GROWTH, YIELD AND PHYSIOLOGICAL PERFORMANCE OF SWEET PEPPER IN DIFFERENT HYDROPONIC SOLUTION

MD. MAZHARUL ISLAM

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

DECEMBER, 2015

GROWTH, YIELD AND PHYSIOLOGICAL PERFORMANCE OF SWEET PEPPER IN DIFFERENT HYDROPONIC SOLUTION

BY

MD. MAZHARUL ISLAM

Reg. No. 10-04035

A Thesis
submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

HORTICULTURE

SEMESTER: JULY-DECEMBER, 2015

Approved by:

Assoc. 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. Tahmina Mustarin

Chairman
Examination Committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH, YIELD AND PHYSIOLOGICAL PERFORMANCE OF SWEET PEPPER IN DIFFERENT HYDROPONIC SOLUTION"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***HORTICULTURE****, embodies the result of a piece of bona fide research work carried out by* ***Md. Mazharul Islam,*** *Registration number 1****0-04035*** *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 duly been acknowledged.

Dated: December, 2015

Dhaka, Bangladesh

Dr. Md. Jahedur Rahman

Associate Professor

Department of Horticulture

Sher-e-Bangla Agricultural University

Dhaka-1207

Supervisor

ACKNOWLEDGEMENTS

All praises, gratitude and thanks are due to ***"Almighty Allah"*** *who enabled the author to complete the work successfully.*

The author would like to convey his heartiest respect and profound appreciation to his Supervisor, ***Dr. Md. Jahedur Rahman,*** *Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his guidance, directions, valuable suggestion and constructive criticism in successful completion of the research work and preparation of the thesis.*

The author would like to express his heartiest respect, deep sense of gratitude sincere and profound appreciation to his Co-Supervisor, ***Prof. Dr. Md. Nazrul Islam,*** *Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his sincere guidance and constructive suggestions during preparation of the thesis.*

Special thanks to honorable ***Prof. Md. Ruhul Amin*** *for his suggestions and co-operation during my research.*

The author would like to thank ***Prof. Dr. Md. Anwarul Haque Beg,*** *honorable former director,* ***SAURES.*** *Moreover, the author would like to thank* ***Prof. Dr. A. K. M. Ruhul Amin , Prof. Dr. M. Salauddin M. Chowdhury , Prof. Dr. Md. Asaduzzaman Khan, and Prof. Dr. Md. Rafiquel Islam*** *for their sincere guidance and constructive suggestions during my research.*

The experiment of this thesis was funded by Bangladesh Academy of Sciences-United State Department of Agriculture program. The author would like to thank specially ***Dr. Md. Idris Ali****, honorable* ***expert fellow of BAS USDA*** *Project.*

Finally, The author is grateful to his supervisor ***Dr. Md. Jahedur Rahman*** *for his ceaseless patience, cordial support and constant inspiration, without which this study would not have been finished.*

Date: June, 2016 — *The Author*

SAU, Dhaka

GROWTH, YIELD AND PHYSIOLOGICAL PERFORMANCE OF SWEET PEPPER IN DIFFERENT HYDROPONIC SOLUTION

By

MD. MAZHARUL ISLAM

ABSTRACT

A poly tunnel controlled experiment was conducted to identify the effect of nutrient solution on growth, yield and physiological performance of sweet pepper. The nutrient solution composition is one of the major component for successful hydroponic crop production. The crop specific nutrient solution is needed to improve the growth and yield of sweet pepper. Three nutrient solutions were considered as treatments, viz S_1 = Hoagland and Arnon (1940), S_2 = Full strength Rahman and Inden (2012) and S_3 = ¾ strength Rahman and Inden (2012). Vegetative growth and yield contributing characters were measured. The highest plant height (119cm), number of fruit per plant (20), individual fruit weight (210g), fruit length (8.7cm), fruit diameter (7.9cm), fruit volume (224cc) and fruits yield (3.99 kg/plant) were found the highest when S_2 nutrient formulation was applied. But statistically similar results were found incase of S_3. While the ascorbic acid (205.8 mg/100g FW), leaf area (136.8 cm2), leaf mass ratio (0.97gg-1) and net assimilation rate (0.000012 unit) were maximum in S_3. Therefore, ¾ strength Rahman and Inden, (2012) nutrient solution can be used for sweet pepper cultivation in hydroponic system in Bangladesh.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATED TERMS

DAT	=	Days After Transplanting
DAS	=	Days After Sowing
EC	=	Electrical Conductivity
LSD	=	Least Significant Difference
LA	=	Leaf Area
LWD	=	Leaf Dry Weight
RDW	=	Root Dry Weight
SAU	=	Sher-e-Bangla Agricultural University
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
LMR	=	Leaf Mass Ratio
RWR	=	Root Weight Ratio
RGR	=	Relative Growth Rate
NAR	=	Net Assimilation Rate
ANOVA	=	Analysis of Variance
NFT	=	Nutrient film technique

CHAPTER I

INTRODUCTION

Fruits of sweet pepper or capsicum (*Capsicum* spp.) among the most consumed species throughout the world. The fruits contain capsaicinoids that give them the characteristic pungent taste. Capsaicin and dihydrocapsaicin, the two major capsaicinoids, are responsible for up to 90% of the total pungency of pepper fruits. Capsaicinoids are currently used in the food industry, for medical purposes as pharmaceuticals, and in defensive sprays. Sweet pepper fruits are used as vegetable and condiments, and the requirement of pungency levels depend on the purpose of the uses. The degree of pungency depends on Capsicum species and cultivars, and the capsaicin contents may be affected by different factors such as the developmental stage of fruits, environmental stresses, and nutrient accumulation in the placental tissue and so on.

In hydroponics, it's absolutely essential to begin with a laboratory analysis of nutrient solution. The three main things are important as the alkalinity, the electrical conductivity (EC) and the concentration specific elements. Alkalinity is a measure of water's ability to neutralize acid. Alkalinity is usually reported in terms of ppm of calcium carbonate equivalents (CaCO3). The greater nutrient solution's alkalinity, the more the pH will tend to rise in the nutrient solution. Water source alkalinity is a much more important to look at than its pH.Nowadays, hydroponics culture is becoming increasingly popular all over the world. It is highly productive in nature, conservative of water and land. Moreover, hydroponics culture is protective to the environment. Hydroponics has proved to be an excellent alternative crop production system (Savvas, 2003). The cultivation of vegetable crops and the achievement of high yields and high quality are possible with hydroponics 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. Furthermore, 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). Moreover, it provides an instant as well as long-term solution to the problem of inability of a household to produce its own vegetables under urban settings.

The nutrient solution is one of the major components for successful hydroponic crop production. The composition of nutrient solutions and the optimization of nutrition in commercial hydroponics can reduce fertilizer costs. Specific formulation of nutrient solution compositions is required for the most horticultural species grown in soilless culture (De Kreij*et al.*, 1999). Moreover, to obtain high yield and good quality in commercial crops grown hydroponically, the nutrient solution supplied to the plants must be specific for the particular crop, the climatic conditions, or hydroponic system used etc.

Improving the yield and yield contributing characteristics in sweet pepper are important factors for soilless culture technique. These may be improved by managing external nutrient availability in the growing substrates. Proper nutrient combinations in the solution may improve the yield and yield contributing characters in the crop. Environmental factors are the limiting factors for the yield of a crop, and proper management of growing environments may play an important role to increase in the yield and yield contributing characters of sweet pepper.

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

1. To develop a low cost hydroponic system for sweet pepper cultivation

2. To get high quality sweet pepper with minimum cost

3. To determine the optimum dose of nutrient solution

CHAPTER II

REVIEW OF LITERATURE

Sweet pepper is a great crop for year-round, greenhouse production, particularly in northern latitudes. Nowadays, a wide variety of sweet pepper and leafy vegetables can be successfully grown in hydroponic systems. Since sweet pepperis a vegetative crop, a well-balanced nutrient formula is necessary to produce a high-quality crop.

Some of the research findings related to the effect of nutrient solution on physiological growth and yield in hydroponic sweet pepper so far have been reviewed here.

Cometti.*et.al* (2013) reported that the temperature of the nutrient solution influenced the behaviour of sweet pepperchanging 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 tropical regions.

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. However, 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.

Trejo-Téllez*et al.* (2007) conducted a study to determine the nitrification rate response in a perlite trickling biofilter (root growth medium) exposed to hydroponic nutrient solution, varying NO_3^-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. 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. Phosphorus is an element which occurs in different forms that are strongly dependent on environment pH.

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 (Na), silicon (Si), vanadium (V), selenium (Sl), cobalt (Co), aluminium (Al) and iodine (I) 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 the essential nutrients in a less specific role. The most basic nutrient solutions consider in its composition only nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) and they are supplemented with micronutrients. The nutrient composition determines electrical conductivity (EC) and osmotic potential (OP) of the solution.

Samarakoon*et al.*(2006) reported that toxicities could occur in nutrient solutions over time, as solution gets concentrated due to rapid water absorption. Therefore, estimation of individual nutrient requirements in different growth stages is needed for the replacement of the nutrient solutions during the growth period. Leaf number and fruit of sweet pepper was not significantly affected by the treatments, since it did not either increase or decrease with increasing nutrient solution concentration.

Garceäs-Claver*et. al.*(2006) producedsweet pepper in stationary (trough) culture of hydroponics successfully under tropical greenhouse conditions (38.5^{o}C). A solution concentration of 0.5 g/L of Albert's solution(havinganECofl.4dS/m) with renewalat 2weeks intervals could be identified as the best fertigation strategy under hot and humid conditions. Increasing solution concentrations above that level upto 2dS/m increased the plant uptake of N,P,K and Ca.However, 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 that 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.

Andriolo*et al.* (2005) found the results whereby leaf number was not affected by salinity levels. Fresh mass decreased with increasing nutrient solution concentration but there was no significant difference between the treatments. This decreases meant that there was a decline in yield of sweet pepper during the spring season.

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 had equal amount of chlorophyll. This indicates 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.

Kang and van Iersel (2004) reported that high concentrated nutrient solutions lead to excessive nutrient uptake and therefore toxic effects may be expected. Conversely, there are evidences of positive effects of high concentrations of nutrient solution. In salvia, the increase of Hoagland concentration at 200% caused that plants flowered 8 days previous to the plants at low concentrations, increasing total dry weight and leaf area.

Fanasca*et al.*(2006) reported that Iron (Fe), copper (Cu), zinc (Zn), boron (B), and manganese (Mn), 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 aminimum.

Voogt (2002) indicates that the nutrient solution composition must reflect the uptake ratios of individual elements by the crop and as the demand between species differs, the basic composition of a nutrient solution is specific for each crop. It must also be taken into account that the uptake differs between elements and the system used. For instance, in open-systems with free drainage, much of the nutrient solution is lost by leachate.

Sarro*et al.* (2007) found decreasing fresh shoot mass with increasing nutrient solution concentration in hydroponic system.

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 and7, 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.

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) reported that Sulphate also forms relatively strong complexes with Ca^{2+} and Mg^{2+} in Nutrient solution in hydroponic system.

De Rijck and Schrevens (1998c) investigated the effects of the mineral composition of the nutrient solution and the moisture content of the substrate on the mineral content of hydroponically grown tomato fruits, using "design and analysis of mixture systems'', a (3.1) simplex lattice design extended with the overall centroid set-up in the cation factor-space (K^+, Ca^{2+} and Mg^{2+}) of the nutrient solution. For each nutritional composition two moisture contents (40 and 80% of volume) of the substrates were investigated. After this short sample illustrates some aspects to be considered in the preparation of nutrient solutions.

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

McRijck*et al.* (1998) conducted an experiment on sweet pepper (*Capsicum annum*) 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 behaviour, 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 $HPO_4^-$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 (K), calcium (Ca) and magnesium (Mg) are available toplants 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.

Chen *et al.* (1997) found that the growth of sweet pepperwas significantly increased when the NO_3 concentration of the solution was reduced below the highest concentration being used by a local commercial hydroponic grower.

Marschner (1995) reported 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.

Van Labeke*et al.* (1995) studied *Eustomagrandiflorum* responses to different nutrient solutions differing in ion ratios using an experimental as a (3.1) simplexcentroid design, one in the cation factor-space and the other in the anion factor-space.

Salisbury and Ross (1994) reported that currently 17 elements are considered essential for most plants, these are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel which must be present in nutrient solution in case of sweet pepper.

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 (1998) indicated 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.

Coic (2003) and steiner (2003) studied that the composition and concentration of the nutrient solution are dependent on culture system, crop development stage, and environmental conditions.

Steiner (1998) 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.

Steiner (1999) studied that nutrient solutions usually contain six essential nutrients: N, P, S, K, Ca and Mg. There by Steiner (1999) created the concept of ionic mutual ratio which is based on the mutual ratio of anions: NO_3^-,

$H_2PO_4^-$ and SO_4^{2-}, and the mutual ratio of cations K^+, Ca^{2+} and Mg^{2+}. Such a relationship is not just about the total amount of each ion in the solution, but in the quantitative relationship that keep the ions together; if improper relationship between them take place, plan performance can be negatively affect.

Steiner (1992) proposed that in soilless cultures any ionic ratio and any total concentration of ions can be given, as precipitation limits for certain combinations of ionsare considered. Thus, the selection the concentration of a nutrient solution should be such that water and total ions are absorbed by the plant in the same proportion in which thoseare present in the solution.

Hewitt (1996) studied that the ionic balance constraint makes it impossible to supply one ion in nutrient solution without introducing a counter ion. A change in the concentration of one ion must be accompanied by either a corresponding change for an ion of the opposite charge, a complementary change for other ions of the same charge, or both.

Steiner(1996) reported that the ratio 3:1 between Ca^{2+} and Mg^{2+} is constant in the nutrient solution. Similarly, the ratio $H_2PO_4^-$:SO_4^{2-} (1:9) is constant, while the changes in the NO_3^- concentration are produced at expense of the $H_2PO_4^-$ and SO_4^{2-} concentrations.Steiner (1996) developed a method to calculate a formula for the composition of a nutrient solution, which satisfies certain requirements. Later on the evaluated five different ratios ofNO_3^-: anions (NO_3^- +$H_2PO_4^-$+SO_4^{2-}) and three of K^+:cations (K^++Ca^{2+}+Mg^{2+}), combining also the two groups, resulting in a full factorial design; all solutions had the same osmotic pressure and pH value. In this system, the relative concentration of K^+ increases at the expense of Ca^{2+}andMg^{2+}concentrations.

CHAPTER III

MATERIALS AND METHODS

3.1 Location:

The experiment was conducted in the polythene shade house at the horticulture farm of Sher-e-Bangla Agricultural University, Dhaka 1207. Bangladesh during April 2015 to March 2016. The site is situated between 23 ^{0} 41$^{/}$ N latitude and 90 ^{o} 22$^{/}$ E longitude.

3.2 Plant materials and growing environments:

Sweet pepper cv. ‘Wonder Bell’ of average fruit weight around 180gis used in this experiment. Seeds of sweet pepper were collected from Siddique Bazar Seed Market, Dhaka.

Plate 1. Solid hydroponic Capsicum experiment at polythene shade house

3.3 Experimental environment:

The seeds were sown in the seed bed prepared by the media mixture of coco peat, broken brick and rice husk at the ratio of 6:2:2 (v/v). Two-week-old seedlings were transferred into the 250-mL plastic pots. Eight-week old seedlings were transferred 20-cm apart into the cork-sheet boxes containing media mixtures of coco peat, broken brick and rice husk at the ratio of 6:2:2 (v/v). The 150-cm × 25-cm × 30-cm cork sheet boxes were prepared by cork-sheets.The boxes were filled with the media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v). Six healthy seedlings were transferred in each box. The pH ≅ 6.0 and EC ≅3.0 – 3.5 $dS \cdot m^{-1}$, respectively maintained in the nutrient solutions.

3.4 Experimental Design and treatments:

The experiment was conducted in a completely randomized design with three replications. Three nutrient solutions considered as treatments viz.:

S_1: Hoagland and Arnon (1940) solution

S_2: Full strength of Rahman and Inden (2012) solution and

S_3: ¾ strengthRahman and Inden (2012) solution.

The nutrient compositions of Hoagland and Arnon (1940) solution were NO_3, NH_4, P, K, Ca, Mg, and S of 14.0, 1.0, 3.0, 6.0, 8.0, 4.0 and 4.0 $meq \cdot L^{-1}$, respectively, and 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 $meq \cdot L^{-1}$, 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 $mg \cdot L^{-1}$, respectively for both the nutrient solutions.All the treatments were started 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≅ 2.8 $dS \cdot m^{-1}$, respectively were maintained in the nutrient solutions. These solutions were used in different boxes. After one week of capsicum seedlings transplantation 1/2 strength of nutrient solution was used. Treatments were applied from the second week of the transplantation. Nine plants were considered as an experimental unit.

3.5 Preparation of nutrient solutions:

In this experiment two nutrient solutions at different concentration were used. One nutrient solutions was Hoagland and Arnon (1940) solution and the other was Rahman and Inden (2012) solution. The concentrations were S_1 – Hoagland and Arnon (1940), S_2 – Full strength of Rahman and Inden (2012) and S_3 – ¾ strength Rahman and Inden (2012). These nutrient solutions are prepared according to their composition. $MgSO_4$, $NH_4H_2PO_4$, KNO_3, $Ca(NO_3)_2$were prepared as macro-nutrient solution and a micro-nutrient stock solution was prepared.

3.6Preparation of growing media for raising ofseedling

The mixture of coco peat, broken bricks (khoa) and ash at the ratio of 50:30:20% (v/v).Coco peat was soaked in a big bowl for 24 hours. It was washed well with water and spread in a polythene sheet for 3hours. Then they are mixed with khoa and ash properly. This mixer was placed in a styrofoam sheet box for using seedbed.

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 spreaded over polythene sheet for 2 hours to dry out the surface water. After that seeds were shown in plastic cups and covered with newspaper under room temperature for raising the seedlings.

3.8 Transplanting of sweet pepper seedling

Sweet pepper seedlings were transplanted into the main boxes containing nutrient solution after two weeks of emerging. The cup contains the mixture of coco peat, khoa and ash. One healthy lettuce plant from seedbed was selected for each cup. Capsicum plants were transplanted carefully so that roots were not damaged (plate 1). After transplanting of capsicum plant in the cup light watering was done with sprayer.

3.9 Data collection

Data on the following parameters were recorded from the plants during the experiment. Data were collected from each plant. Each box was regarded as an experimental unit. Data were collected on different growth and yield componentsviz., plant height at different days after planting, fruit length, fruit diameter, fruit volume, pericarp thickness, number of fruit per plant, individual fruit weight, fruit yield per plant; physiological parameters, viz., leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR). Some of the growth and yield contributing parameters have recorded discussed in the results and discussion section. However, physiological parameters were recorded at the end of the experiment and antioxidants were measured during the experiment.

3.9.1 Plant height

Plant height was measured in centimetre (cm) by a meter scale at 0, 15, 30 ,45, 60, 75,90,105,120,135,150 and180 DAT(days after transplanting) from the point of attachment of growing media up to the tip of the longest leaf.

3.9.2 Number of fruits per plant

Number of fruits per plant werecounted at75(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.

3.9.3 Individual fruit weight

The individual fruit weight was measured by electric balance at department of horticulture, Sher-e-Bangla Agricultural University, Dhaka 1207 and expressed in gram (g).

3.9.4 Fresh weight of plant

Leaves were detached by a sharp knife and fresh weight of the plant was taken by an electric balance at harvest (180DAT) and was recorded and expressed in gram (g).

3.9.5 Individual fruit length

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

3.9.6 Individual fruit diameter

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

3.9.7 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.

3.9.8 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.

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

3.9.9 Measurement of ascorbic acid

Ascorbic acid content in capsicum was measured from Bangladesh Council of scientific and Industrial Research (BCSIR).

3.9.10 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:

LA = Leaf area was measured by drawing Photoshop of leaf

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

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

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

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

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

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

$$\text{RGR} = \frac{\text{PDW}_1 - \text{PDW}_0}{(t_1 - t_0) \times \text{PDW}_0}$$

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

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

Leaf area (LA):

Capsicum plants used in the experiments develop a single stem with 9—12 leaves. The main stem ends with one or two flowers and branches into two or three side branches. At each (first or higher order) branch one leaf develops and the branch terminates in a flower and divides into two or three higher order branches.In this experiment, two first order branches were retained. Subsequently, the largest of each higher order branch was retained, while the smallest one was removed above the first leaf. All other shoots were removed twice a week. This pruning strategy corresponds largely to common practice of commercial growers. A total of 155 leaves from different sweet pepper were measured for leaf area, length and width in the calibration experiment. Area of the leaves ranged from 117 to 136 cm^2.

3.9.11 Statistical analysis of data

The data obtained for different characters were statistically analyzed with SPSS version 21.0 and means separation were done by Tukey's test at $P \leq 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the experiment conducted under greenhouse conditions are presented in several Tables and Figures. The experiment was conducted to study the effect of nutrient solution on antioxidant content and yield contributing characteristic of sweet pepper. The results are presented and discussed under the following parameter.

4.1 Plant height

There was no significant difference in plant height at 0 to 30 days after transplant (DAT), but significant increment in plant height were found at 60, 90,120,150 and 180 DAT among the three nutrient solution concentrations (Table 1). The longest plants at 150 DAT and 180 DAT were found when ¾ concentrationRahman and Inden (2012) was applied. This might be because of proper proportion of nutrient supply in the plants. In case of closed hydroponic system, proper nutrient solution management in the root zone is the first consideration for the adoption of the plants.Bloom*et al*. (2005) stated that sweet pepper growth was affected by different strength of nutrient solutions. The present finding was consisted with the findings of Bloom*et al*. (2005). In the present study, S_3 can supply proper amount of nutrients to the plant resulting higher plant height.

Table 1.Effectof nutrient solution on plant height in sweet pepper.

Treatment	Plant height (cm) at different days after transplanting (DAT)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
S_1	29 a	49 b	61 b	73 b	82b	95b	102b
S_2	31 a	64 a	77 a	95 a	106a	115a	119a
S_3	27 a	61 a	75 a	91 a	103a	112a	117a
P	0.100	<0.001	<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. NSmeans nonsignificant at $P \leq 0.05$. ** significant at $P \leq 0.01$. DAT – Days after transfer.S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

Table 2.Effect of nutrient solution on plant height in sweet pepper.

Treatment	Plant height (cm)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
S_1	29 a	49 b	61 b	73 b	82	95 b	102 b
S_2	31 a	64 a	77 a	95 a	106 a	115 a	119 a
S_3	27 a	61 a	75 a	91 a	103	112 a	117 a
P	0.100	<0.001	<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 means nonsignificant at

P≤ 0.05. ** significant at *P* ≤ 0.01. DAT – Days after transfer. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

4.2 Yield contributing characteristics:

The yield contributing characteristics viz., number of fruit per plant, individual fruit weight, fruit length, fruit diameter and fruit volumein capsicum were significantly affected by different nutrient solution formulation (Table 3). The maximum number of fruit per plant, individual fruit weight, fruit length, fruit diameter and fruit volumewere found in S_3 which was statistically similar to that of S_2. The plants required optimum nutrient combination for proper growth and improved yield contributing characters. Perhaps S_3 and S_2 contained the maximum nutrient combinations that enhanced yield contributing characteristics of sweet pepper. The metabolic function of the plants would progress in the right direction and better rate when all the plant nutrients are supplied (Kumaraswamy, 2004). Moreover, it is fact that in soilless culture the growers have the opportunity to supply proper amount of nutrient combinations, which will improve yield contributing characteristics.

4.3 Yield:

Marketable yield was affected by nutrient solution formulations (Table 3). The highest yield was found in S_3 which was statistically similar to that of S_2. This might be due to that yield contributing characters were performed better in S_3 and S_2 resulting the higher yield in the same treatments.

Table 3. Effect of nutrient solution on number of fruit per plant, individual fruit weight, fruit length, fruit diameter and fruit volume in sweet pepper.

Treatment	**Number of fruit /plant**	**Individual fruit weight (g)**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Fruit volume (cc)**
S1	16 b	170 b	7.2 b	5.8 b	183 b
S2	19 a	210 a	8.7 a	7.9 a	224 a
S3	20 a	220 a	9.1 a	8.1 a	238 a
P	0.020	<0.001	<0.001	<0.001	<0.001
	*	**	**	**	**

[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. * significant at $P \leq 0.05$. ** significant at $P \leq 0.01$. DAT – Days after transfer.S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

4.4 Number of fruit per plant and individual fruit weight per plant

The maximum number of fruit per plant at 120 DAT, 150 DAT and 180 DAT were found when ¾ strength nutrient solution was applied. This might be because of proper supply of nutrient in the plants.Shinohara*et al.* (2005) stated that sweet pepper growth was affected by different strength of nutrient solutions. The present finding was consisted with the findings of Shinohara*et al.* (2005). In the present study, S_3 can supply proper amount in available forms of nutrients to the plants resulting higher fruits per plant.

Table 4.Effect of nutrient solution on number of fruit per plant and individual fruit weight in sweet pepper.

Treatment	Number of fruit per plant and individual fruit weight	
	Number of fruit per plant	Individual fruit weight (gm)
S_1	16 b	170 b
S_2	19 a	210 a
S_3	20a	220 a
P	0.02	<0.001
	*	**

[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 transfer. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

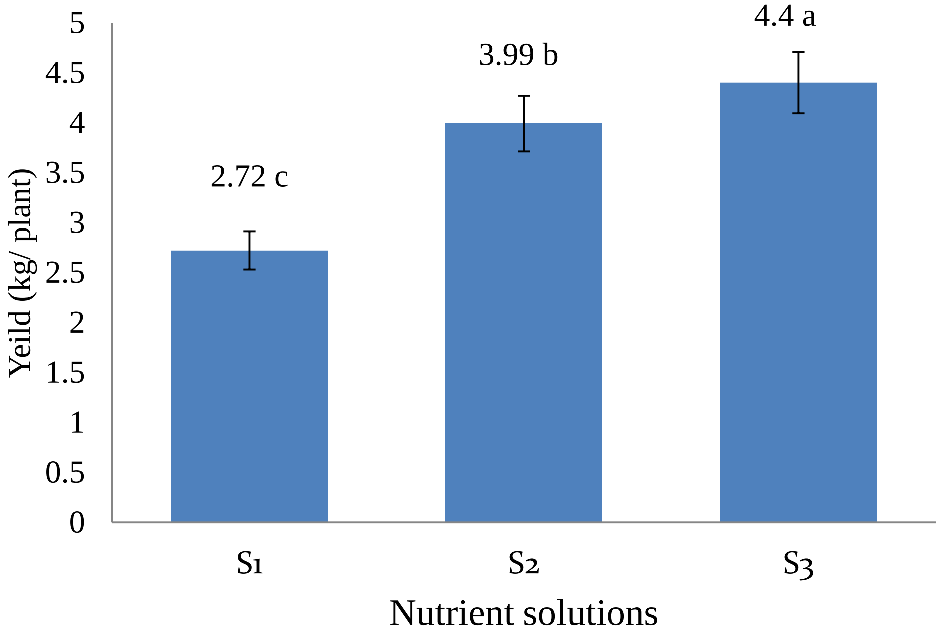

Figure 1.Effect of nutrient solution on yield per plant for two month in sweet pepper. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012) and

S_3:¾Rahman and Inden (2012). Vertical bars represent standard error for the means.

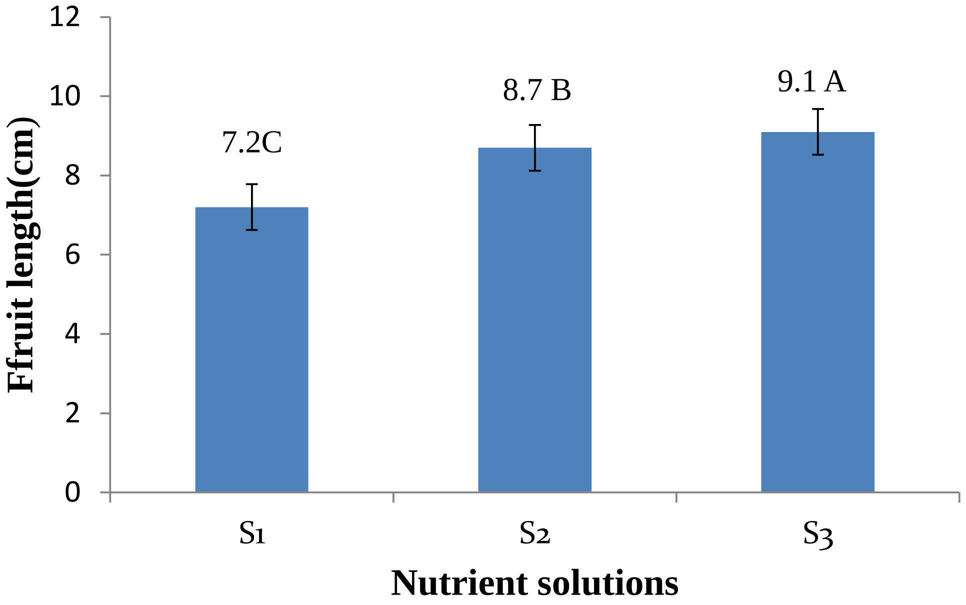

Figure 2.Effect of nutrient solution on fruit length in sweet pepper.S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ Rahman and Inden (2012).

Table 5.Effect of nutrient solution on fruit length, fruit diameter and fruit volume in sweet pepper.

Treatment	**Fruit length, fruit diameter and fruit volume**		
	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cc)
S_1	7.2 b	5.8 b	183 b
S_2	8.7 a	7.9 a	224 a
S_3	9.1 a	8.1 a	238 a
P	<0.001	<0.001	<0.001
	**	**	**

zMeans 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 means nonsignificant at $P \leq 0.05$. **

significant at $P \leq 0.01$. DAT – Days after transfer. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ Rahman and Inden(2012)

Fruit Volume:

The fruit volume was significantly higher in ¾ Rahman and Inden (2012). The fruit volume in the plant where the solution S1 was applied 183 cc that is comparatively lower than the fruit volume where the solution S2 was applied.

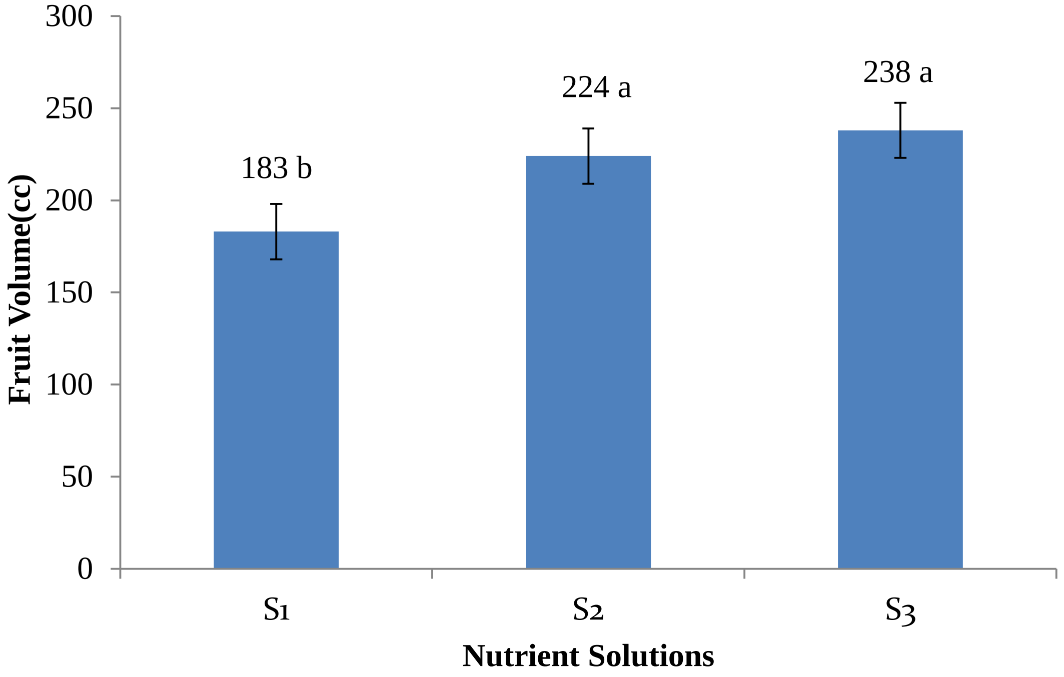

Figure 3.Effect of nutrient solution on fruit length in sweet pepper .S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ Rahman and Inden (2012).

4.5 Fresh weight

Marketable quality of sweet pepper is determined mainly by plant size, which depends on fresh weight. Significant increases in growth were observed among the three concentrations ofRahman and Inden (2012) nutrient solution, where samples showed greater fresh weights were found in S_3 (Figure). In fact, plants were able to grow shoot and roots with at ¾ strength Rahman and Inden (2012) nutrient solution in a closed hydroponic system. Physiological quality of fruiting horticultural crops such as capsicum, tomato, strawberry, etc. can be improved at high electrical conductivity (EC) (Fernadez-Muñoz, 1999; Li and

Stanguellini, 2001). Bloom*et al.* (2005) also stated that EC levels above 2.0 and 2.6 dS m^{-1} reduced fresh yield and plant growth, respectively in sweet pepper. In the present experiment, EC of ¾ strength Rahman and Inden (2012) nutrient solution was less than 2 dS m^{-1} and it might have contributed to supply proper amount of nutrient in available form.

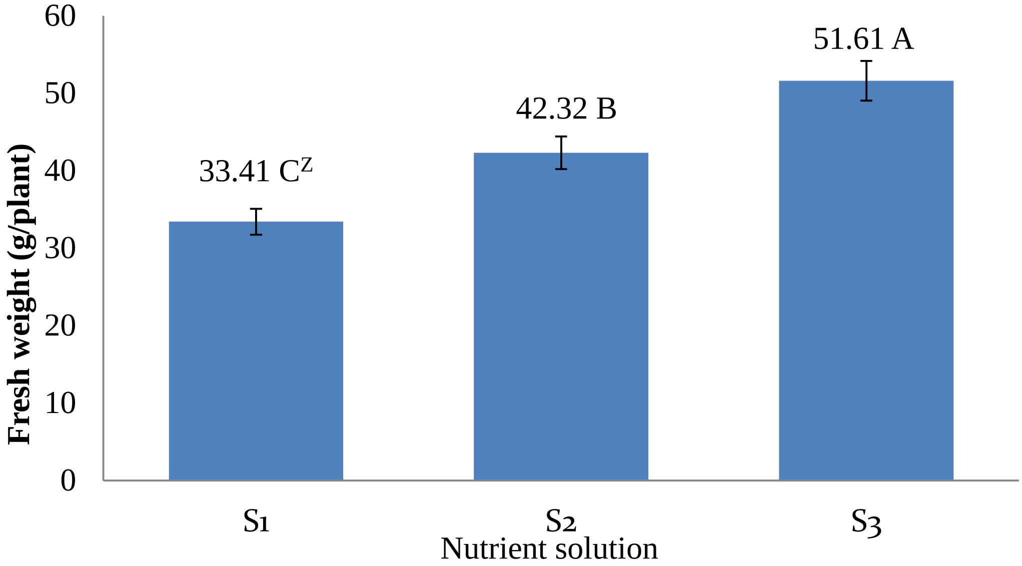

Figure 4.Effect of nutrient solutions on plant fresh weight in sweet pepperat 180 DAT. [z]Means with different s is sweet pepper significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012). Vertical bars represent standard errors of means.

4.6 Plant dry weight

Plant dry weights of sweet pepper significantly varied by three nutrient solutions (Table). The highest dry weights of leaf and root were found in S_3compared to S_2 and S_1. Meanwhile, dry weights of plants drastically decreased control. This might be due to proper supply of nutrition due to application of S_3 solution containing higher Ca^{2+} compared to the control, which contributed to higher dry weights. On the contrary, nutrient solution of S_1contains the lowest amount of Ca^{2+} compared to the other treatments. Epstein and Bloom (2005) reported that Ca^{2+} increased the root dry weight and calcium content in plant tissues. Bar-Tal *et al.* (2001) found that the shoot and root dry weights decreased with increasing Ca^{2+} in sweet pepper. The present findings consisted with the other findings.

Table 6. Effect of nutrient solutions on plant dry weights in sweet pepper

Treatment	Plant dry weight (g/plant)	
	Leaf	Root
S_1	1.58 b[z]	0.33 a
S_2	2.35 a	0.37 a
S_3	1.45 b	0.20 b
P	0.012	0.011
	**	**

[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. ** significant at $P \leq 0.01$. DAT – Days after transfer.S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

4.7 Ascorbic acid content

In Figure 5 the effect of treatments on the ascorbic acid content was observed. Ascorbic acid content increased markedly with the increasing levels of nutrient solution. Ascorbic acid content was higher in the plants grown in ¾ strength of Rahman and Inden (2012). In this experiment, the effect of strength of nutrient solution was studied using hydroponics to control the root zone conditions precisely. Shinohara *et al.*(1978) reported that ascorbic acid content of sweet pepper was increased when grown in ¼strength nutrient solutions compared to the ½ strength nutrient solutions. In the present experiment, ascorbic acid content increased with increased concentration which was not consistent with the others findings. However, it was significant that ascorbic acid content increased in the same treatment with higher yield. On the other hand, when the plants were grown in low nutrient concentrations, leaf constituents implied not to be metabolized sufficiently under low concentration of nutrient solution because of insufficient supply of inorganic matter from roots (Shinohara and Suzuki, 1981). The present result was consistent with their findings. Fanasca*et al.*(2006) stated that the total antioxidant activity increased in tomato with increased supply of Mg^{2+} and K^+ in the nutrient solution.

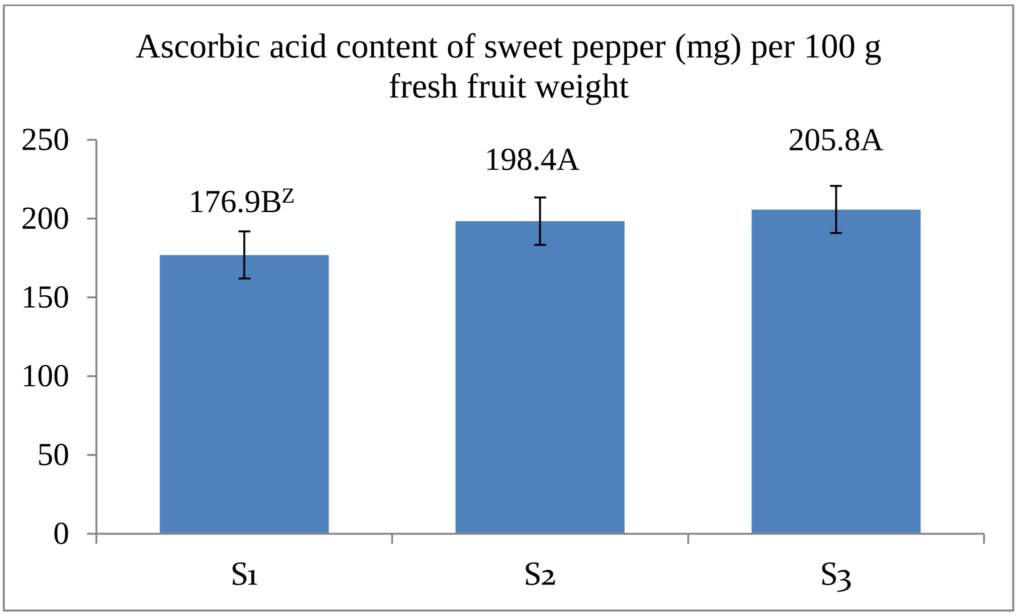

Figure 5. Effect of nutrient solutions on ascorbic acid content in sweet pepper at180 DAT**.**[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$.S_1:Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strengthRahman and Inden (2012). Vertical bars represent standard errors of means.

There have been some reports concerning the effect of nutrient solutions on ascorbic acid in sweet pepper. In this experiment, the effect of strength of nutrient solution was studied using hydroponics to control the root zone conditions precisely. Shinohara *et al.* (1978) reported thatascorbic acidcontent ofsweet pepperwas increased when grown in ¼ strengthnutrientsolutions compared to the ½ strength nutrient solutions. In the present experiment, ascorbic acid content increased with increased concentration which was not consistent with the others findings. However, it was significant that ascorbic acid content increased in the same treatment with higher yield. On the other hand, whenthe plants were grown in low nutrient concentrations, leaf constituents implied notto be metabolizedsufficientlyunderlow concentrationof nutrient solution becauseof insufficientsupplyof inorganicmatterfrom roots (Shinohara and Suzukl, 1981).Fanasca*et al.* (2006) stated that the total antioxidant activity increased in tomato with increased supply ofMg and K in the nutrient solution. In the present study, S_3 contained the higher amount of Mg and K which enhanced the biosynthesis of higher amount of ascorbic acid in sweet pepper.

4.8 Growth and physiological parameter

4.8.1 Leaf Area (LA)

The figures shows that the effect of treatments on the leaf area (LA). According to the figure leaf area increased markedly with increasing levels of nutrient solution concentrations. The leaf area was higher in the plants grown in ¾ strength Rahman and Inden (2012) nutrient solution than those grown in S1 strength and S2 strength Rahman and Inden (2012) nutrient solution. Plant leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Dufour, L. and Guérin, V. 2005). Leaf area can be measured either by destructive or non-destructive measurements. Accurate, non-destructive measurements permit repeated sampling of the same plants over time and have the advantage that biological variation can be avoided. Especially when using unique plants, for example in genetically segregating populations, non-destructive measurements are of great value. A common approach for non-destructive leaf area estimation is to develop ratios and regression estimators by using easily measured leaf parameters such as length and width (Kumaraswamy, K. 2004). Plants produce several types of leaves during development. The first few true leaves produced are usually smaller, simpler, and anatomically different from leaves produced later in development. Zeiger, E and Taiz, L. (1998) showed that in lettuce this ratio of individual leaves decreased with time and eventually became constant. Comparable results were found in red spruce. Consequently the ratio between leaf area and the product of length and width changes with plant age.

In Figure the effect of nutrient solutions on the leaf area was observed. Leaf area increased markedly with the increasing levels of nutrient solution. The leaf area was higher in the plants grown in ¾ strength of Rahman and Inden (2012).

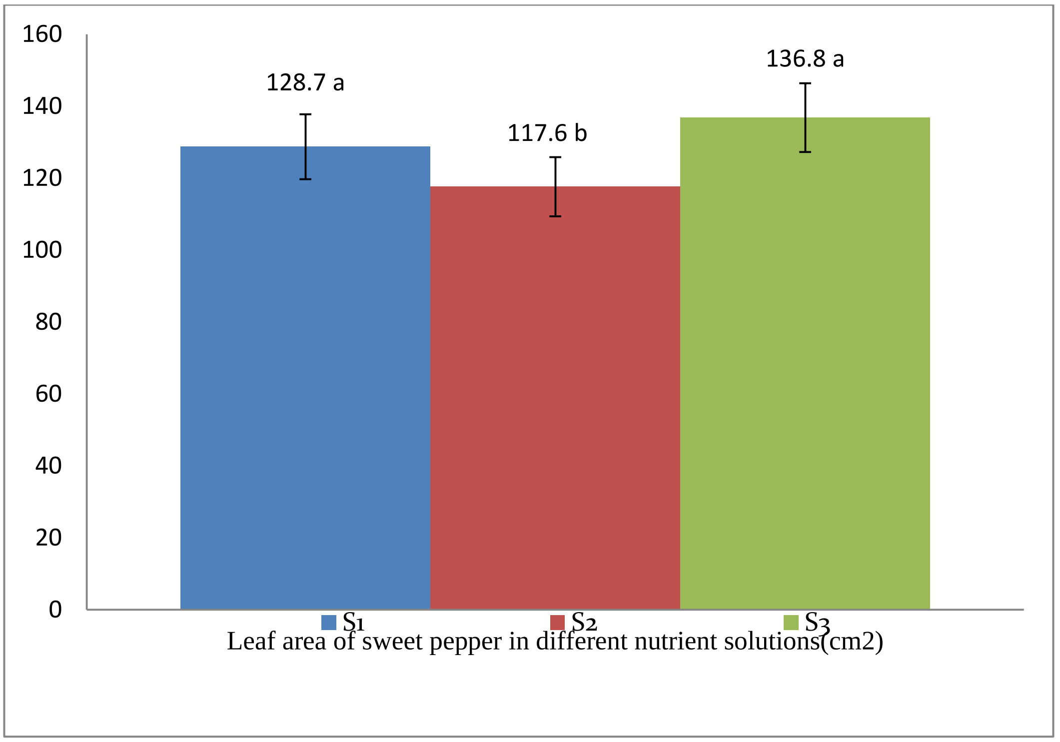

Figure 6.Effect of nutrient solution on leaf area in sweet pepperat 180 DAT. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾Rahman and Inden (2012).

4.8.2 Leaf Mass Ration (LMR)

Growth parameters varied significantly by different nutrient solution (figure 7). Results revealed that LMR increased in S_3 compared to S_1 and S_2. 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. We found higher LMR due to application of S_3 that may have the ability to produce higher metabolites in sweet pepper.

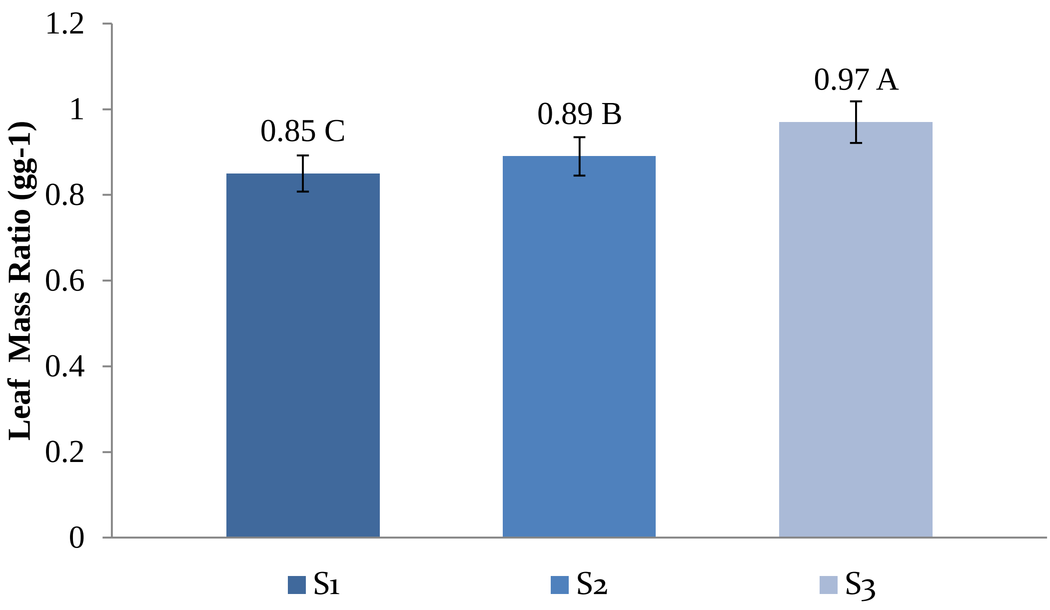

Figure7. Effect of nutrient solutions on leaf mass ratio in sweet pepper at 180 DAT. ^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012). Vertical bars represent standard errors of means.

4.8.3 Leaf Area Ratio (LAR)

Growth parameters varied significantly by different nutrient solution (figure 8). Results revealed that LAR decreased in S_3 compared toS_2 and S_1. Lower LAR is one of the important criteria for producing higher metabolites. Prieto*et al.* (2007) reported that increased LAR gave the plants an increased ability to intercept light. We found lower LAR due to application of S_3 that may have the ability to produce higher metabolites in sweet pepper. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings due to application of nutrient solution in sweet pepper.

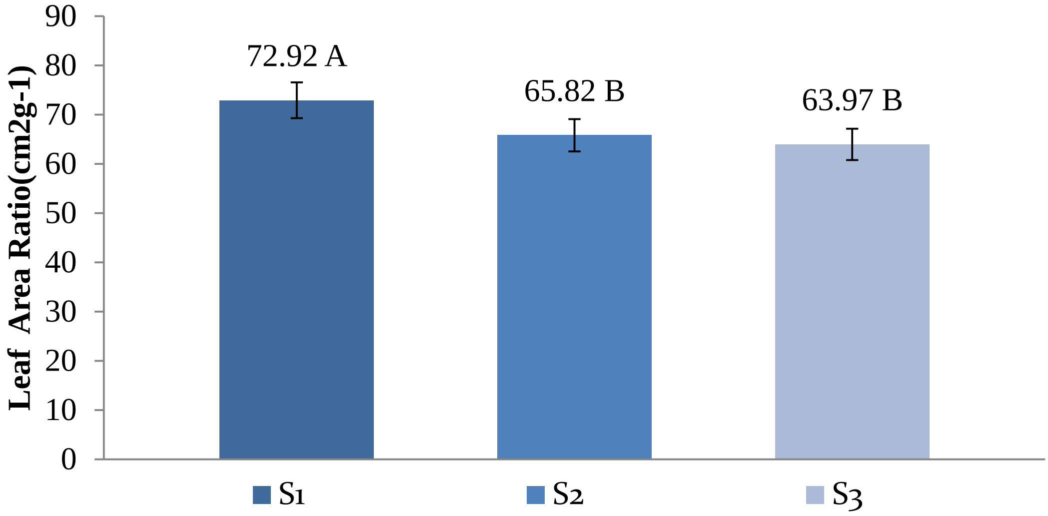

Figure 8.Effect of nutrient solutions on leaf area ratio in sweet pepper at 180 DAT. [z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012). Vertical bars represent standard errors of means.

4.8.4 Root Weight Ratio (RWR)

Growth parameters varied significantly by different nutrient solution (figure 9). Results revealed that RWR decreased in S_3 compared to S_1 but increased to S_2. Lower RWR is one of the important criteria for producing higher metabolites. Prieto*et al.* (2007) reported that increased RWR gave the plants an increased ability to intercept light. We found lower RWR due to application of S_3 that may have the ability to produce higher metabolites in sweet pepper. Decreased RWR was found by Starck (1983) in tomato, which agreed with our findings due to application of nutrient solution in sweet pepper.

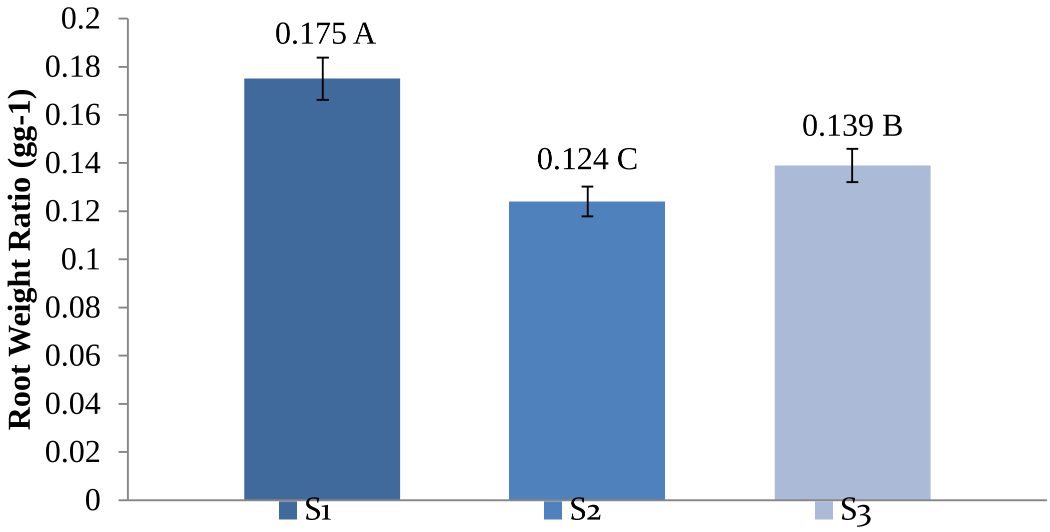

Figure 9. Effect of nutrient solutions on root weight ratio in sweet pepper at 180 DAT. [z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012). Vertical bars represent standard errors of means.

4.8.5 Net Assimilation Rate (NAR)

Growth parameters varied significantly by different nutrient solution (figure 10). Results revealed that NAR increased in S_3 compared to S_1 and S_2.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. We found higher NAR due to application of S_3 that may have the ability to produce higher metabolites in sweet pepper.

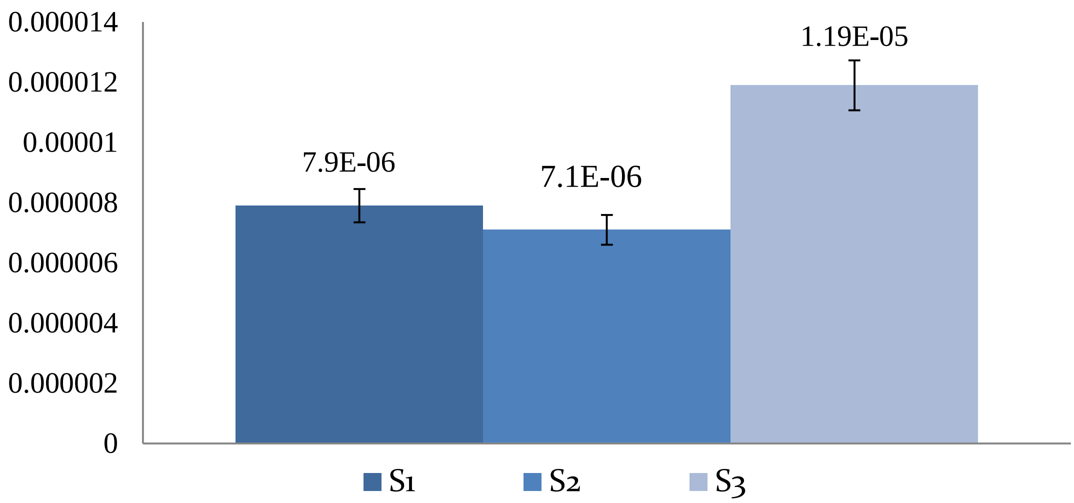

Figure 10. Effect of nutrient solutions on net assimilation ratio in sweet pepper at 180 DAT. [z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012), S_3: ¾ strength Rahman and Inden (2012).

4.8.6 Relative Growth Rate (RGR)

Growth parameters varied significantly by different nutrient solution (figure 11). Results revealed that RGR increased in S_3 compared to S_1 and S_2. Higher RGR 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. We found higher RGR due to application of S_3 that may have the ability to produce higher metabolites in sweet pepper.The plant growth analyses data suggested that S_3 provided better nutrition to the plants, followed by the control. This was most relevant in higher RGR and NAR due to application of S_3. However, plant growth parameters indicated that application of ¾ strength of Rahman and Inden (2012) with a higher level of plant growth.

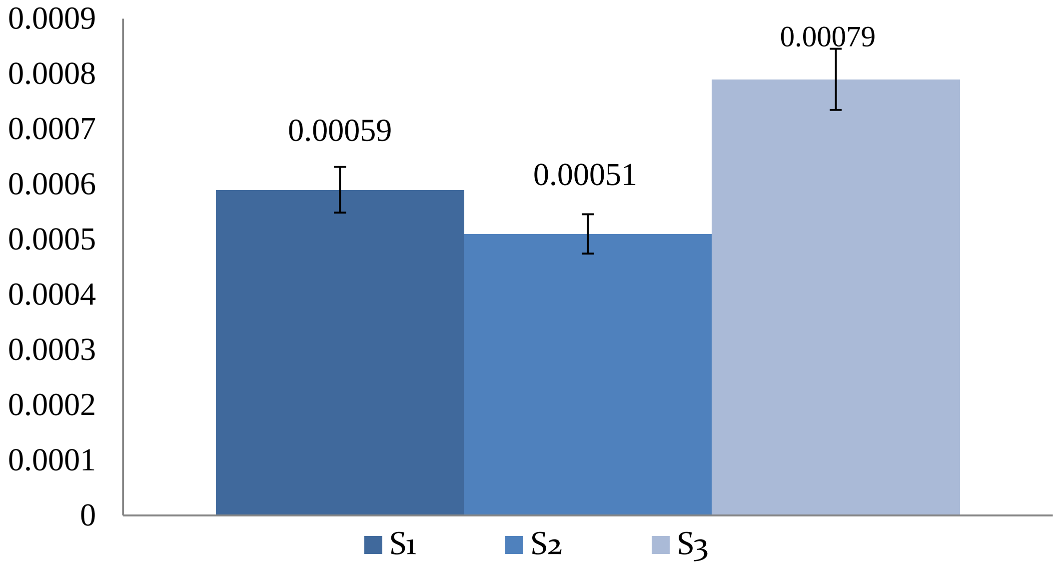

Figure 11: Effect of nutrient solutions on relative growth rate in sweet pepper at 180 DAT. ^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. S_1: Hoagland and Arnon (1940), S_2: Full strength Rahman and Inden (2012),S_3: ¾ strength Rahman andInden (2012).

CHAPTER V

SUMMARY AND CONCLUSION

Everybody can use hydroponics to grow green, red, yellow peppers any time of the year. It is possible to increase pepper size and production with this type of indoor growing system. The plants receive a constant food source from the nutrient-rich water, and they have few problems with pests and diseases that are often found in soil-grown plants. Hydroponic production of vegetables has found in very low and it was found in insignificant scale in the suburbs of large cities on some roof-top as aesthetic purpose. Plants that are not traditionally grown in a climate would be possible to grow using a controlled environment system like hydroponics. NASA has also looked to utilize hydroponics in the space program. Ray Wheeler, a plant physiologist at Kennedy Space Center's Space Life Science Lab, believes that hydroponics will create advances within space travel. He terms this as a bio regenerative life support system.So, there is need to investigate about the quality of hydroponically produced vegetables. In hydroponic production of fruit,vegetables, growers tend to control the concentration of nutrient solution at rather high level. The results of the present experiment indicate that under these conditions the content of nitrate nitrogen is not rather high in ¾ strength nutrient solution, because leaf area as well as fruit volume were high in the same treatment. Moreover, thepresent resultsshow a possibilitythat sweet pepperwith high contentsof ascorbic acidcanbe harvestedif S_3 nutrient solution is applied before harvest.

However, the reasons for growth promotion in hydroponic system are still under investigation, one of the possibilities is the optimum supply of the required plant nutrient in the most available form for the plants as compared to open field condition. Another cause might be that plants do not suffer any type of stress either environmental or nutritional that might common in the open field condition. These seem to positively stimulate plant growth. The negative observation in this experiment was insufficient light and temperaturemanagement system in the greenhouse. As a result, internodes elongation was found.

In conclusion, growth, fresh marketable yield and ascorbic acid concentration were affected by different strength of nutrient solution. The maximum number of fruit, plant height, fresh weight, fruit volume, leaf area and ascorbic acid content were found in S_3. Therefore, sweet pepper can be grown in the greenhouse field using ¾ strength of Rahman and Inden (2012) nutrient solution in Bangladesh with higher yield with lowest crop cultivation cost compared to other nutrient solutions.

CHAPTER VI

REFERENCES

Avidan, A. 2000.The use of substrates in Israel.World congress on Soilless Culture on 'Agriculture in the coming millennium.'MaaleHachamisha, Israel.p.17.

Ayers, C. J. and Westcot, D.W. 1987.La Calidaddel Agua en la Agricultura.FAO.SerieRiegoyDrenaje No. 29. Roma, Italia.

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

Bloom, A.J. and Epstein, E.2005. Mineral nutrition of plants: principles and perspectives. 2nd ed., Sinauer Associates, Inc, Sunderland, MA, USA.

Cardarelli, M., Fallovo, C., Rouphael, Y., Rea, E., Battistelli, A. and Colla, G. 2009b. Yield and quality of sweet pepper in response to nutrient solution composition and growing season. *J. Food Agri. Environ.* 7(2): 456-462.

Chavan, S., Syed, I., Rudaksha, G., Mahiwar, B. G. V. and Baig, M. I. 1997.Effect of various nitrogen levels through FYM and urine on yield, uptake of nutrient, ascorbic acids in chilli. *J. Indian. Soc.Soil Sci.* 45(4):833-835.

Coic, Y. 1973. Les Problèmes de Composition et de Concentration des Solutions Nutritive sen Culture Sans Sol. Proceedings of IWOSC 1973 3rd International Congress on Soilless Culture. Sassari, Italy, May 7-12. pp.158-164.

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

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. 1998c.Comparison of the mineral composition of twelve standard nutrient solutions.*J. Plant Nutr.* 21(10): 2115-2125.

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,

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

Estrada, B., Bernal, M. A., Diaz, J., Pomar, F. and Merino, F. 2000. Fruit development in *Capsicum annuum*: Changes in capsaicin, lignin, free phenolics, and peroxidase patterns. *J. Agric. Food Chem.* 48(12):6234-6239.

Estrada, B., Pomar, F., Diaz, J., Merino, F. and Bernal, A. M. 1999.Pungency level in fruits of the Pardon pepper with different water supply.*Sci. Hort.* 81:385-396.

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.

Fernández-Muñoz, R. and Cuartero, J.1999.Tomato and salinity. *Sci. Hort.* 78: 83-125.

Garceäs-Claver, A., Arnedo-Andreäs, M. S. and Abadiäa, J. 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.

Govindarajan, V. S., Rajalakshmi, D. and Chand, N. 1987.Capsicum production, technology, chemistry and quality Part IV.Evaluation of quality.Crit. Rev. Food Sci. Nutr. 25(3):185-282.

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

Hewitt, E. J. 1996. Sand and water culture methods used in the study of plant nutrition. Technical Communication No.22.Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent, England.

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.

Karmi,L..Bar-Tal, A., Aloni, B.,Oserovitz, J.,Hasan, A.,Avida, A.,Posalski, I.and Rosenberg, R.2001. Nitrogen nutrition of greenhouse pepper. I. Effect of nitrogen concentration and NO3:NH4 on yield, fruit shape and the incidence of blossom-end rot in relation to mineral composition. *Hort. Science*.36:1244-1251.

Kang, J. G. and van Iersel, M. W. 2004. Nutrient solution concentration affects shoot: root ratio, leaf area ratio, and growth of subirrigated Salvia (*Salvia splendens*). *Hort Sci.* 39(1): 49-54

Li, Y.L.andStanghellini, C. 2001. Analysis of the effect of EC and potential transpiration on vegetative growth of tomato.*Sci. Hort.* 89: 9-21.

Maboko, M.M. 2007. Sweet pepper grown in a hydroponics system.*UndercoverFarming* Magazine, Pretoria, South Africa. 3(6): 8.

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

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.

Materska, M. Perucka, I. and 2001.Phenylalanine ammonia lyase and antioxidant activities of lipophilic fraction of fresh pepper fruits (*Capsicum annuum* L.).*Innovative Food Sci. Emerging Technol.* 2:189-192.

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

México, D. F., México.Tyson, R.V., Simonne, E.H., Davis, M., Lamb, E.M., White, J.M. and Treadwell, D.D. 2007.Effect of nutrient solution, nitrate-nitrogen concentration, and pH on nitrification rate in perlite medium.*J. of Plant Nutr.* 30(6): 901-913.

Monforte-González, M., Guzmán-Antonio, A, Uuh-Chim, F. and Vázquez-Flota, F. 2010. Capsaicin accumulation is related to nitrate content in placentas of Habanero peppers (*Capsicum chinensis*Jacq). *J. Sci. Food and Agric.* 90(5):764-768.

Niederwieser, J. G. 2001. Guide to hydroponic vegetable production(2nd ed.). Agricultural Research Council, Roodepla at, Vegetable and Ornamental Plant Institute. Pretoria, South Africa.

Nowak, T. J. 1980. Influence of increased doses of microelements in hydroponic nutrient solution on the yield of *Capsicum annuum* L. fruits and their capsaicin content. *ActaAgrobotanica* 33(1):73-80.

Rahman, M.J. and Inden, H. 2012. Effect of nutrient solution and temperature on capsaicin content and yield contributing characteristics in six sweet pepper (*Capsicum annuum* L.) cultivars.*J. Food, Agric. Environ*., 10(1): 524-529.

Rea, E., Fallovo, C., Rouphael, Y., Battistelli, A. and Colla, G.2009a. Nutrient solution concentration and growing season affect yield and quality of *Lactuca sativa* L. var. acephala in floating raft culture. *J. Sci of Food and Agri.* 89: 1682-1689.

Salisbury, F. B. and Ross, C. W. 1992.Plant physiology.4th ed. Wadsworth inc. P 628.

Sarro, J., Prieto, M., Peñalosa, 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.

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

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

Siddiqui, M.Y. ,Chen, X.G., Gastaldi, C. and Glass, A.D.M. 1997. Growth of sweet pepper crop at low ambient nutrient concentration: a strategy designed to limit the potential of eutrophication. *J. Plant Nutr.* 20(10): 1402-1407.

Shinohara, Y. and Suzuki , Y. 1981. Effects of Light and Nutritional Conditions on the Ascorbic Acid Content of sweet pepper.*J. Jap. Soc. Hort. Sci.*50(2): 239-246.

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

Steiner, A. A. 1984. The universal nutrient solution, Proceedings of IWOSC 1984 6thInternational Congress on Soilless Culture, Wageningen, The Netherlands, pp. 633-650.

Steiner, A. A. 1973. The selective capacity of tomato plants for ions in a nutrient solution, Proceedings of IWOSC 1973 3rd International Congress on Soilless Culture, Sassari, Italy, pp. 43-53.

Steiner, A.A. 1968. Soilless culture, Proceedings of the IPI 1968 6th Colloquium of the Internacional Potash Institute. Florence, Italy. pp: 324-341.

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. 1961. A universal method for preparing nutrient solutions of a certain desired composition.*Plant and Soil.* 15(2): 134-154

Tanaka, K., Shinohara, Y., Suzuki, Y. and Yamasaki, Y. 1978.Growing conditions and quality of vegetables. I. Effects of fertilization and foliar spray treatment on the ascorbic acid content of leaf vegetables. *J. Jap. Soc. Hort. Sci.* 47(1): 63-70.

Trejo-Téllez, L.I., Gómez-Merino, F.C. and Alcántar G.G. 2007.Elementos Benéficos In.

Trudel, M.J. andGosselin, A. 1983. Interactions between air and root temperatures on greenhouse tomato: II. Mineral composition of plants.*J. Amer. Soc. Hort. Sci.* 108: 905-909.

Van Labeke, M. C., Dambre, P., Schrevens.E. and DeRijck G. 1995. Optimisation of the nutrient solution for Eustomagl and iflorum in Soilless Culture.*Act. Hortic.* 401(1): 401-408,

Valenzuela, H., Kratky, B. and Cho, J. 1993.Sweet pepper production guidelines for Hawaii University of Hawaii.

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.

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

Appendices

Appendix I: Analysis of variance (mean square) of plant height

Sources of variation	Degrees of freedom	Mean Square						
		0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
Treatment	2	10.111	189.00*	228.00**	412.00**	513.00**	349.00**	259.00**
Error	4	8.944	18.333	3.833	4.50	5.333	11.833	11.00

* indicates significant at 5% level of probability.

** indicates significant at 1% level of probability.

Appendix II : Analysis of variance (mean square) of fruit parameters

Sources of variation	Degrees of freedom	Mean Square				
		Number of fruits per plant	Fruit weight (gm)	Fruit Diameter (cm)	Fruit Length (cm)	Fruit Volume (cm^3)
Treatment	2	20.111**	2100.00**	4.870*	3.01**	2460.111*
Error	4	1.111	38.000	0.403	0.085	218.611

* indicates significant at 5% level of probability.

** indicates significant at 1% level of probability.

Appendix III. Analysis of variances of the data on different attributes of sweet pepper

Source of variation	Degrees of freedom(df)	Mean square for different attributes of Sweet pepper						
		LDW	RDW	LMR	RWR	LAR	RGR	NAR
Treatment	2	3.025	4.003*	2.203	3.003	346.707**	8.680**	28.262**
Error	4	0.006	0.043	0.0410	0.021	0.574	0.049	0.118

*: Significant at 5% level of probability
**: Significant at 1% level of probability