EFFECT OF GROWING SUBSTRATES ON GROWTH, YIELD AND QUALITY OF DIFFERENT TOMATO CULTIVARS IN HYDROPONIC CULTURE

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CERTIFICATE

This is to certify that thesis entitled, "EFFECT OF GROWING SUBSTRATES ON GROWTH, YIELD AND QUALITY OF DIFFERENT TOMATO CULTIVARS IN HYDROPONIC CULTURE" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (MS) in HORTICULTURE, embodies the result of a piece of bonafide research work carried out by Sharmin Sultana, Registration no. ***14-05807*** *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.

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Dedication

Every challenging work needs self efforts as well as guidance of elders especially those who are very close to our heart.

My humble effort I dedicate to my sweet and loving

Father & Mother,

whose affection, love, encouragement and prays of day and night make me able to get such success and honor,

Along with all hard working

and respected

Teachers

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The Author

EFFECT OF GROWING SUBSTRATES ON GROWTH, YIELD AND QUALITY OF DIFFERENT TOMATO CULTIVARS IN HYDROPONIC CULTURE

ABSTRACT

Mixing of different growing substrates have the ability to improve aeration of the growing substrates. Therefore, a pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from September-2019 to March-2020, to investigate the effect of growing substrates on growth, yield and quality of different tomato cultivars in hydroponic culture. The experiment consisted of two factors, and followed completely randomized design (CRD) with three replications. Factor A: Three tomato cultivars viz;V_1 = Rani; V_2 = Extra profit and V_3 = Roma VF, Factor B: Four different growing substrate viz*;* M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust and + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Results revealed that the highest number of fruits plant^{-1} (24.89), fruit polar length (3.67 cm), fruit radial length (3.60 cm), individual fruit fresh weight (47.64 g), individual fruit dry weight of tomato (2.55 g) and yield plant^{-1} (1.19 kg) was found in 70 % Cocopeat + 30 % Khoa (M_1) based growing substrate. In case of different tomato cultivars the highest yield plant^{-1} (1.14 kg) was found in Rani tomato cultivar (V_1). In case of combination, the highest fruit plant^{-1} (27.67), fruit polar length (4.08 cm), fruit radial length (3.99 cm), individual fruit fresh weight (48.13 g), fruit dry weight (2.77 g), yield plant^{-1} (1.33 kg) and fruit volume (204.50 cc) was found in V_1M_1.Therefore, it can be concluded that Rani tomato cultivar can be grown in M_1substrate with higher yield and quality of tomato in hydroponic culture.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agric.
Agro-Ecological Zone	AEZ
And others	*et al.*
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Centimeter	Cm
Cultivar	Cv.
Degree Celsius	°C
Dry weight	DW
Editors	Eds.
Electrical Conductivity	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
Gram	g
International	Intl.
Journal	J.
Kilogram	kg
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.
Percentage	%

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular vegetables in Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2010). But in Bangladesh, it ranks 2nd which is next to potato (BBS, 2020) and it has great demand throughout the year especially in early winter and summer, but its production is mainly concentrated during the winter season. In Bangladesh recent statistics showed that tomato was grown in 30756 ha of land and the total production was approximately 414 thousand metric tons in 2015. Thus, the average yield of tomato in Bangladesh was 16.58 t ha^{-1} (BBS, 2020), while it was 87.96 t ha^{-1} in USA, 49.87 t ha^{-1} in China and 20.12 t ha^{-1} in India (FAOSTAT, 2012). Increased production of tomato depends on many factors, such as the use of improved varieties, proper management, quality of seed, awareness about improved production technologies like hydroponics and even conventional breeding methods, which may improve production level and quality under the existing environmental conditions.

Cultivation of hybrid tomato varieties has increased considerably throughout the world and has many advantages compared to open pollinated ones. BARI and some seed companies have released a good number of tomato varieties which have high yielding potential with longer harvest duration.

Recently modern production techniques like hydroponics have gain importance. The word hydroponics literally means "working water", but it is a method of growing plants without soil or with an inert substrate added with all necessary nutrients. It is a valuable means of growing fresh vegetables not only in countries having little arable land but also in those which are very small in area yet have a large production. The achievement of maximum yield by supplying sufficient quantity of nutrients and optimum microclimatic conditions is the main goal of hydroponics (Bogovic, 2011). It does not need any fertile soil for the production of crops. Since soil is excluded from production process there will not be any problem related to soil borne diseases, pests and weeds. By the exclusion of these problems, use of harmful plant protection chemicals can be avoided. So the yield from hydroponics is fresh and healthy.

Cocopeat is considered as a good growing substrate component with acceptable pH, electrical conductivity (EC) and other chemical attributes (Abad *et al*., 2002). Carbonized rice husk induced faster cell division and differentiation for root formation (Rahman*et al*., 2018) and it was one of the 3 the best growing substrates for chrysanthemum cutting (Salé *et al*., 2021). Aside its use in nursery production, it may be used as soilless growing media for sweet pepper production. Sawdust is used as growing substrate and is available in almost all over the world and it can be used as a renewable substrate. Wood residues (i.e., sawdust and bark) have been used in containers for growing ornamentals (Ilyushenko *et al*., 2020). But microorganisms involved in decomposition of raw wood residues are more efficient than higher plants in nitrogen absorption and assimilation (Campos*et al*., 2018). Large amount of nitrogen must, therefore, be added to wood residues used as media to grow plants. Wood chips, produced from steam friction of wood, is a very efficient organic substrate for hydroponics. It has the advantage that it keeps its structure for a very long time. However, more recent research suggests that wood chips may have detrimental effects on "plant growth regulators" (Böhme *et al.,* 2008). Furthermore, a suitable hydroponic growing substrate positively influences the growth and yield of horticultural crop production like tomato as a test crop.

By considering the above fact the proposed research work was undertaken with a view to achieve the following objectives;

i. To investigate the performance of different tomato cultivars grown on locally available growing substrates in Bangladesh
ii. To investigate the effect of locally available growing substrates on growth and yield of tomato cultivars in hydroponic culture

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available to investigate the effect of growing substrates on growth and yield of different tomato cultivars inhydroponic culture, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of cultivars

Shah *et al*. (2021) carried out a study to know the performance of tomato cultivars transplanted on various dates under the agro-climatic conditions of district Buner. The treatments were arranged in split plot using RCBD which were replicated thrice. There were two factors, Factor-A was the transplantation date (13th, 20th, 27th March and 03rd April) which were subjected to the main plot and Factor-B was cultivars (Anna, Sahil and Summer Red) which were assigned to the sub plot. The data was recorded on various parameters. Among different cultivars Anna resulted in tallest plant (258.37 cm), more branches plant^{-1} (41.73), fruits plant^{-1} (80.58), fruit weight (133.43 g), fruit diameter (5.00 cm), yield (95.16 tons ha^{-1}), lowest fruit drop (4.87 %) and disease incidence (2.30 %).

Sanjida *et al*. (2020) conducted an experiment to observe the effect of varieties and boron on growth and yield of summer tomato and reported that fruit length and width were varied significantly (p <0.05) among the varieties of summer tomato and boron levels. The longest fruit length (41.87 mm) and maximum fruit width (48.0 mm) were recorded from V_2 (BARI hybrid tomato 8) while the shortest fruit length (33.07 mm) and minimum fruit width (34.60 mm) were observed from V_3(BARI hybrid tomato 10) variety. The marked differences in fruit length and fruit width might be due to the different genetic makeup of the summer tomato varieties.

Sanjida *et al*. (2020) conducted a field research to examine the effect of different levels of boron (B) on physico-chemical quality of different summer tomato (*Lycopersicon esculentum* Mill.). The experiment comprised of two factors, a) summer tomato varieties viz., BARI hybrid tomato 4, 8 and 10; and b) B levels- five levels of B viz., 0, 1, 2, 3 and 5 kg ha^{-1}. The experiment was laid out in a randomized

complete block design (RCBD) with three replications. Experiment results showed that the longest fruit length (41.87 mm) and maximum fruit width (48.0 mm) were recorded from V_2 (BARI hybrid tomato 8) while the shortest fruit length (33.07 mm) and minimum fruit width (34.60 mm) were observed from V_3(BARI hybrid tomato 10) variety. The marked differences in fruit length and fruit width might be due to the different genetic makeup of the summer tomato varieties. Significant variations ($p<0.05$) were observed in case of total soluble solids (TSS) and pH content of summer tomato varieties. The highest TSS (5.41%) was found from V_2 (BARI hybrid tomato 8) which was statistically similar with V_3 (BARI hybrid tomato 10) (5.23%) while the lowest TSS (4.97%) was obtained from V_1 (BARI hybrid tomato 4). The highest (3.88) and lowest (3.71) pH were found from V_3 (BARI hybrid tomato 10) and V_1 (BARI hybrid tomato 4), respectively. Varietal character might influence the variations of TSS and pH in summer tomato.

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetic makeup.

Biswas *et al.* (2017) carried out an experiment which was at the field laboratory of Horticulture Department, Sylhet Agricultural University during winter season from October 2013 to March 2014 with a view to evaluate fruit and seed production potentiality of tomato genotypes. Eight tomato genotypes namely C-11, C-21, C-41, C-51, C-71, FP-5,WP-10 and HT-025 were used for the study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. A remarkable variation was observed among the tomato genotypes at the seedling stage of hypocotyls color, stem length, root length and number of leaves at 1st inflorescences of seedlings etc. The genotype C-41 produced the highest number of fruits (48.00 plant^{-1}) but its corresponding individual fruit weight was the lowest (34.33 g). The lowest number of fruits plant^{-1} was harvested from the line WP-10 (22.33 plant^{-1}), and it had the highest individual fruit weight (66.67 g). Significant variation was observed in weight of fruit plant^{-1}. The highest fruit yield plant^{-1} was recorded from the genotype HT-025 (2.02 kg plant^{-1}) and the lowest was recorded from the line FP-5 (1.17 kg plant^{-1}). The variation in different characters of tomato might be due to difference in cultivars used.

Khondakar *et al.* (2017) reported that the differences in number of branches might be due to the different genetic makeup of the summer tomato varieties.

Ali *et al.* (2016) conducted an experiment to Evaluate various tomato (*Lycopersicon esculentum*Mill.) cultivars for quality, yield and yield component under agro-climatic condition of Peshawar and found significant variation in respect of total soluble solids in different genotypes of tomato and maximum TSS (4.98 %) and minimum TSS (3.70 %) were observed in Bambino and Money maker tomato varieties respectively.

Khan *et al.* (2016) carried out an experiment to know the effect of different mulching materials on weeds and yield of chili cultivars and reported that in production of branches the differences among the cultivars might be due to their hereditary composition.

Helal*et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final yield of the crop.

Aoun*et al*. (2013) reported that tomato quality parameters can be verified by both physical and chemical characteristics of the fruit.

Jilani*et al.* (2013) reported minimum stem diameter (9.11 mm) in tomato cultivar Nema-1200 while the maximum stem diameter (14.95 mm) in tomato cultivar Vegnesh during comparison. He also reported that cultivar Nandi and Vegnesh took least days to flowering.

Singh *et al.* (2013) studied the performance of different tomato hybrids under greenhouse conditions in 2008 to 2009 and 2009 to 2010 at Hissar and reported that Avinash-23 recorded maximum yield per plant of 2.90 kg followed by Richa with a yield of 2.88 kg.

Tyeb*et al.* (2013) reported that the variation in plant height is due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars.

According to Mehmood*et al.* (2012) the tomato germplasm BINA Tomato-6 took maximum time to first flower appearance when compared with the other twentyone germplasms.

Ali *et al.* (2012) found maximum fruit diameter (5.19 cm) and minimum fruit diameter (4.50 cm) in tomato hybrids T-7010 and PTM-1603 respectively during studying the performance of various tomato hybrids.

Islam *et al.* (2012) studied the genetic variability of eleven inbred lines of cherry tomato and reported that line CH155 (5.7%) had the highest total soluble solids followed by CLN1555A (4.9%).

Naz *et al.* (2012) found that number of flower clusters plant^{-1} had significant variation among the tomato varieties.

Chapagain *et al*. (2011) assessed the performance of tomato varieties under plastic house for two successive years from 2009 to 2010 in Nepal. The highest marketable yield was recorded from All Rounder (86.6 t ha-1) followed by Srijana (80.8 t ha^{-1}).

Olaniyi *et al*, (2010) carried out an experiment where the assessment of seven varieties of tomatoes was done. He evaluated the growth, fruit yield and quality of the varieties. The results showed that DT97/162A(R) gave the highest height compared to Ogbomoso local variety. This shows that the yield and the quality of tomato depend on the variety.

Deepa and Thakur (2008) reported that the variations in number of leaves plant^{-1}was possibly due to the varietal characters of summer tomato.

Roy (2009) mentioned that the number of fruits plant^{-1} ranged from 35 to 76.39. The variation of fruits plant^{-1} of tomato might be due to difference of cultivars used.

Patwary (2009) reported that the fruit length and width varied from 3.24 cm to 6.09 cm and 2.99 cm to 6.80 cm, respectively.

Gardner (2006) reported that the maximum average fruit weight of (361 g) was obtained by tomato cultivar Mountain Spring during the comparison of different tomato cultivars.

2.2 Effect of different substrates

Lakshmikanth *et al.* (2020) conducted a study on the development of above ground plant parts of strawberry cv. 'Winter dawn', in naturally ventilated polyhouse with seven different substrate combinations consisting of soil, sand, farmyard manure, cocopeat, vermicompost and vermiculite under vertical faring system and reported that the maximum yield per plant (391.24 g) was found in treatment combination comprising of soil, cocopeat, vermiculite and vermicompost in combination ratio of 1:1:1:1 on volume basis followed by the treatment combination comprising of cocopeat, vermiculite and vermicompost in combination ratio of 1:1:1.

Kilic *et al*. (2018) compared the effect of four substrates on the growth and quality of tomato in the greenhouse. The substrates used were rockwool (R), perlites + carbonized rice hulls (PCRH), Cyprus bark (CB) and coconut coir (CD). Coconut coir (CD) represented higher number of fruits per cluster, increased productivity, which were closely followed by perlites + carbonized rice hulls PCRH treatment.

Raja *et al.* (2018) studied the influence of substrates on different growth and quality parameters of strawberry cv. Chandler under greenhouse conditions and reported that cocopeat, vermiculite with combination ratio of 25:75 showed better performance in respect of maximum petiole length (16.77 cm), diameter of crown (2.10 cm), canopy spread (42.75 cm), fresh weight of shoot (17.16 g), dry weight of shoot (4.36 g), fresh weight of root (16.53 g), dry weight (5.13 g) of root, leaf area (1542 cm2), number of leaves (17), weight of fruit (10.76 g), diameter of fruit (27.48 mm), length of fruit (29.89 mm) whereas the treatment consisting of cocopeat, perlite, and vermiculite with combination ratio of 50:25:25 produced maximum plant height (28.36 cm), length of shoot (23.13 cm), length of root (32.40 cm), TSS (10.8 0B) and lowest titrateable acidity (0.86%).

Shahzad *et al.* (2018) conducted an experiment to evaluate the impact of organic growing media on the growth and yield of strawberry cv. Chandler and reported that peat moss amendment showed the maximum fruit yield (531.56 g) in strawberry.

Shahzad *et al.* (2018) conducted a study regarding variations in growing media for the improved production of strawberry cv. Chandler and revealed that peat moss amendment reported the maximum yield (531.56 g), leaf chlorophyll content (12.53) and TSS (8.45).

Truong *et al.* (2018) reported that the plant height of tomato was maximum in the medium containing mixture of vermicompost, cocopeat and rice husk as the physico-chemical properties of media were optimal for the root growth development.

Thakur and Shylla (2018) carried out a study on impact of different growing media on growth and yield of strawberry cv. Chandler under protected conditions and reported that perlite as a growing media shows maximum number of leaves (18.32), root length (18.91 cm) and number of runners (40.25) significantly.

Mathowa *et al.* (2017) reported that the variation of plant height, leaf number, radius and branches plant^{-1} was due to use of different growing media that vary greatly in composition, particle size, pH, aeration and ability to hold water and nutrients.

Rodriguez-Ortega *et al.* (2017) reported that plants grown hydroponically had the greatest vegetative growth, characterized by their high leaf and stem biomass and large total area.

Dhaker *et al.* (2016) carried out a study on the influence of growing media and various containers on papaya variety Pusa Nanha and resulted that soil, FYM, sand, cocopeat, and vermicompost with combination ratio of 1:1:1:1:1 gave better performance in respect of seedling height (12.30 cm), leaf number per seedling (10.92), area of leaves (28.65 cm), leaf fresh weight (3.88 g), dry weight of leaves (0.43 g), primary root diameter (2.45 mm), index of seedling vigor (1683.52) and root and shoot ratio (0.14).

Godara (2016) conducted an experiment on the impact of different growing systems on roots of strawberry under green house and revealed that the plants grown in treatment combination comprising of cocopeat, perlite and vermicompost (3:1:1) gave highest yield (339.43 g and 345.01 g) whereas, lowest yield (143.93 g and 171.54 g) per plant was recorded from soil (control).

Haghighi *et al.* (2016) observed that the highest fruit weight and yield per plant was obtained in tomato plants grown in substrate combination of control + vermiculite + perlite (C25:V25:PR50) as compared to control.

Dysko*et al*. (2015) carried out a study on lignite as a medium in soilless cultivation of tomato. It showed that, under hydroponics tomato plants produced highest early

marketable and total yield when grown in lignite media and this was not significantly different from the marketable yield obtained under coir pith.

Mazahreh *et al.* (2015) revealed that Perlite + cocopeat (1:1) produced significantly highest total yield (112.9 t ha^{-1}) as compared to cocopeat (46 t ha-1). The total yield (112.1 t ha^{-1}) was on Perlite and Perlite + cocopeat in 2:1 proportion (98.4 t ha^{-1}) in cucumber.

Soumya and Usha (2015) evaluated tomato in soilless culture, the experiment comprised of two pot culture experiments. First experiment was to standardize the growth media for soilless culture. The experiment consisted of eight treatments, namely, Coir pith + FYM (1:1), Coir pith + FYM (1:2), Coir pith compost + FYM (1:1), Coir pith compost + FYM (2:1), Coir pith compost alone, Neopeat + FYM (1:1), Neopeat + FYM (1:2) and potting mixture (1:1:1 soil, sand and FYM), replicated thrice. Coir pith compost +FYM (2:1) was found to be the best soil less media for tomato cultivation in grow bags.

Joseph and Muthuchamy (2014) conducted the case study on productivity, quality and economics of tomato cultivation in aggregate hydroponics. The maximum yield (4.9 kg $plant^{-1}$) was observed for the treatment trough with cocopeat + gravel + silex stone followed by trough with cocopeat + prelite + silex stone (4.2 kg $plant^{-1}$) and trough with cocopeat + pebble + silex stone (3.9 kg $plant^{-1}$). The highest productivity (245.3 t ha^{-1}) was obtained from the treatment trough with cocopeat + gravel + silex stone. The treatment tray with cocopeat + pebble + silex stone yielded (2.8 kg $plant^{-1}$) least productivity (138.3 t ha^{-1}).

Kumawat *et al.* (2014) conducted an experiment on seed germination and seedling growth of papaya (*Carica papaya* L.) cv. Coorg Honey Dew. They revealed that the treatment combination of soil, compost and cocopeat with ratio of 1:1:1 with GA- 150 ppm is better for early as well as higher percentage of germination (83.33 %), pronounced shoot growth (14.27 cm) and growth of tap root (9.15 cm) in papaya seedlings.

Rostami *et al.* (2014) carried a study on application of culture media (date palm waste) for strawberry and its effect on some growth indicators and yield components and reported that maximum plant height (18.63 cm) was obtained under date palm

culture media, which was not significantly different from cocopeat and perlite cultivation substrate.

Olle *et al.* (2014) in greenhouse tomato production concluded that organic growing media gave more yield and number of fruits than conventional growing system.

Aktas *et al.* (2013) compared influence of different growing media *viz.*cocopeat, split mushroom compost, perlite, volcanic tuff and sawdust on growth, yield and quality of brinjal. Maximum plant height (82.2 and 78.7 cm) and number of leaves (51.1 and 51.4) was obtained with cocopeat and spent mushroom compost, respectively.

Gungor and Yildirim (2013) determined the effects of peat and mixture of peat + perlite + sand (1:1:1) in some pepper cultivars grown under greenhouse conditions. The ascorbic acid content (30.80 mg $100ml^{-1}$) and total soluble solids (4.82%) of fruit were higher in peat grown plants than in substrate mixture with different cultivars.

Effect of substrates on growth characteristics in soilless culture in tomato was investigated by Ameri *et al.* (2012) in Iran. Higher leaf area (54.17 cm2) was recorded in 50 per cent cocopeat + 50 per cent perlite, when compared to other substrates (rice hull (48.77 cm^2), sycamore pruning waste (47.90 cm2), 15 per cent vermicompost + 40 per cent perlite + 45 per cent cocopeat (48.30 cm2) and 25 per cent vermicompost + 35 per cent perlite + 40 per cent cocopeat (47.87 cm^2). The total biomass differed significantly between each media.

Borowski and Nurzynski (2012) conducted an experiment in Lublin and showed that photosynthetic pigment content, chlorophyll fluorescence, rate of photosynthesis and substomatal CO_2 concentration in the leaves of tomato grown on rockwool and on rape or triticale straw chaff substrates did not differ significantly. No significant differences were found in total yield of tomato fruits.

Gholamnejad *et al*. (2012) tried different proportions of cocopeat and vermicompost for better seed emergence and some qualitative and quantitative characteristics of sweet pepper transplant (cv. California wonder). The treatments included: vermicompost + cocopeat (3:1), vermicompost + cocopeat (1:3), vermicompost + cocopeat (1:1) (v/v) and normal soil and recorded maximum plant weight (fresh and dry), stem diameter, internode quantity, leaf area and height of transplant under treatment vermicompost + cocopeat (3:1).

Hesami *et al.* (2012) carried out an experiment on date-peat as an alternative in hydroponic strawberry production and suggested that the better amalgamation was taken when an amalgamation of two parts of perlite, one part of date-peat and one part of cocopeat resulted in increased fruit yield (88.88g).

Luitel *et al.* (2012) reported that there was no significant difference in the fruit length (41.8 mm) and TSS (5.4 °Brix) of tomato raised in cocopeat and rockwool (40.2 mm fruit length and 5.3 °Brix) substrates.

Roosta and Afsharipoor (2012) reported better performance of strawberry in aquaponic system when the substrate had a higher percentage of perlite but in hydroponic system the use of sole perlite or cocopeat as substrates had no significant effect in increasing the number of fruits and total yield per plant in strawberry.

Suhaimi *et al.* (2012) opined that ginger grown in 100 per cent coir dust gave the best growth performance and yield as compared to the other treatments. It produced the highest shoot height (123 ± 23 cm), shoot fresh weight (1,340 ± 235 g) and rhizome yield (5,480 ± 325 g plant^{-1}). The lowest rhizome yield (2,570 ± 135 g) was obtained from plants planted with 30 per cent coir dust + 70 per cent burnt paddy husks.

Ghehsareh *et al.* (2011) revealed that TSS content of the fruit was higher in perlite (6.37 °Brix), but was on par with datepalm peat2 incubated (6.25 °Brix) substrate. However, it had significant difference with datepalm peat1 without incubated substrate (5.38 °Brix).

Ikram *et al.* (2012) used different potting media in different combinations of FYM, poultry manure, sand, leaf compost and coconut coir in equivalent ratio in tuberose. Coconut coir + FYM contributed to the maximum values of plant height, leaf area and spike length.

Luitel *et al.* (2012) evaluated different growing media (cocopeat, rockwool and masato) along with varying bed size (20 cm, 40 cm, 60 cm, and 80 cm width) on yield and fruit quality of tomato. Number of fruits per plant were recorded highest (16) under cocopeat followed by rockwool (15.2). Maximum Fruit weight (54.7 g) and yield (571.5 g/plant) was found to be in cocopeat based substrate and minimum fruit weight (50.4 g) and yield per plant (540.7 g) was in masato substrate. Total soluble solids ranged from 5.3 ºBrix (rockwool substrate) to 5.6 ºBrix (masato).

Mazur *et al.* (2012) recommended coconut fiber as an environment friendly medium for cultivation of cherry tomatoes as the plants grown in this media recorded higher fruits number and yield compared to plants grown in mineral wool.

Olle *et al.* (2012) reported that organic growing media gave more yield and number of fruits then conventional growing system in greenhouse tomato production.

Radhouani *et al.* (2011) opined that there were no significant differences in EC, TSS and acidity among different substrates like perlite, sand and compost. The pH was superior in compost (6.98 ± 0.08) and was on par with sand media (6.87 ± 0.09) but differed significantly with perlite (6.66 ± 0.02).

Hansen *et al*. (2010) conducted a study at Ohio State University, USA proved that under hydroponics lettuce gave 23% more yield when coconut fibre was used as the substrate.

Sezen *et al.* (2010) from Turkey evaluated tomato grown under different soilless culture media (volcanic ash, peat and ash + peat) with four different irrigation levels (WL1=75 per cent : WL2 = 100 per cent : WL3 = 125 per cent WL4 = 150 per cent of class A Pan evaporation) and two watering frequencies (once and twice application). Higher fruit number (185) and yield (14.02 kg m^{-2}) were obtained from ash + peat mixture (1:1) with twice a day watering at WL4 irrigation level. The higher irrigation water use efficiency (IWUE) of 121.4 kg m^{-3} was obtained with once a day at WL1 irrigation level with peat + ash (1:1). Irrigation water use efficiency decreased in all treatments as the amount of irrigation water increased.

Wahome *et al*. (2011) reported that high water holding capacity and high nutrient retention capacity induced higher vegetative growth in hydroponic culture.

Borji *et al*. (2010) found that the substrate prepared by mixing date palm peat and coir peat gave significantly higher yield for tomatoes compared to other substrates in hydroponics, in an experiment held at the greenhouse of Islamic Azad University, Khorasgan, Iran.

KacjanMarsi and Jakse (2010) was conducted an experiment on the effect of different soilless substrates on yield of grafted and ungrafted cucumber (*Cucumis sativus* L.) and reported that the growth of cucumber showed better performance in perlite with marketable yield 7.9 kg plant $^{-1}$.

Neocleous and Polycarpou (2010) carried out an experiment at Agricultural Research Institute, Cyprus showed that the use of local gravel for hydroponic cultivation of tomato produced similar yield to those with imported perlite.

According to Awang *et al.* (2009) a suitable medium should anchor or support the plant, serve as reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate. The growing media have proper physiochemical properties such as electrical conductivity, cation exchange capacity, water retention capacity and bulk density influence plant growth and development.

Vinkovic *et al*. (2007) found that the success of tomato production in coco is mainly based on the behavior of the plants growing in it. Better media results in higher yields and improved crop quality. Coconut husk has shorter fibers, adjusted to give a successful growing medium. As an alternative to peat or rock wool, it offers a high moisture and air retention capacity, which enables easy growth and well spread root system. It appears from this study that coco coir is a suitable growing medium for the production of tomatoes under greenhouse conditions.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the effect ofgrowing substrates on growth, yield and quality of different tomato cultivars in hydroponic culture. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from September-2019 to March-2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.2 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Farukh *et al.*, 2019). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-II.

3.3 Experimental materials

Three varieties of tomato namely Rani, Extra profit and Roma VF were used as planting materials. Seeds of Rani tomato were collected from Krishibid Seed Limited; Extra profit from Supreme Seed Company Limited and Roma VF from Afroza Seed

Company. (Khoa+ cocopeat) was collected from Agargoan, Dhaka and other substrates were collected from Hatibandha upazilla, Lalmonirhat.

3.4 Experimental treatment

There were two factors in the experiment namely tomato cultivars and different substrate as mentioned below:

Factor A: Three tomato cultivars denoted as V:

V_1 = Rani
V_2= Extra profit and
V_3 = Roma VF

Factor B: Four different growing substrates denoted as M:

M_1= 70 % Cocopeat + 30 % Khoa
M_2 = 70 % Rice husk+ 30 % Khoa
M_3= 70 % Sawdust+ 30 % Khoa
M_4= 70 % Woodchips+ 30 % Khoa

3.5 Experimental design

The experiment was laid out in completely randomized design (CRD) with 2 factors and three replications. Total 36 unit pots were used in for the experiment with 12 treatment combinations.

3.6 Detail of experimental preparation

3.6.1 Preparation of different substrate

Cocopeat, Rice husk, Sawdust and Woodchips substrates were soaked in different plastic containers overnight. The soaked substrates were washed well in water and spread in a polythene sheet for removing excess moisture. Then each substrate was mixed with khoa and disinfectant substance such as sevin powder and ready for use as a growing media in hydroponic culture.

3.6.2Selection and preparation of the pot

Plastic pots of having 12 inches diameter, 12 inches height with a hole at the centre of the bottom were used. The upper edge diameter of the pots was 30 cm (r=15 cm).

While filling with different substrate, the upper one inch of the pot was kept vacant to provide irrigation and nutrient solution properly. As such the radius of the upper surface was 15 cm and the area of the upper surface was (πr^2 = 3.14x 0.015x 0.015=0.07 m^2).

3.6.3 Nutrient solution

Rahman and Inden (2012) solution was used in the experiment. The ratio of Rahman and Inden (2012) solution were NO_3-N, P, K, Ca, Mg and S of 17.05, 7.86, 8.94, 9.95, 6.0 and 6.0 meq/L respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 mg/L, respectively. The solution was applied in each pot. Nutrient solution was given at half strength from the first day of the seedlings when transferred into the pot. Full strength of the solution was started from the second week of the experiment.

3.6.4 Seed bed preparation for seedling raising

The mixture of cocopeat, broken bricks (khoa) and rice husk at the ratio of 60:30:10 (v/v) were used for seed bed preparation for growing tomato seedling. Cocopeat blocks were soaked in a big bowl for 24 hours. Then they were washed and dried, then mixed with khoa and rice husk properly. This mixture was placed in a styrofoam sheet box and used as seedbed.

3.6.5Seed sowing

The seeds were sown in styrofoam sheet box and covered with net. Seedbeds were kept under normal temperature for raising seedling.

3.6.6Transplanting of tomato seedling

15 days old tomato seedlings were transferred to small pots. 4 weeks after that seedlings were transferred to 12 inch plastic pots containing different substrates. The plants were transplanted carefully to avoid the root damage. Little amount of water and ½ strength of Rahman and Inden solution were applied soon after transplanting of seedling.

3.7 Intercultural operations

3.7.1 Pruning

After transplanting, the lower yellow leaves were removed as and when needed allowing plants to develop an adequate vegetative frame before fruit set.

3.7.2 Irrigation

Immediately after transplanting, light irrigation to individual pot was provided to overcome water deficit. After establishment of seedlings, each pot was watered in alternate days to keep the substrate moist for normal growth and development of the plants. During pre-flowering stage, irrigation was done sincerely.

3.7.3 Weeding

No weeding was done in the experiment.

3.7.4 Stalking

Firstly, a bamboo stick was used to support tomato plant. Secondly, a small plastic pipe was cut roundly different pieces. Then it was used as a hook in plant base and plastic rope used for support the plant.

3.7.5 Insect management

Tomato plants were grown in controlled environment. So, no insecticide was applied in the experiment.

3.7.6 Disease management

Tomato plants were grown in controlled environment in hydroponic culture and all nutrients required for plant were supplied artificially to the plants. The growing environment was kept clean and no pathogen attacked the plant.

3.8 Harvesting

Harvesting of the crop was done according to the different cultivar.

3.9 Data collection

The data were recorded on different growth and yield component traits and quality traits of all the plants in each treatment and each replication.

i) Plant height (cm)

The plant height was measured from the point of attachment of growing media up to the tip using centimeter scale at 20, 40, 60and 80 DAT. Mean plant height of tomato plant was calculated and expressed in cm.

ii) Number of leaves plant^{-1}

Number of leaves per plant was counted at 20, 40, 60 and 80 DAT. All the leaves of each plant were counted separately.

iii)No. of branches plant^{-1}

It was done by counting total number of branches of the plant then the average data were recorded. Data were recorded at 20, 40 and60 DAT.

iv) Stem radius (cm)

Stem radius was measured by using slide calipers and the mean data were recorded in centimeter. Data were recorded at 20, 40 and60 DAT.

v) Days of first flower initiation

The date of flower blooming was measured by recording from the day of first flower initiation.

vi) Number of flower clusters plant^{-1}

Number of flower clusters plant^{-1}were counted and averaged.

vii) Number of fruits plant^{-1}

Number of fruit clusters plant^{-1} were counted and averaged.

viii) Number of fruits plant^{-1}

Number of fruits per plant was counted at every picking, which was finally added up to work out total and average number of fruits per plant.

ix) Fruit polar length (cm)

The individual fruit polar length was measured during harvesting with the help of a slide calipers in centimeter unit.

x) Fruit radial length (cm)

The individual fruit radial length was measured during harvesting with the help of a slide calipers in centimeter unit.

xi) Fruit yield plant^{-1} (kg)

The harvesting was done at half ripe stage for computing yield per plant. Yield was recorded at every picking in grams and added up for all pickings to arrive at the total fruit yield per plant. Finally, fruit yield from all the plants was pooled and average yield plant^{-1} (kg) was recorded.

xii) Average fresh weight of tomato (g)

Total weight of five randomly harvested fruits at every picking was recorded to compute the average fresh fruit weight of tomato in grams.

xiii) Average dry weight of tomato (g)

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

xiv) Individual fruit volume (cc)

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

xv) Total soluble solids (^{0}Brix)

The randomly taken ripe fruits of third harvest were crushed and their juice was passed through a double layer of fine mesh cheesecloth. A drop of juice was placed on the plate of hand refractometer (0-32%) ERMA, JAPAN and the reading was recorded. A mean of five readings was taken in each treatment and every replication.

xvi) pH determination

The pH value of tomato was measured using a digital pH meter. The pH meter was first calibrated with different standard solutions for pH 4, 7 and 10. Then, the tomato

juice was taken in a beaker and the pH meter was immersed in the juice to record the value. The test was performed by triplicate for each treatment at normal temperature.

3.10 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the study have been presented and discussed in this chapter with a view to investigate the effect of growing substrates on growth, yield and quality of different tomato cultivars in hydroponic culture.

4.1Plant height

Performance of cultivars

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Different tomato cultivars significantly influenced plant height at different days after transplanting (Figure 1). Experimental results revealed that Extra profit tomato cultivar (V_2) recorded the highest plant height (59.63, 96.35, 114.10 and 123.10 cm) at 20, 40, 60 and 80 DAT. While growing Roma VF tomato cultivar(V_3) in the pot recorded the lowest plant height (45.40 cm) at 20 DAT. At 40 DAT Rani tomato cultivar (V_1) recorded the minimum plant height (94.24 cm) which was statistically similar with Roma VF tomato (95.05 cm) cultivar. The variation of plant height is probably due to the genetic makeup of the cultivar. Das *et al.* (2019) and Tyeb *et al.* (2013) also found similar results with the present study and reported that height of a plant is determined by genetical character and under a given set of environment different cultivar will acquire their height according to their genetic makeup.

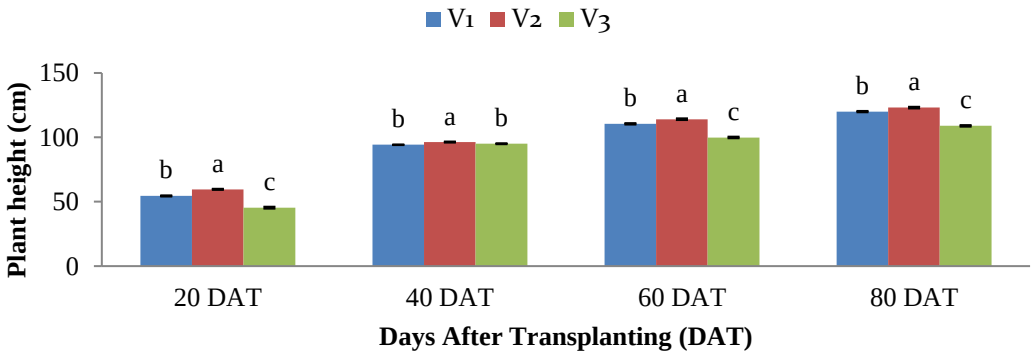

Figure 1. Varietal performance on plant height of tomato at different DAT.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Different substrates used in hydroponic culture significantly affected plant height of tomato at different days after transplanting (Figure 2). Experimental results showed that the highest plant height (60.70, 100.23, 115.23 and 124.90 cm) at 20, 40, 60 and 80 DAT was found in M_1 (70 % Cocopeat + 30 % Khoa). Whereas the lowest plant height (45.17, 91.13, 102.13 and 111.13 cm) at 20, 40, 60 and 80 DAT was found in M_4 (70 % Woodchips+ 30 % Khoa). The variation in plant height may be due to use of different growing media that vary greatly in composition, particle size, pH, aeration and ability to hold water and nutrients. Vinkovic *et al*. (2007) reported that cocopeat offers a high moisture and air retention capacity, which enables easy growth and well spread root system. It appears from this study that coco coir is a suitable growing medium for the production of tomatoes under greenhouse conditions.

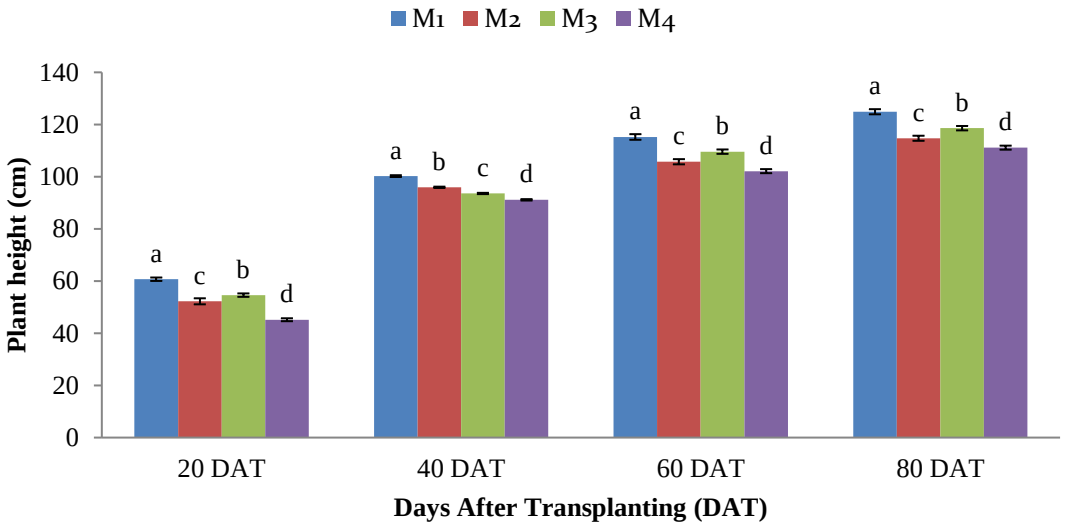

Figure 2. Effect of different substrates on plant height of tomato at different DAT.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars along with different substrates used in hydroponic culture significantly affect plant height at different days after transplanting (Table 1). Experimental results indicate that the highest plant height (66.00, 102.70, 123.70 and 132.70 cm) at 20, 40, 60 and 80 DAT was found in V_2M_1which was statistically similar with V_3S_1 (100.50 cm) at 40 DAT. Whereas the lowest plant height (31.70, 90.00, 92.00 and 101.00 cm) at 20, 40, 60 and 80 DAT was found inV_3M_4which was statistically similar with V_2S_4 (91.40 cm) and V_1S_4 (92.00 cm) at 40 DAT.

Table 1. Combined effect of cultivars and different substrates on plant height of tomato at different DAT

Treatment Combinations	Plant height (cm)			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1M_1	62.50 b	97.50 b	114.50 b	125.50 b
V_1M_2	52.00 de	93.00 d-f	107.50 de	116.50 de
V_1M_3	53.00 de	94.50 cd	111.50 b-d	120.50 c
V_1M_4	50.50 e	92.00 e-g	108.50 c-e	117.50 d
V_2M_1	66.00 a	102.70 a	123.70 a	132.70 a
V_2M_2	58.70 c	94.00 c-e	112.00 bc	121.00 c
V_2M_3	60.50 bc	97.30 b	114.80 b	123.80 b
V_2M_4	53.30 d	91.40 fg	105.90 ef	114.90 e
V_3M_1	53.60 d	100.50 a	107.50 de	116.50 de
V_3M_2	46.00 f	93.70 c-f	97.70 g	106.70 g
V_3M_3	50.30 e	96.00 bc	102.50 f	111.50 f
V_3M_4	31.70 g	90.00 g	92.00 h	101.00 h
$LSD_{(0.05)}$	2.70	2.47	4.44	2.35
CV(%)	3.00	1.53	2.42	1.18

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2 = Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.2Number of leaves plant^{-1}

Performance of cultivars

A leaf is the principal lateral appendage of the vascular plant stem, usually borne above ground and specialized for photosynthesis. Different tomato cultivars significantly influenced number of leaves plant^{-1} at different days after transplanting (Figure 3). Experimental results revealed that the highest number of leaves plant^{-1} (24.92, 37.50, 53.75 and 62.33 A) at 20, 40, 60 and 80 DAT was found in V_1. Whereas the lowest number of leaves plant^{-1} (19.00, 32.75, 47.58 and 51.75) at20, 40, 60 and 80 DAT found in V_2 which was similar with V_3(48.41) at 60 DAT.The variation in number of leaves plant^{-1} was probably due to the genetic makeup of the cultivars. Deepa and Thakur (2008) also found similar result which supported the present finding and reported that the variations of number of leaves plant^{-1}was possibly due to the varietal characters of summer tomato.

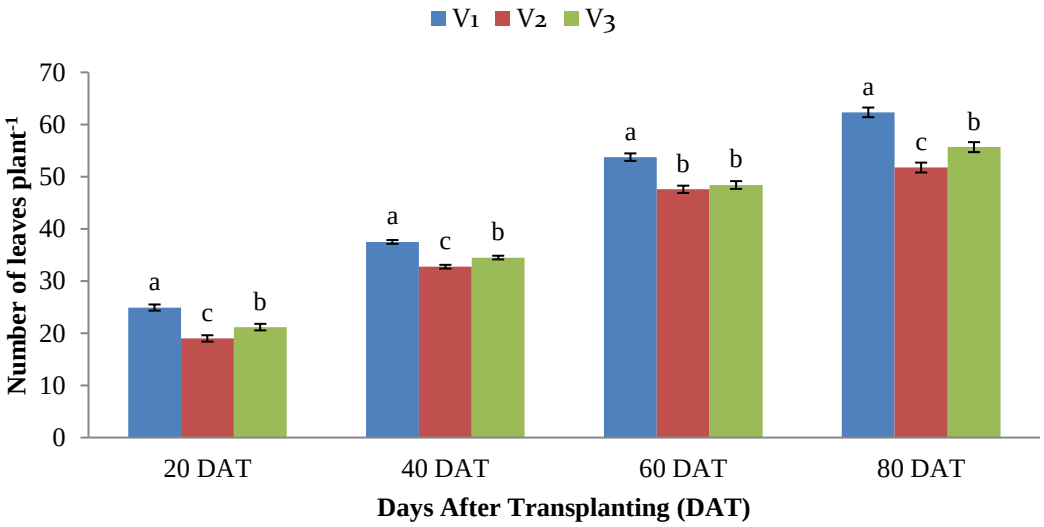

Figure 3. Varietal performance on number of leaves plant^{-1}of tomato at different DAT.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Tomato growing in hydroponic culture in different substrates significantly affect number of leaves plant^{-1} at different days after transplanting (Figure 4). Experimental results revealed the highest number of leaves plant^{-1} (32.44, 39.56, 61.33 and 71.88) at 20, 40 60 and 80 DAT was found in M_1. Whereas the lowest number of leaves plant^{-1} (14.22, 30.00, 41.44 and 44.22) at 20, 40 60 and 80 DAT was found in M_4. The variation in leaf number plant^{-1} was due to the use of different growing media that vary greatly in composition, particle size, pH, aeration and water and nutrients holding capacity. The results obtained from the present study was similar with the findings of Aktas *et al.* (2013) and they reported that the maximum number of leaves was obtained with cocopeat and spent mushroom compost, respectively.

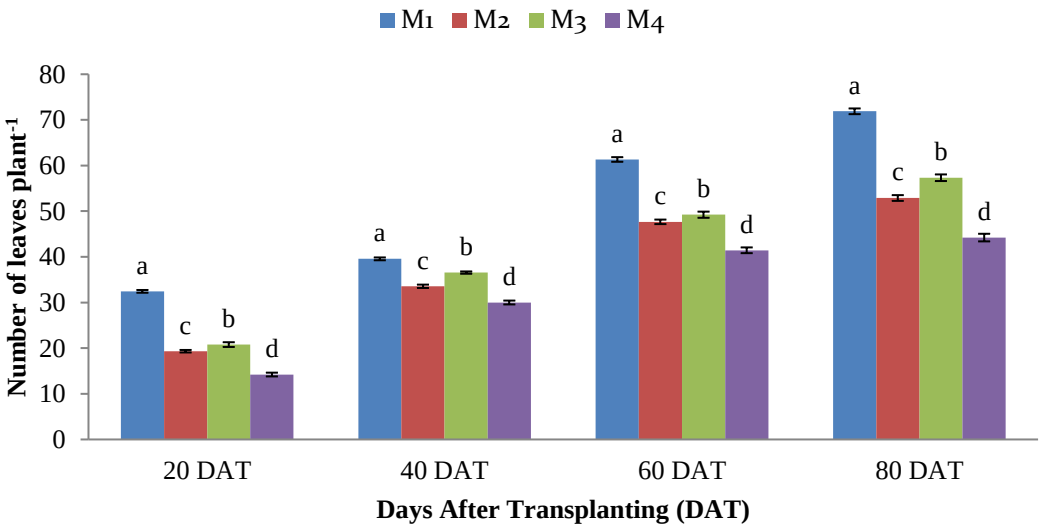

Figure 4. Effect of different substrates on number of leaves plant^{-1}of tomato at different DAT.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly affect number of leaves plant^{-1} at different days after transplanting (Table 2).The highest number of leaves plant^{-1}(34.66, 42.00, 64.00 and 76.33) at 20, 40, 60 and 80 DAT was found in V_1S_1. Whereas the lowest number of leaves plant^{-1} (13.33, 27.67, 39.66 and 41.00) at

20, 40, 60 and 80 DAT was found in V_2S_4 which was similar with V_3S_4 at different DAT.

Table 2. Combined effect of cultivars and different substrates on number of leaves plant^{-1} of tomato at different DAT

Treatment Combinations	Number of leaves plant^{-1}			
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
V_1M_1	34.66 a	42.00 a	64.00 a	76.33 a
V_1M_2	24.33 d	34.33 e	53.33 c	58.66 d
V_1M_3	24.67 d	40.33 b	54.34 c	65.00 c
V_1M_4	16.00 h	33.33 ef	43.33 e	49.33 fg
V_2M_1	30.33 c	38.00 c	59.33 b	68.33 b
V_2M_2	14.67 i	32.33 f	43.34 e	47.00 g
V_2M_3	17.67 g	33.00 ef	46.34 d	50.67 ef
V_2M_4	13.33 j	27.67 g	39.66 f	41.00 h
V_3M_1	32.33 b	38.67 c	60.66 b	71.00 b
V_3M_2	19.00 f	34.00 e	46.33 d	53.00 e
V_3M_3	20.00 e	36.33 d	47.00 d	56.33 d
V_3M_4	13.33 j	29.00 g	41.33 f	42.33 h
$LSD_{(0.05)}$	0.88	1.35	0.94	1.41
CV(%)	2.40	2.28	2.31	3.06

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.3 Number of branches plant^{-1}

Performance of cultivars

Different cultivars significantly influenced number of branches plant^{-1} of tomato at different days after transplanting (Figure 5). Experimental results revealed that the highest number of branches plant^{-1}(4.25, 5.83 and 7.99) at 20, 40 and 60 DAT was found in V_1 which was statistically similar with V_3 at different DAT. Meanwhile the

lowest number of branches plant^{-1} (2.33, 3.99 and 4.32) was found in V_2. The reason of difference in number of branches plant^{-1} is the genetic makeup of the cultivar, which is primarily influenced by heredity. Helal *et al.* (2016) also found similar results which supported the present finding and reported that that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

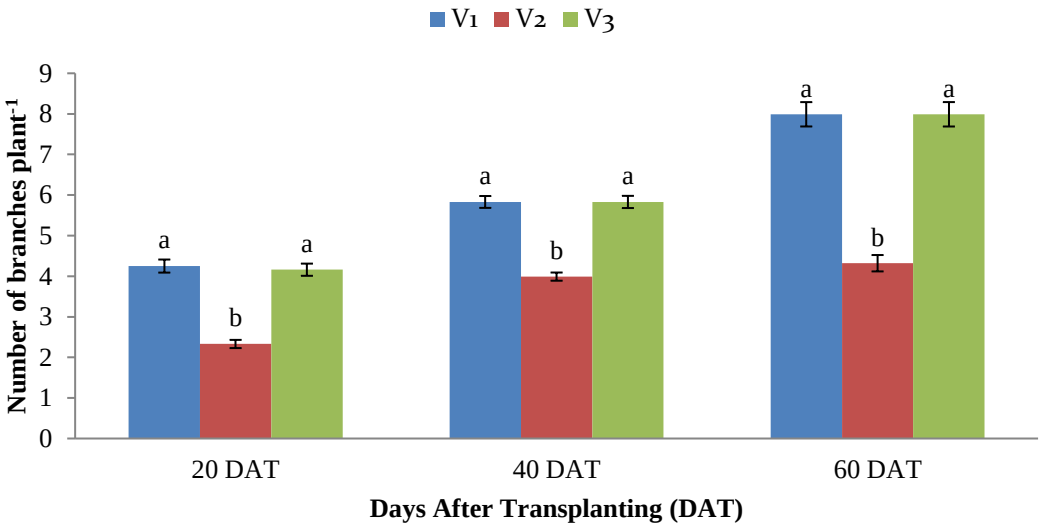

Figure 5. Varietal performance on number of branches plant^{-1}of tomato at different DAT.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Different substrates significantly influenced number of branches plant^{-1} of tomato (Figure 6). Experimental results revealed that the highest number of branches plant^{-1} (4.77, 6.33 and 8.99) at 20, 40 and 60 DAT was found in M_1. Meanwhile the lowest number of branches plant^{-1} (2.66, 4.33 and 4.99) at 20, 40 and 60 DAT was found in M_4 which was statistically similar with M_3 at different DAT. The variation in number of branches plant^{-1} was due to the use of different growing media that vary greatly in composition, particle size, pH, aeration and ability to hold water and nutrients. Awang *et al.* (2009) reported that different growing media have different physiochemical properties such as electrical conductivity, cation exchange capacity, water retention capacity and bulk density which influence plant growth and development.

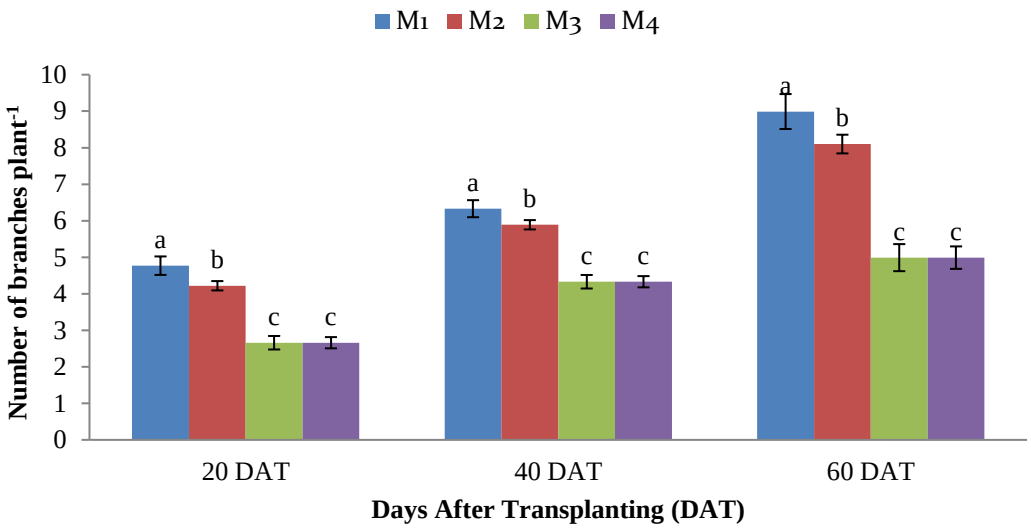

Figure 6. Effect of different substrates on number of branches plant^{-1}of tomato at different DAT.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly affect the number of branches plant^{-1} (Table 3). The highest number of branches plant^{-1} (6.33, 7.67, and 11.67) at 20, 40 and 60 DAT was found in V_1M_1. Meanwhile the lowest number of branches plant^{-1} (1.66, 3.33 and 2.99) at 20, 40 and 60 DAT was found in V_2M_3.

Table 3. Combined effect of cultivars and different substrates on number of branches plant^{-1} of tomato at different DAT

Treatment combinations	Number of branches plant^{-1}		
	20 DAT	40 DAT	60 DAT
V_1M_1	6.33 a	7.67 a	11.67 a
V_1M_2	4.66 d	6.33 d	8.99 d
V_1M_3	3.33 e	5.00 e	6.33 e
V_1M_4	2.66 g	4.33 g	4.99 g
V_2M_1	2.33 h	4.00 h	4.33 h
V_2M_2	2.66 g	4.33 g	4.99 g
V_2M_3	1.66 i	3.33 i	2.99 i
V_2M_4	2.66 g	4.33 g	4.99 g
V_3M_1	5.66 b	7.33 b	10.99 b
V_3M_2	5.33 c	7.00 c	10.33 c
V_3M_3	3.00 f	4.67 f	5.67 f
V_3M_4	2.66 g	4.33 g	4.99 g
$LSD_{(0.05)}$	0.13	0.26	0.23
CV(%)	4.66	2.93	4.26

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.4 Stem radius plant^{-1}

Performance of cultivars

Tomato cultivars grown in hydroponic culture significantly affected the stem radius plant^{-1}at different DAT (Figure 7). Experimental results revealed that, the highest stem radius plant^{-1} (0.23, 0.41 and 0.68 cm) at 20, 40 and 60 DAT was found in V_1. Meanwhile the lowest stem radius plant^{-1} (0.20, 0.37 and 0.62 cm) at 20, 40 and 60 DAT was found in V_2. The differences of stem radius plant^{-1} might be due to the different genetic makeup of the tomato cultivars. The results obtained from the

present study was similar with the findings of Jilani *et al.* (2013) who reported the minimum stem diameter (9.11 mm) in tomato cultivar Nema-1200 while the maximum stem diameter (14.95 mm) in tomato cultivar Vegnesh during comparison.

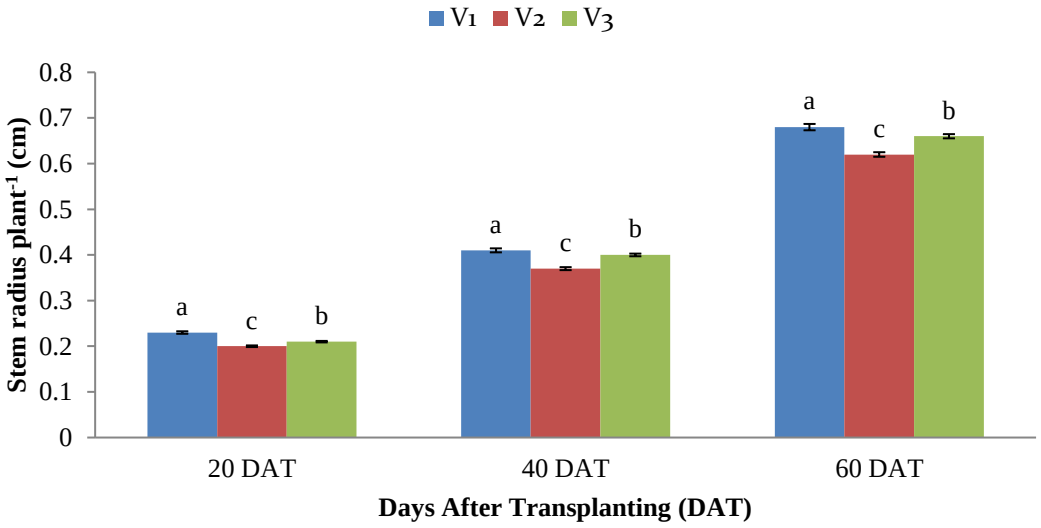

Figure 7. Varietal performance on stem radius plant^{-1} of tomato at different DAT

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Different substrates significantly affect the stem radius plant^{-1} of tomato at different DAT (Figure 8). The highest stem radius plant^{-1} (0.25, 0.45 and 0.74) at 20, 40 and 60 DAT was found in M_1. While the lowest stem radiusplant^{-1} (0.19, 0.35 and 0.59) at 20, 40 and 60 DAT was found in M_4. Among different substrates cocopeat performed best in increasing stem radius plant^{-1} of tomato due to reason that it improves aeration in the root zone for optimal root growth while maintaining the ideal nutrient availability for plants. Mathowa *et al.* (2017) reported that the variation of stem radius plant^{-1} was due to use of different growing media that vary greatly in composition, particle size, pH, aeration and ability to hold water and nutrients.

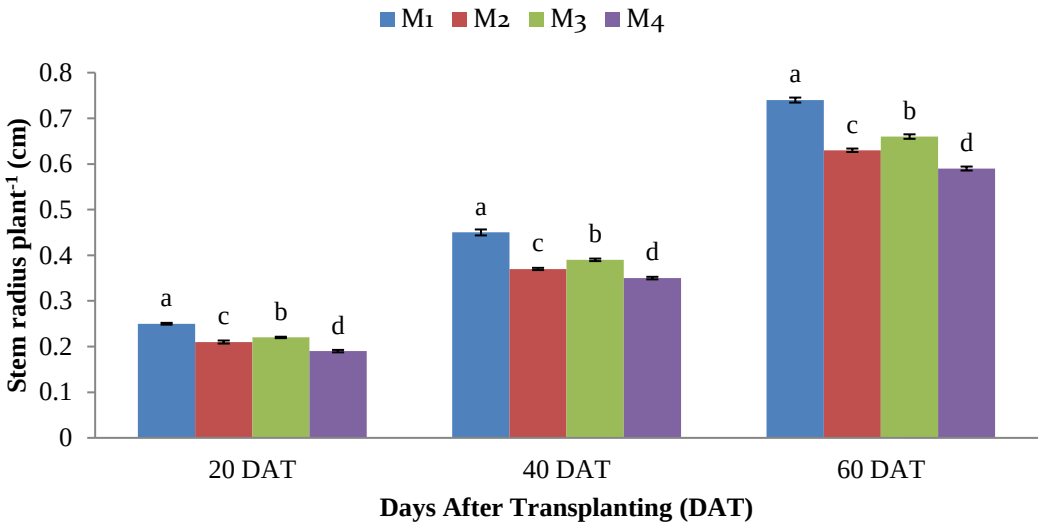

Figure 8. Effect of different substrates on stem radius plant^{-1} of tomato at different DAT.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly influenced stem radius plant^{-1} (Table 4). Experimental results showed that the highest stem radius plant^{-1} (0.27 0.48, 0.79 cm) at 20, 40 and 60 DAT was found in V_1M_1. While the lowest stem radius plant^{-1} (0.18, 0.33 and 0.56 cm) at 20, 40 and 60 DAT was found in V_2M_4.

Table 4. Combined effect of cultivars and different substrates on stem radius plant^{-1} of tomato at different DAT

Treatment combinations	Stem radius(cm) plant^{-1} at		
	20 DAT	**40 DAT**	**60 DAT**
V_1S_1	0.27 a	0.48 a	0.79 a
V_1S_2	0.22 de	0.39 ef	0.66 f
V_1S_3	0.23 bc	0.41 cd	0.69 d
V_1S_4	0.19 gh	0.35 i	0.59 j
V_2S_1	0.23 bc	0.42 c	0.70 c
V_2S_2	0.19 gh	0.35 i	0.59 j
V_2S_3	0.21 e-g	0.37 gh	0.63 h
V_2S_4	0.18 h	0.33 j	0.56 k
V_3S_1	0.24 b	0.44 b	0.73 b
V_3S_2	0.21 d-f	0.38 fg	0.64 g
V_3S_3	0.22 cd	0.40 de	0.67 e
V_3S_4	0.20 fg	0.36 hi	0.61 i
$LSD_{(0.05)}$	0.01	0.01	0.01
CV(%)	4.06	2.05	1.32

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.5 Days to first flowering

Performance of cultivars

Days to first flowering differed significantly due to different cultivars (Figure 9). The highest 35.75 days required for first flowering was found in V_2 which was statistically similar with V_3. Meanwhile the lowest 34.50 days required for first flowering was found in V_1. The variation in production of flower was due to the variation in genetic makeup of the cultivars. Mehmood *et al.* (2012) reported that the tomato germplasm BINA Tomato-6 took maximum time to first flower appearance when compared with the other twenty one germplasms.

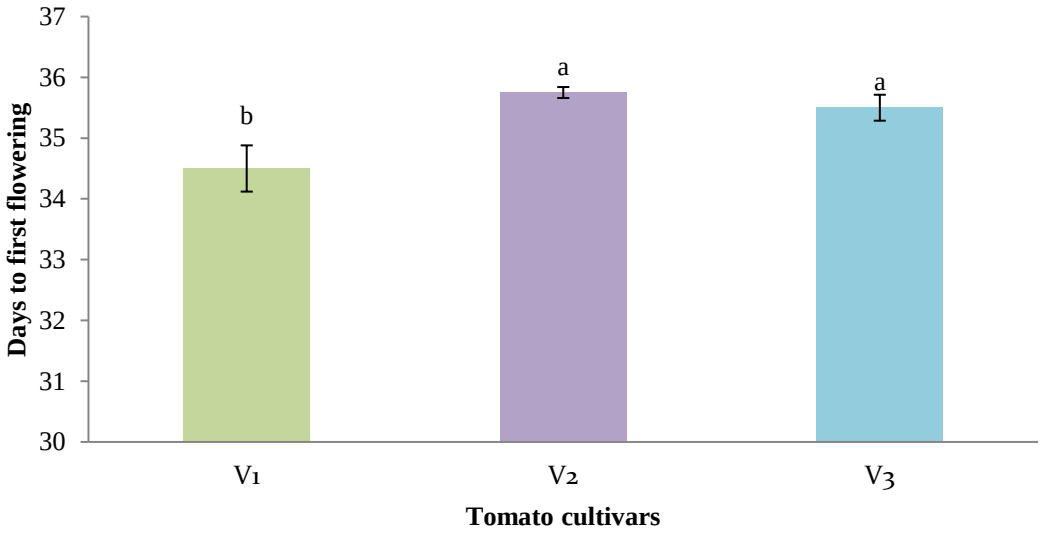

Figure 9. Varietal performance on days required for first flowering of tomato.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Tomato grown in hydroponic culture in different substrates significantly differed in the days to first flowering (Figure 10). Experimental results revealed that the highest 37.66 days required for first flowering was found in M_4. Meanwhile the lowest 33.23 days required for first flowering was found in M_1. Among different substrates cocopeat performed best due to reason that cocopeat is porous and cannot be overwatered easily. Its air filled porosity and high water holding capacity and less nutrient leaching makes it an ideal growing medium which helps proper nutrient

supply in the root zone of the plant which gradually helps in growth and development. As a result, early flowering was occurred comparable to others.

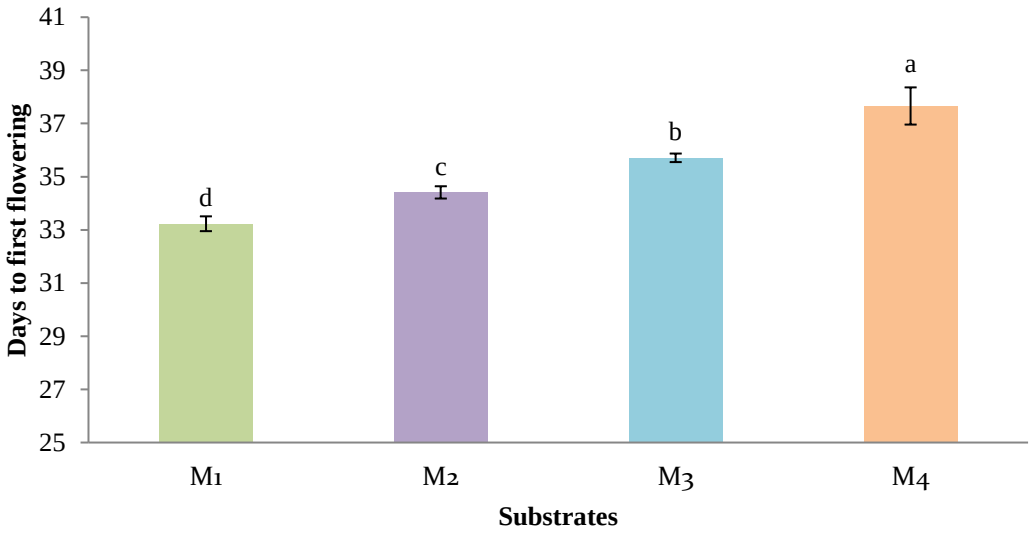

Figure 10. Effect of different substrates on days required for first flowering of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly affect the days required for first flowering of tomato (Table 5). Experimental results showed that, the highest 37.99 days required for first flowering was found in V_2M_4 which was similar with V_3M_4. Meanwhile the lowest 32.34 days required for first flowering was found in V_2M_1.

4.6 Number of flower clusters plant^{-1}

Performance of cultivars

Tomato cultivars growing in hydroponic culture significantly influenced number of flower clusters plant^{-1}at 60 DAT (Figure 11). The highest number of flower clusters plant^{-1} (13.17) at 60 DAT was found in V_1. Meanwhile the lowest number of flower clusters plant^{-1} (8.84) at 60 DAT was found in V_3. The differences of number flower clusters plant^{-1} might be due to the different genetic makeup of the tomato cultivars.

The results obtained from the present study was similar with the findings of Naz *et al.* (2012) who reported that number of flower clusters plant^{-1} had significant variation among the tomato varieties.

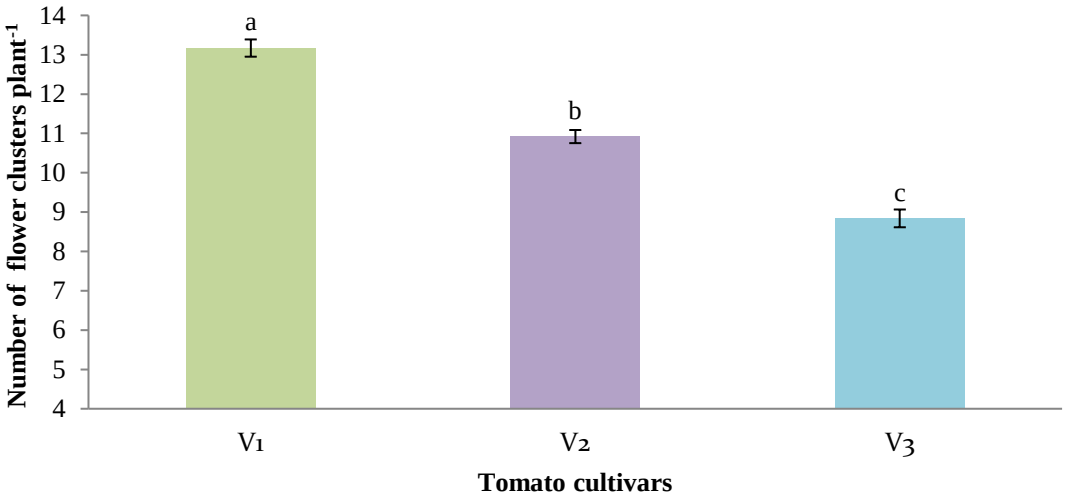

Figure 11. Varietal performance on number of flower clusters plant^{-1} of tomato. Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Different substrates significantly affect the number of flower clusters plant^{-1} of tomato (Figure 12). The highest number of flower clusters plant^{-1} (13.66) at 60 DAT was found in M_1. Meanwhile the lowest number of flower clusters plant^{-1} (9.56) at 60 DAT was found in M_4. Different substrates have different nutrient holding capacity which influences growth and development of the plant.

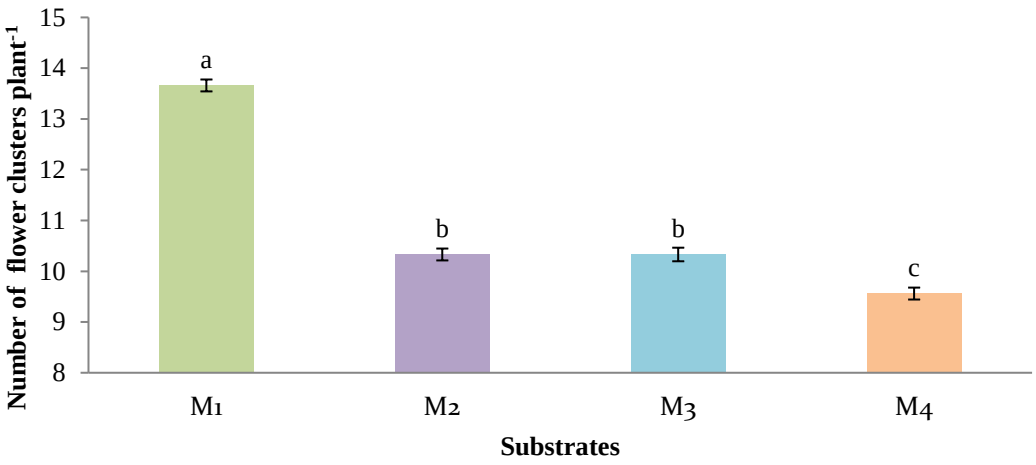

Figure 12. Effect of different substrates on number of flower clusters plant^{-1}of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly influenced number of flower clusters plant^{-1} (Table 5). Experimental results showed that the highest number of flower clusters plant^{-1} (16.33) at 60 DAT was found in V_1S_1. Whereas the lowest number of flower clusters plant^{-1} (7.67) at 60 DAT was found inV_3S_4 which was statistically similar with $V_3S_3$and V_3S_2.

4.7 Number of fruit clusters plant^{-1}

Performance of cultivars

Tomato cultivars growing in hydroponic substrates significantly affect the number of fruits clusters plant^{-1}at 60 DAT (Figure 13). Experimental results revealed that, the highest number of fruit clusters plant^{-1} (4.51) at 60 DAT was found in V_1. Meanwhile the lowest number of fruit clusters plant^{-1} (3.08) at 60 DAT was found in V_2. The differences of number of fruit clusters plant^{-1} might be due to the different genetic makeup of the tomato cultivars.

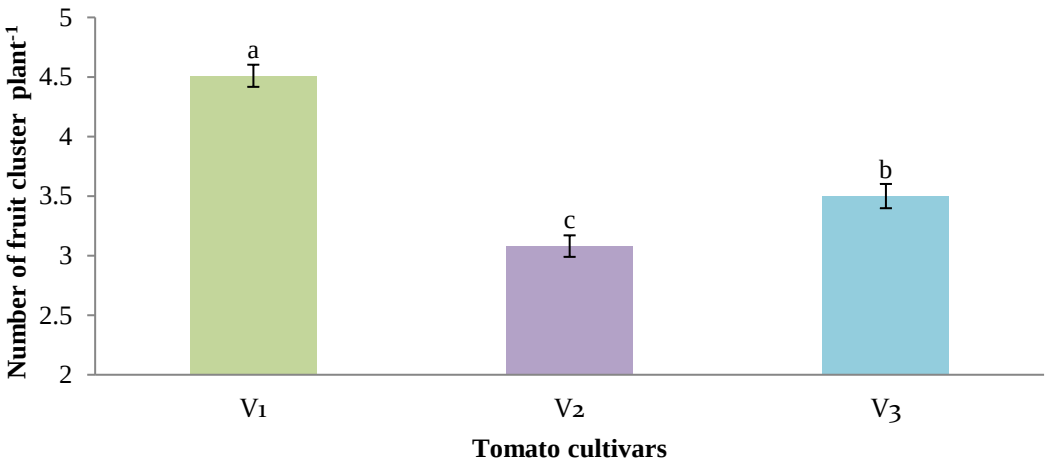

Figure 13. Varietal performance on number of fruit clusters plant^{-1} of tomato. Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Tomato growing in different substrates significantly affect the number of fruit clusters plant^{-1} of tomato 60 DAT (Figure 14). The highest number of fruit clusters plant^{-1} (4.45) 60 DAT was found in M_1. Whereas the lowest number of fruit clusters plant^{-1} (2.56)60 DAT was found in M_4. The variation in fruit clusters plant^{-1} in different substrates may be due to the use of different growing media that varies greatly in composition, particle size, pH, aeration and ability to hold water and nutrients. The results obtained from the present study was similar with the findings of Kilic *et al.* (2018) who reported that coconut coir represented higher number of fruits per cluster, increased productivity, which were closely followed by perlites + carbonized rice hulls PCRH treatment.

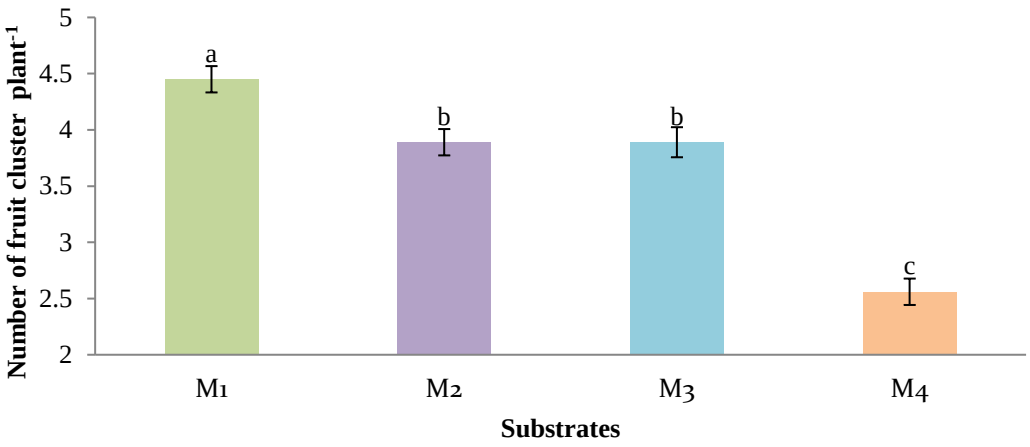

Figure 14. Effect of different substrates on number of fruit clusters plant^{-1} of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly affect number of fruit clusters plant^{-1} at 60 DAT (Table 5). Experimental results showed that the highest number of fruit clusters plant^{-1} (5.00) at 60 DAT was found V_1S_1 which was statistically similar with V_1S_2. While the lowest number of fruit clusters plant^{-1} (2.00) at 60 DAT was found V_2S_4.

Table 5. Combined effect of cultivars and different substrates on days to first flowering, number of flower clusters plant^{-1} and number of fruit clusters plant^{-1} of tomato

Treatment Combinations	Days to first flowering	No. flower clusters plant^{-1} (At 60 DAT)	No. fruit clusters plant^{-1} (At 60 DAT)
V_1S_1	32.34 g	16.33 a	5.00 a
V_1S_2	33.89 f	12.00 cd	5.00 a
V_1S_3	35.45 b-d	13.00 b	4.67 b
V_1S_4	36.33 b	11.33 d	3.36 d
V_2S_1	34.67 d-f	12.33 bc	3.67 c
V_2S_2	34.33 ef	11.33 d	3.33 d
V_2S_3	36.00 bc	10.33 e	3.33 d
V_2S_4	37.99 a	9.67 e	2.00 f
V_3S_1	32.67 g	12.33 bc	4.67 b
V_3S_2	35.00 c-e	7.67 f	3.33 d
V_3S_3	35.67 b-d	7.67 f	3.67 c
V_3S_4	38.67 a	7.67 f	2.33 e
$LSD_{(0.05)}$	1.07	0.70	0.17
CV(%)	1.80	3.80	2.69

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.8 Number of fruits plant^{-1}

Performance of cultivars

Tomato cultivars growing in hydroponic substrates significantly affect number of fruits plant^{-1} (Figure 15). The highest number of fruits plant^{-1} (24.75) was found in V_1. Whereas the lowest number of fruits plant^{-1}(21.17) was found in V_3 which was statistically similar with V_2. The differences in number of fruits plant^{-1} might be due to the different genetic makeup of the tomato cultivars. Biswas *et al.* (2017) also found

similar results which supported the present finding and reported that the highest fruit yield plant^{-1} was recorded from the genotype HT-025 (2.02 kg plant^{-1}) and the lowest was recorded from the line FP-5 (1.17 kg plant^{-1}). The variation in different characters of tomato might be due to difference in cultivars used.

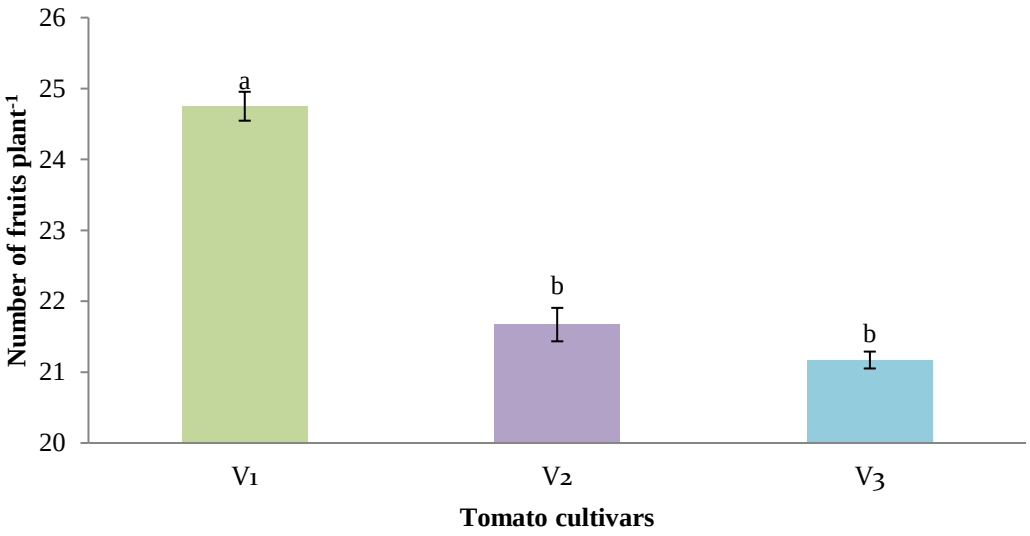

Figure 15. Varietal performance on number of fruits plant^{-1}of tomato.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Different substrates significantly influenced number of fruits plant^{-1} of tomato (Figure 16). The maximum number of fruits plant^{-1} (24.89) was found in M_1. While the lowest number of fruits plant^{-1}(20.11) was found in M_4. The results obtained from the present study was similar with the findings of Mazur *et al.* (2012) who reported that coconut fiber as an environmental friendly medium for cultivation of cherry tomatoes as the plants grown in this media recorded higher fruits number and yield compared to plants grown in mineral wool.

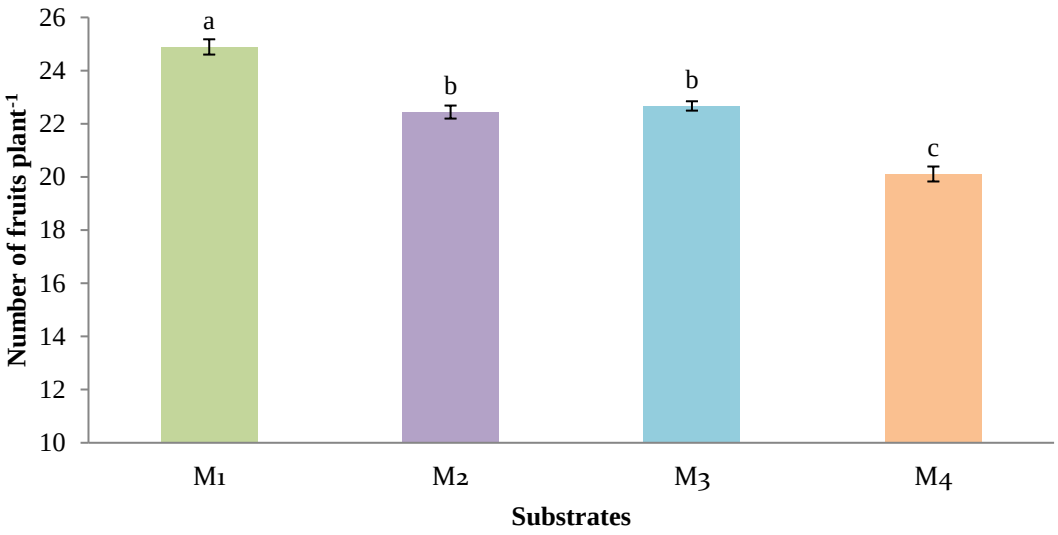

Figure 16. Effect of different substrates on number of fruits plant^{-1}of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Tomato cultivars growing in different substrates significantly influenced number of fruits plant^{-1} (Table 6). Experimental results showed that the highest number of fruits plant^{-1} (27.67) was found in V_1S_1. Meanwhile, the lowest number of fruits plant^{-1} (18.00) was found in V_2S_4.

4.9 Fruit polar length

Performance of cultivars

Different cultivars growing in hydroponic substrates significantly effect on fruit polar length (cm) of tomato (Figure 17). The highest fruit polar length (3.90 cm) was found in V_1. Meanwhile the lowest fruit polar length (3.22 cm) was found in V_2 which was similar with V_3. The significant variation in relation to fruit polar length was probably due to the genetic potentiality of the tomato cultivars. Sanjida *et al*. (2020) also found similar results with the present study and reported that the marked differences in fruit length and fruit width might be due to the different genetic makeup of the summer tomato varieties.

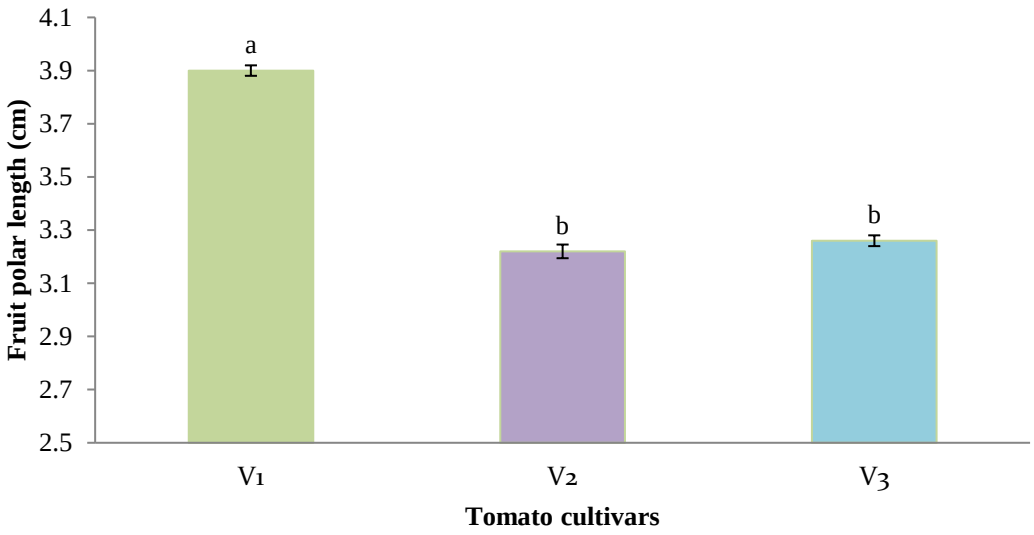

Figure 17. Varietal performance on fruit polar length of tomato.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Tomato growing in different substrates significantly influenced fruit polar length (cm) of tomato (Figure 18). The maximum fruit polar length (3.67 cm) was found in M_1. Meanwhile the lowest fruit polar length (3.17 cm) was found in M_4. The differences in fruit polar length may be due to the variation of substrate properties which influences nutrient supply and water holding capacity and impacts on growth and development of the vegetable crop. Mazur *et al.* (2012) recommended coconut fiber as an environment friendly medium for cultivation of cherry tomatoes as the plants grown in this media recorded higher yield characters compared to plants grown in mineral wool. Olle *et al.* (2012) reported that organic growing media gave more yield and number of fruits then conventional growing system in greenhouse tomato production.

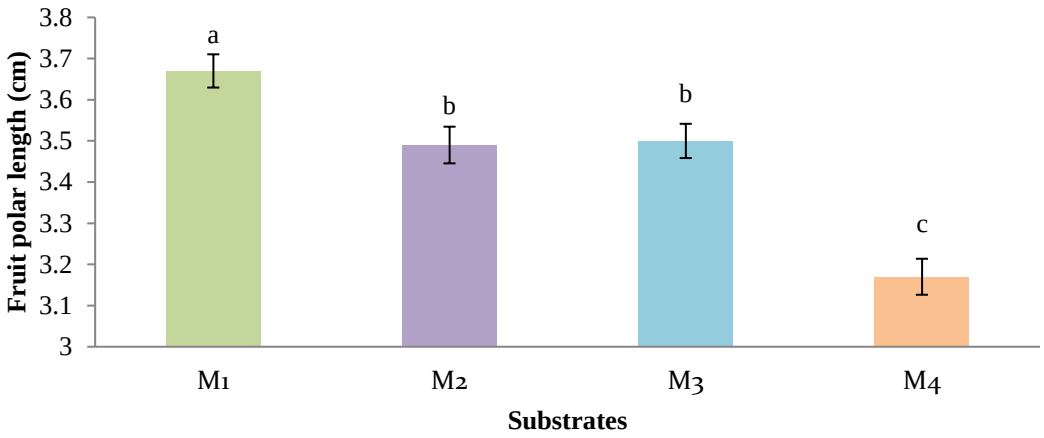

Figure 18. Effect of different substrates on fruit polar length of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly effect on fruit polar length (cm) of tomato (Table 6). The highest fruit polar length (4.08 cm) was found inV_1S_1which was statistically similar with V_1S_3 (3.95 cm). The lowest fruit polar length (2.89 cm) was found in V_2S_4 which was statistically similar with V_3S_4 (2.97 cm).

4.10 Fruit radial length

Performance of cultivars

Tomato cultivars growing in hydroponic substrates significantly vary in fruit radial length (cm) of tomato (Figure 19). The highest fruit radial length (3.68 cm) was found in V_1. Meanwhile the lowest fruit radial length (2.98 cm) was found in V_2. The significant variation in relation to fruit radial length was probably due to the genetic potentiality of the tomato cultivars. Patwary (2009) also found similar results which supported the present finding and reported that the fruit length and width varied from 3.24 cm to 6.09 cm and 2.99 cm to 6.80 cm, respectively.

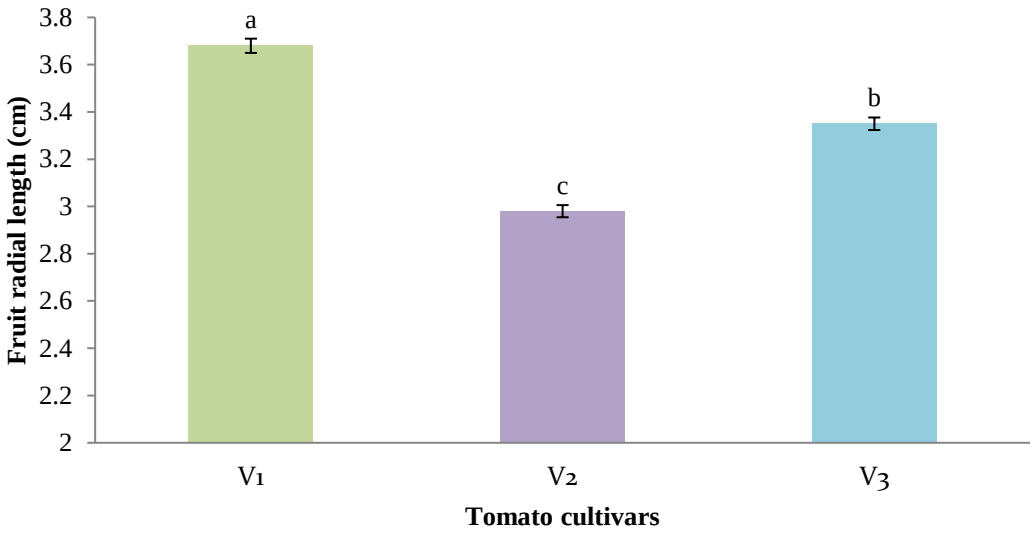

Figure 19. Varietal performance on fruit radial length of tomato.

Here, V_1= Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

Tomato growing in different substrates significantly effects on fruit radial length of tomato (Figure 20). Experimental results revealed that, the highest fruit radial length (3.60 cm) was found in M_1. Whereas the lowest fruit radial length (3.07 cm) was found in M_4. The differences in fruit radial length may be due to variation in substrate properties which influences nutrient supply and water holding capacity and impacts on growth and development of the vegetable crop. Wahome *et al*. (2011) reported that high water holding capacity and high nutrient retention capacity induced higher vegetative growth in hydroponics culture.

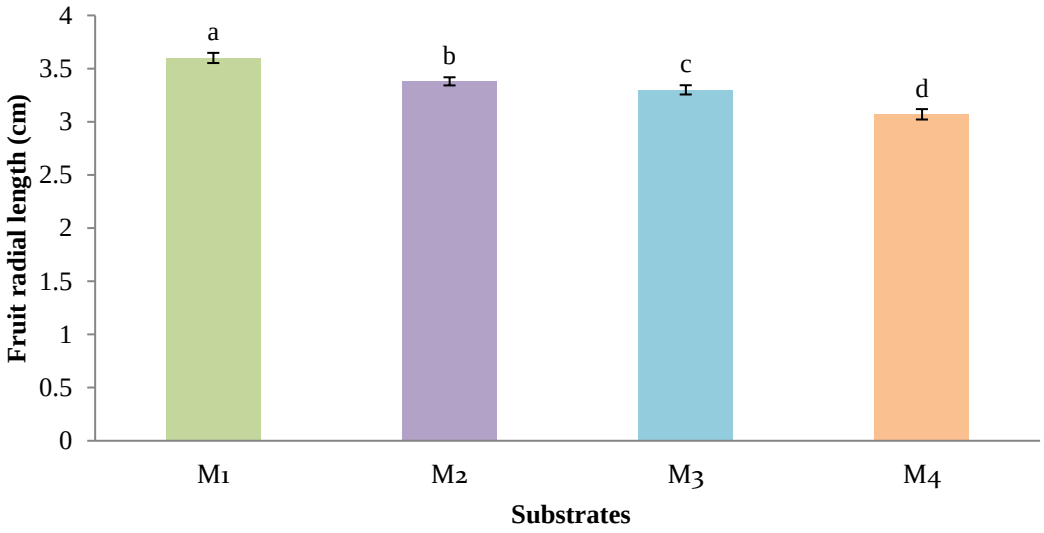

Figure 20. Effect of different substrates on fruit radial length of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced fruit radial length (cm) of tomato (Table 6). Experimental results showed that the highest fruit radial length (3.99 cm) was found in V_1S_1. Whereas the lowest fruit radial length (2.79 cm) was found in V_2S_4which was statistically similar with V_2S_3.

Table 6. Combined effect of cultivars and different substrates on number of fruits plant^{-1}, fruit polar and radial length of tomato

Treatment Combinations	No. of fruits plant^{-1}	Fruit polar length(cm)	Fruit radial length(cm)
V_1S_1	27.67 a	4.08 a	3.99 a
V_1S_2	23.33 cd	3.93 b	3.75 b
V_1S_3	25.67 b	3.95 ab	3.67 bc
V_1S_4	22.33 de	3.65 c	3.31 de
V_2S_1	24.67 bc	3.58 c	3.20 ef
V_2S_2	23.00 d	3.23 ef	3.08 f
V_2S_3	21.00 ef	3.16 f	2.86 g
V_2S_4	18.00 g	2.89 g	2.79 g
V_3S_1	22.33 de	3.36 de	3.61 c
V_3S_2	21.00 ef	3.31 de	3.32 d
V_3S_3	21.33 ef	3.38 d	3.37 d
V_3S_4	20.00 f	2.97 g	3.11 f
$LSD_{(0.05)}$	1.35	0.13	0.12
CV(%)	3.54	2.29	2.04

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa.

4.11 Individual fruit fresh weight

Performance of cultivars

In hydroponic culture different cultivars growing in different substrates significantly vary in individual fruit fresh weight (g) of tomato (Figure 21). Experiment results revealed that, the highest individual fruit fresh weight (45.64 g) was found in V_1. While the lowest individual fruit fresh weight (42.07 g) was found in V_2. The result obtained from the present study was similar with the finding of Shah *et al*. (2021) who reported that fresh weight of tomato was different among cultivars.

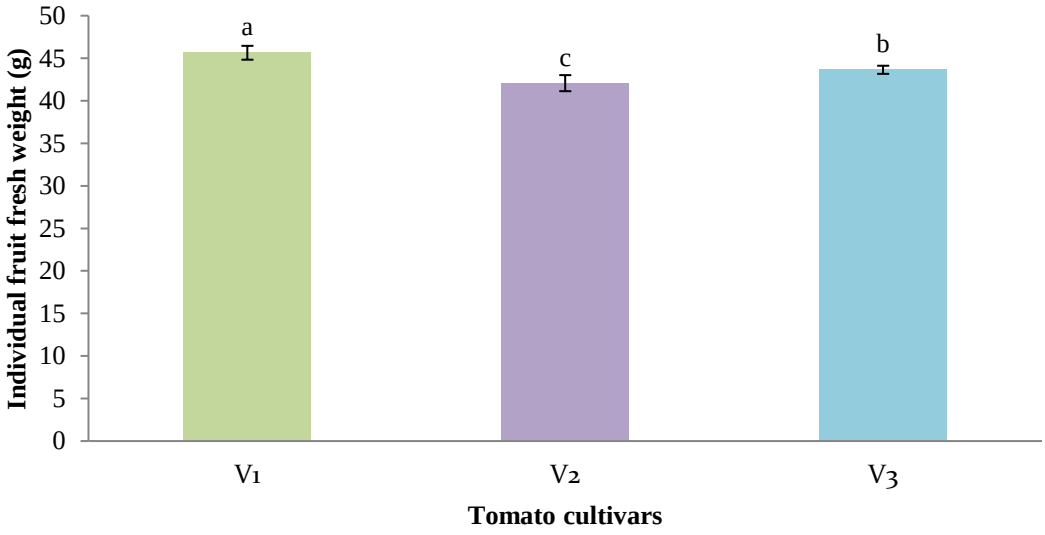

Figure 21. Varietal performance on individual fruit fresh weight of tomato.
Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

In hydroponic culture different substrates significantly influenced individual fruit fresh weight (g) of tomato (Figure 22). Experimental results revealed that the maximum individual fruit fresh weight of tomato (47.64 g) was found in M_1. While the lowest individual fruit fresh weight of tomato (40.65 g) was found in M_4. The differences in individual fruit fresh weight of tomato may be due to variation in substrate properties which influences nutrient supply and water holding capacity and impacts on growth and development of the vegetable crop. The results obtained from the present study was similar with the findings of Luitel *et al.* (2012) and reported that maximum fruit weight (54.7 g) was found to be in cocopeat based substrates due to

the reason that it offers a high moisture, nutrient and air retention capacity, which enables easy growth and well spread root system.

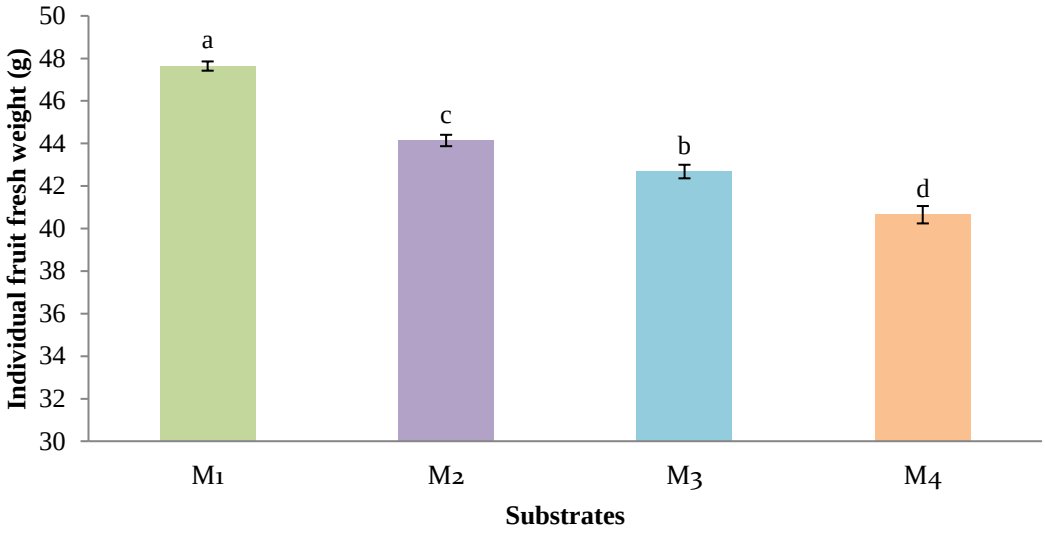

Figure 22. Effect of different substrates on individual fruit fresh weight of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced individual fruit fresh weight of tomato (Table 7). Experimental results showed that the highest individual fruit fresh weight (48.13 g) was found in V_1S_1 which was similar with V_2S_1(47.42 g); V_2S_1 (47.37 g) and V_1S_2 (46.96 g). Whereas the lowest individual fruit fresh weight (38.76 g) was found inV_2S_4which was statistically similar with V_2S_3 (39.01 g).

4.12 Individual fruit dry weight

Performance of cultivars

In hydroponic culture different cultivars growing in different substrates significantly influenced individual fruit dry weight (g) of tomato (Figure 23). Experimental results revealed that, in hydroponic culture the highest individual fruit dry weight (2.59 g)

was found in V_1. While the minimum individual fruit dry weight (2.26 g) was found in V_2.

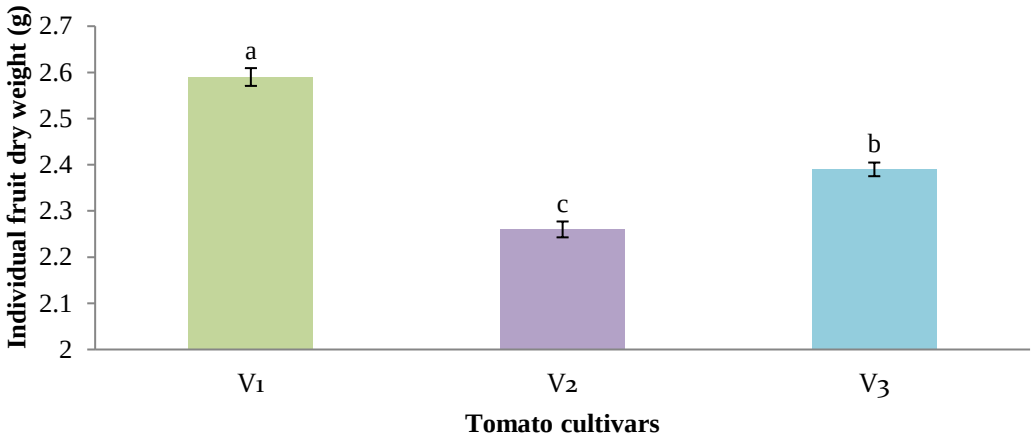

Figure 23. Varietal performance on individual fruit dry weight of tomato. Here, V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

In hydroponic culture different substrates showed significant effect on individual fruit dry weight of tomato (Figure 24). Experimental results revealed that the highest individual fruit dry weight of tomato (2.55 g) was found in M_1. While the lowest individual fruit dry weight of tomato (2.26 g) was found in M_4.

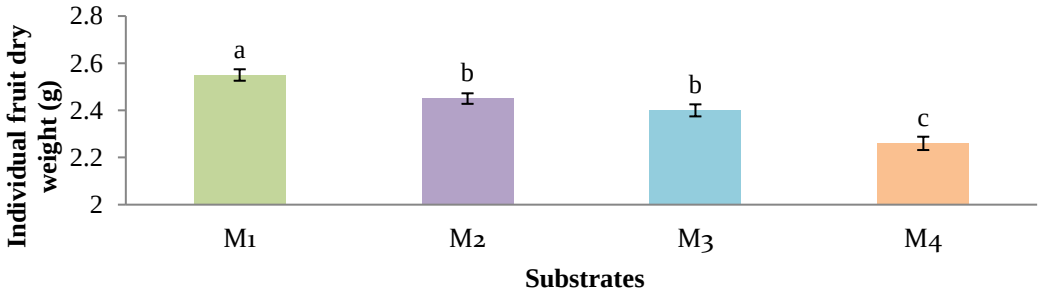

Figure 24. Effect of different substrates on individual fruit dry weight of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced individual fruit dry weight of tomato (Table 7). Experimental results showed that the highest individual fruit dry weight (2.77 g) was found in V_1S_1. Whereas the lowest individual fruit dry weight (2.12 g) was found in(V_2S_4) which was statistically similar with V_2S_3 (2.20 g).

4.13 Yield plant^{-1} (kg)

Performance of cultivars

Different cultivars growing in hydroponic substrates showed significant variation in yield plant^{-1} (kg) of tomato (Figure 25). Experimental results revealed that, the maximum yield plant^{-1} (1.14 kg) was found in V_1. While the minimum yield plant^{-1} (0.92 kg) was found in V_2which was similar with V_3. The significant variation in relation to yield plant^{-1} was probably due to the genetic potentiality of the tomato varieties. The results obtained from the present study was similar with the findings of Singh *et al.* (2013) and they reported that Avinash-23 recorded the maximum yield per plant of 2.90 kg followed by Richa with a yield of 2.88 kg.

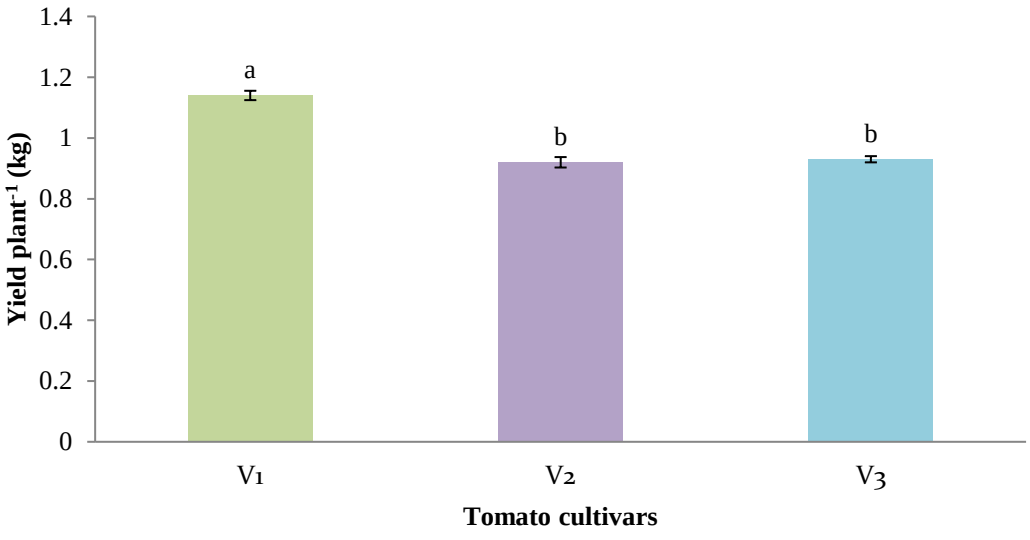

Figure 25. Varietal performance on yield plant^{-1}of tomato.

Here, V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

In hydroponic culture different substrates significantly affect the yield plant^{-1} of tomato (Figure 26). The maximum yield plant^{-1} of tomato (1.19 kg) was found in M_1while the lowest yield plant^{-1} of tomato (0.82 kg) was found in M_4. Hansen *et al*. (2010) reported that in hydroponics, lettuce gave 23% more yield when coconut fibre was used as the substrates. Joseph and Muthuchamy (2014) reported that the maximum yield (4.9 kg plant^{-1}) was observed for the treatment trough with cocopeat + gravel + silex stone followed by trough with cocopeat + prelite + silex stone (4.2 kg plant^{-1}) and trough with cocopeat + pebble + silex stone (3.9 kg plant^{-1}). The highest productivity (245.3 t ha^{-1}) was obtained from the treatment trough with cocopeat + gravel +silex stone. The treatment trough with cocopeat + pebble + silex stone yielded (2.8 kg plant^{-1}) least productivity (138.3 t ha^{-1}). Mazur *et al.* (2012) recommended coconut fiber as an environmental friendly medium for cultivation of cherry tomatoes as the plants grown in this media recorded higher fruits number and yield compared to plants grown in mineral wool.

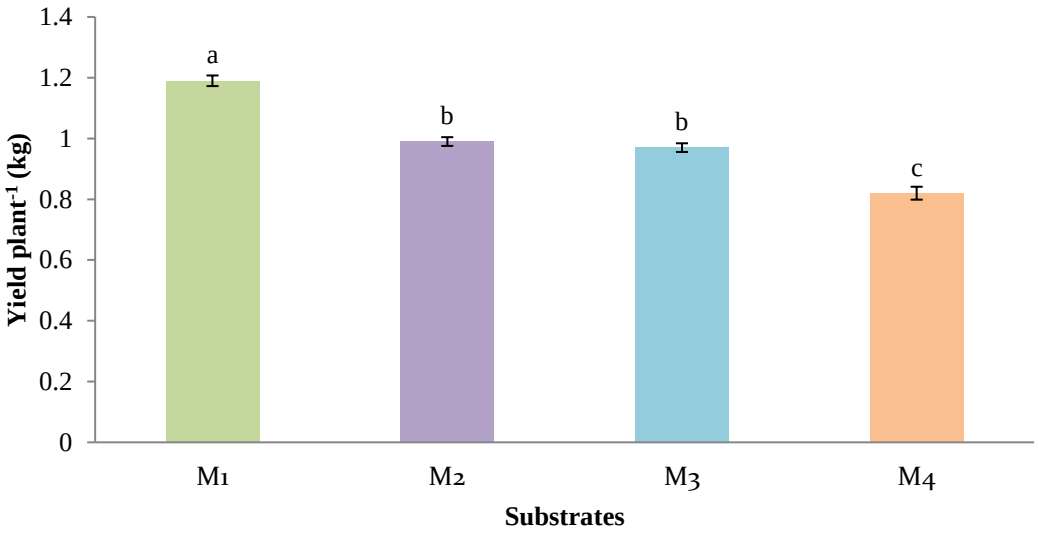

Figure 26. Effect of different substrates on yield plant^{-1}of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced yield plant^{-1}of tomato (Table 7). Experimental results showed that the maximum yield plant^{-1}of tomato (1.33 kg) was found inV_1S_1. Whereas the minimum yieldplant^{-1} (0.70 kg) was found in V_2S_4.

Table 7. Combined effect of cultivars and different substrates on individual fruit fresh weight (g), dry weight (g) and yield plant^{-1} (kg) of tomato

Treatment Combinations	Individual fruit fresh weight (g)	Individual fruit dry weight (g)	Yield plant^{-1}(kg)
V_1S_1	48.13 a	2.77 a	1.33 a
V_1S_2	46.96 ab	2.65 b	1.09 c
V_1S_3	46.26 b	2.63 b	1.19 b
V_1S_4	41.20 d	2.32 d	0.92 e
V_2S_1	47.42 ab	2.41 cd	1.17 b
V_2S_2	43.07 c	2.32 d	0.99 d
V_2S_3	39.01 e	2.20 e	0.82 g
V_2S_4	38.76 e	2.12 e	0.70 h
V_3S_1	47.37 ab	2.46 c	1.06 c
V_3S_2	42.40 cd	2.39 cd	0.89 ef
V_3S_3	42.79 c	2.38 cd	0.91 e
V_3S_4	41.98 cd	2.33 d	0.84 fg
$LSD_{(0.05)}$	1.35	0.11	0.06
CV(%)	1.82	2.80	3.70

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa.

4.14 Fruit volume

Performance of cultivars

Tomato cultivars growing in hydroponic substrates significantly influenced fruit volume (cc) of tomato (Figure 27). Experimental results revealed that, the maximum fruit volume (195.00 cc) was found in V_1. Whereas the lowest fruit volume (184.50 cc) was found in V_3. The variation in fruit volume was the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the performance of the crop.

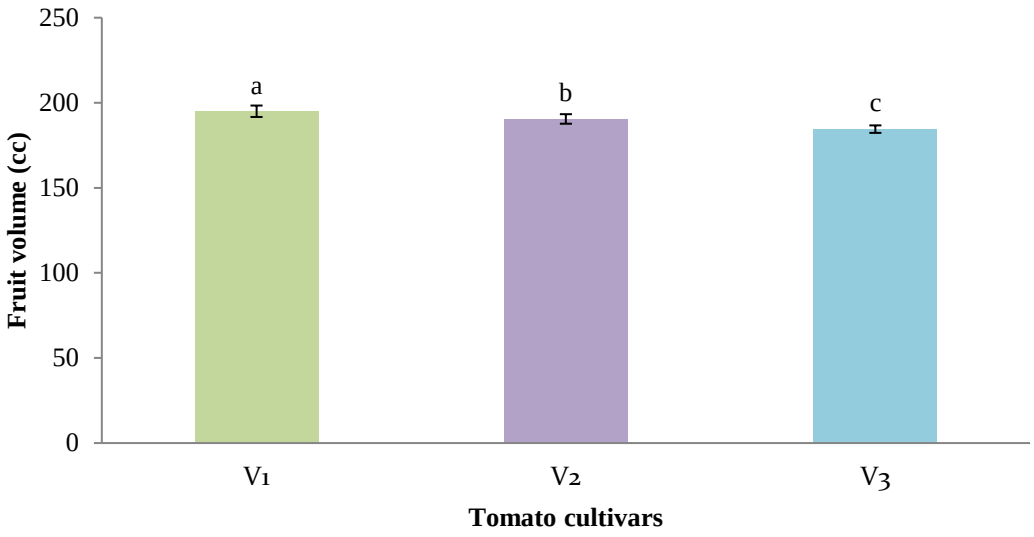

Figure 27. Varietal performance on fruit volume of tomato.

Here, V_1 = Rani, V_2 = Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

In hydroponic culture different substrates significantly influenced the fruit volume of tomato (Figure 28). Experiment results revealed that the maximum fruit volume of tomato (200.83 cc) was found in M_1. Whereas the lowest fruit volume of tomato (180.97 cc) was found in M_4.

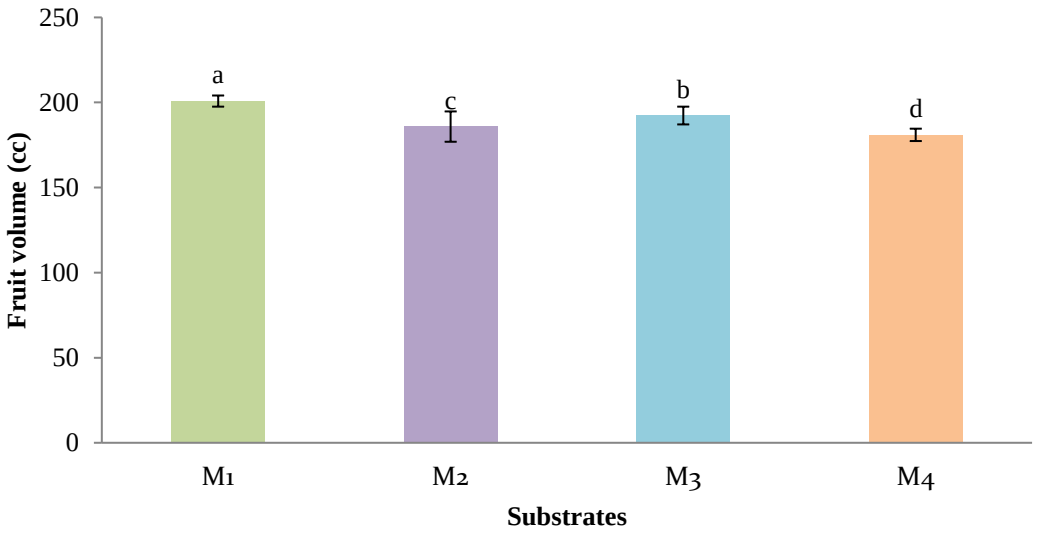

Figure 28. Effect of different substrates on fruit volume of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4= 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced fruit volume of tomato (Table 8). Experimental result showed that the maximum fruit volume of tomato (204.50 cc) was found in V_1S_1which was statistically similar with V_3S_1 (199.50 cc). Whereas the lowest fruit volume of tomato (169.50 cc) was found in V_3S_4.

4.15 Total soluble solids (%)

Performance of cultivars

Tomato cultivars growing in hydroponic substrates significantly affect the total soluble solids (%) of tomato. Experiment results revealed that, the maximum total soluble solids (6.58 %) was found in V_2. Whereas the lowest total soluble solids (6.10 %) was found in V_3. The variation in total soluble solids was the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the performance of the crop. Similar results was also observed by Sanjida *et al*. (2020) who reported that in case of total soluble solids (TSS) of summer tomato varieties, the highest TSS (5.41%) was found from V_2 (BARI hybrid tomato 8) while

the lowest TSS (4.97%) was obtained from V_1 (BARI hybrid tomato 4). The variation was due to the varietal effect of different cultivars.

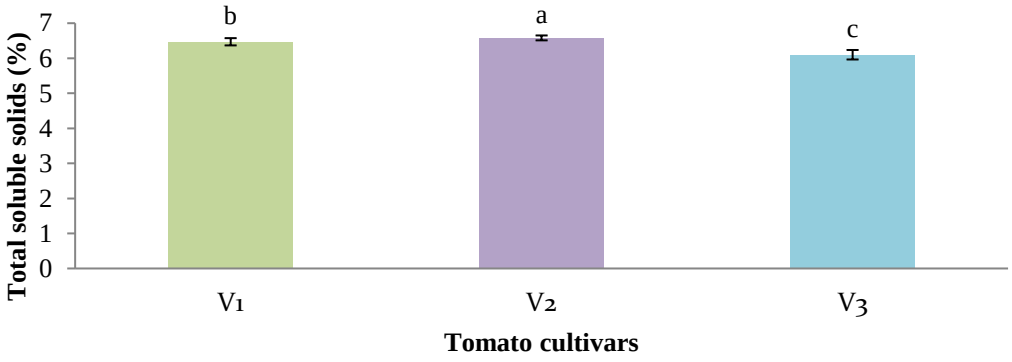

Figure 29. Varietal performance on total soluble solids of tomato.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different substrates

In hydroponic culture different substrates significantly affect total soluble solids (%) of tomato (Figure 30). Experimental results revealed that the highest total soluble solids of tomato (7.18 %) was found in M_2. While the lowest total soluble solids of tomato (5.96 %) was found in M_1 which was statistically similar with M_3 (6.02 %).

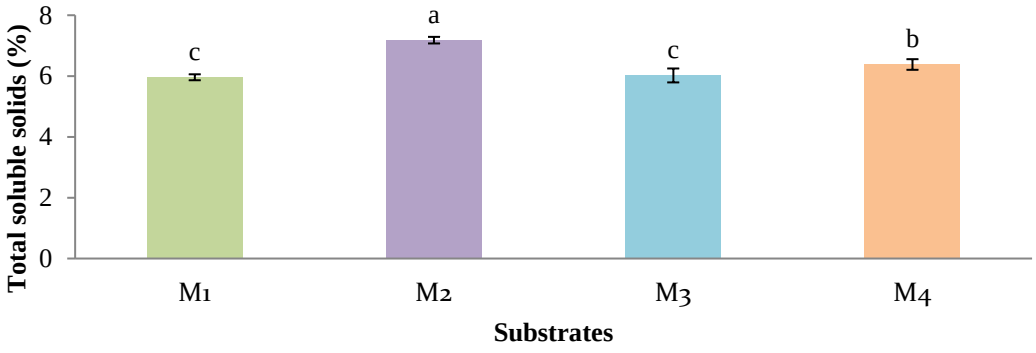

Figure 30. Effect of different substrates on total soluble solids of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates had shown significant effect on total soluble solids (%) of tomato (Table 8). Experiment results showed that the highest total soluble solids of tomato (8.05 %) was found inV_1S_2, while the lowest total soluble solids of tomato (5.43 %) was found in V_3S_3.

4.16 pH

Performance of cultivars

Different tomato cultivars growing in hydroponic substrates had shown significant effect on pH of tomato. Experimental results revealed that, the maximum pH (4.41) was found in V_1. While the lowest pH (4.35) was found in V_2. Sanjida *et al*. (2020) also found similar result with the present study and reported that varietal character might influence the variations of pH in summer tomato. The highest (3.88) and lowest (3.71) pH were found from V_3 (BARI hybrid tomato 10) and V_1 (BARI hybrid tomato 4) respectively.

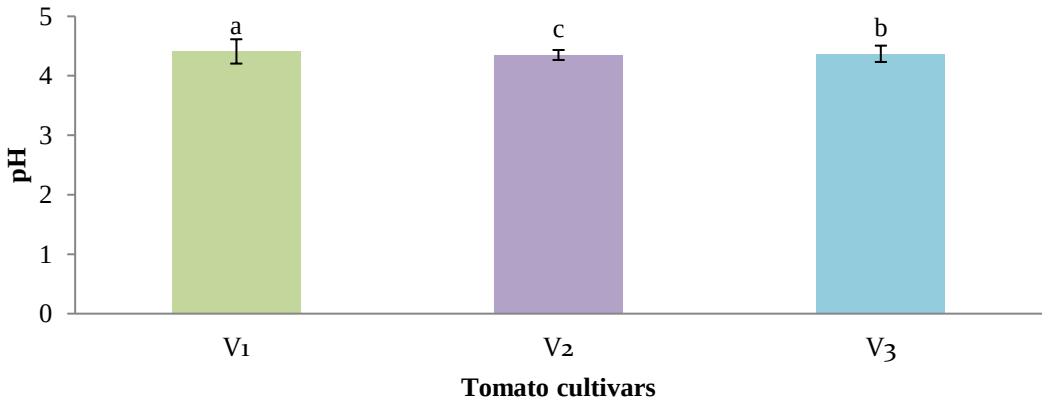

Figure 31. Varietal performance on pH of tomato.

Here, V_1 = Rani, V_2= Extra profit and V_3 = Roma VF tomato. Vertical bars indicate standard error (SE).

Effect of different Substrates

In hydroponic culture different substrates had significant effect on pH of tomato (Figure 32). Experimental results revealed that, the maximum pH (4.44) was found in M_2. Whereas the minimum pH (4.33) was found in M_1 which was similar with M_3 (4.35).

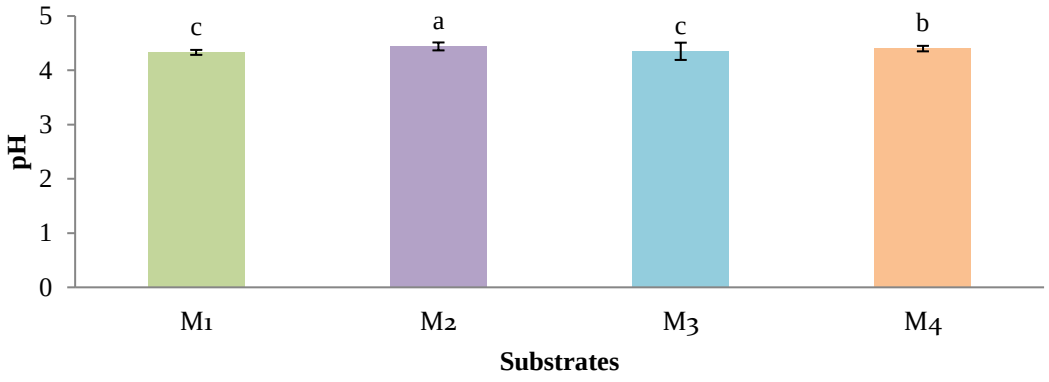

Figure 32. Effect of different substrates on pH of tomato.

Here, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa. Vertical bars indicate standard error (SE).

Combined effect of cultivars and different substrates

Combined effect of cultivars and different substrates significantly influenced the pH of tomato (Table 8). Experimental results showed that the maximum pH (4.64) was found inV_1S_2. Whereas the minimum pH (4.28) was found inV_1S_1.

Table 8. Combined effect of cultivars and different substrates on volume, total soluble solids and pH of tomato

Treatment Combinations	Volume (cc)	Total soluble solids (%)	pH
V_1S_1	204.50 a	5.77 f	4.28 e
V_1S_2	190.50 c	8.05 a	4.64 a
V_1S_3	196.50 b	6.06 e	4.38 c
V_1S_4	188.50 cd	6.01 e	4.35 cd
V_2S_1	198.50 b	6.27 d	4.35 cd
V_2S_2	187.50 cd	6.87 b	4.35 cd
V_2S_3	191.00 c	6.57 c	4.32 d
V_2S_4	184.90 de	6.59 c	4.38 c
V_3S_1	199.50 ab	5.83 f	4.35 cd
V_3S_2	179.50 e	6.61 c	4.32 d
V_3S_3	189.50 cd	5.43 g	4.34 d
V_3S_4	169.50 f	6.53 c	4.48 b
$LSD_{(0.05)}$	5.44	0.18	0.03
CV(%)	1.69	1.66	0.48

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = Rani, V_2= Extra profit, V_3 = Roma VF tomato, M_1= 70 % Cocopeat + 30 % Khoa, M_2 = 70 % Rice husk+ 30 % Khoa, M_3 = 70 % Sawdust + 30 % Khoa and M_4 = 70 % Woodchips+ 30 % Khoa.

CHAPTER V

SUMMARY AND CONCLUSION

Our experimental results suggested that different growing substratesgreatly influenced the yield and yield contributing parameters of tomato cultivars. Among different growing substrates, tomato plant growing in 70 % Cocopeat + 30 % Khoa (M_1) based growing substrate performed well and recorded the highest yield plant^{-1} (1.19 kg) of tomato. Different tomato cultivars have different growth characteristics that influences plant growth. In this experiment among different cultivars, Rani (V_1) tomato performed well when it was growing in different substrates and recorded the highest yield plant^{-1} (1.14 kg). In case of combination Rani tomato cultivar growing in 70 % Cocopeat + 30 % Khoa based growing substrate (V_1S_1) recorded the highest individual fruit fresh weight (48.13 g), fruit dry weight (2.77 g), yield plant^{-1} (1.33 kg) and fruit volume (204.50 cc).

Conclusions

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

i. Improved growth, yield and physicochemical properties can be found in cocopeat based growing substrates mixtures of M_1 for growing tomato in hydroponic culture.
ii. Higher fruit yield and other vegetative growth parameters and physiological traits of tomato were found in Rani tomato cultivar when it was growing in different substrates in hydroponic culture.

Therefore, it can be concluded that Rani tomato cultivar along with cocopeat based growing substrate M_1 performed best for achieving higher yield and quality of tomato comparable to others treatment combinations in hydroponic culture.

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APPENDICES

Appendix I. Map showing the experimental site under study

Appendix II.Monthly meteorological information during the period from October, 2019 to March 2020.

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71

(Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Analysis of variance of the data of plant height of tomato at different DAT

Source	DF	Mean square of plant height at			
		20 DAT	40 DAT		
Replication (R)	2	44.320	48.303		
Cultivar (C)	2	622.852**	13.480**		
Substrate (S)	3	371.029**	135.230**		
C×S	6	39.519**	5.600*		
Error	22	2.545	2.129		
Total	35				

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data of number of leaves plant^{-1} of tomato at different DAT

Source	DF	Mean square of number of leaves plant^{-1} at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication (R)	2	76.681	84.520	321.120	298.570
Cultivar (C)	2	107.506**	69.173**	651.442**	666.392**
Substrate (S)	3	533.308**	150.722**	282.943**	312.176**
C×S	6	7.363**	4.910**	21.562**	16.446**
Error	22	0.270	0.636	6.880	1.930
Total	35				

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of number branches plant^{-1} of tomato

Source	DF	Mean square of No. branches plant^{-1}		
		20 DAT	40 DAT	60 DAT
Replication (R)	2	22.5846	19.6633	87.6505
Cultivar (C)	2	14.1083**	13.4689**	53.8756**
Substrate (S)	3	10.5561**	9.7867**	39.1468**
C×S	6	2.6039**	2.3345**	9.3379**
Error	22	0.0278	0.0234	0.0833
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of stem radius plant^{-1} of tomato

Source	DF	Mean square of stem radius at		
		20 DAT	40 DAT	60 DAT
Replication (R)	2	2.004E-03	0.00370	0.01262
Cultivar (C)	2	1.756E-03**	0.00503**	0.01216**
Substrate (M)	3	5.015E-03**	0.01613**	0.03904**
C×S	6	1.186E-04**	0.00036**	0.00087**
Error	22	7.778E-05	0.00006	0.00007
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of days to first flowering, number of flower clusters plant^{-1} and number of fruits cluster plant^{-1} of tomato

Source	DF	Mean square of		
		Days to first flower	No. flower clusters plant^{-1}	No. fruits cluster plant^{-1}
Replication (R)	2	0.5833	46.0833	11.6044
Cultivar (C)	2	5.2201**	56.2756**	6.4481**
Substrate (M)	3	32.5134**	30.1867**	5.7537**
C×S	6	1.6876**	2.4678**	0.2510**
Error	22	0.4015	0.1742	0.0099
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of fruits plant^{-1}, fruit polar and radius perimeter of tomato

Source	DF	Mean square of		
		No. fruits plant^{-1}	Fruit polar length	Fruit radial length
Replication (R)	2	14.2468	0.63083	1.22934
Cultivar (C)	2	45.2131**	1.78703**	1.46147**
Substrate (M)	3	34.3565**	0.39549**	0.43365**
C×S	6	5.1723**	0.02789**	0.02071**
Error	22	0.6364	0.00629	0.00462
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of individual fruit fresh weight, dry weight and yield plant^{-1}of tomato

Source	DF	Mean square of		
		Individual fruit fresh weight (g)	Individual fruit dry weight (g)	Yield plant^{-1} (kg)
Replication (R)	2	46.8208	0.40396	0.14247
Cultivar (C)	2	38.4753**	0.33031**	0.18098**
Substrate (M)	3	78.1343**	0.13109**	0.20344**
C×S	6	9.3884**	0.01802**	0.01917**
Error	22	0.6364	0.00456	0.00135
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of volume (cc), total soluble solids (%) and pH of tomato

Source	DF	Mean square of		
		Volume (cc)	Total soluble solids (%)	pH
Replication (R)	2	35.583	0.40583	0.02994
Cultivar (C)	2	332.852**	0.74977**	0.01237**
Substrate (M)	3	665.303**	2.83043**	0.02276**
C×S	6	47.153**	0.84138**	0.03416**
Error	22	10.311	0.01129	0.00045
Total	35			

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

PLATES

Plate 1: Photograph showing seedbed preparation for tomato

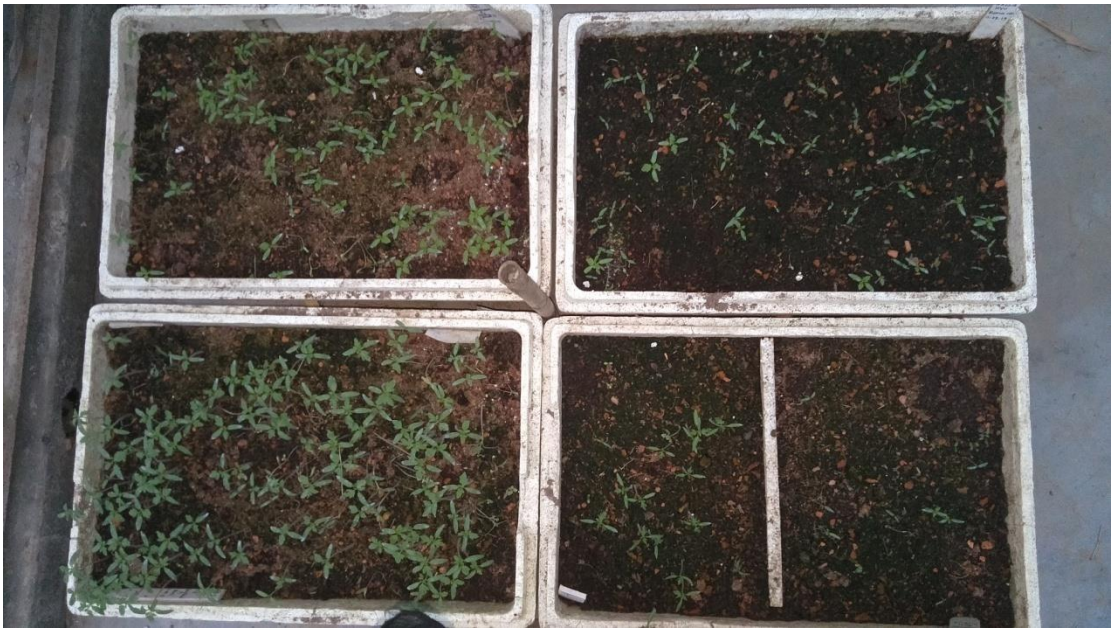

Plate 2: Photograph showing emergence of tomato seedling

Plate 3: Photograph showing transplanting tomato seedling

Plate 4: Photograph showing collecting data for experimental result analysis

Plate 5: Photograph showing inspection of experimental work by supervisor