent V/V) and increase in total pore space will often decrease the water retention, increase oxygen transport and increase root penetration. These, in turn, will influence plant growth.

Jayawardana *et al. (*2016) concluded that the simplified hydroponic system composed of rice hull, as a natural silicon supplement could be used as a low-cost environmental friendly growing method of capsicum to enhance resistance against anthracnose disease, and to improve plant growth and fruit quality.

Saparamadu (2008) reported that concentration of Si leached by rice hull was increased with time while concentration of Si leached by sand was lower and was not increased with time.

Trejo-Téllez *et al.* (2007) reported that with the exception of carbon and oxygen, which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Other elements such as sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine among others, are considered useful because some of them can incite the growth, or can compensate the toxic effects of other elements, or may replace essential nutrients in a less specific role. The most basic nutrient solutions consider in its composition only nitrogen, phosphorus, potassium, calcium, magnesium and sulphur and they are supplemented with micronutrients. The nutrient composition determines electrical conductivity and osmotic potential of the solution.

Dufour and Guérin (2005) carried that when a nutrient solution is used successfully, plants can uptake ions at very low concentrations. So, it has been reported than a high proportion of the nutrients are not used by plants or their uptake does not impact the production. It was determined that in anthodium, 60% of nutrients are lost in the leachate.

Bradly and Marulanda (2000) found that rice hull can be mixed with other materials such as coal scoria, saw dust, river sand and volcanic scoria and can be successfully used as media in simplified hydroponic systems.

Noto (1993) reported that in soilless crops, the substrate replaces the soil because the natural soil is often poorly suited to cultivation due to chemical (reaction, nutrient availability, etc.), physical (density, structure, water retention, etc.), or biological (presence of pathogens, exhaustion, etc.) limitations, or because in this way it controls plant growth better.

Nappi and Barberis (1993) reported that very low pH can result in toxic concentration of ions such as aluminum, zinc and copper, while chemical bindings can occur at pH above 7.5 and EC above 3.5 mS cm^{-1} in substrate causing poor plant growth.

De Rijck and Schreven (1997) reported that with pH 5, 100% of P is present as HPO_4^-, this form change into HPO_4^- at pH 7.3, reaching 100% at pH 10. The pH range that dominates the ion HPO_4^{2-} on $HPO4^-$ is between 5 and 6. Potassium is almost perfectly present as a free ion in a nutrient solution with pH values from 2 to 9; only small amounts of K^+ can form a soluble complex with SO_4^{2-} or can be bound to Cl^-. Like potassium, calcium and magnesium are available to plants in a wide range of pH; however, the presence of other ions interferes in their availability due to the formation of compounds with different grade of solubility.

Winsor and Adams (1987) reported that the total concentration of solutes in the nutrient solution is characterized by the electrical conductivity (EC, dsm^{-1}). Usually EC in commercial tomato production is in the range 2±5 dsm^{-1}. Too low a concentration causes mineral deficiency and restricts plant growth.

Yahya *et al.* (2009) concluded that, certain chemical and physical properties of cocopeat can be improved through incorporation of burnt rice hull. The positive effects of burnt rice hull were seen in the elevation of nutrient availability (as indicated by higher EC), increased bulk density, air-filled porosity, available water and wettability. Improvement in chemical and physical properties following incorporation of burnt rice hull into cocopeat was reflected in a better plant growth.

Verdonck *et al.* (1982) reported that the use of different organic and inorganic substrates allows the plants the best nutrient uptake and sufficient growth and development to optimize water and oxygen holding.

Tehranifar *et al.* (2007) reported that the vegetative growth of a number of strawberry cultivars were higher in media with peat and cocopeat compared with 100% sand and perlite and in cocopeat 40% + perlite 60% some cultivars produced the highest number of fruits and yield per plant. The yield in substrates with peat or cocopeat was higher than in substrates with without peat or cocopeat.

Materska *et al.* (2005) reported that there was no significant difference on root dry mass among treatments because it did not show any specific tendency of either increasing or decreasing with increasing nutrient solution concentration.

However, there was contrasting results between fresh mass and leaf dry mass whereby fresh mass was decreasing with an increase in nutrient concentration while leaf dry mass was increasing with increasing nutrient concentration. This could be attributed to the fact that plants grown at 1 mS/cm had more water content whereas plants grown a higher EC level (4 mS/cm) had less water content but more dry matter content. The chlorophyll content was not significantly different among the different treatments, however, the highest chlorophyll content was recorded in treatments 2 and 3 while treatments 1 and 4 had equal amount of chlorophyll. This indicate that there was very little nutrients (nutrient deficiency) in the lower EC (1 mS/cm) while high salt content resulted in low chlorophyll content in the higher EC levels (4 mS/cm). Nitrogen significantly increased with increasing nutrient solution concentration. Phosphorus is good for root development but there was conflicting relationship between the P content in the leaves and the dry root mass which could not be explained. Calcium (Ca) decreased with increasing the EC level while magnesium (Mg) remained constant, but both were slightly lower than the recommended range. However, potassium (K) was below the recommended range although it did not affect sweet pepper quality/taste.

Bilderback *et al.* (2005) suggested the ranges of physical properties of substrates, these values include 0.19–0.70 g cm^{-3} for bulk density, 10–30% for air porosity, and 50–85% for total porosity.

Chapter III
Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted in the semi-green house at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh during October 2016 to April 2017. The location of the study site is situated in 23º 74$^{/}$ N latitude and 90º 35$^{/}$ E longitude. The altitude of the location was 8 m from the sea level (The Meteorological Department of Bangladesh, Agargaon, Dhaka).

3.2 Plant and other materials

The seeds of sweet pepper cv. 'Red star' were used in the experiment. The seeds were kept in a sealed packet, collected from Gulistan, Dhaka. The styrofoam, plastic pot, plastic tray, wood, polythene sheet etc were collected from Town Hall, Mohammadpur, Dhaka. Experimental chemicals were bought from Tikatolli, Dhaka.

3.3 Experimental Design and treatments

The experiment was conducted in a completely randomized design (CRD) with three replications. Four different types of growing substrate mixtures were considered as treatments denoted as M:

M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%),

M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%),

M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and

M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

3.4 Nutrient solution

Nutrient solution which was used in treatments was Rahman and Inden (2012) solution. The ratio of Rahman and Inden (2012) solution were NO_3-N, P, K, Ca, Mg and S of 17.05, 7.86, 8.94, 9.95, 6.0 and 6.0 meq/L respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 mg/L, respectively. The solution was applied in different boxes. Nutrient solution was given at half strength from the first day of the seedlings when transferred into the boxes. Full strength of the treatments was started from the second week of the experiment. The pH≅ 6.0 and EC≅ 3.8 dS m^{-1}, respectively were maintained in the nutrient solution.

3.5 Experimental environment

Eight different wooden boxes (180cm × 25cm × 25cm) were prepared for culturing the plants. Polythene sheet was placed in the inner side of box so that the nutrient solution could not pass through the wooden box. Boxes were filled with different substrates mixture according to the treatments. For seedling growing, plastic tray filled with media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v) were used. Two-week-old seedlings were transferred into the 250 mL plastic pots. The room was kept clean and tidy during the time of the experiment. The crop was cultivating and it continued until April 2017.

3.6 Growing media preparation

Coconut coir was soaked in a big bowl for 24 hours. It was washed well with water and spread in a polythene sheet for 3 hours. Then they were mixed with khoa and vermi-compost at a ratio of 60:30:10 properly to prepare media mixture $M_{1,}$ rice husk (60%) + coconut coir (30%) + vermi-compost (10%) are mixed together for M_2 treatment, sawdust (60%) + khoa (30% + vermi-compost (10%) mixed for M_3 treatment and ash (60%) + khoa (30%) + vermi-compost (10%) mixed for M_4 treatment.

3.7 Seed sowing

The seeds were soaked in water for 24 hours and then wrapped with piece of thin cloth. The socked seed were then spread over polythene sheet for 2 hours to dry out the surface water. After that seeds were shown in plastic tray and covered with newspaper under room temperature for rising.

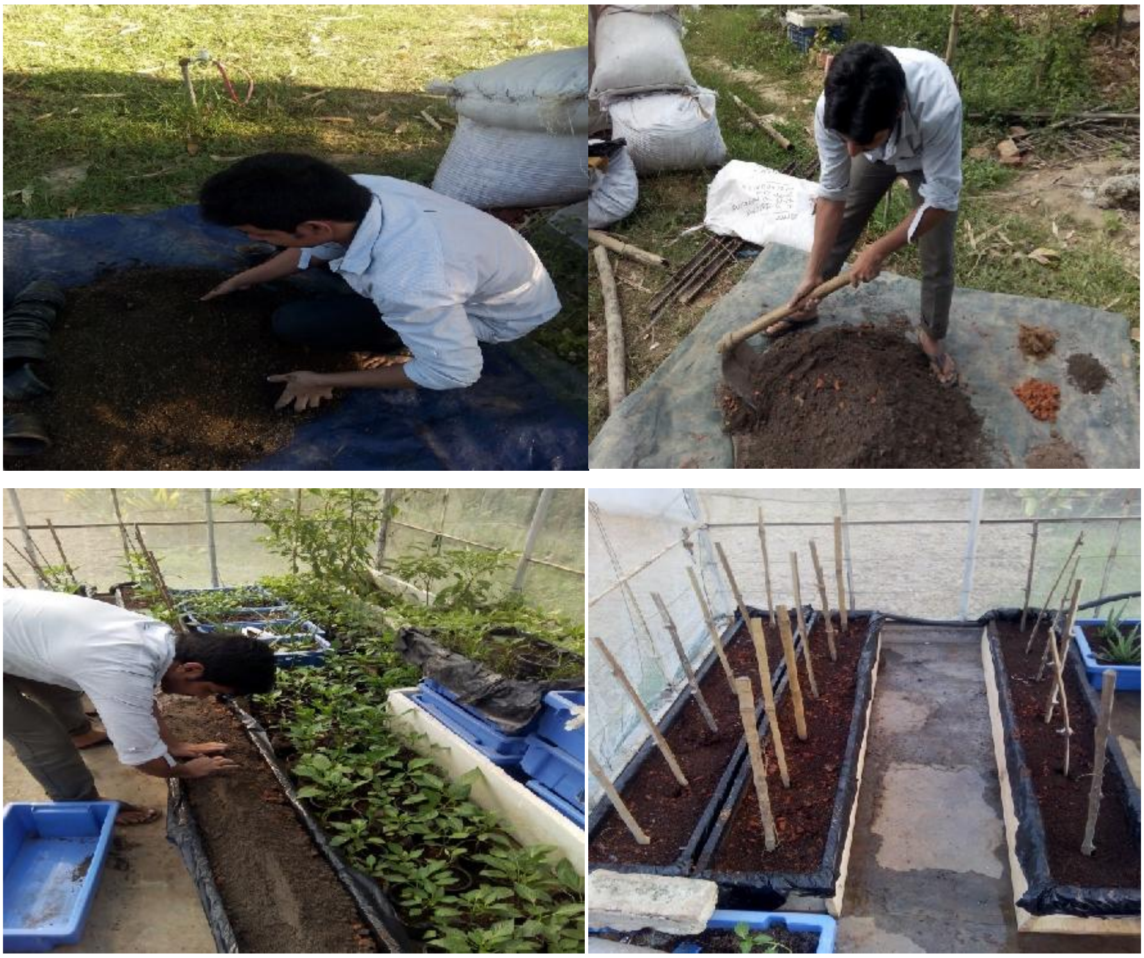

Plate 1: Preparation and placement of media mixture in the box

3.8 Transplanting of sweet pepper seedling

Two weeks old sweet pepper seedlings were transferred to plastic pot contains the mixture of coco peat, khoa and ash. Regular water and ½ strength of Rahman and Inden (2012) solution were given. After four weeks these seedling were transplanted to the main box. The plants were transplanted carefully so that roots were not damaged. After transplanting of sweet pepper plant in the box light watering was done with sprayer.

3.9 Intercultural operations

3.9.1 Pruning

Three weeks after transplanting, the crown flower and the flower on the first node of each stem were removed, allowing plants to develop an adequate vegetative frame before fruit set. Starting four weeks after transplanting, plants are trained with "V" trellis system. In the "V" trellis system, the lateral shoot (the smaller shoot of the pair that bifurcated on a node) were pruned when they reached 3-4cm long.

3.9.2 Weeding

No weeding was done in the experiment.

3.9.3 Insect management

Sweet pepper plants were grown in controlled environment. So, no insecticides were applied in the experiment.

3.9.4 Diseases management

Sweet pepper plants were grown in controlled environment in hydroponic system and all nutrients required for plant were supplied artificially to the plants. The growing environment was clean and no disease attacked to the plants.

Plate 2: Pruning technique

3.10 Harvesting

The crop was harvested after 75, 120 and 180 DAT. Harvesting of the crop was done according to treatment.

3.11 Data collection

Data on physicochemical properties of growing media mixtures were collected before transplanting sweet pepper seedling described below. Different data on the growth and physiological traits were recorded during the experiment. Data were collected from each plant described below.

3.11.1 Properties of growing substrates

The selected properties of growing substrates, namely initial pH and EC, bulk density, water retention, air-filled porosity and dry weight of substrate mixtures were measured. The measurement procedures of the properties were described below.

3.11.2 pH and Electrical Conductivity

The pH and EC values for all media before planting were determined by pH and EC meter.

3.11.3 Bulk density (g.cm-3)

Bulk density was determined by using the core method (Teh and Jamal, 2006).

3.11.4 Water retention (%)

Water retention was measured by using the following formula.

$$\text{Water retention (\%)} = \{(Ws - Wd)/Wd\} \times 100$$

Where, Ws = weight of water saturated substrate mixture, Wd = weight of oven dried substrate mixture.

3.11.5 Air-filled porosity (%)

Air-filled porosity (AFP) was determined using the following formula.

AFP (%) = (Volume of water drained (mL)×100)/(Volume of substrate mixture (mL))

3.11.6 Dry weight
Dry weights of substrate mixtures were also measured.

3.12 Plant growth and yield parameter

3.12.1 Plant height
Plant height was measured in centimeter (cm) by a meter scale at 0, 30, 60, 90, 120, 150 and180 DAT (days after transplanting) from the point of attachment of growing media up to the tip of the longest leaf.

3.12.2 Number of fruits per plant
Number of fruits per plant were counted at 75 (First harvesting), 120 (Second harvesting) and 180 (Third harvesting) DAT. All the fruits of each plant were counted separately. Only the smallest young fruits at the growing point of the plant were excluded from the counting and the average number was recorded.

3.12.3 Individual fruit weight
The individual fruit weights were measured by electric balance at department of horticulture, Sher-e-Bangla Agricultural University, Dhaka 1207.

3.12.4 Individual fruit length
The individual fruit length was measured during harvesting with the help of a large scale in centimeter unit.

3.12.5 Individual fruit diameter
The individual fruit breadth was measured during harvesting with the help of a large scale in centimeter unit.

3.12.6 Individual fruit volume

The individual fruit volume was measured during harvesting with the help of a 500ml beaker in centimeter cube (cc) unit. Another name of cc unit is ml.

3.12.7 Dry weight of 100 g fruit

100gm fruit was collected from each treatment, the fruit was sliced by knife and dried at sun for 2 days separately, after that these was transferred to oven of central laboratory, Sher-e-Bangla Agricultural University. It was collected and weighted by electric balance after 72 hours.

3.12.8 Fresh weight of stem, leaf and root

One plant was uprooted from each treatment at 180 DAT. Leaf was detached from the stem and root was cut at the junction of stem and root. Root was washed by tap water to remove media and sun dried to remove attaching water. All these three part of plant was weighted by electric balance.

3.12.9 Dry weight of stem, leaf and root

Stem, leaf and root was dried by sun for 2 days separately, after that these was transferred to oven of central laboratory, Sher-e-Bangla Agricultural University It was collected and weighted by electric balance after 72 hours.

3.12.10 Percent dry matter of plant

From the random samples of plants weighing then sun dried for seven days. After drying, plants were weighed. An electric balance was used to record the dry weight of plant and it was calculated on percentage basis. The percentage of dry matter of plant was calculated by the following formula.

$$\% \text{ Dry matter of plant} = \frac{\text{Constant dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

3.12.11 Measurement of ascorbic acid

Ascorbic acid content in sweet pepper was measured from Bangladesh Council of Scientific and Industrial Research (BCSIR).

3.13 Growth parameter analysis

Growth parameters (dry weights of stem, leaf and root), and different physiological parameters [Leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR)] were determined in the experiments. The parameters were measured as described below:

$$\mathrm{LAR} = \frac{\mathrm{LA}}{\mathrm{PDW}}$$

Where, LAR = leaf area ratio, LA = Leaf area (cm^2), PDW = plant dry weight (g).

$$\mathrm{LMR} = \frac{\mathrm{LDW}}{\mathrm{PDW}}$$

Where, LMR = leaf mass ratio, LDW = leaf dry weight (g).

$$\mathrm{RWR} = \frac{\mathrm{RDW}}{\mathrm{PDW}}$$

Where, RWR = root weight ratio, RDW = root dry weight (g).

$$\mathrm{RGR} = \frac{\mathrm{PDW_1} - \mathrm{PDW_0}}{(\mathrm{t_1} - \mathrm{t_0}) \times \mathrm{PDW_0}}$$

Where, t = time. Subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$\mathrm{NAR} = \frac{\mathrm{RGR}}{\mathrm{LAR}}$$

3.14 Statistical analysis of data

The data obtained for different characters were statistically analyzed with SPSS version 20.0 and means separation were done by Tukey's test at $P \leq 0.05$.

Chapter IV

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The results of the experiment conducted under semi greenhouse conditions were presented in table 1 to table 9 and figure 1 to figure 2. The experiment was conducted to study the growth and yield of hydroponic sweet pepper as influenced by organic substrates. The results were presented and discussed under the following sub heading.

4.1 Properties of substrate mixtures

4.1.1 Initial pH and EC of substrate mixtures

The initial pH and EC are two important characteristics of growing substrates as these parameters directly influence the availability of nutrients status in the substrates. The initial pH and EC of the growing substrates mixture affected significantly among the treatment (Table 1). The highest pH was recorded in M_4 followed by others. Meanwhile, the lowest pH was recorded in M_2. Blom (1983) stated that most of the plants grew best in slightly acidic pH ranges between 6.2 to 6.8 in soil based substrates and 5.4 to 6.0 in soilless substrates. The present findings stated that the initial pH of the substrate mixtures of M_1 and M_3 were slightly higher than the optimum level that could be optimized by addition of acid based fertilizers. On the other hand M_4 had the higher pH level which is not suitable for sweet pepper production. All these phenomena lead to nutrients unavailability to the plants. However, the optimum pH of container substrates differs with plant species, but a pH of 5.0-6.5 can be tolerated by most of the plants (DeBoodt and Verndonck, 1972). The present findings accorded with these findings.

In case of EC, M_4 possessed the highest initial EC. Meanwhile, M_3 had the lowest EC (Table 1). Too low of a concentration causes mineral deficiency and restricts plant growth (Winsor and Adams, 1987). The EC values reflected the total inorganic ion concentration in the extracts of substrates.

Yahya *et al.* (2009) reported the higher initial EC of burnt rice hull mixture which was accorded with the present findings. However, EC value below 2.0 mS cm^{-1} is generally considered as optimum to support the plant growth in container production system (Milks *et al.* 1989). In this experiment, EC values for all the treatments possessed the optimum levels.

Table 1. Initial pH and EC of substrate mixtures (before transplanting)

Substrate mixtures	pH	EC(ds/m)
M_1	6.40 c^z	0.13 b
M_2	6.10 d	0.12 b
M_3	6.70 b	0.08 b
M_4	7.76 a	0.20 a
Level of significance (*P*)	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%). *P* represents the level of significance of ANOVA.

4.1.2 Bulk density of the substrate mixtures

Bulk density varied significantly among the substrate mixtures (Table 2). The highest bulk density was found in M_2 (0.45 $g \cdot cm^{-3}$) and the lowest bulk density was found in M_3 (0.20 $g \cdot cm^{-3}$). The present result was accorded with the findings of Islam (2008) who found that the bulk density of loose rice husk was significantly lower than coconut coir. Bulk density differed most likely due to the variation in particle size of the materials (Richards and Beardsell, 1986). In this experiment, all the treatments had the bulk density within the optimum range.

4.1.3 Water retention

The water retention is one of the important characters that differently affect the interval of nutrient solution application of the substrate mixtures (Table 2). The highest water retention was recorded in M_2 and the lowest in M_3. This might be due to its high proportion of macro pores. Differences in available water holding capacity of the substrate could be due to their total porosity (Bunt, 1988). Loss of water through gravitational forces can be reduced due to incorporation of finer particles. In this experiment, M_2 contained finer particles than other treatments. Furthermore, the second highest water holding capacity was found in M_1. Therefore, it revealed that the water holding capacity of M_1 and M_2 were comparatively greater and it can help in sustaining root development by releasing nutrients to the plant.

4.1.4 Dry weight of substrate mixtures

Significant variation was found among the different treatments in respect of dry weight of substrate mixtures (Table 2). The highest dry weight observed in M_2 (345.18 g L^{-1}), while the lowest in M_3 (189.20 g L^{-1}). Dry weight affects construction materials for soilless culture. The grower can make hydroponic structure with low-cost materials, if the dry weights of substrate mixtures become low. The results of the present study indicated that coconut coir (M_1) and rice husk (M_2) based substrates can facilitate the growers to construct hydroponic structure with low-cost materials.

Table 2. Bulk density, water retention and dry weight of four substrate mixtures

Substrate mixtures	Bulk density (g cm^{-3})	Water retention (%)	Dry weight (g L^{-1})
M_1	0.29 b^z	259.25 b	205.30 b
M_2	0.45a	298.45 a	345.18 a
M_3	0.20 c	169.50 d	189.20 b
M_4	0.25 bc	230.70 c	191.65 b
P	<0.001	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%). *P* represents the level of significance of ANOVA.

4.1.5 Air-filled porosity of the substrate mixtures

The air-filled porosity (%AFP) of the substrate mixtures differed significantly at both of 2 h and 5 h after drainage (Table 3). Higher %AFP at both of 2 h and 5 h after drainage was observed in M_2. Meanwhile, the lowest %AFP was found in M_3. Result indicated that water was rapidly removed by gravitational forces from M_2 treatment. Increasing proportion of large pores allows more aeration after drainage has stopped (Handreck and Black, 2007). Richards and Beardsell (1986) found that exclusion of particles greater than 2 mm from a mixture of pine bark: sand: brown coal improved total water, available water and days to wilting without creating unfavorable level of aeration. The present findings accorded with these findings.

Table 3. Air-filled porosity (AFP) of four substrate mixtures at 2 and 5 h after drainage

Substrate mixtures	AFP (%) at different times after drainage	
	2 h	5 h
M_1	24.27 b^z	26.48b
M_2	29.75 a	31.80 a
M_3	14.67 c	20.60 c
M_4	26.66 b	28.18 b
P	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%). *P* represents the level of significance of ANOVA.

4.2 Vegetative growth and yield parameters

4.2.1 Plant height

There was no significant difference in plant height at 0 days after transplanting (DAT), but significant increment in plant height were found at 30, 60, 90, 120, 150 and 180 DAT among the four growing substrate mixtures (Table 4). At 30 DAT, the tallest plant (41.6 cm) was found in M_2 and the lowest (29.4 cm) was found in M_4. At 60 DAT, the tallest plant (58.7 cm) was found in M_2 and the lowest (36.2 cm) was found in M_4. At 90 DAT, the tallest plant (63.8 cm) was found in M_2 and the lowest (40.9 cm) was found in M_4. At 120 DAT, the tallest plant (68.3 cm) was found in M_2 and the lowest (43.8 cm) was found in M_4. At 150 DAT, the tallest plant (72.7 cm) was found in M_2 and the lowest (46.7 cm) was found in M_4. At 180 DAT, the tallest plant (78.3 cm) was found in M_2 and the lowest (48.2 cm) was found in M_4. The results revealed that the maximum plant heights at all dates were found in plants grown in media mixture of rice husk (60%) + coconut coir (30%) + vermicompost (10%) (M_2) which was statistically similar to that of media mixture of coconut coir (60%) + khoa (30%) + vermicompost (10%) (M_1). This might be due to the higher water holding capacity, air filled porosity, total porosity and optimum bulk density of M_1 and M_2 which was described earlier.

Meanwhile the lowest plants height at all dates were observed in the plants grown in the media mixture of M_4 = ash (60%) + khoa (30%) + vermicompost (10%). This might be higher pH of ash media mixture. Also rice husk release considerable amount of si to the plant which is a beneficial plant nutrient of plant resulting higher plant height. According to Patel *et al.* (1987), the Silicon content in raw rice husk is 10.3 (wt%). In a recent study conducted by Jayawardana *et al.* (2014) it was found that sweet pepper grown in nutrient solution incorporated with rice hull leachate showed a significant reduction of anthracnose disease (about 50 %) together with enhanced plant growth and yield. The findings of the present study accorded with their findings.

Table 4. Effect of different growing substrate mixtures on plant height at different days after transplanting in sweet pepper

Treatment	Plant height at different days after transplanting (DAT) (cm)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
M_1	23.3a[z]	39ab	53.2b	58.1b	63.4a	66.8b	71.2b
M_2	21.6a	41.6a	58.7a	63.8a	68.3a	72.7a	78.3a
M_3	22.5a	32.8bc	41.5c	46.5c	48.6b	50.8c	53.3c
M_4	23.9a	29.42c	36.2d	40.9d	43.8b	46.7c	48.2d
P	0.604	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
	NS	**	**	**	**	**	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. NS nonsignificant at $P \leq 0.05$. ** significant at $P \leq 0.01$. DAT – Days after transplanting. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.2.2 Fruit length

Fruit length of sweet pepper were significantly affected by different growing substrates (Table 5). The highest fruit length was found in M_2 (7.74 cm) which was statistically similar to that of M_1 (7.27 cm) treatment. This might be due to the higher water holding capacity, air filled porosity, total porosity and optimum bulk density of M_1 and M_2 which was described earlier. The positive effects of burnt rice hull were seen in the elevation of nutrient availability (as indicated by higher EC) and wettability. On the other hand M_3(6.03 cm) and M_4 (5.25 cm) showed lowest fruit length because of lower water holding capacity, air filled porosity, total porosity, bulk density and higher pH which was described earlier.

4.2.3 Fruit diameter

Fruit diameter of sweet pepper were significantly affected by different growing substrates (Table 5).The highest fruit diameter was found in M_2 (5.70 cm) which was statistically similar to that of M_1 (5.67 cm). This was because rice husk media mixture (M_2) and coconut coir media mixture (M_1) having higher water holding capacity, air filled porosity, total porosity and optimum bulk density which was described earlier. On the other hand M_3 (4.83 cm) and M_4 (4.00 cm) showed lowest fruit diameter because of lower water holding capacity, air filled porosity, total porosity and higher pH which was described earlier.

4.2.4 Fruit volume

Fruit volumes of sweet pepper were significantly affected by different growing substrates (Table 5). The highest fruit volume was found in M_2 (95.26 cc) which was statistically similar to that of M_1 (90.85 cc) and the lowest fruit volume was found in M_4 (44.73 cc). There is no significant difference between M_1 and M_2 and also no significant difference showed between M_3 and M_4.

Table 5. Effect of different growing substrate mixtures on fruit length, fruit diameter and fruit volume in sweet pepper

Treatment	Fruit Length (cm)	Fruit diameter (cm)	Fruit volume (cc)
M_1	7.27a^z	5.67a	90.85a
M_2	7.74a	5.70a	95.26a
M_3	6.03b	4.83b	53.42b
M_4	5.25c	4.00c	44.73b
P	<0.001	<0.001	<0.001
	**	**	**

^{z}Means with different letter is significantly different by Tukey's test at P = 0.05. P represents the level of significance of one-way ANOVA. ** = significant at $P \leq 0.01$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.2.5 Number of fruit per plant and individual fruit weight

Number of fruit per plant and individual fruit weight per plant of sweet pepper were significantly affected by different growing substrates (Table 6). The highest number of fruit (11.50) and individual fruit weight (131.99 g) was found in M_2 which was statistically similar to that of M_1 (number of fruit per plant-10.67, individual fruit weight-125.30 g). This might be due to the higher water holding capacity, air filled porosity, total porosity and optimum bulk density of M_1 and M_2 which was described earlier. On the other hand the lowest number of fruit (7.58) and individual fruit weight 55.61 g was found in M_4 because of lower water holding capacity, air filled porosity, total porosity, bulk density and higher pH which was described earlier. Jayawardana *et al.* (2014) reported that sweet pepper plants treated with rice hull leachate showed a significant increase in weight of fruits/plant (51 %), fruit weight (37 %), fruit length (32 %), shoot length (60 %), root length (100 %), no of leaves (55 %) and leaf area (44 %). The result of the present study accorded with the result of Jayawardana *et al.* (2014).

4.2.6 Dry weight of 100 g fruit

Dry weights of 100 g fresh weight of sweet pepper were significantly affected by different growing substrates (Table 6). The highest fruit dry weight was found in M_2 (8.67 g) which was statistically similar to that of M_1 (7.17 g) and the lowest fruit dry weight was found in M_3 (5.68 g) and M_4 (3.63 g). Due to good physicochemical properties M_1 and M_2 showed good result. Due to lower water holding capacity, air filled porosity, total porosity and bulk density and higher pH of M_4 showing lowest result.

Table 6. Effect of different growing substrate mixtures on number of fruit per plant, individual fruit weight and dry weight of 100 g fresh fruit in sweet pepper

Treatment	Number of fruit per plant	Individual fruit weight (g)	Dry weight of fruit / 100 g fresh weight
M_1	10.67a[z]	125.30a	7.17ab
M_2	11.50a	131.99a	8.67a
M_3	9.00b	66.80b	5.68b
M_4	7.58c	55.61b	3.63c
P	<0.001	<0.001	<0.001
	**	**	**

[z]Means with different letter is significantly different by Tukey's test at $P = 0.05$. *P* represents the level of significance of one-way ANOVA. ** = significant at $P \leq 0.01$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.2.7 Fresh weight of Stem

Fresh weight of sweet pepper stem at 180 DAT was significantly affected by different growing substrates (Table 7). Highest stem fresh weight was found in M_2 (75.87 g). This was because rice husk media mixture (M_2), higher water holding capacity, air filled porosity, total porosity, optimum bulk density and pH which was described earlier and lowest stem fresh weight was found in M_4 (39.55 g) because of lower water holding capacity, air filled porosity, total porosity and bulk density and higher pH. The growth and flowering of *Celosia cristata* were the greatest when grown in a mixture of 70% cocopeat: 30% burnt rice hull and perhaps linked with a good balance in the aeration and moisture relationship of the media (Awang *et al. 2009)*. The result of the present study accorded with the result of Awang *et al.* (2009).

4.2.8 Fresh weight of leaf

Fresh weight of sweet pepper leaf at 180 DAT was significantly affected by different growing substrates (Table 7). Highest leaf fresh weight was found in M_2 (69.67 g). This was because rice husk media mixture (M_2) having higher water holding capacity, air filled porosity, total porosity, optimum bulk density and pH which was described earlier and the lowest leaf fresh weight was found in M_4 (37.88 g) because of lower water holding capacity, air filled porosity, total porosity and bulk density and higher pH.

4.2.9 Fresh weight of root

Fresh weight of sweet pepper root at 180 DAT was significantly affected by different growing substrates (Table 7). The highest leaf fresh weight was found in M_2 (32.88 g). This might be due to the higher water holding capacity, air filled porosity, total porosity and optimum bulk density of M_2 which was described earlier. And the lowest stem fresh weight was found in M_4 (20.44 g) because of lower water holding capacity, air filled porosity, total porosity and bulk density and higher pH.

Table 7. Effect of different growing substrate mixtures on plant fresh weights of sweet pepper

Treatment	Fresh weight/plant		
	Stem (g)	Leaf (g)	Root (g)
M_1	68.33a[z]	53.75b	26.44b
M_2	75.87a	69.67a	32.88a
M_3	52.80b	42.28c	22.56bc
M_4	39.55c	37.88d	20.44c
P	<0.001	<0.001	<0.001
	**	**	**

[z]Means with different letter is significantly different by Tukey's test at P = 0.05. P represents the level of significance of one-way ANOVA. ** = significant at $P \leq 0.01$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.2.10 Dry weight of stem

Dry weight of sweet pepper stem at 180 DAT was significantly affected by different growing substrates (Table 8). The highest stem dry weight was found in M_2 (15.55 g) and the lowest stem fresh weight was found in M_4 (5.87 g).

4.2.11 Dry weight of leaf

Dry weight of sweet pepper leaf at 180 DAT were significantly affected by different growing substrates (Table 8).The highest leaf dry weight was found in M_2 (12.75 g) and the lowest stem fresh weight was found in M_4 (6.22 g). There was no significant difference between M_1 (10.37 g) and M_2 (12.75 g).

4.2.12 Dry weight of root

Dry weight of sweet pepper root at 180 DAT were significantly affected by different growing substrates (Table 8).The highest root dry weight was found in M_2 (5.50 g) which was statistically similar to M_1 treatment and the lowest stem fresh weight was found in M_4 (2.75 g).

Table 8. Effect of different growing substrate mixtures on plant dry weights of sweet pepper

Treatment	Dry weight		
	Stem (g)	Leaf (g)	Root (g)
M_1	11.67b^z	10.37 ab	5.00a
M_2	15.55a	12.75 a	5.50a
M_3	8.25c	7.25bc	3.25b
M_4	5.87d	6.22c	2.75b
P	<0.001	0.001	0.002
	**	**	**

^{z}Means with different letter is significantly different by Tukey's test at $P = 0.05$. P represents the level of significance of one-way ANOVA. ** = significant at $P \leq 0.01$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.2.13 Yield

Marketable yield was affected by growing substrate mixtures (Figure 1). The highest yield was found in M_2 which was statistically similar to that of M_1. This might be due to the higher water holding capacity, air filled porosity, total porosity and optimum bulk density of M_1 and M_2 which was described earlier. The positive effects of burnt rice hull were seen in the elevation of nutrient availability (as indicated by higher EC) and wettability and the lowest yield was found in M_4 lower water holding capacity, air filled porosity, total porosity, bulk density and higher pH which was described earlier. Jayawardana *et al.* (2014) reported that Sweet pepper plants treated with rice hull leachate showed a significant increase in weight of fruits/plant (51 %), fruit weight (37 %), fruit length (32 %), shoot length (60 %), root length (100 %), no of leaves (55 %) and leaf area (44 %). The result of the present study accorded with the result of Jayawardana *et al.* (2014).

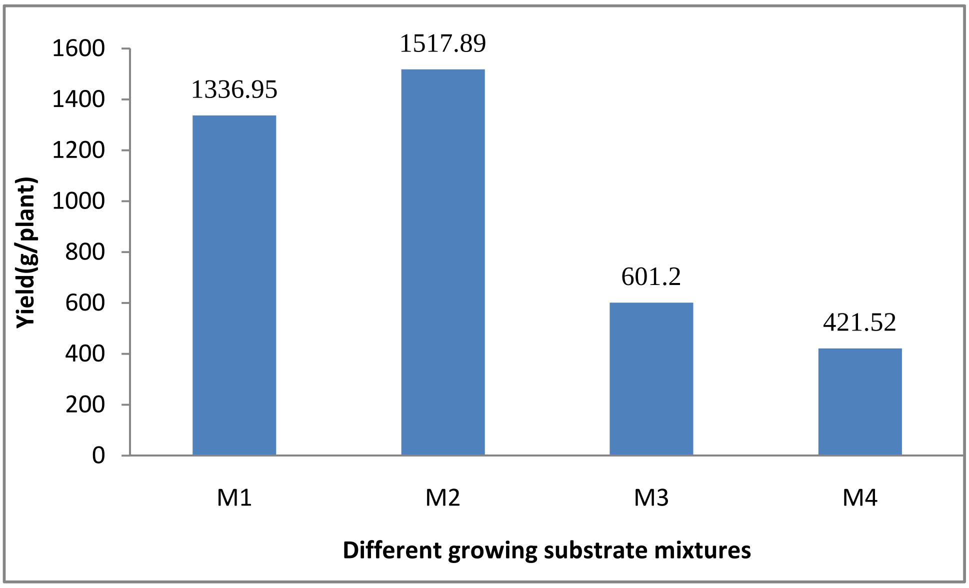

Figure 1: Effect of different growing substrate mixtures on yield per plant in sweet pepper

M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.3 Ascorbic acid content

Ascorbic acid content of sweet pepper was significantly affected by different growing substrates (Figure 2). The highest ascorbic acid content (149.5 mg/100g fresh fruit) was found in the plants grown in M_2, meanwhile the lowest ascorbic acid content (89.7 mg/100 g fresh fruit) was found in the plants grown in M_3. This might be because of rice husk-based media mixture (M_2) having higher water holding capacity, air filled porosity, total porosity, optimum bulk density and pH which were described earlier. On the contrary, M_3 growing media mixtures had lower water holding capacity, air filled porosity, total porosity and bulk density resulting poor ascorbic acid content in the plants.

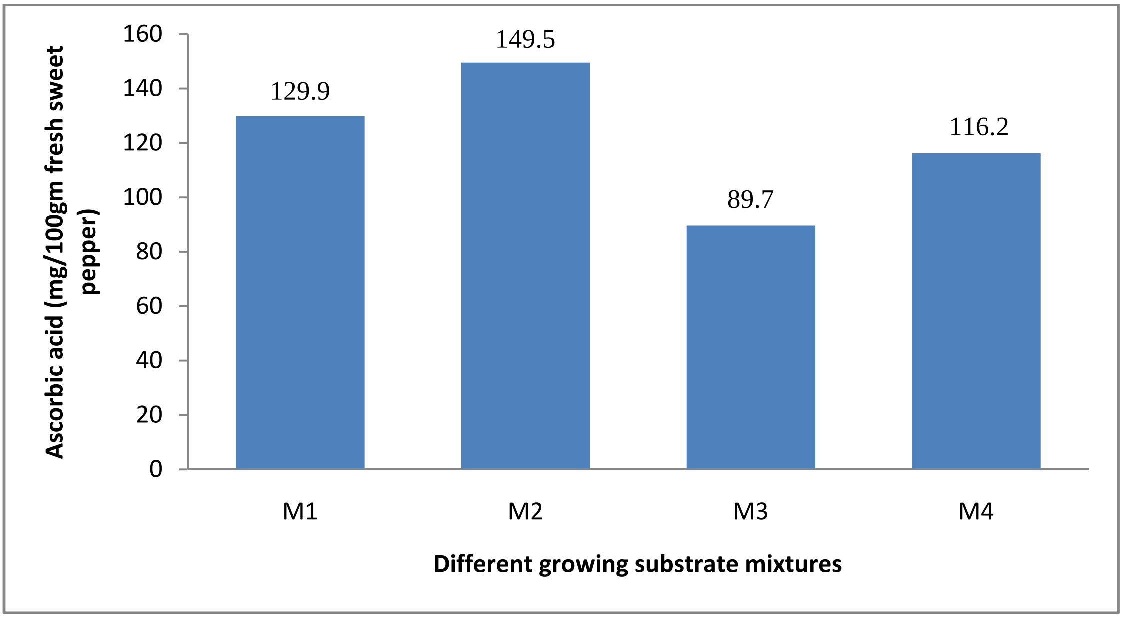

Figure 2: Effect of different growing substrate mixtures on ascorbic acid content per 100 g fresh sweet pepper

M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

4.4 Physiological growth traits

The physiological growth parameters of sweet pepper plants were significantly influenced by different growing substrate mixtures (Table 9). In case of leaf area (LA), the higher leaf area (LA) was found in the plants grown in rice husk based media mixture (M_2) and the lower was found in ash based media mixture (M_4). Leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Dufour and Guérin 2005). In case of Leaf Mass Ratio (LMR), the higher LMR was found in M_2 and the lower was found in $M_{4.}$ Higher LMR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased LMR gave the plants an increased ability to intercept light. In case of Leaf Area Ratio (LAR), the lower LAR was found in M_2 while the higher was found in $M_{4.}$ Lower LAR is one of the important criteria for producing higher metabolites. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings. In case of Root Weight Ratio (RWR), the lower RWR was found in M_2 while the higher was found in $M_{4.}$ Lower RWR is one of the important criteria for producing higher metabolites. Decreased RWR was found by Starck (1983) in tomato, which agreed with our findings. In case of net assimilation rate (NAR), the higher NAR was found in M_2 and the lower was found in $M_{4.}$ Higher NAR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased NAR gave the plants an increased ability to intercept light. . In case of Relative Growth Rate (RGR), the higher RGR was found in M_2 and the lower was found in M_4. Higher NAR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased RGR gave the plants an increased ability to intercept light which was similar with these findings.

Table 9: Effect of different growing substrate mixtures on physiological growth of sweet pepper

Treatment	Growth parameters					
	LA (cm^2)	LMR ($g\ g^{-1}$)	LAR ($cm^2\ g^{-1}$)	RWR ($g\ g^{-1}$)	NAR ($g\ cm^{-2}\ d^{-1}$)	RGR ($g\ g^{-1}\ d^{-1}$)
M_1	598.30 b[z]	1.07 b	64.01 c	0.149 c	0.0000094 b	0.00091 b
M_2	639.35 a	1.18 a	61.02 c	0.129 d	0.0000198 a	0.00097 a
M_3	546.01 c	0.99 c	78.84 b	0.176 b	0.0000081 c	0.00068 c
M_4	538.02 c	0.95 d	89.58 a	0.193 a	0.0000065 d	0.00057 d
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	**	**	**	**	**	**

[z]Means with different letter is significantly different by Tukey's test at $P = 0.05$. P represents the level of significance of one-way ANOVA. ** = significant at $P \leq 0.01$. M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%).

LA: Leaf area, LMR: Leaf Mass Ratio, LAR: Leaf Area Ratio, RWR: Root Weight Ratio, NAR: Net assimilation rate, RGR: Relative Growth Rate.

Chapter V
Summary and Conclusion

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SUMMARY AND CONCLUSION

The experiment was conducted in the semi green house at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh during November 2016 to April 2017. Four different types of growing substrate mixtures, viz M_1 = coconut coir (60%) + khoa (30%) + vermicompost (10%), M_2 = rice husk (60%) + coconut coir (30%) + vermicompost (10%), M_3 = sawdust (60%) + khoa (30%) + vermicompost (10%), and M_4 = ash (60%) + khoa (30%) + vermicompost (10%); and a variety of sweet pepper, such as, 'Red star' was used in this experiment. Physicochemical properties of growing substrates mixtures, crop growth, yield and physiological traits of sweet pepper were measured in the experiment. The summary was described here.

In case of physicochemical properties of growing substrate mixtures, the suitable pH and EC were found M_2 and lowest was recorded in M_3. The highest bulk density was found in M_2 (0.45 g cm^{-3}) and the lowest in M_3 (0.20 g cm^{-3}) and water retention capacity was the highest in M_2 (298.45 %) and lowest was 169.50 % in M_3. In case of dry weight of substrates, the highest dry weight observed in M_2 (345.18 g $L\text{-}^1$) while the lowest in M_3 (189.20 g $L\text{-}^1$). The air-filled porosity (%AFP) of the substrate mixtures differed significantly at both of 2 h and 5 h after drainage. Higher %AFP at both of 2 h and 5 h after drainage was observed in M_2. Meanwhile, the lowest %AFP was found in M_3.

In case of growth parameters of sweet pepper, tallest plant (78.3 cm) was recorded from plant grown in M_2 while the shortest plant height (48.2 cm) was recorded from M_4, in case of fruit length, highest fruit length (7.74 cm) was recorded from the plant grown in M_2 which was statistically similar to that of M_1 (7.27 cm) and lowest fruit length (5.25 cm) recorded from the plant grown in M_4, in case of fruit diameter, higher fruit diameter (5.70 cm) was recorded from plant grown in M_2 which was statistically similar to that of M_1 (5.67 cm) and lower fruit diameter (4.00 cm) recorded from plant grown in M_4, in case of fruit volume, higher fruit volume (95.26 cc) was recorded from plant grown in M_2 which was statistically similar to that of M_1 (90.85 cc) and lower fruit volume (44.73 cc) recorded from plant grown in M_4, in case of number of fruit per plant, the maximum (11.50) number of fruit per plant was recorded from plant grown in M_2 which was statistically similar to that of M_1 (10.67) while the minimum number of fruit/plant (7.58) was recorded plant grown in M_4, in case of individual fruit weight, the highest (131.99 g) individual fruit weight was recorded from plant grown in M_2 which was statistically similar to that of M_1 (125.30 g) while the lowest individual fruit weight (55.61 g) was recorded plant grown in M_4, in case of dry weight of 100 g fresh weight of sweet pepper, the higher fruit dry weight was found in M_2 (8.67 g) which was statistically similar to that of M_1 (7.17 g) and the lowest fruit dry weight was found in M_4 (3.63 g), in case of stem fresh weight at 180 DAT, the maximum stem fresh weight (75.87 g/plant) was recorded from the plant grown in M_2 and minimum stem fresh weight (39.55 g/plant) recorded from the plant grown in M_4, in case of leaf fresh weight at 180 DAT, the maximum leaf fresh weight (69.67 g/plant) was recorded from the plant grown in M_2 and the minimum leaf fresh weight (37.88 g/plant) recorded from the plant grown in M_4, in case of root fresh weight at 180 DAT, the maximum root fresh weight (32.88 g/plant) was recorded from the plant grown in M_2 and the minimum root fresh weight (20.44 g/plant) recorded from the plant grown in M_4. In case of dry weight of sweet pepper stem at 180 DAT, the highest stem dry weight was found in M_2 (15.55 g) and the lowest stem fresh weight was found in M_4 (5.87 g), in case of dry weight of sweet pepper leaf at 180 DAT, the highest leaf dry weight was found in M_2 (12.75 g) and the lowest leaf fresh weight was found in M_4 (10.37 g), in case of dry weight of sweet pepper root at 180 DAT, the highest root dry weight was found in M_2 (5.50 g) and the lowest root fresh weight was found in M_4 (2.75 g). In case of ascorbic acid content of 100 g sweet pepper, the highest ascorbic acid content was found in M_2 (149.5 mg) and the lowest ascorbic acid content was found in M_3 (89.7 mg).

Different physiological parameters; viz. in case of leaf area (LA), the higher leaf area (LA) was found in the plants grown in rice husk based media mixture (M_2) and the lower was found in ash based media mixture (M_4), in case of Leaf Mass Ratio (LMR), the higher Leaf Mass Ratio (LMR) was found in M_2 and the lower was found in $M_{4,}$ in case of Leaf Area Ratio (LAR), the lower Leaf Area Ratio (LAR) was found in M_2 while the higher was found in M_4, in case of Root Weight Ratio (RWR), the lower Root Weight Ratio (RWR) was found in M_2 while the higher was found in M_4, in case of Net Assimilation Rate (NAR), the higher Net Assimilation Rate (NAR) was found in M_2 and the lower was found in M_4, in case of Relative Growth Rate (RGR), the higher Relative Growth Rate (RGR) was found in M_2 and the lower was found in M_4. Best result was found from plant grown in M_2 followed by M_1. That means, the rice husked based growing substrates gave highest yield and ash based growing substrates gave lowest yield.

CONCLUSIONS

According to the findings of the present experiment, the following conclusions were drawn.

1. Improved physicochemical properties were found in rice husk based growing substrate mixtures of M_2 for growing sweet pepper in hydroponic system.

2. Higher fruit yield and other vegetative growth parameters and physiological traits of sweet pepper were found in M_2 treatment in aggregate hydroponic system.

Therefore, it can be concluded that sweet pepper can be grown in rice husk based growing substrate mixture in aggregate system in Bangladesh.

References

REFERENCES

Avidan, A. (2000). The use of substrates in Israel. World congress on ‘Soilless Culture on Agriculture in the coming millennium’ Maale Hachamisha, Israel. p. 17.

Awang, Y., Shaharom, A.S., Mohamad, R.B. and Selamat, A. (2009). Chemical and Physical Characteristics of Cocopeat-Based Media Mixtures and Their Effects on the Growth and Development of Celosia cristata. *American J. Agric. & Biol. Sci*. **4** (1): 63-71.

Ayers, C.J. and Westcot, D.W. (1987). Water Quality in Agriculture. FAO. Irrigation and Drainage Series No. 29. Rome, Italy.

Bergquist, S.A.M., Gertsson, U.E., Nordmark, L.Y.G. and Olsson, M.E. (2007). Effects of shade nettings, sowing time and storage on baby spinach flavonoids. *J. Sci. Food Agric*. **87**:2464-2471.

Bilderback, T.E., Warren, S.L., Owen, J.S. Jr. and Albano, J.P. (2005). Healthy substrates need physicals too. *HortTechnology* **15**: 747–751.

Blom, J.J. (1983). Working with soil less mixes. *Florists’ Rev*.**173**: 29-34.

Bradly, P. and Marulanda, C. (2000). Home Hydroponic gardens. Institute for simplified hydroponics, P.O. Box 151, Corvallis, Oregon 97339.

Bunt, A.C. (1988). Media substrate and mixes for container grown plants. 1st Edn., Springer, London, ISBN: **10**: 0046350160.

De Boodt, M. and Verndonck, O. (1972). The Physical Properties of Substrates in Horticulture. *Acta. Hort*. **26**: 37-44.

De Rijck, G. and Schrevens E. (1997). pH Influenced by the elemental composition of nutrient solutions. *J. Plant Nutr*. **20**(7-8): 911-923. ISSN. 0190- 4167.

De Rijck, G. and Schrevens, E. (1998a). Cationic speciation in nutrient solutions as a function of pH. *J. Plant Nutr.* **21**(5): 0190-4167.

De Rijck, G. and Schrevens, E. (1998b). Elemental bioavailability in nutrient solutions in relation to complexation reactions. *J. Plant Nutr*. **21**(10): 2103-2113.

De Rijck G. and Schrevens, E. (1999).Anion speciation in nutrient solutions as a function of pH. *J. Plant Nutr.* **22**(2): 269-279.

Donnan, R. (1998). Hydroponics around the world. Practical Hydroponics and Greenhouses, July/August 1998. **41**:18-25.

Dufour, L. and Guérin, V. (2005). Nutrient solution effects on the development and yield of anthurium and reanum Lind. In Tropical Soilless Conditions. *Sci. Hortic.* **105**(2): 269-282, ISSN 0304-4238.

Dyśko, J., Kaniszewski, S. and Kowalczyk, W. (2008). The effect of nutrient solution pH on phosphorus availability in soilless culture of tomato. *J. Elem.* **13**(2): 189-198

Epstein E (1994). The anomaly of silicon in plant biology. *Proc. Natl. Acad. Sci.* USA **91**:11–17.

Fanasca, S., Colla, G., Maiani, G., Venneria, E., Rouphael, Y., Azzini, E. and Saccardo, F. (2006). Changes in antioxidant content of tomato fruits in response to cultivar and nutrient solution composition. *J. Agric. Food Chem.* **54**(12): 4319–4325.

Garceäs-Claver, A., Arnedo-Andreäs, M.S., Abadiäa, J., Gil-Orteqa, R. and Alvarez-Fernandez (2006). Determination of capsaicin and dihydrocapsaicin in capsicum fruits by liquid chromatography-electrospray/time-of-flight mass spectrometry. *J. Agric. Food Chem.* **54**:9303-9311.

Ghehsareh, A.M. (2013). Effect of date palm wastes and rice hull mixed with soil on growth and yield of cucumber in greenhouse culture. *Int. J. Recycle Org. Waste Agric.* **2**:17.

Grunert O., Perneel M. and Vandaele S. (2008). Peat-based organic grow bags as a solution to the mineral wool waste problem. *Int. Mire Cons. Grp.* **3**: 1–5.

Handreck, K.A. and Black, N.D. (2007). Growing media substrate for ornamental plants and turf. 3rd Edn., UNSW Press, Sydney, ISBN:**13**:9780868407968.

Hansen, M. (1978). Plant Specific Nutrition and Preparation of Nutrient Solutions. *Act. Hort.* **82**(1): 109-112.

Hell, L.R., Cometti, N.N., Bremenkamp, D.M., Galon, K. and Zanotelli, M.F. (2013).Cooling and concentration of nutrient solution in hydroponic sweet pepper crop. *Hortic. Brasileira*. **31**: 287-292.

Islam, S. (2008). Evaluating performance of ecologically sound organic substrates under different temperature regimes. *Int. J. Agric. Biol.* **10**: 297-300.

Jayawardana, R.K., Weerahewa, D. and Saparamadu, J. (2016). The effect of rice hull as a silicon source on anthracnose disease resistance and some growth and fruit parameters of capsicum grown in simplified hydroponics. *Int. J. Recycle Org. Waste Agric.* Vol. **5**, Issue 1, pp 9–15.

Jayawardana, H.A.R.K., Weerahewa, H.L.D., Saparamadu, M.D.J.S. and Rathnayaka, R.M.A.C. (2014). A novel approach for growing capsicum: a hydroponic system treated with rice hull leachate for enhanced performance of *Capsicum annuum* L. In: Proceedings of the Peradeniya university, International Research Sessions, Sri Lanka, 18, p. 543.

Mansaray, K. and Ghaly, A.E. (1997). Physical and thermo chemical properties of rice husk. *Energy Sources.* **19** (9):989–1004.

Marschner, H. (1995). Mineral nutrition of higher plants, academic press, ISBN 0-12-473542-8, New York, U. S. A.

Marulanda, C. and Izquierdo, J. (1993). Technical manual Popular hydroponic gardens Audio Visual Course. FAO Regional office for Latin America and the Caribbean, Santiago.

Materska, M. and Perucka, I. (2005). Antioxidant activity of the main phenolic compounds isolated from hot pepper fruit (*Capsicum annuum* L.). *J. Agric. Food Chem.* **53**(5):1750-1756.

McRijck, G. and Schrevens, E. (1998). Elemental bioavailability in nutrient solutions in relation to complexation reactions. *J. Plant Nutr*. **21**(10): 2103-2113, ISSN 0190-4167.

Michael, R. and J. H. Lieth (2008). Soilless culture: Theory and Practice. 1st Edition. Elsevier.

Milks, R.R., W.C. Fonteno, and R.A. Larson. (1989). Hydrology of horticultural substrates: Predicting properties of media substrate in containers. *J. Amer. Soc. Hort. Sci.***114**:53-56.

Montano, J.M., Fisher, J.T. and Cotter, D.J (1977). Sawdust for growing containerized forest tree seedling. *Agril. Expt. Sta*. New Mexico State University, Las Cruces, New Mexico 88003, Journal article 612.

Munoz, H. (2010). Hydroponics Manual, Home-Based Vegetable Production System. Guyana.

Nappi, P. and Barberis, R. (1993). Compost as a growing medium: chemical, physical and biological aspects. *Acta. Hort*. **342**: 249-256.

Noto, G. (1993). Growing substrates. *Tech. Agric*. **45**: 3 - 39.

Okafor, F.O. and Okonkwo, U.N. (2009). Effects of rice husk ash on some geochemical properties of Lateritic soil. *Leonardo Electron. J. Pract. Technol.* **15**:67–74.

Patel, M., Karera, P. and Prasanna, P. (1987). Effect of thermal and chemical treatments on carbon and silica contents in rice husk. *J. Mater Sci.* **22**:2457–2464.

Prieto, M., Peñalosa, J., Sarro, M.J., Zornoza, P. and Gárate, A. (2007). Seasonal effect on growth parameters and macronutrient use of sweet pepper. *J. Plant Nutr.* **30**: 1803-1820.

Rahman, M.J. and H. Inden. (2012). Effect of nutrient solution and temperature on capsaicin content and yield contributing characters in six sweet pepper (*Capsicum annuum* L.) cultivars. *J. Food, Agric. Environ.* **10**: 524-529.

Richards, D.M.L. and Beardsell, D.V. (1986). The influence of particle-size distribution in pinebark:sand: Brown coal potting mixes on water supply, aeration and plant growth. *Scientia. Hort*. **29**: 1-14.

Samarakoon, U.C. Weerasinghe, P. A. & Weerakkody, A. P. (2006). Effect of Electrical Conductivity [EC] of the Nutrient Solution on Nutrient Uptake, Growth and Yield of Leaf Lettuce (*Lactuca sativa* L.) in Stationary Culture. *Trop. Agril. Res.* Vol.**18**, No. 1, pp. 13-21 ISSN 1016.1422.

Saparamadu, MDJS (2008). Development of a user friendly and cost effective nutrient management strategy for simplified hydroponics. Dissertation, University of Colombo, Sri Lanka, p. 293

Saparamadu, MDJS., Weerakkody, WAP., Gunawardana, HD. and Wijesekara, RD. (2008). Development of a low cost and productive nutrient formulation for simplified hydroponics using commercial grade chemicals. *Trop. Agril. Res.* **20**:400–404.

Savvas, D. (2003). Hydroponics: A modern technology supporting the application of integrated crop management in greenhouse. *J. Food Agric. Environ*. **1**: 80-86.

Schmilewski G. (2009). Growing media constituents in the EU. *Acta Hort.* 819 pp. 33-45.

Schnitzler, W.H., Sharma, A.K., Gruda, N.S. and Heuberger, H.T. (2004). A low-tech hydroponic system for bell pepper (*Capsicum annuum* L.) production. *Acta Hort.* 644:47-53.

Sedaghat, M., Kazemzadeh-Beneh, H., Azizi, M. and Momeni, M. (2017). Optimizing Growing Media for Enhancement to Vegetative Growth, Yield and Fruit Quality of Greenhouse Tomato Productionin Soilless Culture System. *World J. Agric. Sci.* **13** (2): 82-89.

Starck, Z. (1983). Photosynthesis and endogenous regulation of the source-sinkrelation in tomato plants. *Photosynthetica*. **17**: 1-11.

Steiner, A.A. (1966). The influence of chemical composition of a nutrient solution on the production of tomato plants. *Plant and Soil.* **24**(3): 454-466.

Steiner, A.A. (1984). The Universal Nutrient Solution, Proceedings of IWOSC 1984 6th Internationlal Congress on Soilless Culture, pp. 633-650, ISSN 9070976048.

Trejo-Téllez, L.I., Gómez-Merino, F.C. and Alcántar, G.G. (2007). Beneficial Elements, In: Nutrition of Crops, G. Alcántar G and L.I. Trejo-Téllez, L.I. (Eds.), 50-91.

Tyson, R.V., Simonne, E.H., Davis, M., Lamb, E.M., White, J.M. & Treadwell, D.D. (2007). Effect of Nutrient Solution, Nitrate-Nitrogen Concentration, and pH on Nitrification Rate in Perlite Medium. *J. Plant Nutri.* Vol.**30**, No.6, (Jun, 2007), pp. 901-913, ISSN 0190-4167.

Tehranifar, A., Poostchi, M., Arooei, H. and Nematti, H. (2007). Effects of seven substrates on qualitative and quantitative characteristics of three strawberry cultivars under soilless culture. *Acta Hort.* (ISHS) **761**:485-488.

Teh, C.B.S. and Jamal, T. (2006). Water Retention. I**n:** Soil Physic Analyses. University Putra Malaysia Press, Selangor, Malaysia, pp: 14-17.

University of the District of Columbia, (2013). Peppers. Center for Nutrition, Diet and Health, Vol. **1** No. 10.

Urrestarazu, M. (2004). Treaty of Cultivation without Soil. Mundi-prensa, ISBN 84-8476-139-8.

Urrestarazu, M. & Mazuela, P.C. (2005). Effect of Slow-Release Oxygen Supply by Fertigation on Horticultural Crops under Soilless Culture. *Scientia Horticulturae*, Vol. **106**, No.4, pp. 484-490, ISSN 0304-4238.

Verdonck, O., De Vleeschauwer, D. and De Boodt, M. (1982). The influence of the substrate to plant growth. *Acta Hort.* **126**:251-258.

Voogt, W. (2002). Potassium management of vegetables under intensive growth conditions, In: Potassium for Sustainable Crop Production. N. S. Pasricha And S. K. Bansal SK (eds.), 347-362, International Potash Institute, Bern, Switzerland.

Winsor, G. and Adams, P. (1987). Diagnosis of mineral disorders in plants. In: Robinson, J.B.D. (Ed.), Glasshouse Crops, Vol. **3**. Crown, London, p 166.

Yahya, A., Shaharom, A.S., Mohamad, R.B. and Selamat, A. (2009). Chemical and Physical Characteristics of coco peat-based media substrate mixtures and their effects on the growth and development of Celosia cristata. *American J. Agric. Biol. Sci.* **4**: 63-71.

Zeiger, E. and Taiz, L. (1998). Plant physiology Sinauer Associates, Inc. Publishers Sunderland, Massachusetts, U. S. A.

Appendices

APPENDICES

Appendix I: Analysis of variances of plant height at different days after transplanting (DAT) of sweet pepper

Sources of variation	**Degrees of freedom (df)**	**Mean Square for Pant height(cm)**						
		0 DAT	**30 DAT**	**60 DAT**	**90 DAT**	**120 DAT**	**150 DAT**	**180 DAT**
Treatment	3	2.894^{NS}	94.186^{**}	321.187^{**}	329.681^{**}	410.146^{**}	466.694^{**}	615.028^{**}
Error	8	4.437	8.078	3.750	3.391	4.208	4.833	2.958

^{NS} indicates nonsignificant

** indicates significant at 1% level of probability.

Appendix II: Analysis of variances of fruit parameters

Sources of variation	Degrees of freedom (df)	Mean Square				
		Fruit length	Fruit diameter	Fruit volume	Fruit fresh weight/plant	Fruit dry weight/100 g fresh weight
Treatment	3	3.897**	1.952**	1981.665**	4632.863**	13.886**
Error	8	0.075	0.059	14.422	25.770	0.549

** indicates significant at 1% level of probability.

Appendix III: Analysis of variances of plant fresh weights of sweet pepper at harvest time

Sources of variation	Degrees of freedom (df)	Mean Square Of Fresh weight/plant		
		Stem	Leaf	Root
Treatment	3	788.313**	604.260**	89.570**
Error	8	9.750	2.553	2.453

** indicates significant at 1% level of probability.

Appendix IV: Analysis of variances of dry weights of 100 g fresh weight of sweet pepper

Sources of variation	Degrees of freedom (df)	Mean Square Of Dry weight/plant		
		Stem	Leaf	Root
Treatment	3	53.262**	26.643**	3.823**
Error	8	0.517	1.465	0.283

** indicates significant at 1% level of probability.