EFFECT OF NUTRIENT SOLUTION ON GROWTH AND YIELD OF TOMATO CULTIVARS IN HYDROPONIC CULTURE

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF NUTRIENT SOLUTION ON GROWTH AND YIELD OF TOMATO CULTIVARS IN HYDROPONIC CULTURE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in HORTICULTURE** embodies the result of a piece of bona-fide research work carried out by **FATEMA-TUJ-ZOHORA**, Registration no. **14-06143** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
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Dedicated To

My Beloved Parents

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ABSTRACT

Specific nutrient solution is one of the important components for growing tomato in hydroponic culture. Therefore, an experiment was conducted at semi-greenhouse at Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during August, 2019 to March, 2020 to study the effect of nutrient solution on growth and yield of tomato cultivars in hydroponic culture. The experiment consisted of two factors and followed Completely Randomized Block Design (RCBD) with three replications. Factor A: Three tomato cultivars [viz; V_1 = Rani (Krishibid Seed Ltd.), V_2 = Extra profit (Supreme Seed Co. Ltd.) and V_3 = Roma VF (Afroza Seed Company.)]; and Factor B: Four types of nutrient solution [viz; NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ strength of Rahman and Inden nutrient solution, NS_3 = ¾ strength of Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution]. Results revealed that the highest number of leaf per plant (40.09), earliest day to first flowering (26.44 DAT), highest number of flower cluster per plant (18.78), highest number of fruits per plant (26.33), fruit length (4.46 cm), fruit diameter (4.21 cm), individual fruit fresh weight (105.21 g), individual dry weight of tomato (8.36 g) and fruit yield per plant (5.30 kg) found in ½ strength of Rahman and Inden nutrient solution (NS_2). In case of different tomato cultivars, the highest yield per plant (4.18 kg) was found in Rani tomato cultivar (V_1). In case of combination, the highest number of leaves per plant (44.93), earliest day to first flowering (26.00 DAT), highest number of flower cluster per plant (19.67), the highest number of fruits per plant (34.33), fruit length (4.50 cm), fruit diameter (4.23 cm), individual fruit fresh weight (110.95 g), fruit dry weight (8.44 g) and yield per plant (7.13 kg) was found in V_1NS_2. Therefore, it can be concluded that Rani tomato cultivar along with ½ strength of Rahman and Inden nutrient solution can be cultured with higher yield in hydroponic culture.

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviated form	Full form
%	Percentage
@	At the rate of
AEZ	Agro-Ecological Zone
Agril.	Agricultural
Agric.	Agriculture
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
BBS	Bangladesh Bureau of Statistics
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAP	Days After Planting
DAS	Days After Sowing
Dev.	Development
Ecol.	Ecology
eds.	editors
Environ.	Environmental
et al.	et alia (and others)
etc.	et cetera (and other similar things)
Exptl.	Experimental
FAO	Food and Agricultural Organization
g	Gram (s)
Hortc.	Horticulture
i.e.	id est (that is)
J.	Journal
kg	Kilogram (s)
L.	Linnaeus
LSD	Least Significant Difference
M.S.	Master of Science
m2	Meter squares
mg	Milligram
MoP	Muriate of Potash
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
SAU	Sher-e-Bangla Agricultural University

LIST OF ABBREVIATIONS

Abbreviated form	Full form
Sci.	Science
Soc.	Society
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	variety
viz.	videlicet (L.), Namely
Vm	Vermicompost
µMol	Micromole

CHAPTER I

INTRODUCTION

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), a member of the family Solanaceae is one of the most important vegetables grown in Bangladesh. It has been originated in tropical America that includes Peru, Ecuador, Bolivia and areas of Andes (Kallo, 1986). It ranks third next to potato and sweet potato in terms of world vegetable production (FAO, 2015) and top the list of canned vegetable (Choudhury, 1979). But in Bangladesh, it ranks second which is next to potato (BBS, 2016). It has diversified use as raw like salad, soup etc.

Tomato is highly nutritious as it contains 94.1% water, 23 calories energy, 1.90 g protein, 1.00 g calcium, 7.00 mg magnesium, 1,000 IU vitamin A, 31 mg vitamin C, 0.09 mg thiamine, 0.03 mg riboflavin, 0.8 mg niacin per 100 g edible portion (Rashid, 1983). Food value of tomato is very rich because of its higher content of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato adds flavour to the foods and it is also rich in medicinal value (Uddain *et al*., 2009; Rashid, 1983; Davies and Hobes, 1981). Recent studies have directly linked lycopene to the prevention of certain types of human cancer, particularly prostate cancer and with a lower incidence of heart disease such as arteriosclerosis. Tomato consumption has been associated with decreased risk of breast cancer, head and neck cancers and might be strongly protective against neurodegenerative diseases in human. Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). Tomatoes are rich in Vitamin-K which plays a major role in blood clotting.

In Bangladesh tomato has great demand throughout the year but its production is mainly concentrated during the winter season. Recent statistics showed that tomato was grown in 17.790 hectares of land and the total production was approximately 202.000 metric tons in Bangladesh during the year 2014–2015. Thus, the Average yield of tomato was 18.35 t ha^{-1} (BBS, 2015). While it was 69.41 t ha^{-1} in USA, 65.45 t ha^{-1} in Japan, 48.13 t ha^{-1} in China, 23.79 t ha^{-1} in Thailand, 21.27 t ha^{-1} in India and 19.67 t ha^{-1} in Pakistan (FAO, 2014). The low yield of tomato in Bangladesh is however, not an indication of low yield potentiality of this crop, but of the fact that the lower yield may be attributed to a number of reasons, *viz.* changeable environmental conditions, unavailability of quality seeds of improved genotypes, lack of knowledge of suitable management operations, days of transplanting, fertilization and plant growth regulators etc. Soilless growing is becoming an attractive option because of the unpredictable problems of soil due to fluctuating temperatures, moisture holding capacity, obtain ability of nutrients, salinity, root aeration, undesirable microbial activities and nematode, disease and pest to overcome these problems with soilless.

Hydroponic crop production has significantly increased in recent years worldwide is the growing of plants in a soilless medium or an aquatic based environment. In hydroponics, nutrient solution is one of the important factors. The three main things are important as the alkalinity, the electrical conductivity (EC) and the concentration of specific elements in the nutrient solution for success of hydroponic culture.

In order to solve these problems, hydroponic culture started to be developed in Bangladesh, once they were already widely accepted in Japan and The Netherlands. Hydroponic culture provides better yield scheduling, avoiding crop rotation; better fruit quality; better crop handling; and better control over the environmental conditions and the nutritional needs (Martinez, 1999). On the other hand, hydroponic culture demands high technology and are not cost effective yet. Hydroponic products attract consumers due to their better appearance. In addition, the rigid control over nutrient supplies enhances the longevity of the product for both, shelf and refrigerated conditions, when compared to conventional systems of cultivation (Garcia *et al.*, 1997). According to these authors, this is particularly important for highly perishable vegetables, such as tomatoes.

In hydroponics it is possible to use both, determinate and indeterminate varieties, which are chosen based on their cycles, as done in soil cultivation systems. For tomato hydroponics, the varieties mostly used are the long-life indeterminate ones (Martinez, 1997). In commercial and research hydroponic culture, maintain in balanced nutrient solution typically requires periodic water refills, fertilizer replenishments, or complete nutrient solution replacements (Bugbee, 2004; Christie, 2014 and Resh, 2015).

The major merit of hydroponics is that it potentially produces much higher yields and can be used in those places where land is not suitable or ground agriculture and gardening is not possible (Polycarpou *et al.*, 2005). Recently nutrient solution management is one of the biggest challenges in hydroponics (Bugbee, 2004). Different types of nutrient solution are used for the production of different crops in hydroponics and it plays versatile function for the growth and development of the plant. In Bangladesh, appropriate nutrient solution composition will be triggered spreading hydroponics in the farmers or commercial levels. In this study, tomato is using as a hydroponic culture. Tomato is now grown in both summer and winter season. Therefore, it is imperative to apply a balanced solution that contains all plant nutrients, at the right balance. There are various nutrient solutions, such as the Hoagland and Arnon solution (1940), Steiner solution, Bollard solution, Rahman and Inden solution (2012) and others. Several important factors have to be considered when choosing chemicals and preparing hydroponic nutrient solutions as an appropriate strength for the tomato to obtain high-quality fruit with a higher yield.

Objectives:

1. To identify the most effective nutrient solution for the growth and development of tomato,

2. To find out different responses of tomato cultivars in the different nutrient solution.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The present chapter attempted to collect the literature regarding the effect of nutrient solution on growth and yield of tomato cultivars in hydroponic culture. Some of the important findings have been reviewed below, which would be useful and relevant to the present study:

2.1 Cultivation of tomato in different hydroponic system

Ali *et al.* (2021) conducted an experiment to identify a suitable strength of nutrient solution for cherry tomato in hydroponic system. In this research work, the seeds of cherry tomato (*Solanum lycopersicum* var. cerasiforme), Ireland and local market were used. Treatment considered six levels of nutrient solution [viz., S1: ½ strength Rahman and Inden (2012), S2: ¾ strength Rahman and Inden (2012), S3: Full strength Rahman and Inden (2012), S4: ½ strength Arnon and Hoagland (1940), S5: ¾ strength Arnon and Hoagland (1940) and S6: Full strength Arnon and Hoagland (1940) and two varieties [viz., V1: Local market cherry tomato (red), V2: Irelands cherry tomato (yellow)]. The maximum plant height, number of leaves per plant, first flowering, number of flowers per cluster, number of fruits per cluster, number of clusters per plant, average individual fruit weight and average cluster weight per plant were found in S3. Meanwhile, V2 performed better in respect of plant height, number of leaves per plant, first flowering, number of flowers per cluster, number of fruits per cluster, number of clusters per plant, average individual fruit weight and average cluster weight per plant. Therefore, cherry tomato cv. V2 can be cultured in hydroponic system with applying S3 (Full strength Rahman and Inden nutrient solution).

Krause *et al.* (2021) evaluated recycling fertilizers for tomato cultivation in hydroponics, and their impact on greenhouse gas emissions. Using the nutrient film technique (NFT), three recycling-based fertilizer variants were tested against standard synthetic mineral fertilization as the control, with 11 tomato plants (*Solanum lycopersicum* L. cv. Pannovy) per replicate and treatment: two nitrified urine-based fertilizers differing in ammonium/nitrate ratio (NH_4^+:NO_3^-), namely (1) "Aurin" (AUR) and (2) "Crop" (CRO); as well as (3) an organo-mineral mixture of struvite and vinasse (S+V); and (4) a control (NPK). The closed chamber method was adapted for gas fluxes (N_2O, CH_4, and CO_2) from the root zone. There was no indication in differences of the total shoot biomass fresh matter and uptake of N, P and K between recycling fertilizers and the control. Marketable fruit yield was comparable between NPK, CRO and S+V, whereas lower yields occurred in AUR. The higher NH_4^+:NO_3^- of AUR was associated with an increased susceptibility of blossom-end-rot, likely due to reduced uptake and translocation of Ca. Highest sugar concentration was found in S+V, which may have been influenced by the presence of organic acids in vinasse. A nitrified urine with a low NH_4^+:NO_3^- (e.g., CRO) has a high potential as recycling fertilizer in NFT systems for tomato cultivation, and S+V proved to supply sufficient P and K for adequate growth and yield.

Gomez *et al.* (2020) carried out an experiment with objectives to 1) evaluate the effect of biweekly nutrient solution replacements (W) vs. biweekly fertilizer addition without a nutrient solution replacement (W/O) on final growth, yield, and nutrient uptake of hydroponic tomato (*Solanum lycopersicum*) plants grown in a greenhouse, and 2) characterize growth over time in a greenhouse or an indoor environment using W. For each environment, 'Bush Goliath' tomato plants were grown for 12 weeks in 6.5-gal hydroponic culture. The W/O treatment resulted in a higher-than desired electrical conductivity (EC) and total nutrient concentration by the end of the experiment. In addition, compared with the W treatment, W/O resulted in less leaf area, more shoot growth, less water uptake, and similar fruit number—but increased blossom-end-rot incidence, delayed fruit ripening, and lower fruit fresh weight. Nonetheless, the final concentration of all nutrients was almost completely depleted at week 12 under W, suggesting that the applied fertilizer concentration could be increased as fruiting occurs. Surprisingly, shoot biomass, leaf area, and leaf number followed a linear trend over time in both environments. Nonetheless, given the higher DLI and temperature, greenhouse-grown plants produced 4 to 5 kg more of fruit than those grown indoors, but fruit from plants grown indoors were unaffected by blossom-end-rot.

Rodríguez-Ortega *et al.* (2019) studied a commercial variety of tomato ‘Optima’, with different soilless culture systems (deep flow technique, nutrient film technique, and the perlite substrate) and three levels of salinity (2.2, 6.3, and 10.2 $dS \cdot m^{-1}$) typical of South-eastern Spain. At 14 DAT, the plants of each culture system were divided into three groups, to which distinct salinity treatments were applied: control (S0), 40 mM NaCl (S1), and 80 mM NaCl (S2). Alterations in the water status of the plants, Cl^- and Na^+ toxicity, and nutritional imbalances altered the vegetative growth and physiology of the plants. The marketable yield was affected by both soilless culture system and salinity. Regarding the soilless culture system, yield decreased in the order: deep flow technique > perlite > nutrient film technique. The salinity treatments improved the fruits quality by increasing the total soluble solids and titratable acidity. Plants cultivated with the nutrient film technique had the highest concentrations of Cl^- and Na^+ and the highest Na^+/K^+ ratio. The concentrations of Cl^- and Na^+ in the plants were not related directly to the yield loss. Therefore, the influence of the toxicity, osmotic effect, and nutritional imbalance seems to have been responsible for the yield loss.

Islam *et al.* (2018) conducted a study to investigate the effects of nutrient and salinity concentrations on the quality of deep-flow technique hydroponic system cultivated cherry tomatoes (*Lycopersicon esculentum* Mill ‘Unicorn’). The conditions were: (1) control (NS-1 × nutrient Solution, Electrical Conductivity – EC: 2.5 $mS \cdot cm^{-1}$); (2) 2 × NS (2 × NS-Double NS, EC: 5 $mS \cdot cm^{-1}$); (3) NS + 4.23 mM NaCl (NaCl-Sodium Chloride, EC: 5 $mS \cdot cm^{-1}$); and (4) NS + 13.70 mM Sea Water – SW (EC: 7.5 $mS \cdot cm^{-1}$). NS + 13.70 mM SW treatment showed the lowest fresh weight loss. Visual quality as well as shelf life was the longest in NS (1 × nutrient solution) treated tomato fruits. The longest shelf life at 5°C, 11°C and 24°C were 21, 16, and 8 days, respectively, in NS (1 × nutrient solution) treated tomato fruits. The highest firmness was recorded in NS (1 × nutrient solution) treated tomato fruits, which was retained after storage. Moreover, NS + 13.70 mM SW treatment increased the cherry tomato fruit's quality, especially soluble solids and sugar contents. These results indicated that salinity concentration affected the soluble solids and sugar of cherry tomato fruits. In addition, nutrient concentration influenced the shelf life and firmness of cherry tomato fruits.

Reshma and Sarath (2017) conducted an experiment for standardization of growing media for the hydroponic cultivation of tomato. The tomato variety Anagha was raised in Ebb and flow hydroponic system (flood and drain system) to evaluate the ideality of growing media (coco peat, expanded clay pellets and pebbles). The treatments were F_1- Ebb and flow method, S_1 – Cooper's nutrient solution, M_1 – Coco peat medium, M_2 – Expanded clay pellet medium and M_3 – Pebble medium and the combinations were $F_1S_1M_1$ - Ebb and flow method + Cooper's nutrient solution + Coco peat medium, $F_1S_1M_2$ - Ebb and flow method + Cooper's nutrient solution + Expanded clay pellet medium and $F_1S_1M_3$ - Ebb and flow method + Cooper's nutrient solution + Pebble medium. Plants grown in coco peat medium performed the best in terms of yield per plant (1.67 kg), average fruit weight (45.86g), plant height (69.36 cm), crop duration (85.73 days) etc. followed by pebbles. The coco peat medium contained comparatively high amount of potassium (0.36 %) and also possessed high water holding capacity. Performance of plants grown in expanded clay pellets was very poor. Fruit quality in terms of total soluble solid content and titrable acidity was not significantly affected by the treatments.

Kaur *et al.* (2016) evaluated the effect of Hoagland solution for growing tomato hydroponically in greenhouse. The experiment was carried out in fan pad cooled greenhouse, using substrate with cocopeat, perlite and vermiculite (3:1:1 v/v). An NFT was developed for hydroponically grown tomatoes to supply nutrient solution to plants placed in net pots in PVC pipes. Three kinds of nutrient solution were used for each replication: 1) Hoagland solution at 100% concentration as treatment 1; 2) Hoagland solution at 75% concentration as treatment 2 and 3) Hoagland solution at 50% concentration as treatment 3. Plant growth, total fruit yield, TSS (total soluble solids) and titrable acidity were higher in Hoagland solution at 100% concentration than the others, but there was no significant difference between the three solutions in terms of diameter of stem, moisture content, firmness and lycopene. The result showed that Hoagland solution at 100% concentration increased the height of plants as well as total fruit production including fruit quality i.e. TSS and titrable acidity.

Suvo *et al.* (2016) carried out an experiment was to determine the effect of four different media-based hydroponics on tomato plant growth, yield and nutritional values. Tomato plants were grown in closed soilless system where Hoagland solution as nutrient solution and jute fiber, cotton (jhut), coconut husk as substrate. Five different tomato varieties (three Bangladeshi variants named Ratan, Roma VF, Ratan HYV and two Indian varieties named Patharkuchi, Pusharubi) were used as plant material. The nutrient media were considered as treatments of the experiment where four types of media used that was T_1 (Hoagland solution with well deride jute fiber), T_2 (Hoagland solution with coconut fiber), T_3 (Hoagland solution with cotton) and T_4 (only Hoagland solution) when jute fiber, coconut fiber and cotton fiber were used as substrate. Among four types of media, the media composed with Hoagland solution and jute fiber showed good impact on growth and nutritional values than the other three media (media of Hoagland solution with coconut husk, Hoagland solution with cotton and only Hoagland solution. It was revealed that the highest plant height, yield, vitamin C, fruit protein, fat and fiber content of all were related to media combination of jute fiber and Hoagland solution. Among all the varieties, the highest plant height (106 cm), yield (5.3 kg plant^{-1}), fruit Vitamin C content (64.54 mg 100 g^{-1}), fruit protein (17.67%), fat (5.2%) and fiber (7.9%) content was recorded from Patharkuchi tomato variety.

Signore *et al.* (2016) studied the effect of several values of the electrical conductivity (EC) of NS in an NFT (Nutrient Film Technique) system on a cherry type tomato crop, and defined a NS (called recovery solution), based on the concept of “uptake concentration” and transpiration–biomass ratio, that fits the real needs of the plant with respect to water and nutrients. Three levels of EC set point (SP), above which the NS was completely replaced (SP5, SP7.5, and SP10 for the EC limit of 5, 7.5, and 10 $dS·m^{-1}$, respectively), were established. The SP10 treatment yield was not different from other treatments, and it allowed a better quality of the berries (for dry matter and total soluble solids) and higher environmental sustainability due to a lower discharge of total nutrients into the environment (37 and 59% with respect to SP7.5 and SP5, respectively). The recovery solution used in the second trial allowed a more punctual NS management, by adapting to the real needs of the crop. Moreover, it allowed a lesser amount of water and nutrients to be discharged into the environment and a better use of brackish water, due to a more accurate management of the EC of the NS. The targeted management, based on transpiration–biomass ratio, indicated that, in some stages of the plant cycle, the NS used can be diluted, in order to save water and nutrients. With such management a closed cycle can be realized without affecting the yield, but improving the quality of the tomato berries.

Haghighi and Da Silva (2013) investigated the amendment of hydroponic nutrient solution with humic acid and glutamic acid in tomato (*Lycopersicon esculentum* Mill.) culture. Tomato cv. “Hongyangli” seeds were planted. Seedlings at the 4–5 leaf stage (approx. 5 weeks old) were fertigated for 1 week with half-strength nutrient solution (NS) and then with full-strength NS. Tomato seedlings were grown in six nutrient solutions: (1) control (C), (2) C + 25 $mg·L^{-1}$ HA (humic acid) (HA1); (3) C + 50 $mg·L^{-1}$ HA (HA2); (4) C + 100 $mg·L^{-1}$ GA (glutamic acid); (5) HA1 + GA; (6) HA2 + GA. HA increased photosynthesis rate and mesophyll conductance. HA did not significantly affect transpiration, stomatal conductance, titratable acidity, or antioxidant activity. In addition, GA improved protein and sugar content, mesophyll conductance and yield. The combination of HA and GA was more effective, especially with 50 mg·L^{-1} HA. The activity of superoxide dismutase (SOD) and peroxidases (POD) did not change in the presence of HA or GA. Malondialdehyde (MDA) content increased by 30% in HA2 together with GA. HA (Humic Acid) has a positive effect on tomato hydroponic growth when applied with GA (Glutamic Acid). This expands the use of HA and GA for horticultural commodities in hydroponic culture.

Feltrin *et al.* (2012) held an experiment using the nutrient film technique, aiming to evaluate the physico-chemical characteristics and the productivity of 'Cascade' and 'Sweet Million' cherry tomato cultivar grown in five ionic concentration of nutrient solutions with different electric conductivities (1.5, 2.0, 2.5, 3.0 and 3.5 dS·m^{-1}). The cherry tomato productivity cultivated in nutrient solutions with EC 1.5, 3.0 and 3.5 dS·m^{-1} were reduced around 10%, 14% and 31%, respectively. The productivity of two hybrids tested did not present significant differences. The results of physico-chemical analyses were around 50% increased for total soluble solid (5.6 until 8.3°Brix), lycopene results were up to 70% increased (8.2 until 14.35 mg/100 g). The best results were obtained with nutrient solutions with 2.5 and 3.0 dS·m^{-1}. Plants cultivated in NFT hydroponic system with the highest ionic concentrations of nutrient solutions presented the highest values for TSS (Total Soluble Solid) and lycopene.

Maboko *et al.* (2011) evaluated the performance of four cultivars in an open and a closed hydroponic (gravel-film technique) system. The commonly grown cultivars evaluated in each of the two hydroponic culture were 'FA593', 'Malory', 'Miramar' and 'FiveOFive'. Although no significant differences in total yield could be established - neither in the open nor in the closed hydroponic system - differences in marketable yield were observed. 'Miramar' and 'FiveOFive' produced the highest marketable yield in the closed system; the high unmarketable yield of 'FA593' and 'Malory' in the closed hydroponic system could be attributed to the high number of cracked fruit due to their inherent larger fruit size. There were no significant differences in ºBrix between cultivars in the closed system. Cultivar 'FiveOFive', 'FA593' and 'Miramar' produced higher marketable yields than cultivar 'Malory' when grown in the open-bag system. 'Malory' and 'FA593' produced the highest number of fruits exhibiting fruit cracking in the open bag system. In the open system, only cultivar 'Malory' had a higher ºBrix than 'Miramar' and 'FiveOFive'. The most promising cultivars for local hydroponic tomato production, with regard to yield and quality, were identified as 'Miramar' and 'FiveOFive', with 'FA593' performing equally in the open system only.

Shah *et al.* (2011) conducted a study was to evaluate two prominent nutrient solution recipes of different strengths (½ and full) to grow tomatoes in a non-circulating hydroponics system. For this purpose, plants of the tomato variety 'Rio-Grande' were grown in 13-litre plastic trash bins type containers using (1) Cooper's 1988 and (2) Imai's 1987 nutrient solutions. The tomato crop grown in Cooper's 1988 recipe (Half (1a) and full strength (1b) solutions, respectively) produced flowers significantly earlier (54.78 and 55.45 days of seed sowing), fruits also matured/harvested earlier (98.44 and 96.67 days of seed sowing), plants developed more flower clusters (14.70 and 13.48 plant^{-1}), more flowers cluster^{-1} (10.33 and 8.00), more fruits plant^{-1} (36.03 and 31.56), higher average fruit weight (77.38 g and 61.70 g), wider fruit diameter (4.57 cm and 4.27 cm), higher number of leaves plant^{-1} (72.89 and 64.89), and the fruit yield plant $^{-1}$ was also better (2.787 kg and 1.935 kg) than those grown in 2a and 2b solutions, plants consumed more nutrient solution (89.23 and 44.61 litres per plant), the cost of nutrient solution chemicals was higher (Rs 145.31 and Rs 51.08), but the crop revenues obtained plant^{-1} or crop revenues container^{-1} were also higher (Rs 97.54 and Rs 67.83) as compared to those plants grown in the corresponding strengths of the Imai's 1987 recipe solutions. Similarly, the cost benefit ratio (CBR) values on total cost container^{-1} basis were better (0.96:1.00 and 0.83:1.00) for ½ strengths solutions grown plants of the Cooper's 1988 recipe than those obtained in the corresponding strengths of Imai's 1987 recipe solutions because of the higher cost of chemicals used (Lab grade chemicals). However, CBR values (on solution chemical cost basis) were better for Imai's 1987 recipe grown plants (1.20:1.00 and 2.13:1.00).

Maboko *et al*. (2009) observed that soilless cultivation of fresh-market tomatoes has gained popularity in recent years in South Africa due to improved growth, yield and quality of commodities grown in such systems. The majority of South African producers cultivate tomato in the open field, with a small number producing in soilless systems under protection.

Wu and Kubota (2008) set up an experiment to study the effects of electrical conductivity of hydroponic nutrient solution on leaf gas exchange of five greenhouse tomato cultivars. Five cultivars (Blitz, Mariachi, Quest, Rapsodie, and Trust) of tomato (*Solanum lycopersicum*) were grown hydroponically in a greenhouse to determine photosynthetic and transpirational responses to three electrical conductivities (EC) [2.3 (control), 4.8, and 8.4 $dS \cdot m^{-1}$] of inflow nutrient solution. During the vegetative growth stage, high EC treatment of 8.40/14.30 $dS \cdot m^{-1}$ inflow/efflux solution reduced leaf conductance and transpiration rate by 28% and 29%, respectively, compared with low EC treatment (2.30/5.90 $dS \cdot m^{-1}$), regardless of cultivar. For 'Mariachi', moderate EC (4.80/8.70 $dS \cdot m^{-1}$) and high EC treatments in the vegetative growth stage reduced the maximum photosynthetic rate by 49% compared with the low EC treatment. However, for 'Rapsodie', the moderate EC treatment increased the maximum photosynthetic rate during the vegetative stage by 8% and 47% compared with low and high EC treatments, respectively. During reproductive growth stage, EC treatment did not significantly affect the transpiration rate, but high EC treatment reduced the leaf conductance by 15%, regardless of cultivar. Compared with the low EC treatment, the moderate EC treatment did not significantly affect the maximum photosynthetic rate of any cultivar except 'Rapsodie', which showed the greatest maximum photosynthetic rate in the moderate EC treatment. The results showed that the plant physiological response under elevated EC was cultivar and growth-stage specific, and increasing the inflow EC to the moderate level of around 4.80 $dS \cdot m^{-1}$ during the reproductive growth stage would not negatively impact photosynthesis, transpiration, and leaf conductance of all the tomato cultivars tested in the present experiment.

Nishimura *et al.* (2006) carried out an experiment where tomato plants were grown using a nutrient film technique in a hydroponic system to evaluate the effects of starting time and duration of salinity treatment and the interaction between salinity and planting density on fruit yield and quality. Tomato cultivar 'House Momotaro', (Takii & Co., Ltd., Japan) seeds were sown in trays with moist vermiculite in a greenhouse. When the cotyledons were fully open, the seedlings were transplanted and grown in a deep flow technique (DFT) system with Otsuka-A nutrient solution adjusted to an electrical conductivity (EC) of 1.2 $dS \cdot m^{-1}$ and pH of 6.5–7.0. After 2 weeks, the seedlings were transplanted to a nutrient film technique (NFT) system in a greenhouse. Otsuka-B nutrient solution, adjusted to an EC of 2.5 $dS \cdot m^{-1}$ and pH of 6.5–7.0 was supplied in all experiments. The average fruit weights in the whole, early, and late treatments were 46%, 71% and 58% of the control weight, respectively. Fruit radius and cell size were also reduced under each salinity treatment; however, the estimated number of cells per fruit was not significantly affected by the salinity treatment. The levels of total soluble solids (%Brix) were 6.2 in the control and 9.9, 7.7, and 9.1 in the whole, early, and late treatments, respectively. Incidences of blossom-end rot were 0%, 33%, 25% and 16% in the control, whole, early, and late treatments, respectively.

Sato *et al.* (2006) investigated the effects of NaCl application to hydroponic nutrient solution on fruit characteristics of tomato. NaCl was applied to nutrient solution (5 $dS \cdot m^{-1}$ versus 1.4 $dS \cdot m^{-1}$ in the control) of hydroponically-grown tomato and its effects on taste grading and chemical composition of fruit were investigated. Taste panels indicated NaCl treatment increased sweetness, acidity, umami (i.e. the taste of deliciousness) and overall preference. Hexose concentration of the fruit grown on NaCl treated plants significantly increased; and at the same time, chloric ion, organic and amino acids in general had higher concentrations in NaCl treated plants than the control. The results showed that (1) consumer grading of the tomato fruit was influenced not only by sugar content but also by the organic and amino acids; (2) increased concentration of soluble solids in the fruit of NaCl treated plants was not the result of simple overall condensation due to the reduction of water transport.

Kao (2005) developed and evaluated the dynamic root floating (DRF) hydroponic technique, in which he obtained a yield of 2.70 kg tomatoes·panel^{-1}.

Moraru *et al.* (2004) carried out an experiment to observe the characteristics of 10 processing tomato cultivars grown hydroponically for the NASA Advanced Life Support (ALS) program. The researchers mentioned from their experimental results that the lycopene content of tomato fruits showed values ranging from 7.7 to 15.0 mg/100 g in the study held in tomato growths in NFT.

Wu *et al.* (2004) carried out an experiment to study the effects of nutrient solution EC, plant microclimate and cultivars on fruit quality and yield of hydroponic tomatoes (*Lycopersicon esculentum*). Four cultivars (Blitz, Mariachi, Quest and Rapsodie) of tomato were grown hydroponically on rockwool in two microclimates (east and west) inside the greenhouse (Tucson, AZ) under two nutrient solution electrical conductivity (EC) levels (2.6 or 4.5 dS·m^{-1}), adjusted by adding NaCl and $CaCl_2$ after the setting of first fruit truss. In all cultivars, total soluble solid (TSS, %Brix at 20°C) and lycopene concentration of fruits increased by 12–23 % and 34–85 %, respectively, with increasing EC level. Fruits harvested from the east side of the greenhouse had higher TSS than those from the west side, due to the different plant microclimate varying by daily PPF (photosynthetic photon flux) and VPD (vapor pressure deficit). However, lycopene concentration in fruits was not significantly affected by plant microclimate regardless of cultivars or EC. The cultivar Mariachi had the strongest effect in response to nutrient solution EC levels regarding both TSS and lycopene concentration among the cultivars examined. The cumulative yield at 7 weeks had no significant differences between nutrient solution EC and locations, regardless of cultivars.

Gualberto *et al.* (2002) carried out three trials under greenhouse conditions using the hydroponic nutrient film technique, in order to evaluate yield and quality of long-life salad tomato (*Lycopersicon esculentum*) varieties. Four varieties (Carmen, Diva, Graziela, and Vita) were tested. The variety × crop season interaction effect was significant, meaning that varieties have distinct performances during the different cropping seasons. The Vita variety presented commercially valid yield, with mean fruit weights higher than the other varieties. Farmers were interested in hydroponic tomato cultivation because of the high demand of high-quality products by the consumers.

Tuzel *et al.* (2002) compared the open and closed hydroponic culture on yield and quality of greenhouse grown tomatoes. In the research, three variables: nutrition system, substrate and irrigation schedule, were tested. The nutrient solution was supplied in closed or open systems. The substrates were volcanic tuff, perlite, perlite + peat (3:1, v/v) and perlite + peat (1:1, v/v) and irrigation was scheduled based on indoor solar radiation levels of 1.0, 2.0, 3.0 and 4.0 $MJ \cdot m^{-2}$. The closed system gave yields as high as in the open system without quality loss, and reduced the amount of wasted water by up to 3.4 times compared to the open system. Perlite and volcanic tuff gave higher yields than perlite and peat mixtures. It was recommended that tomato plants should be grown in volcanic tuff or perlite in a closed system with irrigation provided at an indoor solar radiation level of 1 $MJ \cdot m^{-2}$.

Meric (2001) conducted a research in an unheated greenhouse to compare different substrates in open and closed hydroponics systems for tomato production and noticed variations in tomato yield and water/nutrients consumption in spring and autumn seasons. The tested substrates were perlite, volcanic tuff, perlite + peat (4:1, v/v) and volcanic tuff + peat (4:1, v/v). Substrates were filled into horizontal containers as 8 litres per plant. Cultivars

Gökçe F1 and FA 361 F1 were grown in autumn and spring seasons, respectively. There were no significant differences between open (15.7 and 19.0 $kg \cdot m^{-2}$) and closed systems (17.0 and 18.0 $kg \cdot m^{-2}$) in respect to total yield. Perlite and peat mixture gave the highest yields in both seasons among the tested substrates. The total water consumption ranged between 51.1 and 69.8 L per plant in autumn and from 91.2 to 119.0 L per plant in the spring, whereas the total nutrient consumption changed between 37.1 and 45.6 g per plant in autumn and 66.7 and 82.1 g per plant in spring. Regarding the substrates, the highest water and nutrient consumptions were obtained from perlite + peat (4:1, v/v). The results indicated that in the closed system could save up to 24 % water and 34 % nutrient.

Bradley and Marulanda (2000) calculated the cost economics of simplified hydroponics tomato bed grower of 2 m^{-2} and mentioned as cost US$ 2.84 and US$ 10.06 as net return. They obtained 3.1 kg tomato yield per plant.

Gul *et al.* (2000) compared the results of continuous and intermittent solution circulation on tomato growth and yield in NFT hydroponics and reported that there was not much difference in fruit grade and quality parameters in both the systems.

Schmoll *et al.* (2000) conducted a greenhouse study to determine the effects of sublethal dicamba concentrations in the nutrient media on hydroponically grown tomato plants. Tomato leaf area was the most sensitive vegetative growth parameter measured in response to dicamba concentrations, ranging from 0 to 22 µg/L, Leaf area was reduced 31% and 76%, and specific leaf weights, a relative measure of leaf thickness ($g \cdot cm^{-2}$), increased 26% and 121% after 30-d exposure to dicamba concentrations of 2.2 and 22 µg/L, respectively. In long-term experiments conducted until plants produced first ripe fruit, regression analysis indicated leaf area reductions of 8% and 66% from initial dicamba concentrations of 1 and 10 µg/L, respectively. Reductions in total fruit fresh weight were highly correlated ($r^{\cdot}$ = 0.93) with leaf area reductions caused by dicamba. A hyperbolic regression model gave predicted losses in fruit fresh weight per plant of 6% at 1 µg/L dicamba and 73% at 10 µg/L dicamba (r^2 = 0.87). Results generally indicated that the level of dicamba in the nuttiest media of hydroponically grown tomatoes that produced no observable effect was ≤ 1 µg/L.

CHAPTER III

MATERIALS & METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the effect of nutrient solution on growth and yield of tomato cultivars in hydroponic culture. The details of the materials and methods of this research work were described in this chapter as well as on experimental materials, site, climate and weather, experimental design, materials used for experiment, raising of seedling, treatments, media preparation, preparation of nutrient solution, transplantation of seedlings, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

3.1 Experimental period

This research work was carried out from August, 2019 to March, 2020.

3.2 Location of the research area

The experiment was conducted in the semi-greenhouse at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh. The location of the study site is situated in $23^0 46^/$N latitude and $90^0 22^/$E longitude. The altitude of the location was 8 meters from the sea level (The meteorological department of Bangladesh, Agargaon, Dhaka). Experimental location presented in Appendix I.

3.3 Climate of the experimental area

During the experimental period the maximum temperature (36.8°C), highest relative humidity (87%) and highest rainfall (273 mm) was recorded for the month of August, 2019 whereas, the minimum temperature (14.60°C), minimum relative humidity (64%) and no rainfall was recorded for the month of January, 2020. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.4 Plant materials

Tomato seeds was used as planting material. Seeds of tomato cv. 'Rani', 'Extra profit' and 'Roma VF' were used in the experiment. The seed were collected from Seed Market, Siddique Bazar, Dhaka and they were kept in a sealed packet.

3.5 Experimental materials

Styrofoam, plastic pot, polythene sheet, coco peat, broken brick etc. were collected from Town Hall Market. Experimental chemicals were bought from Tikatoli, Dhaka.

3.6 Experimental design

The two factors experiment was laid out in Completely Randomized Block Design (RCBD) with three replications.

3.7 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Three (3) Varieties viz.

i. V_1 = Rani (Krishibid Seed Ltd.),
ii. V_2 = Extra profit (Supreme Seed Co. Ltd.) and
iii. V_3 = Roma VF (Afroza Seed Company).

Factor B: Four (4) types nutrient solution viz.

i. NS_1 = Rahman and Inden nutrient solution,
ii. NS_2 = ½ Rahman and Inden nutrient solution,
iii. NS_3 = ¾ Rahman and Inden nutrient solution and
iv. NS_4 = Hoagland and Arnon No. 2 nutrient solution.

There were total 12 (3 × 4) combination as a whole *viz.*, V_1NS_1, V_1NS_2, V_1NS_3, V_1NS_4, V_2NS_1, V_2NS_2, V_2NS_3, V_2NS_4, V_3NS_1, V_3NS_2, V_3NS_3 and V_3NS_4.

3.8 Preparation of nutrient Solution

In this experiment, two nutrient solutions at different concentration were used. One nutrient solution was Hoagland and Arnon solution and the other was Rahman and Inden solution. The concentrations were Hoagland and Arnon (1940), Rahman and Inden, ½ strength of Rahman and Inden and ¾ strength of Rahman and Inden. 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.

The nutrient compositions of Hoagland and Arnon solution were NO_3-N, NH_4-N, P, K, Ca, Mg, and S of 14.00, 1.00, 3.00, 6.00, 8.00, 4.00 and 4.00 meq L^{-1}, respectively and Rahman and Inden solution were NO_3-N, P, K, Ca, Mg, and S of 17.05, 7.86, 8.94, 9.95, 6.00 and 6.00 meq L^{-1}, respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo and Mn of 3.00, 0.50, 0.10, 0.03, 0.025 and 1.00 mg 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 pots. Full strength of the treatments was started from the second week of the experiment. The pH 6.00 and EC 2.80 ds m^{-1}, respectively were maintained in the nutrient solutions. These solutions were used in different pots.

3.9 Experimental environment

Seeds were sown in styrofoam. Polythene sheet was placed in the inner side of the styrofoam so that nutrient solution could not pass through the styrofoam boxes. Twelve-inch 36 plastic pots were prepared for culturing the plants. Plastic pots were filled with substrate mixture of coco peat and broken brick. Five-week-old seedlings were transferred into the main pots. The experiment was conducted in a semi-greenhouse under intensive care. The room was kept clean and tidy during the experiment.

3.10 Growing media preparation

The mixture of coco peat and broken bricks (khoa) at the ratio of 80:20 (v/v) were prepared. Coconut coir was soaked in a big bowl for 24 hours. Then they were mixed with khoa properly. This mixture was placed in a styrofoam sheet box and plastic pot for culturing plants of tomato.

Plate 1. Different steps of growing media preparation

Plate 2. Different steps of growing media preparation

Plate 3. Different steps of growing media preparation

Plate 4. Different steps of growing media preparation

3.11 Seed sowing

Seeds were sown in styrofoam sheet box and covered with net under room temperature for raising seedlings properly.

Plate 5. Seed sowing

3.12 Transplanting of seedling

Two-week old tomato seedlings were transferred into the plastic small pots containing the mixture of coco peat, khoa. Hoagland and Arnon, Rahman and Inden, ½ strength of Rahman and Inden and ¾ strength of Rahman and Inden were given to the seedlings regularly along with fresh water as per treatment. After that, five-week old seedlings were transplanted to the twelve-inch plastic pot. The seedlings were transplanted in the afternoon carefully to minimize transplanting shock. After transplanting of tomato seedlings in the boxes, light watering was done with water can.

Plate 6. Seedling and seedling transplanting in the pot

3.13 Intercultural operations

3.13.1 Weeding

No weeding was done in the experiment.

3.13.2 Insect management

Tomato plants were grown in a semi-controlled greenhouse. So, no insecticides were applied in the experiment.

3.13.3 Diseases management

Tomato plants were grown in a semi-controlled greenhouse in hydroponic culture and all nutrients required for plant were supplied artificially to the plants. The growing environment was clean and no disease attacked to the plants.

3.13.4 Stalking

After the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright because tomato is an herbaceous plant with higher fruit weight.

Plate 7. Intercultural operation

Plate 8. Intercultural operation

3.13.5 Harvesting

Fruits were harvested at 5 days interval during early ripe stage when they developed slightly red colour. Harvesting of tomato (1st November, 2019 transplanting) was started from 19th December, 2019 and was continued up to 25th February, 2020.

3.14 Data collection

The following data were recorded

i. Plant height (cm) at 30, 60, 90 and 120 days after transplanting (DAT),
ii. Number of leaves per plant,
iii. Leaf area (cm^2),
iv. Number of branches per plant,
v. Dry matter per plant (%),
vi. Fruit length (cm),
vii. Fruit diameter (cm),
viii. Fruit weight (g),
ix. Fruit dry weight (g),

x. First flowering (DAT),

xi. First fruiting (DAF),

xii. Number of flower cluster per plant,

xiii. Number of fruits per plant,

xiv. Yield per plant (kg),

xv. Yield (t ha^{-1}),

xvi. Fruit pH,

xvii. Fruit brix (%),

xviii. Leaf Mass Ratio (LMR) (g g^{-1}),

xix. Leaf Area Ratio (LAR) (cm^2 g^{-1}) and

xx. Root weight Ratio (RWR) (g g^{-1}).

Plate 9. Leaf length measurement

Plate 10. Plant height measurement

Plate 11. Data collection

3.15 Detailed procedures of data collection

3.15.1 Plant height

Plant height was measured from the sample plants in centimetre from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded 30, 60, 90 and 120 days after transplanting (DAT) to observe the growth rate.

3.15.2 Number of leaves per plant

Number of leaves was counted from the ground level to the tip of the longest stem and mean value was calculated.

3.15.3 Leaf area

Green leaf area (LA) was measured manually using ruler and then transformed into leaf area index (LAI).

3.15.4 Number of branches per plant

The primary and secondary branches were counted from the selected plant at harvest time and mean value was determined.

3.15.5 Dry matter per 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.

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

3.15.6 Fruit length

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determining the length of fruit by slide callipers. The length of fruit was calculated by making the average of five fruits.

3.15.7 Fruit diameter

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the diameter of fruit by slide callipers. The diameter of fruit was calculated by making the average of five fruits.

3.15.8 Fruit weight

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the individual fruit weight in gram. The weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from four times harvesting data.

3.15.9 Fruit dry weight

Fruit was dried by sun for 5 days, 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.

3.15.10 First flowering (DAT)

First flowering was observed 26 days after transplanting.

3.15.11 First Fruiting (DAF)

First fruiting was observed 13 days after flowering.

3.15.12 Number of flower cluster per plant

The number of flower clusters was counted from the sample plants periodically and the average number of flower clusters produced per plant was calculated.

3.15.13 Number of fruits per plant

Total number of fruits was counted from selected plants and their average was taken as the number of fruits per plant at harvest.

3.15.14 Yield per plant

Yield per plant was determined with the following formula.

Yield per plant (kg) = Individual fruit weight (g) × Number of fruits per plant

3.15.15 Yield

Yield was determined with the following formula.

$$\text{Yield (t/ha)} = \frac{\text{Yield per plant} \times 50000}{1000 \times 1000}$$

where, 50000 = number of plant ha^{-1}, 1000 g = 1.0 kg and 1000 kg = 1.0 ton

3.15.16 Fruit pH

Fruit pH was measured with the help of a glass electrode pH meter using fruit water suspension ratio being maintained at 1:2.5 (Jackson, 1962).

3.15.17 Fruit brix

TSS of harvested fruits was determined with a drop of tomato juice by using Hand Sugar Refractometer "ERMA" Japan, Range: 0–32% according to (AOAC, 1990) and expressed as BRIX value.

3.15.18 Leaf Mass Ratio (LMR)

Leaf mass ratio was determined using the following formula.

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

Where, LMR = Leaf Mass Ratio, LDW = Leaf dry weight (g) and PDW = Plant dry weight (g).

3.15.19 Leaf Area Ratio (LAR)

Leaf area ratio (LAR) was determined using the following formula.

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

Where, LAR = Leaf Area Ratio, LA = Leaf area (cm^2) and PDW = Plant dry weight (g).

3. 15.20 Root Weight Ratio (RWR)

Root weight ratio (RWR) was determined using the following formula.

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

Where, RWR =Root Weight Ratio, RDW = Root dry weight (g) and PDW = Plant dry weight (g).

3.16 Statistical analysis

The data obtained for different characters were statistically analysed 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 condition were presented in table 1 to table 10 and figure 1 to figure 13. The experiment was conducted to study the effect of varieties and nutrients solution of hydroponic tomato. The results were presented and discussed under the following sub-heading.

4.1 Plant height

There was significant difference in plant height at 30, 60, and 120 days after transplanting (DAT) except 90 DAT in respect of variety of tomato (Figure 1). At 30 and 60 DAT, the tallest plant (25.73 and 53.04 cm, respectively) was found in V_1 (Rani) treatment and the shortest plant (22.98 and 48.81 cm) was found in V_3 (Roma VF) treatment which was statistically identical to V_2 (22.98 cm) at 30 DAT. At 90 DAT, the numerically tallest plant (77.75 cm) was found in V_1 (Rani) whereas, the numerically lowest (77.46 cm) was found in V_2 (Extra profit) treatment. At 120 DAT, the tallest plant (121.92 cm) was found in V_1 (Rani) treatment and the lowest (116.32 cm) was found in V_3 (Roma VF) treatment. In case of plant height, variety Rani showed better performance than variety Roma VF and extra profit. Varietal influence on plant height could be the reason behind different stature of tomato plants. Plant height is one of the most important parameters, which is positively correlated with the yield of cherry tomato (Asri *et al.*, 2015). Islam *et al.* (2012) stated that the plant height of cherry tomato lines depends on genetically character. Kumar (2011) experimented on 74 Lines of tomatoes in Vanarashi, India and observed that the plant height was varied by different tomato varieties. Ali *et al.* (2021) reported that Irelands cherry tomato (yellow) performed better in respect of plant height compared to local market cherry tomato (red). Suvo *et al.* (2016) observed that the highest plant height (106 cm) was recorded from Patharkuchi tomato variety in compare to

Bangladeshi variants Ratan, Roma VF, Ratan HYV and Indian variety Pusharubi.

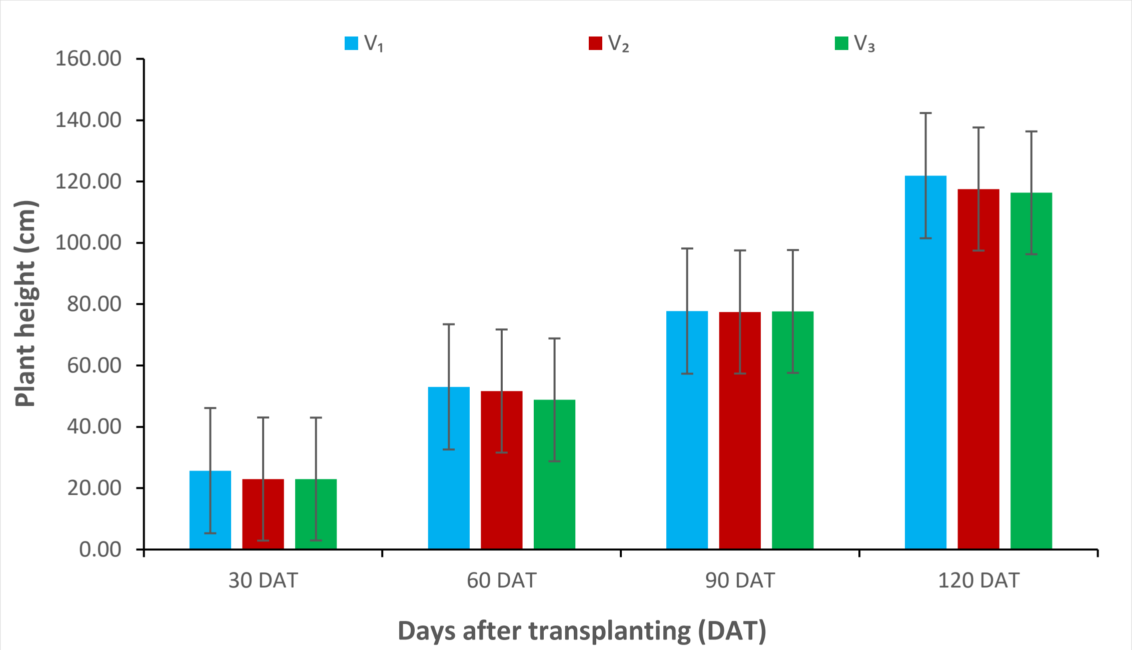

Figure 1. Varietal performance on plant height at different days after transplanting (DAT) of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

There was significant difference in plant height at 30, 60, 90 and 120 days after transplanting (DAT) in respect of different nutrient solution of tomato (Figure 2). At 30, 60, 90 and 120 DAT, the tallest plant (27.84, 58.40, 89.48 and 150.70 cm, respectively) was found in NS_2 (½ Rahman and Inden nutrient solution) treatment whereas, the shortest plant (20.48, 45.60, 70.64 and 95.27 cm, respectively) was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. The results revealed that the plant height increased with the advancement of plant nutrient solution. In case of nutrient solution, NS_2 (½ Rahman and Inden nutrient solution) showed better growth performance than other solutions used in this experiment. NS_2 can supply proper amount of nutrients to the plant resulting in taller plants. Ali *et al.* (2021) concluded that full strength Rahman and Inden nutrient solution performed better in respect of plant height compared to other ones. Kaur *et al.* (2016) mentioned that Hoagland solution at 100% concentration increased the height of tomato plants. Suvo *et al.* (2016) recorded that the tallest plant of tomato was related to media combination of jute fiber and Hoagland solution and plants grown on cotton fiber substrate treatments showed poor growth where the plants grown on control (only nutrient solution) showed good height. Rahman and Ali (2020) found that the highest plant heights of sweet pepper at 30 DAT, 60 DAT, 90 DAT, 120 DAT, 150 and 180 DAT were found in the ¾ strength Rahman and Inden (2012) + 0.5 mlL^{-1} SIB (salt industries by product) treatment.

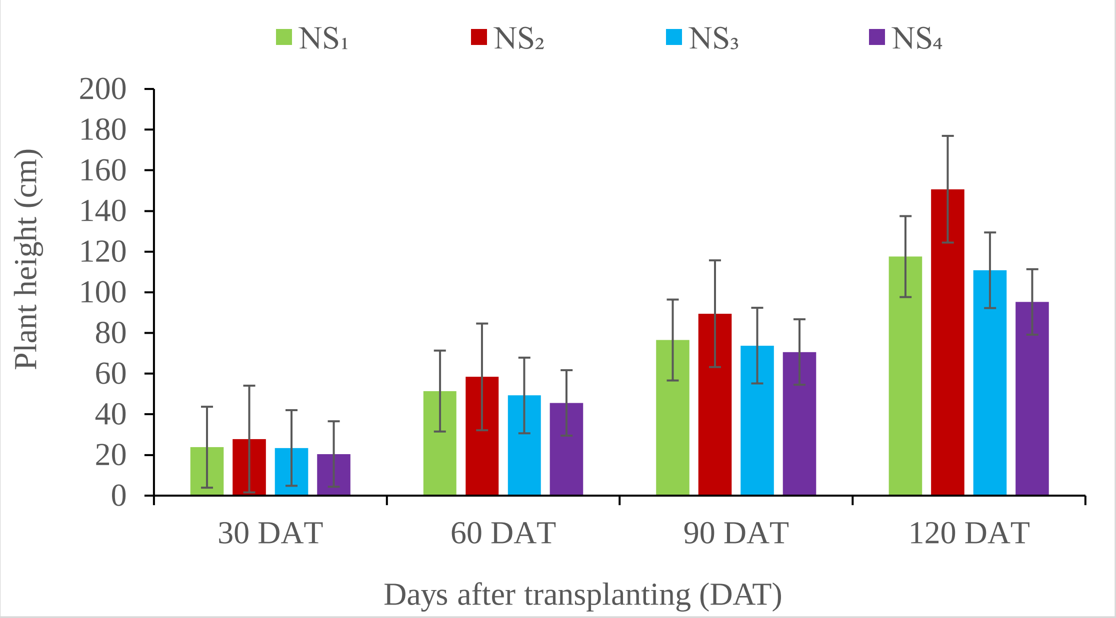

Figure 2. Effect of different nutrient solution on plant height at different days after transplanting (DAT) of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

The combined effect of different variety and nutrient solution showed a significant impact on plant height of tomato. There was significant difference in plant height at 30, 60, 90 and 120 days after transplanting (DAT) in respect of interaction effect of variety and nutrient solution of tomato (Table 1). At 30, 60, 90 and 120 DAT, the tallest plant (30.17 cm, 59.07 cm, 90.10 cm and 152.80 cm, respectively) was found in V_1NS_2 (Rani with ½ Rahman and Inden nutrient solution) treatment combination whereas, the shortest plant at 30, 60 90 and 120 DAT (19.60, 40.40, 69.97 and 93.17 cm, respectively) was found in V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) treatment combination. The variations among the treatment combinations might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied. Ali *et al.* (2021) from their experiment found that the tallest plants of tomato at 15, 30, 45, 60, 75 and 90 DAT (29.62 cm, 59.25 cm, 69.25 cm, 109.25 cm, 121.75 cm and 126.25 cm, respectively) were found in Local market cherry tomato (red) with Full strength Rahman and Inden solution.

Table 1. Interaction effects of varietal performance and nutrient solution on plant height at different days after transplanting (DAT) of tomato

Treatment combination	Plant height (cm) at			
	30 DAT	**60 DAT**	**90 DAT**	**120 DAT**
V_1NS_1	24.97 d	52.47 d	77.00 c	116.37 e
V_1NS_2	30.17 a	59.07 a	90.10 a	152.80 a
V_1NS_3	26.17 c	51.28 e	75.27 e	110.13 f
V_1NS_4	21.60 g	50.17 fg	70.90 g	94.93 i
V_2NS_1	23.83 e	51.20 e	75.90 e	120.27 d
V_2NS_2	26.47 c	58.25 b	90.07 a	148.77 c
V_2NS_3	21.40 g	50.23 f	72.80 f	116.90 e
V_2NS_4	20.23 h	46.23 h	71.07 g	97.70 h
V_3NS_1	22.67 f	50.63 f	76.70 d	116.07 e
V_3NS_2	26.90 b	57.90 c	88.27 b	150.53 b
V_3NS_3	22.77 f	46.30 h	73.30 f	105.50 g
V_3NS_4	19.60 i	40.40 i	69.97 h	93.17 j
LSD (0.05)	**0.32**	**0.56**	**0.78**	**1.13**

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

4.2 Number of leaves per plant

Significant difference was found in number of leaves per plant and number of leaves increased significantly at all growing stage due to the different varieties of tomato (Table 2). The maximum number of leaves per plant (35.82) was found when 'Rani' variety which was statistically identical to 'Extra profit' (34.95) variety while, the minimum number of leaves per plant was (32.37) found in

‘Roma VF’ variety. In case of number of leaves, variety Rani was better than other two varieties which could be related to the genetic make-up of this variety. A good number of leaves indicted better growth and development of crop. It is also possibly related to the yield of tomato. The greater number of leaves, the greater the photosynthetic area which may result higher fruit yield. Ali *et al.* (2021) found that Irelands cherry tomato (yellow) performed better in respect of number of leaves per plant.

The number of leaves per plant increased significantly at all growing stage due to the application of different strength nutrient solutions (Table 2). The maximum number of leaves per plant (40.09) was found when ½ strength of Rahman and Inden nutrient solution (NS_2) was applied. On the other hand, the minimum number of leaves per plant (25.71) was found when Hoagland and Arnon No. 2 nutrient solution (NS_4) was applied. This might be because of proper supply of nutrient in the plants. Here, plants treated with ½ strength of Rahman and Inden nutrient solution showed higher number of leaves per plant. In the present study, NS_2 supplied proper amount of nutrient in available forms to the plants resulting higher number of leaves per plant. Ali *et al.* (2021) mentioned that the maximum number of leaves per plant were found in plants treated with full strength Rahman and Inden nutrient solution. Hira (2014) observed that the maximum number of leaves per plant was found at 28 DAT (9.88), 35 DAT (11.17) and 42 DAT (12.66) when ¾ strength of Rahman and Inden nutrient solution was applied in lettuce while minimum number of leaves per plant was found at 28 DAT (6.83), 35 DAT (7.67) and 42 DAT (8.67) from application of ½ strength of Hoagland and Arnon nutrient solution in hydroponic culture.

Table 2. Varietal performance and effect of nutrient solution on number of leaves per plant, number of branches per plant and dry matter per plant of tomato

	No. of leaves per plant	No. of branches per plant	Dry matter per plant (%)
Effect of variety			
V_1	35.82 a	7.71	19.15 a
V_2	34.95 a	7.54	17.85 c
V_3	32.37 b	7.64	18.93 b
LSD $_{(0.05)}$	**2.45**	**0.34 (NS)**	**0.29**
Effect of nutrient solution			
NS_1	37.38 b	9.00 b	17.37 c
NS_2	40.09 a	11.00 a	20.73 a
NS_3	34.33 c	7.30 c	18.26 b
NS_4	25.71 d	3.22 d	18.22 b
LSD $_{(0.05)}$	**2.45**	**0.34**	**0.29**

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

The interaction between different varieties and nutrient solution was found significant on the number of leaves per plant (Table 3). The maximum number of leaves per plant (44.93) was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment combination whereas, the minimum (24.67) was found in V_1NS_4 (Rani with Hoagland and Arnon No. 2 nutrient solution) treatment combination which was statistically identical to V_2NS_4 (25.60) and V_3NS_4 (26.87) treatment combination. The variations among the treatment combinations were the characteristics of different varieties and variation of different strength of nutrient solutions. The variations among the treatment combinations might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Ali *et al.* (2021) observed that at 15, 30, 45, 60, 75 and 90 DAT (8.85, 13.85, 20.85, 25.85, 31.85 and 34.85 number of leaves per plant, respectively), Irelands cherry tomato (yellow) cultured in Full strength Rahman and Inden treatment combination produced the maximum number of leaves per plant of tomato.

Table 3. Interaction effects of varietal performance and nutrient solution on number of leaves per plant, number of branches per plant and dry matter per plant of tomato

Treatment combination	No. of leaves per plant	No. of branches per plant	Dry matter per plant (%)
V_1NS_1	36.93 c	9.33 b	17.46 g
V_1NS_2	44.93 a	11.00 a	21.21 a
V_1NS_3	33.53 d	7.33 d	19.84 c
V_1NS_4	24.67 e	3.17 e	19.18 d
V_2NS_1	37.73 c	8.50 c	15.32 i
V_2NS_2	41.00 b	11.00 a	20.13 c
V_2NS_3	35.47 cd	7.33 d	17.76 f
V_2NS_4	25.60 e	3.33 e	17.10 h
V_3NS_1	37.47 c	9.17 b	19.33 d
V_3NS_2	34.33 d	11.00 a	20.86 b
V_3NS_3	34.00 d	7.23 d	17.18 gh
V_3NS_4	26.87 e	3.17 e	18.37 e
LSD $_{(0.05)}$	2.45	0.34	0.29

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

4.3 Number of branches per plant

Effect of different varieties non-significantly influenced number of branches per plant (Table 2). Numerically, the highest number (7.71) of branches per plant was recorded from the 'Rani' (V_1) varietal treatment. On the other hand, the lowest number (7.54) of branches per plant was recorded from the 'Extra profit' (V_2) varietal treatment. This study revealed that tomato variety Rani produced maximum number of branches per plant. In case of number of branches, variety Rani was better than other two varieties which could be related to the genetic make-up of this variety. A good number of branches indicted better growth and development of crop.

Effect of different nutrients solution application significantly influenced number of branches per plant (Table 2). The highest number (11.00) of branches per plant was recorded from the ½ strength of Rahman and Inden nutrient solution (NS_2) treatment. On the other hand, the lowest number (3.22) of branches per plant was recorded from the Hoagland and Arnon No. 2 nutrient solution (NS_4) treatment. This might be because of proper supply of nutrient in the plants. Here, plants treated with ½ strength of Rahman and Inden nutrient solution showed higher number of branches per plant. In the present study, NS_2 supplied proper amount of nutrient in available forms to the plants resulting higher number of branches per plant.

The combined effect of different varieties and application of nutrient solution was also found to be statistically significant in this respect (Table 3). The highest number (11.00) of branches per plant was recorded from V_1NS_2, V_2NS_2 and V_3NS_2 treatment combination. On the other hand, the lowest number (3.17) of branches per plant was observed from V_1NS_4 and V_3NS_4 treatment combination of tomato which was statistically identical to V_2NS_4 (3.33) treatment combination. The variations among the treatment combinations in case of branch number might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study.

4.4 Dry matter per plant

Significant variation in dry matter of tomato plant at harvest stage was observed in different varieties (Table 2). The maximum dry matter of vegetative growth (19.15 %) was recorded from V_1 (Rani) treatment, while the minimum dry matter of vegetative growth (17.85 %) was observed in V_2 (Extra profit) treatment. In case of dry matter per plant of tomato, variety Rani was better than other two varieties which could be related to the genetic make-up of this variety. Rahman *et al.* (2017) mentioned that variety 'Legacy' had the highest dry matter weight per plant of lettuce; compare to ‘Red fire’ and ‘Green wave’ variety which might be because of the genetic variations among the varieties.

Different nutrient solution application showed significant influence on dry matter of vegetative growth of tomato (Table 2). The maximum dry matter of vegetative growth (20.73 %) was recorded from NS_2 (½ strength of Rahman and Inden nutrient solution) treatment. On the other hand, the minimum dry matter of vegetative growth (17.37 %) was observed in NS_1 (Rahman and Inden nutrient solution) treatment. This might be because of proper supply of nutrient in the plants. Here, plants treated with ½ strength of Rahman and Inden nutrient solution showed higher dry matter of vegetative growth. In the present study, NS_2 supplied proper amount of nutrient in available forms to the plants resulting higher dry matter of vegetative growth. Bajya *et al.* (2017) showed that integrated nutrient solution significantly affected fresh weight, dry weight during all stages of growth of tomato. Rahman and Ali (2020) recorded that the highest dry matter weights of capsicum plant were found in ¾ strength Rahman and Inden (2012) + 0.5 ml. L^{-1} SIB treatment. Hira (2014) stated that plant dry weights of lettuce were varied significantly by three different nutrient solutions where the highest dry weights of leaf and root were found in ¾ strength of Rahman and Inden solution compared to ½ strength of Rahman and Inden and ½ strength of Hoagland and Arnon solution.

The combined effect of different varieties and nutrient solution application was found to be statistically significant on dry matter of vegetative growth of tomato (Table 3). The maximum dry matter of vegetative growth (21.21%) was recorded from V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment combination. On the other hand, the minimum dry matter of vegetative growth (15.32%) was observed in V_2NS_1 (Extra profit with Rahman and Inden nutrient solution) treatment combination. The variations among the treatment combinations in case of dry matter might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study.

4.5 Fruit length

There was non-significant difference in fruit length in respect of varieties of tomato (Figure 3). The highest fruit length (3.58 cm) of tomato was found in V_1 (Rani). On the other hand, the lowest fruit length (3.40 cm) was in V_2 (Extra profit). The results revealed that the highest fruit length of tomato was found in Rani variety. In case of fruit length of tomato, variety Rani was better than other two varieties which could be related to the genetic make-up of this variety.

There was significant difference in fruit length in respect of different nutrient solution (Figure 4). The highest fruit length (4.46 cm) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution). On the other hand, the lowest (2.84 cm) fruit length of tomato was NS_4 (Hoagland and Arnon No. 2 nutrient solution). The results revealed that the highest fruit length was found in the application of ½ strength of Rahman and Inden nutrient solution. In the present study, NS_2 supplied proper amount of nutrient in available forms to the plants resulting in longer fruits. Rahman and Ali (2020) recorded that the maximum fruit length (8.90 cm) of capsicum was found in ¾ strength Rahman and Inden (2012) + 0.5 ml. L-1 SIB treatment whereas the lowest value (4.90 cm) was found in ¾ strength Rahman and Inden (2012) + 1.0 ml L^{-1} SIB treatment.

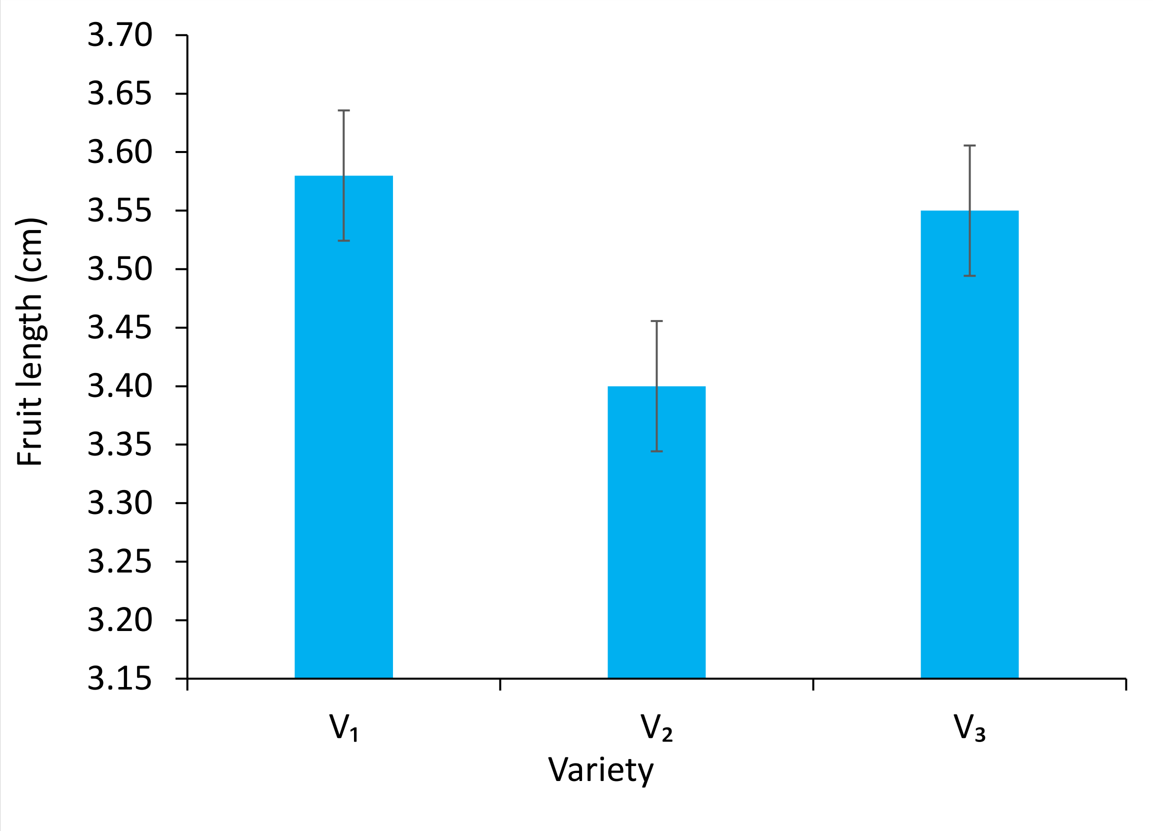

Figure 3. Varietal performance on fruit length of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

There was significant difference in fruit length in respect of combined effect of varieties and application of different nutrient solution (Table 4). The highest fruit length (4.50 cm) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) which was statistically identical to V_2NS_2 (4.47 cm) and V_3NS_2 (4.40 cm) treatment combination. On the other hand, the lowest (2.83 cm) fruit length was found in V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution) which was statistically identical to V_3NS_4 (2.83 cm) and V_1NS_4 (2.87 cm) treatment combination. The results revealed that V_1NS_2 indicated the highest fruit length, whereas treatment V_3NS_4 denotes the lowest fruit length. The variations among the treatment combinations in case of fruit length might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study.

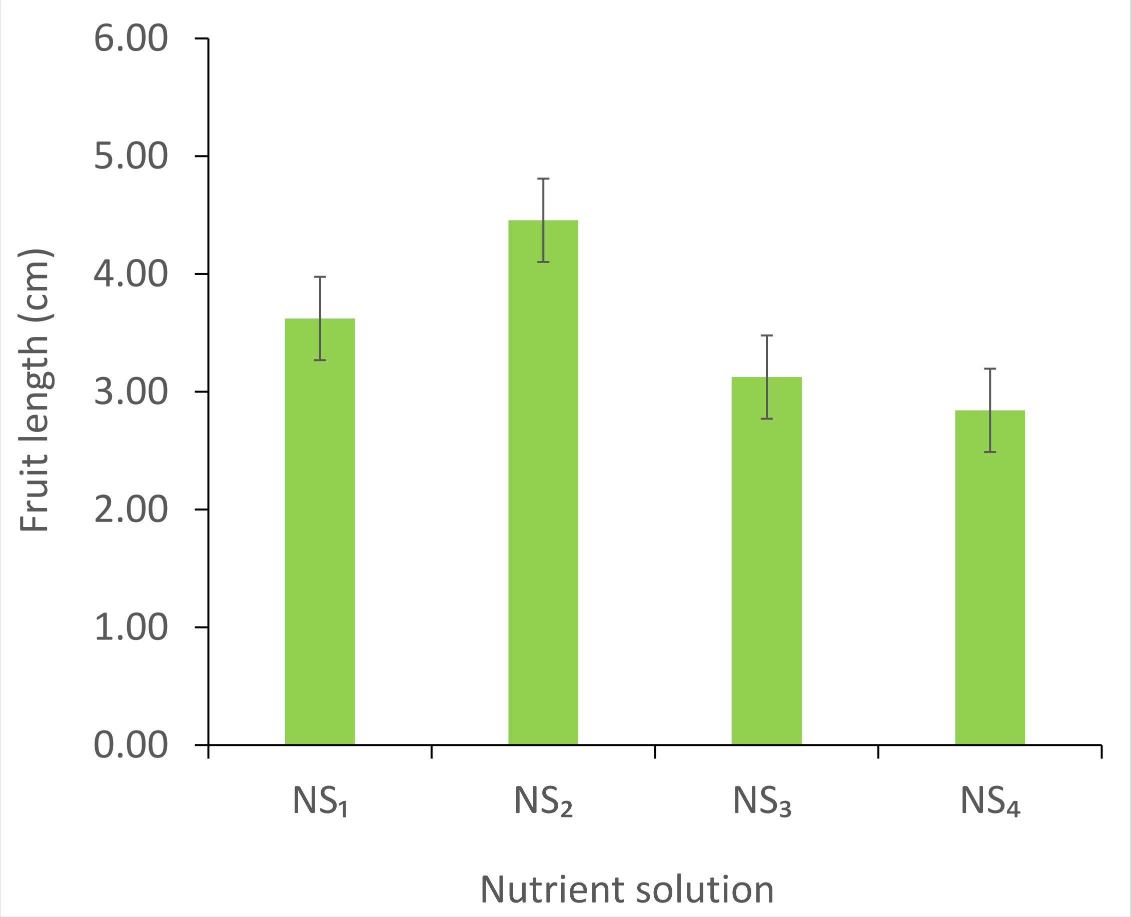

Figure 4. Effect of different nutrient solution on fruit length of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

4.6 Fruit diameter

There was non-significant difference in fruit diameter in respect of varieties of tomato (Figure 5). The maximum fruit diameter (3.63 cm) of tomato was found in V_1 (Rani) whereas, the minimum (3.59 cm) was in V_1 (Roma VF). The results revealed that the highest fruit diameter of tomato was found in Rani variety. In case of fruit diameter of tomato, variety Rani showed better performance than other two varieties which could be related to the genetic make-up of this variety.

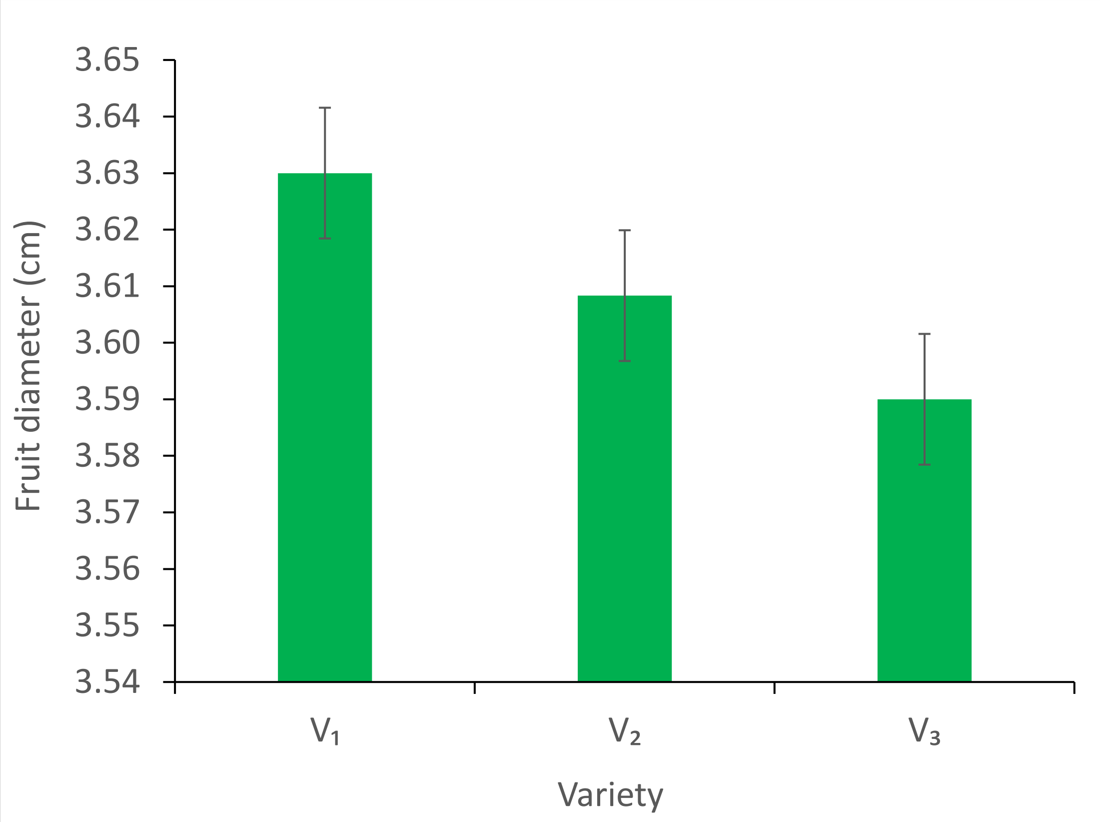

Figure 5. Varietal performance on fruit diameter of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

There was significant difference in fruit diameter in respect of different nutrient solution (Figure 6). The maximum fruit diameter (4.21 cm) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution) while, the minimum fruit diameter (3.04 cm) fruit length of tomato was NS_4 (Hoagland and Arnon No. 2 nutrient solution). The results revealed that the highest fruit diameter was found in the application of ½ strength of Rahman and Inden nutrient solution. The ½ strength of Rahman and Inden nutrient solution seemed significantly enough for producing larger tomato fruits in hydroponic culture compare to other nutrient solution under the present study. Rahman and Ali (2020) found that the maximum fruit diameter (7.60 cm) of sweet pepper was recorded from ¾ Rahman and Inden (2012) + 0.5 ml of SIB treatment and the minimum fruit diameter (4.50 cm) was obtained from ¾Rahman and Inden (2012) + 1.0 ml of SIB treatment.

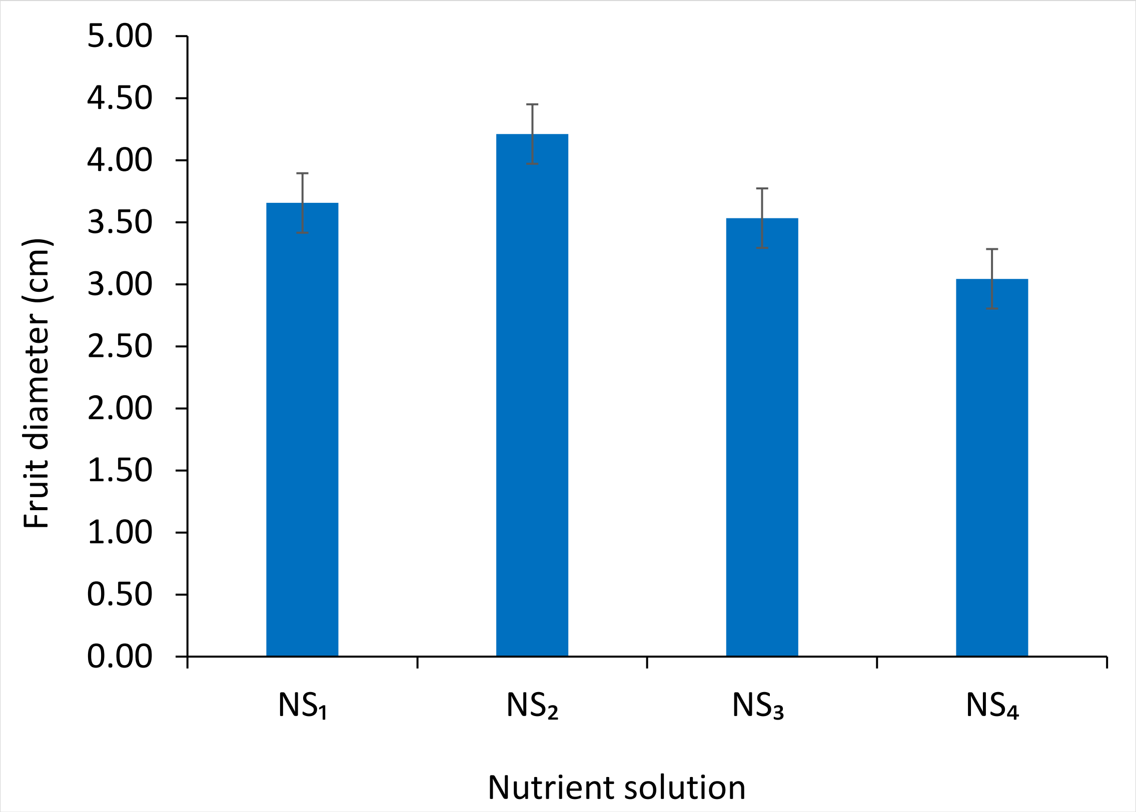

Figure 6. Effect of different nutrient solution on fruit diameter of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

There was significant difference in fruit diameter in respect of combined effect of varieties and application of different nutrient solution (Table 4). The maximum fruit diameter (4.23 cm) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) which was statistically identical to V_2NS_2 (4.20 cm) and V_3NS_2 (4.20 cm) treatment combination. On the other hand, the minimum fruit diameter (3.03 cm) was found in V_1NS_4 (Rani with Hoagland and Arnon No. 2 nutrient solution) which was statistically identical to V_3NS_4 (3.03 cm) and V_2NS_4 (3.07 cm) treatment combination. The results revealed that V_1NS_2 indicated the highest fruit diameter, whereas treatment V_1NS_4 denotes the lowest fruit diameter. The variations among the treatment combinations in case of fruit diameter might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Tomato variety Rani grown in ½ strength of Rahman and Inden nutrient solution showed a better combination if larger tomato fruits are to be grown by the producer/farmer.

4.7 Fruit weight

Individual fruit weight of tomato is highly influenced by different variety (Figure 7). The maximum fruit weight (88.35 g) was obtained from the 'Rani' (V_1). On the other hand, the minimum fruit weight (82.68 g) was obtained from the 'Extra profit' (V_2). Variety 'Rani' seemed to produce heavier fruit compare to other two varieties under study which could be attributed to the genetic make-up of the variety. The fruit weight varied with fruit size and shape which are the varietal characters. The results of present investigation were in accordance with the finding of Prema *et al.* (2011) and Islam *et al.* (2012) in cherry tomato. Ali *et al.* (2021) observed that the highest individual fruit weight (26.33 g) was attained from Irelands cherry tomato (yellow), whereas the lowest (21.83 g) was recorded from Local market cherry tomato (red).

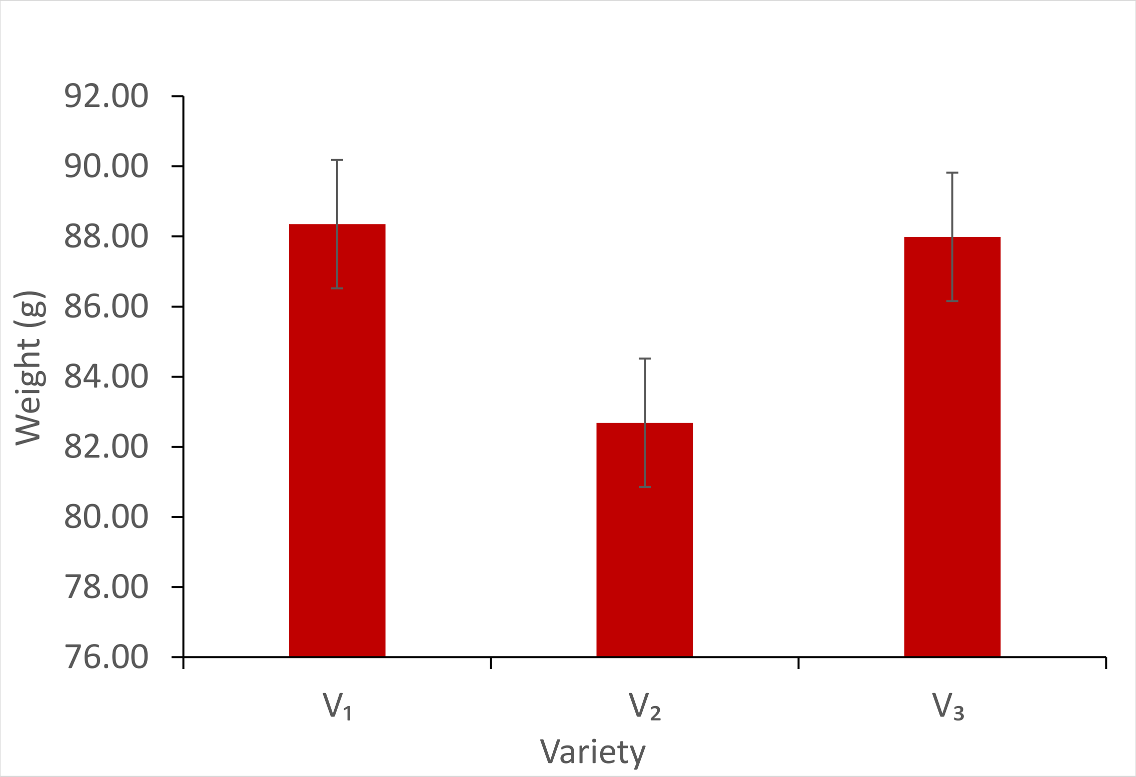

Figure 7. Varietal performance on fruit weight of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

In case of different nutrient solution application significant difference was found on individual fruit weight of tomato (Figure 8). The maximum fruit weight (105.21 g) was obtained from NS_2 (½ strength of Rahman and Inden nutrient solution) treatment. On the other hand, the minimum weight of fruit (63.86 g) was found from NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. NS_2 (½ strength of Rahman and Inden nutrient solution) treatment provided enough nutrient which returned with heavier tomato fruits under this study. This might be due to that ½ strength of Rahman and Inden contained all plant nutrient elements in proper proportion which helped the plants developing a larger size and shape of fruits. The plants required optimum nutrient combination for proper growth and better yield stated by Quamruzzaman *et al.* (2017). Rahman and Ali (2020) reported that the biggest fruit of sweet pepper (210 g) was recorded from ¾ strength Rahman and Inden (2012) + 0.5 ml. L^{-1} SIB treatment whereas ¾ strength Rahman and Inden (2012) + 1.0 ml. L^{-1} SIB treatment was scored as the lowest (182 g) at final harvest. Ali *et al.* (2021) recorded that the maximum individual fruit weight (33.75 g) was recorded from full strength Rahman and Inden nutrient solution and the minimum (17.75 g) was recorded from ½ strength Rahman and Inden nutrient solution.

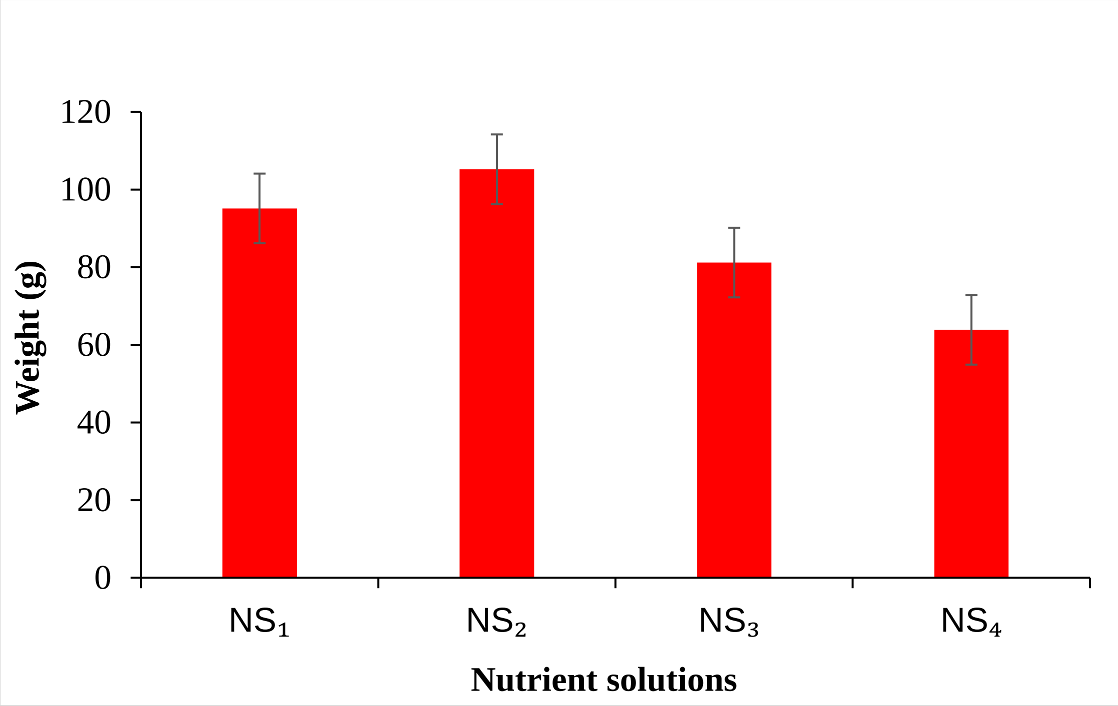

Figure 8. Effect of different nutrient solution on fruit weight of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

The significant difference was found from the combined effect of different variety and application of nutrient solution (Table 4). The maximum fruit weight (110.95 g) was obtained from V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment. On the other hand, the minimum weight of fruit (59.03 g) was found from V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) treatment. Tomato variety Rani provided with ½ strength of Rahman and Inden nutrient solution in hydroponic system could be an effective way for producing heavier fruit as shown in this study. Ali *et al.* (2021) mentioned significant difference on individual fruit weight due to interaction effect among the different strengths of nutrient solution and varieties of tomato.

4.8 Fruit dry weight

Fruit dry weight of tomato is highly influenced by different variety (Figure 9). The highest fruit dry weight (7.43 g) was obtained from the 'Rani' (V_1) whereas, the lowest fruit dry weight (7.03 g) was obtained from the 'Extra profit' (V_2)

treatment. Variety 'Rani' seemed to produce more dry weight of tomato fruit compare to other two varieties under study which could be attributed to the genetic make-up of the variety.

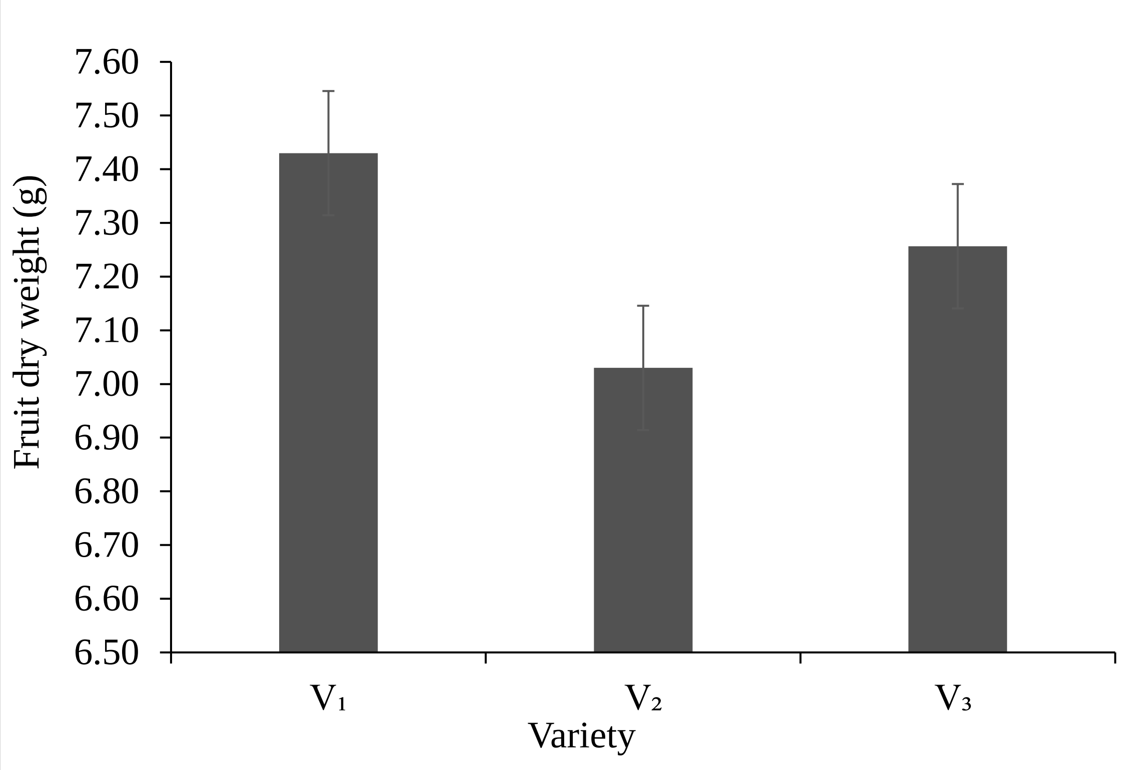

Figure 9. Varietal performance on fruit dry weight of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

In case of different nutrient solution application significant difference was found on fruit dry weight of tomato (Figure 10). The highest fruit dry weight (8.36 g) was obtained from NS_2 (½ strength of Rahman and Inden nutrient solution) treatment whereas, the lowest dry weight of fruit (6.24 g) was found from NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. NS_2 (½ strength of Rahman and Inden nutrient solution) treatment provided enough nutrient which returned with more dry weight in tomato fruits compare to other nutrient solutions under this study.

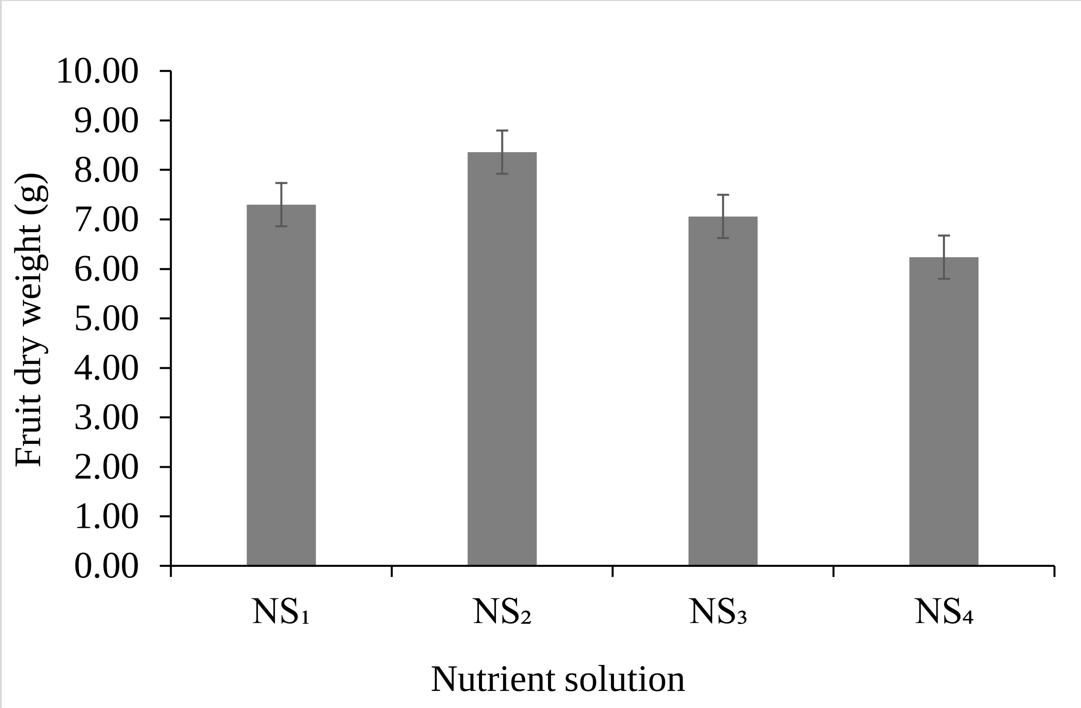

Figure 10. Effect of different nutrient solution on fruit dry weight of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

The significant difference was found from the combined effect of different variety and application of nutrient solution (Table 4). The highest fruit dry weight (8.44 g) was obtained from V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment which was statistically similar to V_2NS_2 (8.37 g) treatment combination. On the other hand, the lowest dry weight of fruit (6.08 g) was found from V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) treatment. Tomato variety Rani provided with ½ strength of Rahman and Inden nutrient solution in hydroponic system could be an effective way for producing tomato fruits with more dry weight as shown in this study.

Table 4. Interaction effects of varietal performance and nutrient solution on fruit length, fruit diameter, fruit weight and fruit dry weight of tomato

Treatment combination	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit dry weight (g)
V_1NS_1	3.13 c	3.77 b	89.35 e	7.70 c
V_1NS_2	4.50 a	4.23 a	110.95 a	8.44 a
V_1NS_3	3.10 c	3.37 f	83.91 f	7.23 e
V_1NS_4	2.87 d	3.03 g	69.33 h	6.43 i
V_2NS_1	3.87 b	3.57 e	93.80 d	6.63 h
V_2NS_2	4.47 a	4.20 a	98.11 c	8.37 ab
V_2NS_3	3.17 c	3.57 e	75.63 g	6.84 g
V_2NS_4	2.83 d	3.07 g	63.33 i	6.20 j
V_3NS_1	3.87 b	3.63 de	102.30 c	7.57 d
V_3NS_2	4.40 a	4.20 a	106.67 b	8.27 b
V_3NS_3	3.11 c	3.67 d	84.08 f	7.11 f
V_3NS_4	2.83 d	3.03 g	59.03 j	6.08 k
LSD (0.05)	0.20	0.09	4.27	0.11

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

4.9 First flowering

There was no significant difference in first flowering in respect of varieties of tomato (Table 5). Therefore, early first flowering (35.42 DAT) of tomato was found in V_1 (Rani). On the other hand, Extra profit (V_2) and Roma VF (V_3) tomato varieties (35.58 DAT) showed late first flowering because of less vegetative growth. Early flowering is an indication of early fruit formation and consequently helps in getting early and high yields. The early flower initiation in variety Rani might be due to higher capacity of these growing types to make available assimilates to the reproductive site during sensitive phase before flower initiation and congenial micro climate inside the semi-greenhouse. Ali *et al.* (2021) found that minimum days required for first flowering was observed in

Irelands cherry tomato (yellow) (19.50 DAT) and the maximum was found in Local market cherry tomato (red) (20.75 DAT). Similar results reported by Thangam and Thamburaj (2008) in tomato and Prema *et al.* (2011) in cherry tomato.

Table 5. Varietal performance and effect of nutrient solution on first flowering (DAT), first fruiting (DAF), number of clusters per plant and number of fruits per plant of tomato

	First flowering (DAT)	**First fruiting (DAF)**	**No. of flower cluster per plant**	**No. of fruit per plant**
Effect of variety				
V_1	35.42	15.58 b	12.92 a	26.33
V_2	35.58	16.67 a	11.83 c	25.92
V_3	35.58	16.75 a	12.25 b	25.50
LSD $_{(0.05)}$	2.51 (NS)	0.23	0.38	0.84 (NS)
Effect of nutrient solution				
NS_1	34.67 c	16.00 b	12.78 b	29.44 b
NS_2	26.44 d	14.56 c	18.78 a	33.89 a
NS_3	39.11 b	16.11 b	10.67 c	23.00 c
NS_4	41.89 a	18.67 a	7.11 d	17.33 d
LSD $_{(0.05)}$	2.51	0.23	0.38	0.84

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

There was significant difference in first flowering day in respect of application of nutrient solution (Table 5). The earliest first flowering (26.44 DAT) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution). On the other hand, NS_4 (Hoagland and Arnon No. 2 nutrient solution) showed the latest first flowering (41.89 DAT) of tomato. Results revealed that first flowering was differed with the different concentration of nutrient solution. This might be because of balanced nutrients supplied by the ½ strength of Rahman and Inden solution which consequent increment in photosynthesis. On the contrary, other strengths of nutrient solutions were supply lower amount of nutrient and probably the result of such phenomenon reduces photosynthesis of the plants. Ali *et al.* (2021) concluded that the minimum days required for first flowering was observed in the plants when applied Full strength Rahman and Inden (18.50 DAT) while the maximum days required for the first flowering was observed in ½ strength Arnon and Hoagland (21.88 DAT).

There was significant difference of combined effect of variety and application of nutrient solution on first flowering of tomato (Table 6). The early first flowering (26.00 DAT) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) which was statistically identical to V_3NS_2 (26.67 DAT) and V_2NS_2 (26.67 DAT). On the other hand, V_1NS_4 (Rani with Hoagland and Arnon No. 2 nutrient solution) and V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) were showed late first flowering (42.00 DAT) of tomato because of less vegetative growth which was statistically identical to V_2NS_4 (41.67 DAT) and similar with V_3NS_3 (40.00 DAT). The results revealed that V_1NS_2 indicated the early first flowering, whereas treatment V_1NS_4 and V_3NS_4 denotes late first flowering. The variations among the treatment combinations in case of first flowering might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Ali *et al.* (2021) noted insignificant variation on the first flowering influenced by combined effect of different strength of nutrient solutions and tomato varieties. The minimum days required for first flowering was recorded from the treatment combination Local market cherry tomato (red) cultured with Full strength Rahman and Inden solution (18.00 DAT) and the maximum days was found in Irelands cherry tomato (yellow) cultured with ½ strength Arnon and Hoagland (22.75 DAT).

4.10 First fruiting

First fruiting of tomato was significantly affected by different varieties of tomato and different application of nutrient solution (Table 5). The earliest first fruiting (15.58 DAF) of tomato was found in V_1 (Rani). On the other hand, V_3 (Roma VF) showed latest first fruiting (16.75 DAF) because of less vegetative growth and late flowering which was statistically identical to V_2 (16.67 DAF). Earliness plays important role on fetching higher price and more income. Therefore, early varieties are generally preferred for cultivation on commercial scale. Early harvest in this experiment might be due to the varietal response to the congenial growing environment in semi-greenhouse and early flowering. Whereas delayed fruit ripening was due to late flowering. Similar results obtained by Prema *et al.* (2011) in cherry tomato. Ali *et al.* (2021) recorded that first fruiting of cherry tomato was significantly affected by different varieties. Irelands cherry tomato (yellow) variety required the shortest days (29.58 DAT) for first fruiting and Local market cherry tomato (red) required the maximum days (31.42 DAT) for first fruiting of cherry tomato.

Table 6. Interaction effects of varietal performance and nutrient solution on first flowering (DAT), first fruiting (DAF), number of flower clusters per plant and number of fruits per plant of tomato

Treatment combination	First flowering (DAT)	First fruiting (DAF)	No. of flower cluster per plant	No. of fruits per plant
V_1NS_1	35.33 c	16.33 c	12.33 f	29.00 b
V_1NS_2	26.00 d	13.67 h	19.67 a	34.33 a
V_1NS_3	38.33 b	17.33 b	10.00 h	25.00 c
V_1NS_4	42.00 a	18.67 a	7.33 i	17.67 f
V_2NS_1	34.33 c	16.00 d	13.33 d	29.67 b
V_2NS_2	26.67 d	14.67 f	17.67 c	33.67 a
V_2NS_3	39.00 b	17.33 b	12.00 g	22.67 d
V_2NS_4	41.67 a	18.67 a	6.67 j	17.67 f
V_3NS_1	34.33 c	15.67 e	12.67 e	29.67 b
V_3NS_2	26.67 d	14.33 g	19.00 b	33.67 a
V_3NS_3	40.00 ab	14.67 f	10.00 h	21.33 e
V_3NS_4	42.00 a	18.67 a	7.33 i	16.67 g
LSD $_{(0.05)}$	2.51	0.23	0.38	0.84

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

Again, the early first fruiting (14.56 DAF) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution). On the other hand, NS_4

(Hoagland and Arnon No. 2 nutrient solution) was showed latest first fruiting (18.67 DAF) of tomato. Results revealed that first fruiting was differed with the different concentration in nutrient solution. However, ½ strength Rahman and Inden solution produced the first flower in the shortest days after transplanting of cherry tomato. This was because ½ strength Rahman and Inden solution can have ability to maintain nutrient element in root zone enhances the protein synthesis, cell division, cell elongation and thereby stimulated fruiting. Ali *et al.* (2021) stated that the different strengths of the nutrient solution did not show significant effect on first fruiting of cherry tomato. The minimum days required for first fruiting was observed in the plants when applied full strength Rahman and Inden (27.75 DAT). The maximum days required for the first fruiting was observed in ½ strength Arnon and Hoagland (33.38 DAT).

There was significant difference of combined effect of varieties and different application of nutrient solution on first fruiting of tomato (Table 6). The early first fruiting (13.67 DAF) of tomato was found in V_1NS_2 (Rani with ½ Rahman and Inden nutrient solution). On the other hand, V_1NS_4 (Rani with Hoagland and Arnon No. 2 nutrient solution), V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution) and V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) was showed late first fruiting. The results revealed that V_1NS_2 indicated the early first fruiting, whereas treatment V_1NS_4, V_2NS_4 and V_3NS_4 denotes late first fruiting. The variations among the treatment combinations in case of first fruiting of tomato might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Ali *et al.* (2021) found insignificant variation on first fruiting influenced by combined effect of different strength of nutrient solutions and tomato varieties. The minimum days required for first fruiting was recorded from Irelands cherry tomato (yellow) with Full strength Rahman and Inden (27.00 DAT) and the maximum days required for first fruiting was found in Local market cherry tomato (red) with ½ strength Arnon and Hoagland (34.75 DAT).

4.11 Number of flower cluster per plant

In this experiment, there was a significant difference in number of flower clusters per plant at different variety of tomato (Table 5). The highest number of flower cluster per plant (12.92) was found from V_1 (Rani) whereas, the lowest number of cluster (11.83) was recorded from V_2 (Extra profit). These results indicated that higher temperature reduces the formation of number of flower clusters per plant. This variation in number of flowers per cluster production among tomato genotypes might be attributed to the inherent genetic potentiality of the genotypes to produce flowers at controlled environmental condition. Similar results were obtained by Parvej *et al.* (2010) in poly house tomato and Prema *et al.* (2011) in cherry tomato. Aguirre and Cabrera (2012) reported that number of inflorescences and stigma exertion are inherent characters. Suvo *et al.* (2016) reported that the maximum number of flowers of tomato plants was observed in tomato variety Patharkuchi in compare to Bangladeshi variants Ratan, Roma VF, Ratan HYV and Indian variety Pusharubi.

Number of flower cluster per plant differed with different level of nutrient solution (Table 5). The highest number of flower cluster per plant (18.78) was found from NS_2 (½ strength of Rahman and Inden nutrient solution) whereas, the lowest number of cluster (7.11) was recorded from NS_4 (Hoagland and Arnon No. 2 nutrient solution). The result revealed that number of flowers clusters per plant was related with the strength of nutrient solutions. Treatment NS_2 produced the highest number of flowers that might be due to maintain optimum amount of macro and micro nutrients to allow grow faster, rate of metabolism, cell division, cell elongation. It also might maintain optimum EC level which increased in leaf water potential, leaf area and the consequent increment in photosynthesis that enhances the protein synthesis and thereby stimulated flower production. Garrison *et al.* (2010) reported that increasing levels of nitrogen increased flower formation of several clusters of processing cherry tomato. Suvo *et al.* (2016) concluded that number of flowers of tomato plants was influenced by Hoagland solution with different substrates and the highest number of flowers of tomato was related to the plants grown on jute fiber treatments.

The combined effect of different variety and nutrient solution had significant variation in number of flower cluster per plant of tomato (Table 6). The highest number of flower cluster per plant (19.67) was found from V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment combination. On the other hand, the lowest number of flower cluster per plant (6.67) was recorded from V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution) treatment combination. The variations among the treatment combinations in case of number of flower cluster per plant of tomato might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Ali *et al.* (2021) found that combined effect of different strength of nutrient solutions and varieties showed significant variation on number of flowers per cluster.

4.12 Number of fruits per plant

There was no significant difference in number fruit per plant of tomato in respect of variety of tomato (Table 5). The maximum number of fruits per plant (26.33) of tomato was found in V_1 (Rani). On the other hand, the minimum number of fruits per plant (25.50) was found in V_3 (Roma VF). The results revealed that the highest number of fruits per plant was found in variety V_1. Meanwhile, variety V_3 denoted the lowest number of fruits per plant. The capability of variety Rani for producing more fruits per plant compare to other varieties could be inherited from its genetic superiority to other tomato varieties. This variation in number of fruits per plant production among tomato genotypes might be attributed to the inherent genetic potentiality of the genotypes to produce flowers at controlled environmental condition. Similar results were obtained by Parvej *et al.* (2010) in poly house tomato. Ali *et al.* (2021) reported that the highest number of fruits clusters per plant (12.23) was recorded from Irelands cherry tomato (yellow) and the lowest number of fruits clusters per plant (10.70) was recorded from Local market cherry tomato (red).

There was significant difference in number of fruits per plant of tomato in respect of different application of nutrient solution (Table 5). The maximum number fruit per plant (33.89) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution) treatment. On the other hand, the minimum number of fruits per plant (17.33) was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. The results revealed that the highest number fruit per plant of tomato was found in NS_2 treatment. Meanwhile, NS_4 treatment denoted the lowest number fruit per plant. Treatment NS_2 (½ strength of Rahman and Inden nutrient solution) produced the highest number of clusters per plant that might be due to maintain optimum amount of macro and micro nutrients to allow grow faster, rate of metabolism, cell division, cell elongation. The results of the present research were consisted with the findings of Garrison *et al.* (2010). Ali *et al.* (2021) recorded that the highest number of fruits clusters per plant (15.88) was recorded from full strength Rahman and Inden treatment, whereas the lowest number of fruits clusters per plant (8.10) was found from ½ strength Arnon and Hoagland treatment. Rahman and Ali (2020) observed that the maximum number of sweet pepper fruits per plant (9.0) was found in ¾ strength Rahman and Inden (2012) + 0.5 ml. L^{-1} SIB whereas the lowest (3.0) was found in ¾ strength Rahman and Inden (2012) + 1.0 ml. L^{-1} SIB treatment.

There was significant difference in number fruit per plant of tomato in respect of combined effect of variety and application of nutrient solution (Table 6). The maximum number of fruits per plant (34.33) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) which was statistically identical with V_2NS_2 (33.37) and V_3NS_2 (33.37) treatment combination. On the other hand, the minimum number of fruits per plant (16.67) was found in V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) treatment combination. The results revealed that the highest number of fruits per plant of tomato was found in V_1NS_2 treatment combination. Meanwhile, V_3NS_4 treatment combination denoted the lowest number of fruits per plant. This might be due to the combined effect of variety and application of nutrient solution. Treatment combination V_1NS_2 or V_2NS_2 was successful in producing higher number of tomato fruits per plant compare to other combinations under this study showed greater responsiveness of the tomato varieties to NS_2 nutrient solution for producing more fruits. The variations among the treatment combinations in case of number of fruits per plant of tomato might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. Ali *et al.* (2021) found combined effect of different strength of nutrient solutions and varieties significant on number of fruits clusters per plant where the highest number of fruits clusters per plant (17.00) was observed from Irelands cherry tomato (yellow) with Full strength Rahman and Inden nutrient solution and the lowest number of clusters per plant (7.50) was attained from Local market cherry tomato (red) with ½ strength Arnon and Hoagland nutrient solution.

4.13 Yield per plant

There was significant difference in yield per plant of tomato in respect of variety of tomato (Table 7). The highest yield per plant (4.18 kg) of tomato was found in V_1 (Rani) treatment whereas, the lowest yield per plant (3.48 kg) was found in V_2 (Extra profit) treatment. The results revealed that the highest yield per plant was found in V_1 varietal treatment. Meanwhile, V_2 varietal treatment denoted the lowest yield per plant. This might be due to the varietal difference among the tomato varieties. In case of yield, variety Rani was better than Roma VF or Extra profit. Here, the varietal difference could be the reason behind better yield performance of Rani. Ali *et al.* (2021) in their experiment mentioned that the highest (3821.00 g) average fruit weight per plant was recorded in Irelands cherry tomato (yellow) and the lowest (2416.00 g) in local market cherry tomato (red). Suvo *et al.* (2016) observed that the highest yield of tomato (5.31 kg $plant^{-1}$) was recorded from Patharkuchi variety and the total amount of yield obtained from Roma VF was satisfactory. The varietals differences in growth and yield might be attributed to the differences in ecological distribution of the tomato varieties (Olaniyi, 2007). The variation in yield may also be due to genetic differences among the varieties since they were grown under the same environmental conditions (Olaniyi and Fagbayide, 1999).

There was significant difference in yield per plant of tomato in respect of different level of nutrient solution (Table 7). The highest yield per plant (5.30 kg) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution) whereas, the lowest yield per plant (2.17 kg) was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution). The results revealed that the highest yield per plant of tomato was found in NS_2 treatment. Meanwhile, NS_4 treatment denoted the lowest yield per plant. This might be due to NS_2 produced higher number of fruits per plant and number of flower clusters per plant. ½ strength Rahman and Inden solution might provide all nutrients in a balanced way and a slight acidic condition which helped to grow vegetative growth of plant. The results corroborate with the findings of Shah *et al.* (2011) who reported that half-strength nutrient solution performed better in producing higher yield per plant of tomato. Ali *et al.* (2021) from their experiment recorded that the highest average fruit weight per plant (7250.10 g) was found in full strength Rahman and Inden and the lowest (1028.50 g) in ½ strength Arnon and Hoagland nutrient solution. Rahman and Ali (2020) reported that he highest fruit yield of capsicum (2.30 kg/plant) was found in ¾ Rahman and Inden (2012) + 0.5 ml SIB treatment while the lowest yield (0.90 kg/plant) was found in ¾ Rahman and Inden (2012) + 1.0 ml of SIB treatment. Suvo *et al.* (2016) concluded that total amount of yield of tomato plants grown on Hoagland solution with jute fiber treatment was significantly higher by 28%, 86% and 37% compare to Hoagland solution with coco fiber, cotton fiber and control, respectively.

There was significant difference in yield per plant of tomato in respect of combined effect of variety and application of nutrient solution (Table 8). The highest yield per plant (7.13 kg) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution). On the other hand, the lowest yield per plant (2.00 kg) of tomato was found in V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution). The results revealed that the maximum yield per plant of tomato was found in V_1NS_2 treatment combination. Meanwhile, V_3NS_4 treatment combination denoted the lowest yield per plant. The variations among the treatment combinations in case of fruit yield per plant of tomato might be due to the characteristics of varieties and variation of strengths of nutrient solutions applied in the present study. V_1NS_2 combination seemed to be a better treatment if higher tomato yield per plant to be obtained. Ali *et al.* (2021) observed significant variation on average fruit weight per plant by combination of different strengths of nutrient solution and tomato varieties. The highest (7883.5 g) average fruit weight per plant was recorded from Irelands cherry tomato (yellow) with full strength Rahman and Inden solution and the lowest (770.16 g) were found in Local market cherry tomato (red) with ½ strength Arnon and Hoagland nutrient solution.

4.14 Yield (t ha^{-1})

There was significant difference in yield of tomato in respect of variety of tomato (Figure 11). The maximum yield (25.34 t ha^{-1}) of tomato was found in the variety of 'Rani' (V_1). On the other hand, the minimum yield (19.71 t ha^{-1}) of tomato was found in the variety of 'Extra profit' (V_2). The results revealed that the highest yield was found in V_1 treatment. Meanwhile, V_2 treatment denoted the lowest yield of tomato. In case of yield, variety Rani was better than Roma VF or Extra profit. Here, the varietal difference could be the reason behind better yield performance of Rani.

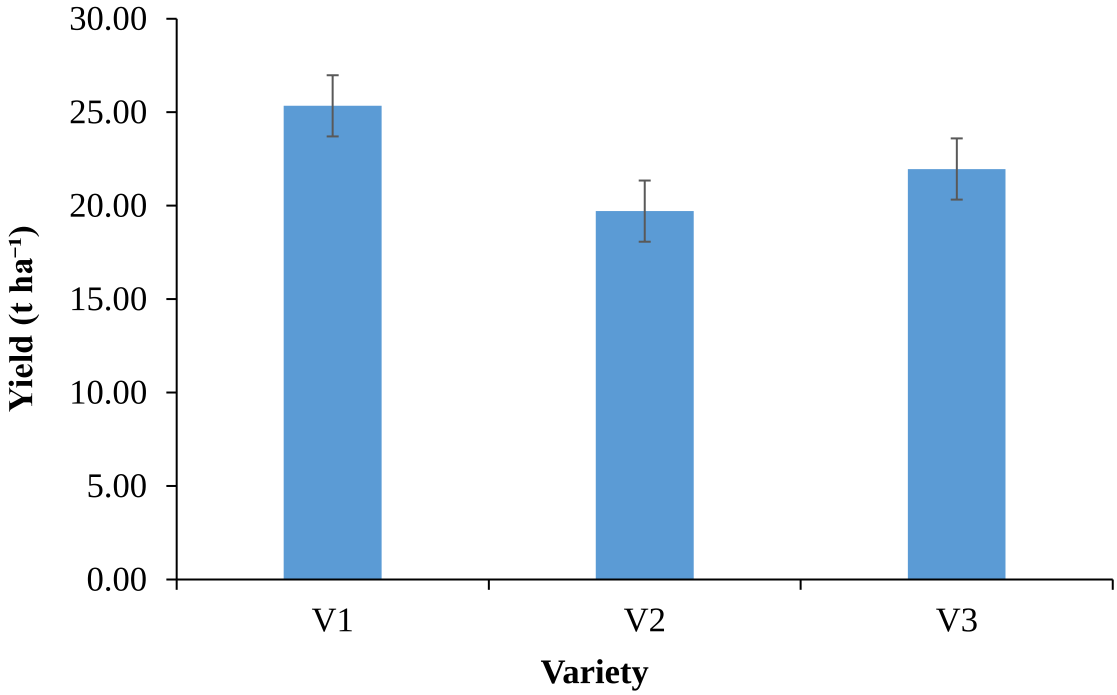

Figure 11. Varietal performance on yield of tomato. V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF. Vertical line on the graph represents standard error bar.

There was significant difference in yield of tomato in respect of different level of nutrient solution (Figure 12). The maximum yield (38.37 t ha^{-1}) of tomato was found in the application of ½ strength of Rahman and Inden nutrient solution (NS_2). On the other hand, the minimum yield (9.33 t ha^{-1}) of tomato was found in the application of Hoagland and Arnon No. 2 nutrient solution (NS_4). The results revealed that the highest yield of tomato was found in NS_2 treatment. Meanwhile, NS_4 treatment denoted the lowest yield of tomato. This might be due to the application of nutrient solution. This might be due to NS_2 produced higher number of fruits per plant and number of flower clusters per plant. ½ strength Rahman and Inden solution might provide all nutrients in a balanced way which helped to grow vegetative growth of plant which result in higher yield of tomato. Kaur *et al.* (2016) recorded that the maximum yield of tomato (72.57 t per ha) was found with (Hoagland solution at 100%) followed by Hoagland solution at 75% and Hoagland solution at 50% (50.76 t per ha). Higher yield was due to 100% concentration of Hoagland solution. This may be attributed to higher concentration of nutrients or better availability of nutrients which enhances the cell metabolisms resulting in better yield.

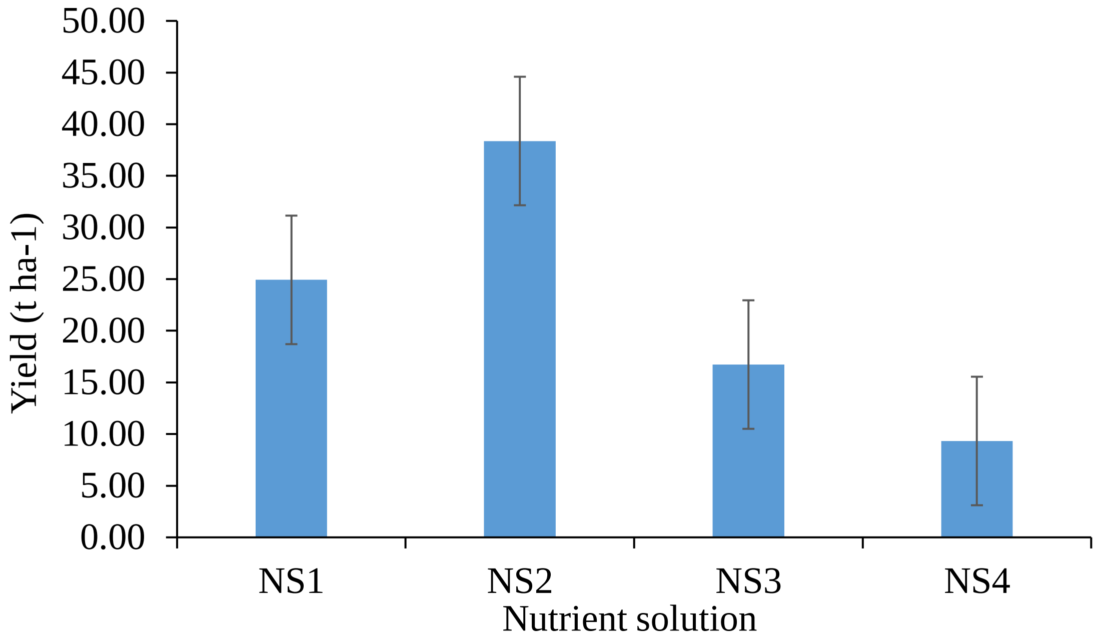

Figure 12. Effect of different nutrient solution on yield of tomato. NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

There was significant difference in yield of tomato in respect of combined effect of variety and application of nutrient solution (Figure 13). The maximum yield (40.33 t ha^{-1}) of tomato was found in the variety of 'Rani' with the application ½ strength of Rahman and Inden nutrient solution (V_1NS_2). On the other hand, the minimum yield (8.40 t ha^{-1}) of tomato was found in the variety of 'Roma VF' with the application of Hoagland and Arnon No. 2 nutrient solution (V_3NS_4). The results revealed that the maximum yield of tomato was found in V_1NS_2 treatment combination. Meanwhile, V_3NS_4 treatment combination denoted the lowest yield of tomato. This might be due to the characteristics of varieties and variation of strengths of nutrient solutions. The mean values for the commercial yield and fruit weight found in the present study were lower than those for the same varieties growing either in greenhouse (conventional system) or open field (Gualberto *et al.*, 1998). The lower yields may be partially due to a failure in controlling the nutrient solution supply, since it was performed according Resh (1997), a procedure suggested for tropical countries, not adjusted for the particular conditions of Brazil. According to Makishima and Miranda (1995), one of the major problems of using the NFT hydroponics for tomatoes is that it requires highly specialized technical support in order to properly replenish the nutrient solution in all the growing phases of the crop.

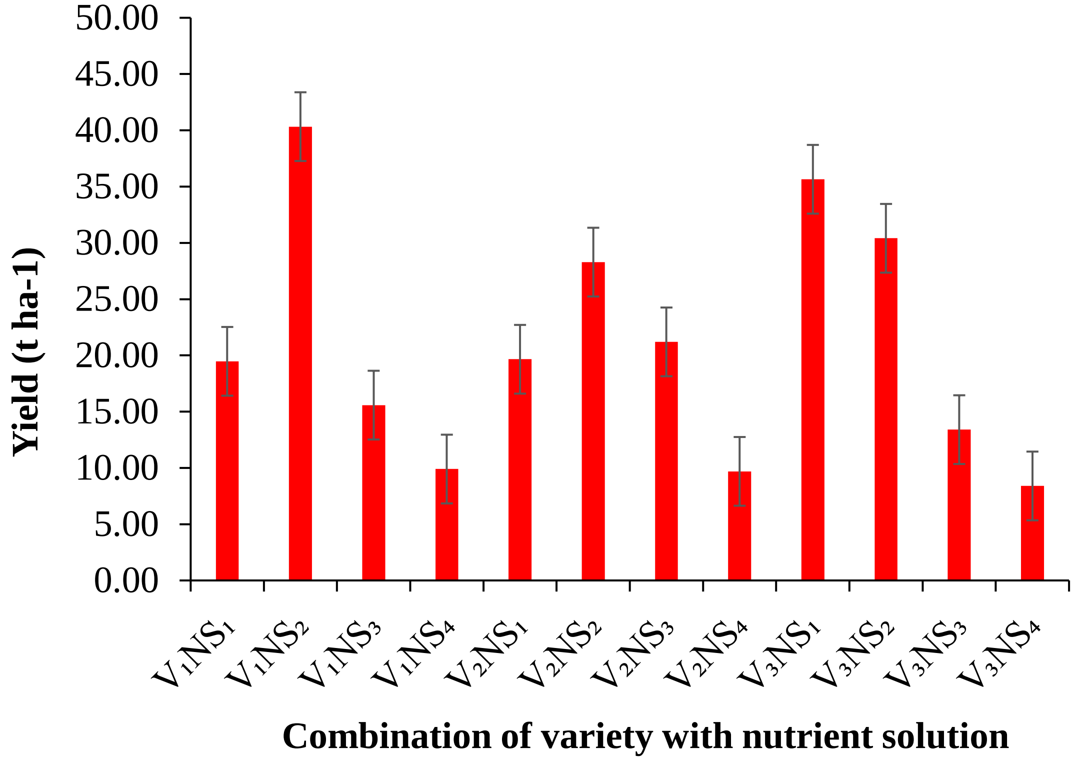

Figure 13. Interaction effects of varietal performance and nutrient solution on yield of tomato. V_1: Rani, V_2: Extra profit, V_3: Roma VF, NS_1: Rahman and Inden nutrient solution, NS_2: ½ Rahman and Inden nutrient solution, NS_3: ¾ Rahman and Inden nutrient solution and NS_4: Hoagland and Arnon No. 2 nutrient solution. Vertical line on the graph represents standard error bar.

4.15 Fruit pH

Non-Significant variation was found on fruit pH due to different variety of tomato (Table 7). Numerically, the highest fruit pH (4.31) was recorded from the variety of 'Rani' (V_1) and the lowest one (4.29) was recorded from the variety of 'Roma VF' (V_3) and 'Extra profit' (V_2). In case of fruit pH, variety Rani was better than Roma VF or Extra profit. Here, the varietal difference could be the reason behind higher fruit pH of Rani.

Significant variation was found on fruit pH of tomato due to different application of nutrient solution (Table 7). The highest fruit pH (4.75) of tomato was recorded when the application of ½ strength of Rahman and Inden nutrient solution (NS_2) and the lowest one (4.04) was recorded when the application of Hoagland and Arnon No. 2 nutrient solution (NS_4). In case of fruit pH, the differences among the concentration of different nutrient solutions could be the reason behind the differences in fruit pH.

Table 7. Varietal performance and effects of nutrient solution on yield per plant, fruit pH and fruit brix of tomato

	Yield per plant (Kg)	**Fruit pH**	**Fruit brix (%)**
Effect of variety			
V_1	4.18 a	4.31	6.34 a
V_2	3.48 c	4.29	6.04 b
V_3	3.71 b	4.29	6.10 b
$LSD_{(0.05)}$	0.07	0.06 (NS)	0.08
Effect of nutrient solution			
NS_1	4.42 b	4.26 b	6.40 b
NS_2	5.30 a	4.75 a	8.05 a
NS_3	3.27 c	4.13 c	5.37 c
NS_4	2.17 d	4.04 d	4.81 d
$LSD_{(0.05)}$	0.07	0.06	0.08

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

Significant variation was found on fruit pH of tomato due to interaction effect of variety and different application of nutrient solution (Table 8). The highest fruit pH (4.75) of tomato was attained by treatment combination V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) and V_3NS_2 (Roma VF with ½ strength of Rahman and Inden nutrient solution) which was statistically identical with V_2NS_2 (4.73). On the other hand, the lowest fruit pH (4.02) of tomato was attained by treatment combination V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution) which was statistically similar to V_1NS_4 (4.05), V_3NS_4 (4.05) and V_2NS_3 (4.11) treatment combination. The differences among the fruit pH values might be due to the characteristics of varieties and variation of strengths of nutrient solutions.

4.16 Fruit brix (%)

Different variety of tomato had significantly different value regarding fruit brix (%) (Table 7). The maximum fruit brix (6.34%) of tomato was recorded from the variety of 'Rani' (V_1). On the other hand, the minimum fruit brix (6.04%) of tomato was obtained from the variety of 'Extra profit' (V_2) which was statistically identical to V_3 (6.10 %) treatment. In case of fruit brix, variety Rani was better than Roma VF or Extra profit. Here, the varietal difference could be the reason behind higher fruit pH of Rani.

Different application of nutrient solution had significant influenced on the fruit brix (%) (Table 7). Results exposed that, treatment NS_2 (½ strength of Rahman and Inden nutrient solution) produced maximum fruit brix (8.05%) of tomato. On the other hand, the minimum fruit brix (4.81%) was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. In case of fruit brix, the differences among the concentration of different nutrient solutions could be the reason behind the differences in fruit brix. Kaur *et al.* (2016) observed that the maximum fruit brix was found in Hoagland solution at 100% concentration followed by Hoagland solution at 75% concentration and Hoagland solution at 50% concentration. The fruit brix in tomato decreased with decrease in concentration of Hoagland solution.

Table 8. Interaction effects of varietal performance and nutrient solution on yield per plant, fruit pH and fruit brix of tomato

Treatment combination	Yield per plant (Kg)	Fruit pH	Fruit brix (%)
V_1NS_1	3.89 f	4.24 b	6.37 c
V_1NS_2	7.13 a	4.75 a	8.19 a
V_1NS_3	3.30 g	4.12 c	5.11 e
V_1NS_4	2.40 i	4.05 de	4.92 f
V_2NS_1	4.53 d	4.26 b	6.41 c
V_2NS_2	4.07 e	4.73 a	7.78 b
V_2NS_3	3.21 h	4.11 cd	5.85 d
V_2NS_4	2.13 j	4.02 e	4.89 f
V_3NS_1	4.84 b	4.27 b	6.42 c
V_3NS_2	4.69 c	4.75 a	8.18 a
V_3NS_3	3.31 g	4.16 c	5.16 e
V_3NS_4	2.00 k	4.05 de	4.63 g
LSD $_{(0.05)}$	0.07	0.06	0.08

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting.]

Significant variation was found among different variety and nutrient solution application on fruit brix of tomato (Table 8). The maximum (8.19%) fruit brix of tomato exhibited by V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) which was statistically identical to V_3NS_2 (8.18 %) treatment combination. On the other hand, the minimum fruit brix (4.63 %) of tomato was exhibited by V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) combination treatment. The differences among the fruit brix values might be due to the characteristics of varieties and variation of strengths of nutrient solutions.

4.17 Leaf area (cm^2)

Leaf area (cm^2) was non-significantly influenced by variety on tomato (Table 9). Numerically, the highest leaf area (567.73 cm^2) was found due to the 'Rani' (V_1) varietal treatment. On the other hand, numerically the lowest leaf area (564.70 cm^2) was found due to the 'Roma VF' (V_3) varietal treatment. Varietal influence on leaf structure could be the reason behind different leaf area of tomato plants.

Rahman *et al.* (2017) reported that the values of leaf area were the highest in 'Legacy' variety of lettuce compared to other varieties which might be because of the genetic variations among the varieties.

The leaf area of plant is one of the major determinants of its growth. Leaf area was significantly influenced by the application of different nutrient solution at different growth stages (Table 9). ½ strength of Rahman and Inden nutrient solution (NS_2), maintained the superior leaf area (595.95 cm^2) as compared to other treatment whereas, the lowest leaf area (542.32 cm^2) was found due to the application of Hoagland and Arnon No. 2 nutrient solution (NS_4). In case of leaf area, the differences among the concentration of different nutrient solutions could be the reason behind the differences in leaf area of tomato plants. Hira (2014) stated that leaf area varied significantly by different nutrient solution in lettuce and leaf area increased in ¾ strength of Rahman and Inden nutrient solution (199.45 cm^2) compared to ½ strength of Hoagland and Arnon nutrient solution (155.01 cm^2) and ½ strength of Rahman and Inden nutrient solution (121.91 cm^2). Higher leaf area is one of the important criteria for producing higher metabolites.

Leaf area (cm^2) was significantly influenced by different varieties and nutrient solution at different growth stages (Table 10). The highest leaf area (597.53 cm^2) was recorded to the Rani with ½ strength of Rahman and Inden nutrient solution (V_1NS_2) which was statistically identical to V_2NS_2 (595.97 cm^2) and V_3NS_2 (594.34 cm^2) treatment combination. On the other hand, the lowest leaf area (541.80 cm^2) was recorded to the Extra profit with Hoagland and Arnon No. 2 nutrient solution (V_2NS_4) which was statistically identical to V_3NS_4 (541.87 cm^2) and V_1NS_4 (543.30 cm^2) treatment combination. The differences among the leaf area values might be due to the characteristics of varieties and variation of strengths of nutrient solutions.

4.18 Leaf Mass Ratio (LMR)

There was non-significant difference in leaf mass ratio in respect of variety of tomato (Table 9). Numerically, the highest leaf mass ratio (0.42 g g^{-1}) of tomato was found in V_2 (Extra profit) treatment. On the other hand, numerically, the lowest leaf mass ratio (0.39 g g^{-1}) of tomato was found in V_1 (Rani) and V_3 (Roma VF) treatment. The results revealed that the highest leaf mass ratio was found in V_2 (Extra profit) treatment. Meanwhile, V_1 (Rani) and V_3 (Roma VF) treatment denoted the lowest leaf mass ratio. This might be due to the varietal effect. Prieto *et al.* (2007) reported that increased LMR gave the plants an increased ability to intercept light. Rahman *et al.* (2017) reported variety 'Legacy' had the lowest LMR in lettuce, while 'Red fire' had the highest LMR which might be because of the genetic variations among the varieties.

There was no significant difference in leaf mass ratio in respect of application of nutrient solution (Table 9). Numerically, the highest leaf mass ratio (0.43 g g^{-1}) of tomato was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. On the other hand, numerically, the lowest leaf mass ratio (0.37 g g^{-1}) of tomato was found in NS_1 (Rahman and Inden nutrient solution) and NS_3 (¾ Rahman and Inden nutrient solution) treatment. The results revealed that the highest leaf mass ratio was found in NS_4 treatment. Meanwhile, NS_1 and NS_3 treatment denoted the lowest leaf mass ratio. In case of LMR, the differences among the concentration of different nutrient solutions could be the reason behind the differences in LMR of tomato plants. Hira (2014) stated leaf mass ratio of lettuce varied significantly by different nutrient solution. Results revealed that LMR increased in ¾ strength of Rahman and Inden nutrient solution (0.97) compared to ½ strength of Hoagland and Arnon nutrient solution (0.89) and ½ strength of Rahman and Inden nutrient solution (0.85).

There was significant difference in leaf mass ratio of tomato in respect of combined effect of variety and application of nutrient solution (Table 10). Numerically, the highest leaf mass ratio (0.47 g g^{-1}) of tomato was found in

V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution). On the other hand, numerically, the lowest leaf mass ratio (0.36 g g^{-1}) of tomato was found in V_3NS_3 (Roma VF with ¾ Rahman and Inden nutrient solution). The results revealed that the highest leaf mass ratio was found in V_2NS_4 treatment combination. Meanwhile, V_3NS_3 treatment combination denoted the lowest leaf mass ratio. The differences among the LMR values might be due to the characteristics of varieties and variation of strengths of nutrient solutions.

4.19 Leaf Area Ratio (LAR)

Leaf area ratio of tomato was significantly affected by different variety and different application of nutrient solution (Table 9). The maximum leaf area ratio (27.41 cm^2 g^{-1}) of tomato was found in V_2 (Extra profit) treatment which was statistically identical with V_3 (27.40 cm^2 g^{-1}) treatment. On the other hand, the minimum leaf area ratio (24.06 cm^2 g^{-1}) of tomato was found in V_1 (Rani) treatment. Lower LAR is one of the important criteria for producing higher metabolites. The results revealed that the lowest leaf area ratio of tomato was found in V_1 treatment. Meanwhile, V_2 treatment denoted the highest leaf area ratio of capsicum. Varietal influence on leaf structure could be the reason behind different LAR of tomato plants. Rahman *et al.* (2017) reported that variety ‘Legacy’ had the lowest LAR in lettuce, while ‘Red fire’ had the highest LAR; this might be because of the genetic variations among the varieties.

Table 9. Varietal performance and effect of different nutrient solution on physiological growth parameter of tomato

	Growth parameter			
	Leaf area (cm^2)	**LMR ($g\ g^{-1}$)**	**LAR ($cm^2\ g^{-1}$)**	**RWR ($g\ g^{-1}$)**
Effect of variety				
V_1	567.73	0.39	24.06 b	0.13
V_2	567.37	0.42	27.41 a	0.13
V_3	564.70	0.39	27.40 a	0.13
LSD $_{(0.05)}$	3.78 (NS)	0.12 (NS)	1.26	0.05 (NS)
Effect of nutrient solution				
NS_1	571.97 b	0.37	20.56 c	0.13
NS_2	595.95 a	0.42	19.72 c	0.12
NS_3	556.16 c	0.37	25.81 b	0.14
NS_4	542.32 d	0.43	39.07 a	0.13
LSD $_{(0.05)}$	3.78	0.12 (NS)	1.26	0.05 (NS)

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting. LMR = Leaf Mass Ratio, LAR = Leaf Area Ratio, RWR = Root weight Ratio, NS = Non-significant]

Again, the minimum leaf area ratio (19.72 $cm^2\ g^{-1}$) of tomato was found in NS_2 (½ Rahman and Inden nutrient solution) which was statistically identical with NS_1 (20.56 $cm^2\ g^{-1}$) treatment. On the other hand, the maximum leaf area ratio (39.07 $cm^2\ g^{-1}$) of was found in NS_4 (Hoagland and Arnon No. 2 nutrient solution) treatment. Lower LAR is one of the important criteria for producing higher metabolites. The results revealed that the lowest leaf area ratio of tomato was found in NS_1 treatment. Meanwhile, NS_4 treatment denoted the highest leaf area ratio of tomato. This might be due to the application of nutrient solution of different concentrations. Lower LAR was found by Starck (1983) in tomato, which agreed with our findings. Hira (2014) observed that leaf area ratio of lettuce varied significantly by different nutrient solution. Results revealed that LAR decreased in ¾ strength of Rahman and Inden nutrient solution (63.97) compared to ½ strength of Hoagland and Arnon nutrient solution (65.82) and ½ strength of Rahman and Inden nutrient solution (72.92). Lower LAR is one of the important criteria for producing higher metabolites.

There was significant difference in leaf area ratio of tomato in respect of combined effect of variety and application of nutrient solution (Table 10). The minimum leaf area ratio (15.41 cm^2 g^{-1}) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment combination. On the other hand, the maximum leaf ratio (41.31 cm^2 g^{-1}) of was found in V_3NS_4 (Roma VF with Hoagland and Arnon No. 2 nutrient solution) which was statistically identical (41.21 cm^2 g^{-1}) with V_2NS_4 (Extra profit with Hoagland and Arnon No. 2 nutrient solution) treatment combination. Lower LAR is one of the important criteria for producing higher metabolites. The results revealed that the lowest leaf area ratio was found in V_1NS_2 treatment combination. Meanwhile, V_3NS_4 treatment combination denoted the highest leaf area ratio. This might be due to the combined effect of variety and application of different nutrient solution. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings.

4.20 Root Weight Ratio (RWR) (g g^{-1})

Root weight ratio of tomato was not significantly affected by different variety of tomato (Table 9). Numerically, the root weight ratio (0.13 g g^{-1}) of tomato was found in all tomato variety. Varietal influence on root structure could be the reason behind different RWR of tomato plants. Lower RWR is one of the important criteria for producing higher metabolites. Rahman *et al.* (2017) reported that the value of RWR was the maximum in 'Legacy' variety of lettuce compared to other varieties which might be because of the genetic variations among the varieties.

There was no significant difference in leaf mass ratio in respect of application of nutrient solution (Table 9). Numerically, the lowest root weight ratio (0.12 g g^{-1}) of tomato was found in NS_2 (½ strength of Rahman and Inden nutrient solution) treatment whereas, the highest root weight ratio (0.14 g g^{-1}) of tomato was found in NS_3 (¾ strength of Rahman and Inden nutrient solution) treatment. The results revealed that the lowest root weight ratio was found in NS_2 (½ strength of Rahman and Inden nutrient solution) treatment. Meanwhile, NS_3 (¾ strength of Rahman and Inden nutrient solution) treatment denoted the highest root weight ratio. This differences among RWR might be due to the application of nutrient solution of different concentrations. Hira (2014) observed that root weight ratio of lettuce varied significantly by different nutrient solution. Results revealed that RWR decreased in ½ strength of Rahman and Inden nutrient solution (0.124) compared to ¾ strength of Rahman and Inden nutrient solution (0.139) and ½ of Hoagland and Arnon nutrient solution (0.175). Lower RWR is one of the important criteria for producing higher metabolites.

Table 10. Interaction effects of different varieties and nutrient solution on physiological growth parameter of tomato

Treatment combination	Growth parameter			
	Leaf area (cm^2)	LMR ($g\ g^{-1}$)	LAR ($cm^2\ g^{-1}$)	RWR ($g\ g^{-1}$)
V_1NS_1	571.65 b	0.37	21.44 f	0.13
V_1NS_2	597.53 a	0.40	15.41 h	0.11
V_1NS_3	559.99 c	0.38	24.70 d	0.14
V_1NS_4	543.30 e	0.42	34.70 b	0.14
V_2NS_1	571.62 b	0.39	18.58 g	0.12
V_2NS_2	595.97 a	0.43	23.60 de	0.12
V_2NS_3	558.53 c	0.37	26.28 c	0.13
V_2NS_4	541.80 e	0.47	41.21 a	0.13
V_3NS_1	572.65 b	0.37	19.14 g	0.14
V_3NS_2	594.34 a	0.43	22.69 ef	0.12
V_3NS_3	549.95 d	0.36	26.44 c	0.13
V_3NS_4	541.87 e	0.39	41.31 a	0.12
LSD $_{(0.05)}$	3.78	0.12 (NS)	1.26	0.05 (NS)

[Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF, NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. DAT = Days after transplanting. LMR = Leaf Mass Ratio, LAR = Leaf Area Ratio, RWR = Root weight Ratio, NS = Non-significant]

There was no significant difference in root weight ratio of tomato in respect of combined effect of variety and application of nutrient solution (Table 10). The lowest root weight ratio (0.11 $g\ g^{-1}$) of tomato was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution). On the other hand, the highest root weight (0.14 $g\ g^{-1}$) of tomato was found in V_1NS_3 (Rani with ¾ strength of Rahman and Inden nutrient solution), V_1NS_4 (Rani with Hoagland and Arnon

No. 2 nutrient solution) and V_3NS_1 (Roma VF with Rahman and Inden nutrient solution). The results revealed that the lowest root weight ratio was found in V_1NS_2 (Rani with ½ strength of Rahman and Inden nutrient solution) treatment combination. The differences among the RWR values might be due to the characteristics of varieties and variation of strengths of nutrient solutions.

CHAPTER V

SUMMARY AND CONCLUSION

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An experiment was conducted at semi-greenhouse at Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from August, 2019 to March, 2020 to study the effect of nutrient solution on growth and yield of tomato cultivars in hydroponic culture. The experiment was consisted of two factors: Factor A: Three tomato cultivars viz; V_1 = Rani (Krishibid Seed Ltd.), V_2 = Extra profit (Supreme Seed Co. Ltd.) and V_3 = Roma VF (Afroza Seed Company.); Factor B: Four types of nutrient solution viz; NS_1 = Rahman and Inden nutrient solution, NS_2 = ½ Rahman and Inden nutrient solution, NS_3 = ¾ Rahman and Inden nutrient solution and NS_4 = Hoagland and Arnon No. 2 nutrient solution. The two factors experiment was laid out in Completely Randomized Block Design (RCBD) with three replications. Total 36 unit-pots was used for the experiment with 12 treatments. Each pot was of 12-inch. Data on different growth and yield parameter of tomato were recorded and significant variation was recorded for different treatments.

The result revealed that tomato variety V_1 (Rani) exhibited its superiority to other tested variety Extra profit and Roma VF in terms of fruit yield, the former out-yielded over V_3 (Roma VF) by 12.67% higher yield. V_1 (Rani) also showed the highest weight of fruits (110.95 g) and the maximum number of fruits per plant (26.33) than other tested varieties in this experiment. On the other hand, the variety V_2 (Extra profit) returned with 20.11% lower yield than variety V_1 (Rani) which was significantly the lowest compare with other varieties under study.

Significant differences existed among different nutrient solutions with respect to yield and yield attributing parameters of tomato. A yield advantages of 0.88 kg per plant, 2.03 kg per plant and 3.13 kg per plant over NS_1 [Rahman and Inden nutrient solution], NS_3 (¾ Rahman and Inden nutrient solution) and NS_4 [Hoagland and Arnon No. 2 nutrient solution] treated plot, respectively was found which was possibly aided by taller plant at harvest (150.70 cm), higher number of leaves plant^{-1} (40.09), larger leaf area (595.95 cm^2), higher number of branches plant^{-1} (11.00), higher percentage of dry matter plant^{-1} (20.73%), lengthier fruit length (4.46 cm), larger fruit diameter (4.21 cm), heavier individual fruit weight (105.21 g), higher number of flower cluster plant^{-1} (18.78), higher number of fruit plant^{-1} (33.89), higher fruit pH (4.75) and higher fruit brix (8.05) in the NS_2 [½ Rahman and Inden nutrient solution] treatment. On the other hand, NS_1 [Rahman and Inden nutrient solution] show the second-best result followed by NS_2 treatment in some parameters like—plant height, number of leaves plant^{-1}, leaf area, number of branches plant^{-1}, fruit length, fruit diameter, fruit weight, number of flower cluster plant^{-1}, number of fruit plant^{-1}, fruit pH and fruit brix. On the other hand, treatment NS_4 [Hoagland and Arnon No. 2 nutrient solution] showed the worst result compared with other nutrient solution treatments.

Interaction results of variety and nutrient solution indicated that all the studied parameters were influenced significantly except leaf mass ratio and root weight ratio of tomato. Significantly the highest fruit yield per plant (7.13 kg) and yield ha^{-1} (40.33 t) of tomato was found in V_1NS_2 [Rani × ½ strength Rahman and Inden nutrient solution] interaction due to the largest leaf area (595.97 cm^2), highest number of branches plant^{-1} (11.00), lengthiest fruit length (4.50 cm), largest fruit diameter (4.20 cm), heaviest individual fruit weight (110.95 g) and the maximum number of fruits plant^{-1} (33.67) production. It was also observed that V_3NS_1 combination [Roma VF × full strength Rahman and Inden nutrient solution] showed the second highest fruit yield per plant (4.84 kg) and yield ha^{-1} (35.65 t) aided by length of fruit (3.87 cm) and number of fruit plant^{-1} (29.67).

CONCLUSION

It was revealed that V_1 (Rani) and NS_2 [½ strength Rahman and Inden nutrient solution] treatment gave higher fruit yield along with higher values in most of the growth and yield attributing parameters. Interaction of V_1NS_2 [Rani × ½ strength Rahman and Inden nutrient solution] performed the best in respect of growth, yield attributing parameters including fruit yield. From the result of the experiment, it may be concluded that Rani cultivated with ½ strength Rahman and Inden nutrient solution seems promising for tomato production in hydroponic culture.

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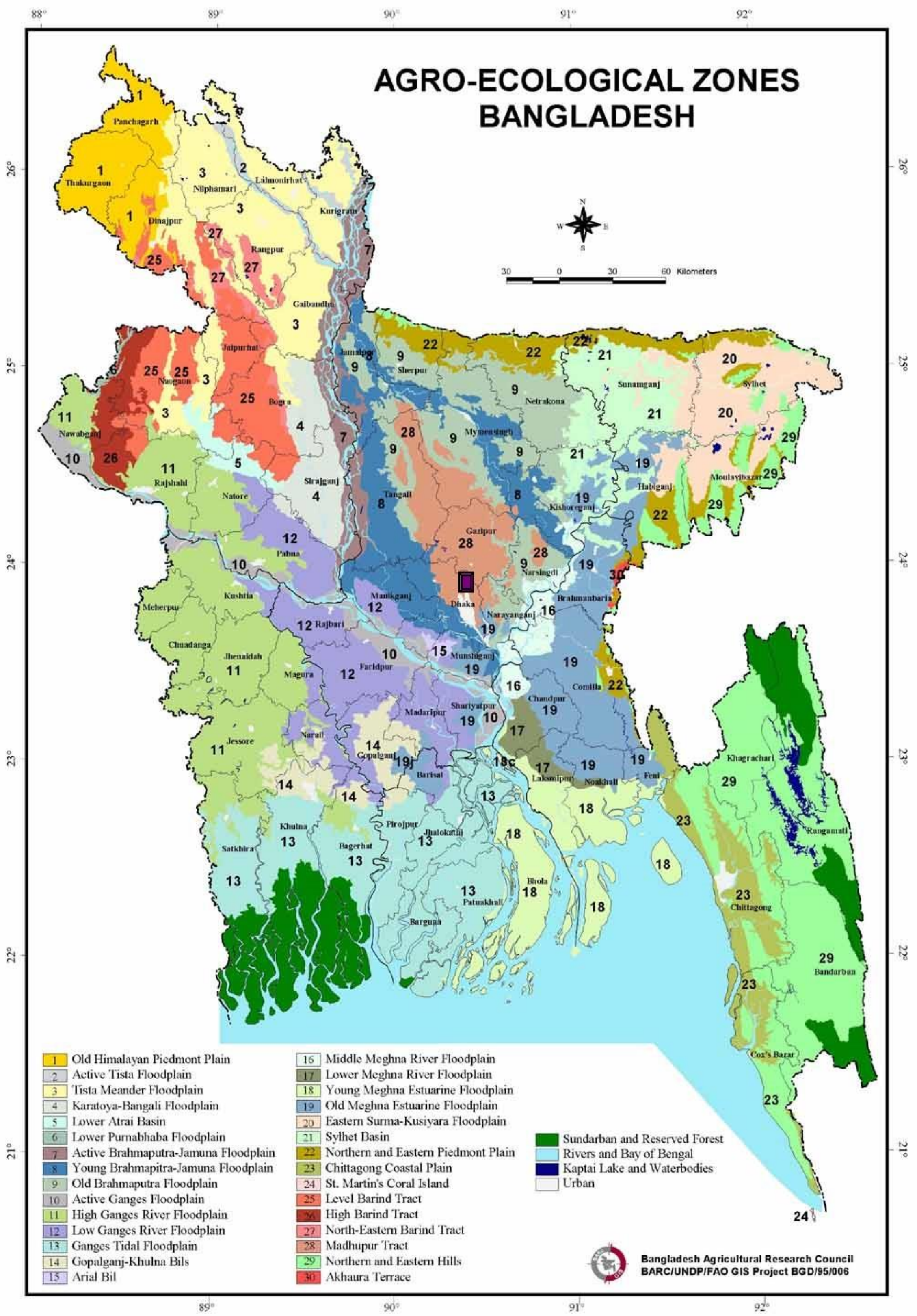
APPENDICES

APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from September, 2019 to March, 2020

Month	Air temperature (°C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
August, 2019	33.45	24.87	87	96
September, 2019	30.57	21.45	83	71
October, 2019	31.82	14.04	81	24
November, 2019	23.40	10.50	76	5
December, 2019	20.18	7.04	73	0
January, 2020	18.20	9.70	77	15
February, 2020	23.57	15.78	86	74

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix III. Analysis of variance (mean square) of plant height at different days after transplanting (DAT) of tomato

Source of variation	Degrees of freedom (df)	Plant height			
		30 DAT	60 DAT	90 DAT	120 DAT
Variety (V)	2	10.897*	49.245*	170.324^{NS}	50.408*
Nutrient solution (NS)	3	6.051**	49.026**	110.420*	9.672**
V × NS	6	0.549*	3.452**	9.923*	0.577*
Error	24	1.305	8.520	29.517	2.325

* and ** indicate significant at 5% and 1% level of probability, respectively.
NS = non-significant

Appendix IV. Analysis of variance (mean square) of number of leaves per plant, leaf area (cm^2), number of branches per plant and dry matter per plant (%) of tomato

Source of variation	Degrees of freedom (df)	No. of leaves per plant	Leaf area	No. of branches per plant	Dry matter per plant
Variety (V)	2	13.411*	571.676^{NS}	53.933 ^{NS}	27.136**
Nutrient solution (NS)	3	16.141**	546.668*	3.034*	17.304**
V × NS	6	0.396*	8.145*	6.954*	10.001**
Error	24	0.283	0.825	0.585	6.063

* and ** indicate significant at 5% and 1% level of probability, respectively
NS = non-significant

Appendix V. Analysis of variance (mean square) of fruit length (cm), fruit diameter (cm), fruit weight (g) and fruit dry weight (g) of tomato

Source of variation	Degrees of freedom (df)	Fruit length	Fruit diameter	Fruit weight	Fruit dry weight
Variety (V)	2	50.408^{NS}	119.856^{NS}	49.245*	5.300*
Nutrient solution (NS)	3	9.672*	26.023*	49.026**	9.191**
V × NS	6	0.577*	6.475*	3.452*	3.825*
Error	24	2.327	13.856	8.520	25.214

* and ** indicate significant at 5% and 1% level of probability, respectively
NS = non-significant

Appendix VI. Analysis of variance (mean square) of first flowering (DAT), first fruiting (DAF), number of clusters per plant and number of fruits per plant

Source of variation	Degrees of freedom (df)	First flowering	First fruiting	No. of cluster per plant	No. of fruit per plant
Variety (V)	2	62.519^{NS}	65.135*	8.090**	46.212^{NS}
Nutrient solution (NS)	3	3.558*	11.910*	2.122**	25.339*
V × NS	6	3.345**	2.393*	1.673**	2.480*
Error	24	20.387	48.889	20.423	10.007

*** and ** indicate significant at 5% and 1% level of probability, respectively**
NS = non-significant

Appendix VII. Analysis of variance (mean square) of yield and fruit quality of tomato

Source of variation	Degrees of freedom (df)	Yield per plant	Yield	Fruit pH	Fruit brix %
Variety (V)	2	0.633**	145.606**	53.933^{NS}	37.946*
Nutrient solution (NS)	3	1.753**	12.964**	3.034*	27.845*
V × NS	6	0.355**	3.995**	6.954*	2.737*
Error	24	0.365	0.310	0.585	14.829

* and ** indicate significant at 5% and 1% level of probability, respectively
NS = Non-significant

Appendix VIII. Analysis of variance (mean square) of physiological growth parameter of tomato

Source of variation	Degrees of freedom (df)	LMR	LAR	RWR
Variety (V)	**2**	**0.420^{NS}**	**12.536****	**0.618^{NS}**
Nutrient solution (NS)	**3**	**0.923^{NS}**	**24.267****	**0.715^{NS}**
V × NS	**6**	**0.517^{NS}**	**15.272***	**0.262^{NS}**
Error	**24**	**0.251**	**0.825**	**0.834**

* and ** indicate significant at 5% and 1% level of probability, respectively
NS = Non-significant

PLATES

Plate 12. Tomato plants

Plate 13. Flower clusters in tomato plant

Plate 14. Tomato fruits (Unripe and half ripe)

Plate 15. Ripen tomato fruits