NUTRITIONAL STUDIES FOR SOIL AND SOILLES PRODUCTION OF STRAWBERRY (*Fragaria × ananassa*) CV. CHANDLER

by

Sanjay Kumar

(J-19-M-657)

A Thesis submitted to Faculty of Agriculture

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

HORTICULTURE (FRUIT SCIENCE)

Division of Fruit Science

Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu
Main Campus, Chatha, Jammu - 180009

2021

CERTIFICATE – I

This is to certify that the thesis entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture Horticulture (Fruit Science)** to the Faculty of Agriculture Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is original work and has similarities with published work not more than minor similarities as per UGC norms of 2018 adopted by the University. Further the level of minor similarities has been declared after checking the manuscript with Urkund software provided by the University.

The work has been carried out by **Mr. Sanjay Kumar,** Registration No. **J-19-M-657,** under my supervision and guidance. No part of the thesis has been submitted for any other degree of diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

Dr. Mahital Jamwal
(Major Advisor)

Place: Jammu

Date: 28.10.2021

28/10/2021
Head of the Division

Dean

CERTIFICATE- II

We, the members of the Advisory Committee of **Mr. Sanjay Kumar,** Registration No. **J-19-M-657,** a candidate of the degree of **Master of Science in Agriculture Horticulture (Fruit Science),** have gone through the manuscript of the thesis entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the degree.

Dr. Mahital Jamwal
Deputy Director (Research)/
Assoc. Prof. (Fruit Science),
Directorate of Research, Chatha
(Major Advisor & Chairman Advisory Committee)

Place: Jammu

Date: 28.10.2021

Advisory Committee Members

Dr. Parshant Bakshi
Assoc. Professor (Fruit Science),
ACHR, Udhaywalla
(Member from Major Subject)

28/10/21

Dr. Gurdev Chand
Asstt. Prof. & Head,
Division of Physiology
(Member from Minor Subject)

28/10/2021

Dr. M. Iqbal Jeelani Bhat
Assistant Professor,
Division of Statistics & Computer Science
(Member from Supporting Subject)

28/10/21

Dr. Satish Kumar
Jr. Scientist (Bio-Chemistry),
RHRSS, Bhaderwah
(Dean's Nominee)

CERTIFICATE -III

This is to certify the thesis entitled **"Nutritional Studies for Soil and Soilless Production of Strawberry (*Fragaria* × *ananassa*) cv. Chandler"**, submitted by **Mr. Sanjay Kumar,** Registration No. **J-19-M-657**, to the faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture in Horticulture (Fruit Science),** was examined and approved by the advisory committee and external examiner (s) on 25/11/2021.....

25/11/2021

Dr. R.M. Sharma
(External Examiner)

Dr. R.M. Sharma
Principal Scientist
Division of Fruits & Horticultural Technology
ICAR-Indian Agricultural Research Institute
New Delhi-110012

Dr. Mahital Jamwal
Dy. Director Research/
Assoc. Prof. (Fruit Science)
(Major Advisor)

25/11/2021

Dr. Amit Jasrotia
Head of the Division

25/11/2021

Dean, FoA
SKUAST-Jammu
Chatha

Acknowledgement

First and foremost, praises and thanks to the God, who is forever at utmost of Knowledge and guidance for humanity as a whole and with who's delighting the present endeavor has been beautiful.

I am extremely grateful to my grandparents Ch. Amar Singh Malethia and Smt. Angoori Devi and my parents Shri. Sudhir Kumar (Father), Smt. Krishna Devi (Mother), Shri. Raj Kumar (Uncle), Smt. Surekha Devi (Aunty) for their love, valuable prayers, and sacrifices and for educating and supporting me throughout my life.

I emphatically dedicate my whole work to all my teachers (and first teacher is my mom) and farmers (who feed the world) that encouraged me to come so far and I was able to complete M.sc and research work.

I would like to express my deepest sense of gratitude and indebtedness to One Man Army my major advisor, ***Dr. Mahital Jamwal*** *(Associate Professor, Division of Fruit Science and Deputy Director Research, SKUAST-Jammu) for giving me the opportunity to do this research and providing invaluable guidance throughout the course of this study. His dynamism, vision, sincerity and motivation have deeply inspired me. It was a great privilege and honor to work and study under his guidance. I am extremely grateful for what he has offered me.*

I express my special gratitude to honorable members of my advisory committee, and specially to my minor advisor ***Dr. Gurdev Chand****, (Assistant Professor and Head, Division of Plant Physiology) who taught me the methodology to carry out the research and to present the research works as clearly as possible, Dr. Parshant Bakshi, (Associate Professor, Division of Fruit Science), Dr. M. Iqbal Jeelani Bhat (Assistant Professor, Division of Statistics & Computer Science) and Dr. Satish Kumar (Jr. Scientist, Bio-Chemistry, RHRSS, Bhaderwah) for the generous help and encouragement throughout the course of the study.*

I equally reiterate my gratitude and indebtedness to Dr. Amit Jasrotia, Associate Professor and Head (Division of Fruit Science), Dr. Nirmal Sharma (Assistant Professor, Division of Fruit Science) who constantly guided me through my thesis and the cooperation and sever willing support of non-teaching staff of the division especially Neeharika Pandita Mam (Stenographer, Division of Fruit Science), Krishan Lal Ji (FCLA, Division of Fruit Science).

I would like to express my heartfelt thanks to my seniors Dr. Devender Rana, Dr. Ashok Godara, Dr. Manmohan Lal, Dr. Gurwinder Singh for their constant support, thoughts, well wishes, phone calls, and being there whenever I needed.

I would like to express my heartfelt thanks to group ***#Gopalmatth*** *Rahul Haryanvi, Rafakat, Ashish Yadav Ji, Sumit, Kaushik, Kapil, Saksham, Bhim, Surrender, Yogesh, Bhadu, Kartikey, Arun, Nikhil, Ankush, Vikram, Vijaya, Shakti, Talim, Lucky, Rahul Dadri for their constant support, thoughts, well wishes, phone calls, and being there whenever I needed a friend.*

I would like to express my heartfelt thanks to my cousins Ritu, Ranjana, Chandan, Anukul, Davinder and Vineet for always being there for me and for their endless and incomparable love and affection.

At last but not least gratitude goes to my classmates Khalid Ferooz, Tanuj Bhardwaj, Neha Raj, Reetika Sharma, Richa Sharma and Priyanka Dahiya for constant support in academics and worthy suggestions whenever needed.

On a different note, many people have been a part of my education and I offer my regards to all of those who supported me in any respect during the completion of my study.

All can't be mentioned but none has been forgotten.

I solely claim the responsibility for error and omissions in this work.

Sanjay Kumar

Sanjay

Place : Jammu

Date 16-12-2021.

ABSTRACT

Title of the Thesis	:	**NUTRITIONAL STUDIES FOR SOIL AND SOILLESS PRODUCTION OF STRAWBERRY (*Fragaria × ananassa*) CV. CHANDLER**
Name of the Student	:	Sanjay Kumar
and Registration No.	:	J-19-M-657
Major Subject	:	Fruit science
Name and Designation of Major Advisor	:	Dr. Mahital Jamwal Associate Professor/ Deputy Director Research, SKUAST- Jammu
Degree to be awarded	:	M.Sc. Agriculture Horticulture (Fruit Science)
Year of award of degree	:	2021
Name of University	:	Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu (J&K)

ABSTRACT

The present investigation entitled "Nutritional studies for soil and soilless production of strawberry (*Fragaria × ananassa*) cv. Chandler" was carried out at experimental area in the Division of Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21. The objective of this investigation was to find out the nutritional response in soil and soilless medium for optimum strawberry production and to find out the economics for soil and soilless strawberry production. The experiment was laid out in hydroponics system and potted soil culture in completely randomized design (CRD) with seven treatments replicated thrice and the vegetative, reproductive, physical and biochemical parameters of Chandler strawberry were recorded. It was observed that minimum number of days were taken for runner establishment (6.41) and the maximum average number of leaves per plant was 28.64. Highest values were recorded for average leaf area per plant (135.46 cm^2), leaf chlorophyll content (55.35), plant spread (42.47 cm) and root/shoot ratio (1.53) under T_3 treatment i.e. cocopeat + vermiculite + vermicompost (1:1:1). Minimum values were obtained for number of days taken for first bud formation (64.74), days for first flower initiation (68.80) and maximum values were recorded for average number of buds per plant (25.47) and average number of flowers per plant (25.33) under T_3 treatment i.e. cocopeat + vermiculite + vermicompost (1:1:1). Maximum fruit length (3.92 cm), fruit breadth (3.40 cm), fruit size (13.32 cm^2), fruit colour (dark red), fruit weight (19.48 g), fruit volume (17.57 cc), specific gravity (1.11 g/cm^3), number of fruits per plant (25.19) and yield per plant (490.69 g) were also recorded with T_3 treatment i.e. cocopeat + vermiculite + vermicompost (1:1:1). Maximum total soluble solids (9.94 ºB), total sugars (8.03 %), reducing sugars (6.21 %), non reducing sugars (1.73 %), ascorbic acid (51.10 mg/100g), anthocyanin content (48.40 mg/100g), carotenoid content (18.04 mg/g) and minimum titratable acidity (0.81 %) were recorded under T_3 treatment i.e. cocopeat + vermiculite + vermicompost (1:1:1). As per economic analysis, it was found that maximum B:C ratio (1:2.5) was recorded under T_3 treatment cocopeat + vermiculite + vermicompost (1:1:1). It was concluded that substrate combination of cocopeat + vermiculite + vermicompost in the ratio of 1:1:1 in Hydroponics (NFT) may be beneficial for better yield and quality production of strawberry cv. Chandler as compared to soil culture.

Key words: *Chandler strawberry, soil, soilless medium, hydroponics (NFT)*

Signature of the Major Advisor **Signature of the Student**

CONTENTS

CHAPTER NO.	TOPIC	PAGE NO.
I	**INTRODUCTION**	**1-3**
II	**REVIEW OF LITERATURE**	**4-20**
III	**MATERIALS AND METHODS**	**21-29**
IV	**RESULTS**	**30-37**
V	**DISCUSSION**	**38-43**
VI	**SUMMARRY AND CONCLUSION**	**44-45**
	REFERENCES	**46-60**
	APPENDIX	
	VITA	

LIST OF TABLES

Table No.	Particulars	After Page No.
1	Effect of substrate combinations on number of days taken for runner establishment, average number of leaves per plant, average leaf area per plant (cm^2), leaf chlorophyll content (SPAD), plant spread (cm) and root/shoot ratio	31
2	Effect of substrate combinations on days taken for first bud formation, days for the first flower initiation, average number of buds per plant, number of flowers per plant and average number of flowers per plant	33
3	Effect of substrate combinations on fruit length (cm), fruit breadth (cm), fruit size (cm^2) and fruit colour (UPOV)	33
4	Effect of substrate combinations on fruit weight (g), fruit volume (cc), specific gravity (g/cm^3), number of fruits per plant and yield per plant (g)	35
5	Effect of substrate combination on total soluble solids (^oB), total sugars (%), reducing sugars (%) and non reducing sugars (%)	35
6	Effect of substrate combination on titratable acidity (%), ascorbic acid (mg/100g), anthocyanin content (mg/100g) and carotenoid content (mg/g)	35
7	Cost of cultivation for different substrate combination	37
8	Cost and benefit analysis of strawberry production	37

LIST OF FIGURES

Table No.	Particulars	After Page No.
1	Effect of different substrates on average number of leaves per plant	31
2	Effect of different substrates on average number of buds per plant	31
3	Effect of different substrates on number of flowers per plant	33
4	Effect of different substrates on number of fruits per plant	35
5	Effect of different substrates on yield per plant (g)	35

LIST OF PLATES

Plate No.	Particulars	After Page No.
1(a)	Strawberry runners at time of planting in soilless medium	29
1(b)	Strawberry runners at time of planting in potted soil medium	29
2	Complete over view of experimental site	29
3(a)	Strawberry plants at flowering stage in soilless medium	31
3(b)	Strawberry plants at flowering stage in potted soil medium	31
4	Fruit size of Chandler strawberry under T_3 treatment i.e. cocopeat + vermiculite + vermicompost (1:1:1)	33

Chapter-1

Introduction

CHAPTER – 1

INTRODUCTION

Strawberry is widely distributed soft fruits in the whole world due to its genotypic diversity, broad range of environmental adaptations and highly heterozygous nature (Childers *et al.,* 1995). Although it is native of temperate climate, but varieties are available which can be cultivated in tropical and sub-tropical climate. China is the leading country in Strawberry fruit production with approximate yield of 2.99 million MT (Zhang *et al.,* 2014) followed by USA (1.36 million MT), Mexico (0.37 million MT), Turkey (0.37 million MT), Spain (0.31 million MT) (Anon., 2014). India has total cultivated area of about 1000 ha under strawberry cultivation with 5000 MT production (Anon., 2018). It is most commonly grown in hilly parts of India. Maharashtra is the state with the most strawberry production among the states. Nainital and Dehradun (Uttarakhand), Punjab, Haryana, Himachal Pradesh, Mahabaleshwar (Maharashtra), Jammu and Kashmir, Bangalore, and Kalimpong (West Bengal) are the other major areas of cultivation. Strawberry has been successfully cultivated in plain parts of the nation in recent years.

Strawberry (*Fragaria* × *ananassa* Duch.) belongs to family Rosaceae and genus *Fragaria.* It is basically a small herbaceous perennial plant. Strawberry is a monoecious octoploid (2n = 56) hybrid of two dioecious octoploid species i.e. *Fragaria chiloensis* Duch. and *Fragaria virginiana* Duch. having basic chromosome number (x) of 7 (Bowling, 2000). The strawberry is an aggregate fruit, having achenes on the surface of red fleshy receptacle (Darnell, 2003). It is quite delicious fruit with attractive and pleasant aroma. It is used in making excellent ice cream, crush, pies, Jam, fruit juices and milk shakes on account of its rich aroma. The strawberry contains 89.9 per cent water, 8.4 per cent carbohydrates, 1.3 per cent fibre, 0.7 per cent protein, 0.5 per cent ash, 0.5 per cent fat, 164 mg potassium, 21 mg calcium, 1.0 mg sodium, 1.0 mg iron, 60 I.U. vitamin A, 59 mg/ 100 g vitamin C, 0.03 mg thiamin, 0.07 mg riboflavin and 0.6 mg niacin (Considine, 1982). It is rich in anthocyanin content and possesses high antioxidant activity (Sun *et al.,* 2002).

Being short-day plant, strawberry thrives well in temperatures ranging from 22 °C to 25 °C during the day and 7 °C to 13 °C at night (De and Bhattacharjee, 2012). A well-drained medium loamy soil with enough of organic matter is ideal for

strawberry production having pH range from 5.7 to 6.5 i.e. acidic in nature. Plant leaves turn yellow when there is excessive calcium in the soil. Runner formation is better in light soils and soils with lots of organic matter. Alkaline soil and soil infested with nematodes should be avoided for strawberry production as it inhibits its growth and development. Soil is generally the most available growing medium for plants. It provides anchorage, air, water, nutrients etc. for successful plant growth. However, soils do possess some serious limitations for both plant growth and development like presence of unfavorable soil compaction, unsuitable soil reaction, poor drainage, degradation due to erosion, disease causing organisms and nematodes etc. In addition, conventional crop growing in soil is somewhat difficult as it involves large space, large volume of water and lot of labour.

Moreover, in metropolitan areas, soil is not available for crop growing at all and in some areas, scarcity of fertile cultivable arable lands is major problem due to their unfavorable topographical or geographical conditions. Another serious problem experienced in conventional open field agriculture is to hire labour. Under such circumstances, soil-less culture can be introduced successfully (Sengupta and Banerjee, 2012). With the decline in arable land, there is a need of alternative to meet the demand of increasing population, and in this regard, hydroponics serves as an additional channel for crop production.

Hydroponics is growing plants in soil-less condition with their roots immersed in nutrient solution. Terrestrial plants can be grown with their roots in the mineral nutrient solution (minerals in the raw water and nutrients added with fertilizers) only or in an inert medium, such as perlite, gravel, or mineral wool. Hydroponics is an emerging sector in horticulture that deals with growing of plants in soilless nutrient solution. Hydroponics is a Horticultural type and hydroculture subset, in which crops are grown without using soil medium, by providing mineral nutrient solutions in an aqueous solvent (Resh and Howard, 2012).

This technique has been utilised for thousands of years, and it can be attributed to Babylon's hanging gardens and China’s floating gardens. The quality of the raw water to be utilised has a big impact on the fertiliser, dosage, and concentration in the hydroponic nutrient solution (Sardare and Admane, 2013). This technology contributes in addressing climate change problems as well as production system management for effective natural resource usage and malnutrition reduction.

Bradley *et al*. (2000) found that hydroponic technology lowered agricultural land requirements by 75 per cent or more and preserved 90 per cent of water. Moreover, various hydroponics researchers have demonstrated significant profit as well as food that is free of microbes (Karayamparambil and Bhaskar, 2018).

Strawberry is a high value crop, so the use of new technologies in modern agriculture related such as polyhouse, low tunnels, plastic films, shading screens and plastic mulch is increasing to obtain higher productivity and quality of fruits. Greenhouse structures require expensive startup cost and the plant size of strawberry is small, to make the greenhouse cost effective the vertical space needs to be utilized for high productivity by modifying the plant geometry (Linsley-Noakes *et al.*, 2006). The yield of the strawberry is mainly related to the number of plants rather than the area. The planting density can be increased three to four times by using a vertical system (Ozeker *et al.*, 1999).

Hydroponically fruits and vegetables grown in greenhouses are gaining popularity and potentially represent a compliment toward sustainable food sources. Growing fresh produce in soilless systems may be a potential solution to food insecurity issues regardless of soil quality, climate or space (Resh and Howard, 2012). Additionally, soilless growing systems can provide several other environmental benefits such as reduction of water, increased product yields, and less pesticide use. These advantages allow soilless systems to address several environmental issues while providing sustainable systems in food deserts, in arid or urban regions. As nutrition is one of the primary motivations of purchase and consumption, it will be vital to investigate the nutritional composition of soilless in contrast to traditional farming methods as soilless food production becomes more widespread (Glanz *et al*., 1998).

Therefore, the present investigation entitled “Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler” was conducted with the following objectives:

1. To find out the best soil and soilless medium for optimum strawberry production.
2. To find out the economics for soil and soilless strawberry production.

Chapter-2

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

The present study "**Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler**" was carried out at experimental area in the Division Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21. The literature pertaining to the present study has been reviewed as under:

Soilless growing methods can have a number of environmental advantages, including reduced water usage, higher product yields, and reduced pesticide use. Several researches on the nutritional value of soilless food have recently been published. As nutrition is one of the primary motivations of purchase and consumption, it will be vital to investigate the nutritional composition of soilless with contrast to traditional farming methods as soilless food production becomes more widespread (Glanz *et al*., 1998).

Strawberry production is mostly determined by the number of plants planted rather than the area of the field. Using a vertical method, the planting density may be enhanced three to four times (Ozeker *et al*., 1999). Bradley *et al*. (2000) observed that hydroponic technology reduced agricultural land requirements by 75 percent or more while preserving 90 percent of water. Strawberry is a high value crop, so the use of new technologies in modern agriculture related such as polyhouse, low tunnels, plastic films, shading screens and plastic mulch is increasing to obtaining higher productivity and quality of fruits. Because greenhouse structures are expensive to set up and strawberry plants are small, vertical space must be utilised for maximum production by altering plant geometry (Linsley-Noakes *et al*., 2006).

Hydroponics is the practise of growing plants in the absence of soil, with their roots submerged in nutritional solution. Terrestrial plants can be grown with their roots in the mineral nutrient solution (minerals in the raw water and nutrients added with fertilizers) only or in an inert medium, such as perlite, gravel, or mineral wool. Hydroponics is an emerging sector of horticulture that involves growing plants in nutrient solutions that do not require soil. Hydroponics is a horticultural type and hydroculture subset, in which crops are grown without using soil medium, by providing mineral nutrient solutions in an aqueous solvent (Resh and Howard, 2012).

Types of Hydroponics system

1. Wick System

The wick system is the most basic form of hydroponics, requiring no electricity, pumps, or aerators (Shreshtha and Dunn, 2013). Plants are planted in an absorbent media such as coco coir, vermiculite, or perlite, with a nylon wick going from the plant roots into a nutrient solution reservoir. Water and nutrients are delivered to plants via capillary action, which requires no energy. This system's main benefit is that it is self-regulating and does not require any energy.

2. EBB and flow system

The EBB and Flow system is the first commercially available flood and drain system. A water pump floods nutrient solution and water from the reservoir into the grow bed until it reaches a certain level and stays there for a set period of time, providing nutrients and moisture to the plants. Furthermore, while it is possible to cultivate a variety of crops, root rot, algae, and mould may be a problem, necessitating the use of a few modified systems with filtering units (Nielsen *et al.*, 2006).

3. Deep water culture System

Plant roots are directly suspended in nutrient-rich water in deep water culture, and air is given to the roots via an air stone. Plants are grown in net pots with their roots hanging in a nutrient-rich solution, where they rapidly grow into a massive mass. Because algae and moulds can grow quickly in the reservoir, it is necessary to monitor oxygen and nutrient levels, as well as salinity and pH (Domingues *et al*., 2012). This method is perfect for growing large fruiting plants, such as cucumbers and tomatoes, which thrive well in this environment.

4. Drip system

The nutrient solution from the reservoir is delivered with the help of a pump and provided to the plant roots by drip emitters on a regular schedule in an appropriate proportion. Depending on the stage of development of the plant and the amount of available light, the emitters are normally set to run for about 10 minutes every hour. The drip cycle flushes the growing medium, supplying fresh nutrients, water, and oxygen to the plants. Both home and commercial hydroponic systems that grow long-term crops like tomatoes, cucumbers and peppers frequently use the drip method (Sheikh 2020).

5. Nutrient film technique

NFT is the most widely used technique in the strawberry production. Strawberry runners are planted in net pots in which the roots are covered with substrate media in the root zone, which helps to increase the plant's strength. They can also be plugged into the net pots that are framed in the NFT channels with plugs. During the first weeks of root development, it must be put such that it is in constant contact with the nutritional solution flow. During the functioning of the system with 14–16 hours of sunshine, the optimal amount of oxygen must also be maintained. With the circulation pump running all the time, the nutrient discharge should be 1–2 litres per minute (Kumar and Saini, 2020).

Fruits and vegetables produced hydroponically in greenhouses are gaining popularity and might be a good potential to sustainable food sources. Regardless of soil quality, climate, or space, growing fresh produce in soilless systems might be a viable solution to food insecurity (Resh and Howard, 2012).

This technique has been utilised for thousands of years and it can be attributed to Babylon's hanging gardens and China’s floating gardens. The quality of the raw water to be utilised has a big impact on the fertiliser, dosage, and concentration in the hydroponic nutrient solution (Sardare and Admane, 2013). This technology contributes in addressing climate change problems as well as production system management for effective natural resource usage and malnutrition reduction. Moreover, various hydroponics researchers have demonstrated significant profit as well as qualitative food that is free of microbes (Karayamparambil and Bhaskar, 2018).

Physiological parameters

Joshi (2003) conducted a study to determine the influence of growing media and nutrients on growth of Chandler strawberry and reported that when combination of soil + FYM + vermiculite used as a growing media resulted in better aeration and nutrient supply. Further, this combination resulted in significant increase in plant height (20.89 cm), leaf area (113.10 cm^2), and number of flowers/plant (19.58). Whereas, minimum number of days taken for first flower initiation (112.8) were recorded under vermiculite and soil + vermiculite combination.

Arancon *et al*. (2004) determined the influence of vermicompost processed commercially from food waste and paper trash on the growth and yield of strawberry cv. Chandler. The vermicomposts were mixed into the top 10 cm of soil, and

amounts of inorganic NPK fertilisers were estimated based on chemical analyses to equalise the initial fertiliser rates of 85–155–125 kg/ha NPK applied to the inorganic fertiliser plots. Vermicompost application significantly boosted strawberry growth and yield, with an increase up to 37% in leaf area, 37% in plant shoot biomass, 40% in number of flowers, 36% in number of plant runners and 35% in marketable fruit weights.

Bartczak *et al*. (2007) observed that type of applied substrate influenced number of leaves in the strawberry plants. The crown's average diameter was between 10.0 and 18.0 mm. The plants that were grown on rockwool had the most leaves on average (11.8). The plants that were grown in coconut fibre and a mixture of brown coal and disintegrating rockwool had the least leaves (10.5). When strawberry plants were rooted in rockwool, the fresh weight of the whole plants and the dry matter content of the root systems were the highest. Plants grown in rockwool had the highest weight (29.2 g), while those grown in a mix of brown coal and disintegrating rockwool had the lowest weight (11.7 g). The first plant from the stolon rooted in rockwool ('Elsanta' and 'Honeoye' 24.4 g and 18.8 g respectively) had a considerably higher mean weight than the third plant from the stolon ('Elsanta' and 'Honeoye' 12.9 g and 12.8 g, respectively).

Cantliffe *et al*. (2007) revealed that more leaves per plant obtained from plants grown in peat-mix (26.6) than perlite (23.4) media. They also concluded that media (pine bark and coconut coir) used did not significantly affect the number of leaves but media (pine bark and coconut coir) significantly affected plant height.

According to Ghazvini *et al*. (2007), Strawberry plants grown with perlite/zeolite in ratio of 3:1 or 1:1 considerably enhanced the number of crowns per plant (3.5 and 4.6 respectively). Moreover, perlite + zeolite (3:1) produced more number of flowers (41) than either 100 % perlite (35.18) or 100 % zeolite (25.78).

Tehranifar *et al*. (2007) recorded significantly higher petiole length (96.06 mm) under 100 % cocopeat as compared to 100 % sand (89.21 mm). Further, total number of leaves (63.5) were maximum under media peat 40% + perlite 60% in Camarosa strawberry production.

Singh *et al*. (2008) evaluated the influence of vermicompost on growth and development of strawberry cv. Chandler. The result showed that application of vermicompost significantly increased plant spread (10.7 %), leaf area (23.1%), dry matter (20.7%).

Yavari *et al*. (2008) studied the effect of different organic substrates on productivity of Selva strawberry plants. Results indicated that plants grown in liquorice processing waste (50 %) + mineral soil (50 %) recorded highest number of floral buds (3.8), fresh shoot weight (82.27 g), fresh root weight (39.63 g), dry shoot weight (13.78 g) and dry root weight (8.97 g).

Awang *et al*. (2009) studied the physio-chemical characteristics of cocopeat based substrate combinations (100% cocopeat, 70% cocopeat: 30% burnt rice hull, 70% cocopeat: 30% perlite, 70% cocopeat: 30% kenaf core fiber and 40% cocopeat: 60% kenaf core fiber) and their effect on the growth and development of Celosia cristata plants. A substrate combination of 70% cocopeat: 30% burnt rice hull significantly increased the growth and flowering parameters which is connected to a favourable balance in the aeration and moisture relationship of the medium.

Ayesha *et al*. (2011) observed the influence of various growth media on the reproductive growth parameters of strawberry. The results stated that different growing media significantly changed different growth and reproductive parameters of the strawberry plant and coconut coir dust based medium was proved to be the best medium. It was also observed that average number of flowers (96), flower size (1.90 cm^2), average number of fruit set (16) was found maximum in coconut coir dust.

Ebrahimi *et al*. (2012) investigated the influence of substrate on herbaceous pigments of strawberry plants in hydroponic system in the greenhouse. In the old and young leaves of strawberry cultivars, cocopeat + perlite substrate had a considerable influence on shoot dry weight (12.90 g/plant), chlorophyll a (0.61), chlorophyll b (0.06), and total chlorophyll (0.22). They also observed that sand + large grain perlite produced highest amount of FV/FM (0.81).

Hesami *et al*. (2012) conducted an experimented with different mixtures of date-peat, cocopeat, and perlite in the hydroponic custom straw production beds. The optimum combination was found to be two parts perlite, one part date-peat, and one part cocopeat, which resulted in greater chlorophyll content (47.4) and leaf area (201.4 cm^2).

Karimi *et al*. (2013) studied the effect of various soilless systems on growth of Festival strawberry and found that open-trough showed good growth and performance with respect to yield and quality as compared to either lay-flat-bag or verti-gro system. However, plants grown under open-trough system recorded maximum leaf area (2478.66

cm^2), highest shoot fresh weight (60.97 g), largest crown diameter (33.75 mm), highest shoot dry weight (21.10 g), root fresh weight (16.50 g) and root dry weight (5.74 g). Moreover, earliness in the flowering (43 days), highest number of flowers (37.00) were also achieved in plants grown under open-trough system.

Marinou *et al*. (2013) reported that runners number increased up to 70% in plants grown in coco soil compared with the pumice whereas, the leaf number doubled in plants grown in sawdust. Furthermore, in coco soil leaf and stem fresh weight as well as leaf area increased by 32, 24 and 44 %, respectively.

Bakshi *et al*. (2014) investigated the influence of different mulching material on growth of strawberry cultivar Chandler and recorded higher plant height (21.67 cm), plant spread (31.24 cm), number of leaves per plant (18.33), number of flowers per plant (28.33) with black polythene mulch.

Asker (2015) investigated the potential of a nutrient film technique (NFT) hydroponics system for the production of Asiatic hybrid lily cv. Blackout flowers and bulbs. The NFT hydroponic system was reported to be an excellent method for producing lily flowers in 55 days because the growth conditions under NFT are favourable for plant growth because the roots of the plants are constantly in contact with a thin film of an oxygen-rich nutrient solution, allowing the roots to uptake adequate supplies of water, oxygen, and nutrients. The application of flower buds and the removal of bulb scales raised the weight of bulblets by 77.97 % and the weight of stem roots by 117.2 %, respectively. The plants grown in MS S. produced the most bulblets with the highest weight (11.42 g) and number (10.22). The largest weights of daughters (30.64 g), stem roots (4.56) and bulblets roots were obtained from Hoag S plants (2.89). The removal treatments produced the highest number of bulblets (10.77) and weight (13.99 g) in MS S while, the highest number of daughters (2.22) and weight (31.4 g) in Hoag S.

Lee *et al*. (2015) investigated the influence of four nutrient concentrations on the growth of Goha and Albion strawberry plants with different electrical conductivity i.e., 0.5, 1.0, 1.5, and 2.0 dSm^{-1}. In both cultivars, when the nutrient solution EC raised from 0.5 to 1.0 dSm^{-1} resulted in higher plant height and shoot dry weight. Moreover, roots became longer (29.2 cm) in Goha strawberry plants. Similarly, increasing the EC of solution to 1.0 dSm^{-1}, increased leaf area (1069.1 cm^2) significantly in Goha strawberry.

Niu *et al*. (2015) conducted a study to determine the feasibility of hydroponically producing eucalypt seedlings and to examine if seedling growth and morphology could be manipulated by nutrient supply regulation. They revealed that hydroponic system could be utilised to successfully grow high-vigor seedlings of woody plants. The roots and shoot of the eucalyptus seedlings were sufficiently grown, even the root lengths were generally greater than 30 cm.

EL-Sayed *et al*. (2016) conducted an experiment to assess the influence of substrate mixtures on growth and yield of strawberry under closed hydroponic system and revealed that vegetative growth parameters, leaf chemical contents and yield were effectively responded by perlite: peat-moss.

Mohammed *et al*. (2016) reviewed the highlights of a two-year hydroponic study conducted at Iere Village Branch Road Princes Town, Trinland. The nutrition film technique was used in this experiment to grow iceberg lettuce and celery while all macro and micro nutrients were continuously re-circulated throughout the system. Within three weeks, they observed abundant Iceberg lettuce and celery production. The nutritional solution's pH and EC were 5.5-6.5 and 2.2, respectively. A hundred lettuce heads were picked once a week, each lettuce was 0.23 m tall and 0.25 m wide and Celery reached a height of 0.38 m.

Murthy *et al*. (2016) reported that first tier showed significantly higher number of leaves (39), leaf area (2002.64 cm^2) and crown diameter (31 mm), earliness in flowering (57 days), higher number of flowers (29) as compared to the remaining tiers which were lower in the column under vertical soilless system in four tiers with soilless media.

Chavada *et al*. (2017) carried out an experiment to study the influence of different potting media on growth of rose cv. Top secret and observed maximum leaf area (36.98 cm^2), plant height (60.46 cm), stalk length of cut flower (36.23 cm), number of leaf per flowering stalk (20.23) and minimum number of days for bud initiation (13.23) and days taken for bud opening (12.72) were recorded with media combination of soil + cocopeat + leaf mould (1:1:1). Moreover, flower diameter (8.23 cm), length of petal (3.76 cm), breadth of petal (3.85 cm) and number of flowers per plant (19.48) were also recorded maximum with soil + cocopeat + leaf mould (1:1:1).

Vikas *et al*. (2017) conducted an experiment to check out the effect of various nutrient concentration on strawberry plants grown under hydroponics system. Maximum

plant height (7.23 cm) was found under 20% sewage sludge + 80% cocopeat. Whereas, maximum stem girth (0.27 mm), leaf area (34.86 cm^2), and number of branches per plant (5.33) were found under control treatment. However, with 30% sewage sludge + 70% cocopeat, the highest number of leaves (15.66) were recorded ().

Raja *et al*. (2018) determined the influence of different substrates on growth and quality of strawberry cv. chandler in soilless culture and found that coco peat + vermiculite (25: 75) produced high petiole length (16.77 cm), plants spread (42.75 cm), number of leaves (17), total leaf area (1542 cm^2), crown width (2.10 cm) and higher shoot dry weight (4.36 g) as well as root dry weight (5.13 g). However, coco peat + perlite + vermiculite (50: 25: 25) produced maximum plant height (28.36 cm), shoot length (23.13 cm) and root length (32.40 cm).

Shahzad *et al*. (2018) evaluated the effect of soil combined with peat moss on Chandler strawberry plants and reported maximum chlorophyll content (12.53 mg/g). Thakur and Shylla (2018) investigated the influence of various growing media on growth and fruit yield of Chandler strawberry plants. Results showed that the maximum plant height (29.19 cm), number of leaves (18.31) and leaf area (135.08 cm^2) was recorded under perlite + FYM as compared to the other treatments. They also reported that perlite when used alone was proved to be very effective in improving plant growth characteristics viz., number of leaves (17.44), root length (19.13 cm) and number of runners (39.25).

Shylla *et al*. (2018) stated that Soil-borne diseases, specifically viruses transmitted by nematode vectors, cause severe productivity losses in strawberry production. In addition to improving the quality of the food, using soilless substrates can help to reduce soil-borne diseases. The effectiveness of several combinations of soilless media, such as perlite and cocopeat were evaluated to prevent the transmission of viruses transmitted by nematodes, such as Strawberry Latent Ringspot Virus (SLRSV), Tobacco Ringspot Virus (TRSV), and Raspberry Ringspot Virus (RRSV). Based on the O.D values, DAS-ELISA testing indicated that plants grown under perlite were virus-free.

Spehia *et al*. (2018) used the Nutrient Film Technique to compare the effects of Hoagland Nutrient Solution (HNS) and jeevamrut (made from 10 kg cow dung + 10 L cow urine added to 100 L water + 2 kg jaggery, prepared filtered, boiled, sugarcane juice that is concentrated and cooled to produce jaggery blocks + 2 kg flour and a small amount

of soil fermented for 7 days) on growth, yield and quality of lettuce. Treatment with Hoagland Nutrient Solution + 5% jeevamrut increased the number of leaves (29), root length (24 cm), leaf area (2137 cm^2), and yield (180 g/plant) by 40, 34, 24, and 24 percent, respectively, with comparison to control (fertigation with Hoagland Nutrient Solution in grow bags). When compared to grow bags, hydroponics utilized 22 times less water. Using the Nutrient Film Technique to grow lettuce in hydroponics fertilized with Hoagland Nutrient Solution + 5% application of jeevamrut provided good quality lettuce with higher yields.

Sharma *et al*. (2019) examined the effect of soilless cultivation on the Sweet Charlie strawberry's vegetative growth and root system. Plants grown in 90 mm PVC pipes with a vertical soilless growing system produced the highest root/shoot ratio (0.77), length of most developed root (19.10 cm), fresh and dry root weight (9.23 g and 4.59 g respectively), number of primary roots (63.33), and total root length (2237.11 cm), while control plants produced the highest shoot length (18.07 cm), fresh shoot weight (14.90 g) and dry shoot weight (6.30 g) in soil cultivation. The findings revealed that proper soilless media management in a vertical growing system provides a favourable environment for vegetative growth and development of root system of strawberry plants.

Singh *et al*. (2019) experimented with various liquid nutrient concentrations and observed different changes in growth of strawberry plants. The nutrient circulation was maintained at various intervals of 24, 18 and 12 hours. Strawberry plants with 1388.1 ml liquid nutrients and 24 hour continuous nutrient circulation obtained the best results, with height of 14.6 cm, plant spread of 154.62 cm, leaf area of 15.43 cm^2 and root length of 50.33 mm, as well as minimum days taken to first flowering i.e., 42.

Maher *et al*. (2020) conducted an experiment to check the response of strawberry cv. Chandler to different soilless substrates and found that the least number of days (115.10 days) taken for first flower initiation were under substrate combination (perlite (50%) + FYM (50%) + jeevamrit) whereas, maximum number of flowers (20.12) were observed under substrate combination (perlite (75%) + cocopeat (25%) + jeevamrit).

Quality parameters

Physical parameters

Anagnostou and Vasilakakis (1993) carried out an experiment to study the effect of substrate and cultivar on plant productivity of strawberry. They observed that total

yield of Fern (321.43 g/plant) was maximum under perlite whereas, in Selva (268.26 g/plant) the highest yield was observed under (60% perlite + 40% peat) treatment.

Gul and Sevgican (1994) conducted a study to verify the suitability of ten soilless media for long term greenhouse tomato production and found that increase in cumulative yield relative to soil was highest in perlite-sand (165.20 %).

Yau and Murphy (2000) reported that tomato plants developed higher dry root weight (22 percent), fruit number (43 percent), and total yield (64 percent) when composted coco peat was utilized as the substrate in soilless culture. El-Behairy and Abou-Hadid (2001) conducted an experiment to evaluate the effect of orientation and soilless culture systems on production and quality of strawberry cultivars viz., Chandler, O.G and Selva. They reported that the best grown cultivar in nutrient film technique was Chandler followed by Selva and O.G. Further, treatments oriented to the south direction gave early and higher yield (783.77, 373.80, 916.42 g/plant) as compared to north facing direction (528.38, 329, 579.13 g/plant) for Chandler, Selva and O.G respectively in NFT.

Colla *et al*. (2003) determined the effect of different substrates on yield of soilless grown cucumbers plants. They observed that plants grown in coir (3.4 kg/plant), perlite (3.6 kg/plant) and pumice (2.9 kg/plant) yielded more than those grown in rockwool (2.4 kg/plant).

Joshi (2003) determined the influence of growing media and nutrients on physical characteristics of Chandler strawberry and observed that soil + FYM + vermiculite gave best results for number of fruits/plant (16.74), fruit length (34.73 mm), fruit breadth (23.89 mm), fruit weight (11.77 g), fruit volume (11.77 cc), yield/plant (196.90 g).

Rauphael *et al*. (2005) investigated the effects of two of the most promising and widely used irrigation systems (drip and sub irrigation) and two cropping seasons (spring-summer and summer-fall) on the growth, yield, and water use efficiency of zucchini plants (*Cucurbita pepo* L.) grown in closed soilless systems. The zucchini yield (total and marketable) was 18% lower with the sub irrigation system than with the drip-irrigation system during the spring-summer season. Plants grown in the summer-fall season had a 35% and 33% lower total and marketable yield, respectively, than those grown in the spring-summer season, although they offered earlier production (10 days) and showed higher water use efficiency.

Cantliffe *et al*. (2007) revealed that substrate media did not effected number of fruit produced per plant whereas, the marketable fruit weight obtained from plants grown in perlite (175 g/plant) was significantly greater than that obtained from plants grown in peat mix (167 g/plant) or pine bark (166 g/plant).

Tehranifar *et al*. (2007) reported that fruit weight (9.75 g) was maximum with peat 67% + sand 33%. Further, yield (291.22 g/plant) was maximum with cocopeat 40% + perlite 60% in Camarosa strawberry production.

Singh *et al*. (2008) evaluated the influence of vermicompost on fruit yield of strawberry cv. Chandler and found that application of vermicompost significantly increased total fruit yield by 32.7 %. Yavari *et al*. (2008) carried out the study to determine the effect of different organic substrates on productivity of Selva strawberry plants and observed that plants grown in liquorice processing waste (50 %) + mineral soil (50 %) recorded highest fruit yield (51.11 g).

Valenzano *et al*. (2008) compared the yield of tomato (*Solanum lycopersicum* L.) plants grown in soil to those grown in two hydroponic systems: The nutrient film technique (NFT; closed cycle) and rockwool (open cycle). One trial was conducted in the winter-spring season, while the other conducted in the autumn-winter season. In the WS and AW trials, respectively, the two hydroponic systems showed greater earliness, 10 and 8 days earlier than soil. The growth system had an impact on overall fruit yield. In the WS and AW trials, total yields in the hydroponic systems were 11 percent and 7% greater than in the soil system, respectively.

Maboko and Plooy (2009) conducted an experiment to compare yield and quality parameters of tomato cultivars cultivated in an open bag hydroponic system in a plastic tunnel with soil under a shade net structure. The results showed that plants grown in the soilless system gave higher total yield and developed faster as compared with conventional system. The average marketable yield using soilless system was 92.1%, while in conventional system was only 77.0%.

Ayesha *et al*. (2011) observed the influence of various growth media on the fruit quality of strawberry plants and found that average number of fruits (72.96) and fruit size (3.01 cm) were found maximum in coconut coir dust. Ebrahimi *et al*. (2012) assessed the influence of different substrates on the qualities of pepper fruit. They observed that the

peat + perlite substrate produced the highest number of fruit (15.5), fruit length (10.85 cm), average fruit weight (129.14 g) and fruit yield (2003.91 g).

Ebrahimi *et al*. (2012) evaluated the effect of different types of substrate combinations named peat + sand + perlite, cocopeat + perlite and sand + perlite on strawberry cultivars Camaosa, Silva and Parus to check the yield parameters of strawberry in hydroponic system. The findings revealed that the substrate comprised of cocopeat + perlite increased total plant yield (816.3 g/plant) and fruit number (75.59) whereas, species Parus offered the highest total yield under cocopeat + perlite substrate (921.84 g per plant).

Hesami *et al*. (2012) found that the best substrate combination was two parts of perlite, one part of date-peat whereas, substrate combination one part of cocopeat resulted in increased fruit yield (88.88 g/plant), fruit number (13.75) per plant. Karimi *et al*. (2013) found that highest number of fruits (22.66) and fruit weight (281.83 g) were achieved in plants grown under open-trough system. Marinou *et al*. (2013) reported that fruit number increased up to 50% in plants grown in Pumice.

Bakshi *et al*. (2014) investigated the influence of various mulching material on yield of strawberry cultivar Chandler and observed higher fruit weight (11.83 g), fruit length (3.93 cm), fruit breadth (3.00 cm) with black polythene mulch. Similarly, number of achenes/fruit (317.70), number of fruits per plant (12.12) and yield (143.38 g/plant) were also increased significantly with black polythene mulch.

Joseph and Muthuchamy (2014) conducted an experiment in a naturally ventilated polyhouse to establish low-cost aggregate hydroponic techniques for tomato production. The experiment was set up in three different hydroponic systems: tray, trough, and pot, with three different media combinations: cocopeat+gravel+silex stone, cocopeat+pebble+silex stone, and cocopeat+perlite+silex stone as treatment factors. The treatment trough with cocopeat+gravel+silex stone produced the highest yield (4.9 kg/plant). Similarly, trough with cocopeat+gravel+silex stone yielded the maximum production of 245.3 t/ha. In terms of colour values, all hydroponic treatments had a* / b* values greater than 0.95, suggesting that the plants were fully mature while, trough with cocopeat+gravel+silex stone had the greatest L* value (44.45).

Adak and Gubbuk (2015) studied the effect of different growing media i.e. peat, perlite, cocopeat, volcanic tuff and their combinations on yield of camarosa strawberry

plants grown under soilless culture and found that coconut coir and coconut coir + volcanic tuff media was more favorable regarding fruit yield (865 g/plant and 903.33 g/plant, respectively).

Barbosa *et al*. (2015) concluded that lettuce produced in hydroponics gave 11 ± 1.7 times higher yield but utilized 82 ± 11 times more energy as compared to lettuce produced in conventional system. Lee *et al*. (2015) reported EC at 1.5 dSm^{-1} increased the number of fruits (27.4), but the average weight (6.4 g) of individual fruit was found lowest in Goha strawberry.

Murthy *et al*. (2016) observed that first tier showed significantly higher total number of fruits (18.00), average fruit length (30.75 mm), average fruit breadth (26.25 mm), average fruit weight (11.47 g). Moreover, first tier resulted in higher yield (195 g/plant), better quality and marketable fruits (68.33 %) as compared to the remaining tiers which were lower in the column with soilless media under vertical soilless system.

Vikas *et al*. (2017) investigated that maximum number of fruits per plant (2.66) were recorded under 20 per cent sewage sludge + 80 per cent cocopeat. However, maximum yield per plant (27.83 g) was recorded with 30 per cent sewage sludge + 70 per cent cocopeat.

Wysocki *et al*. (2017) conducted an experiment in the soilless system to compare the effects of two types of peat-coconut substrates used for strawberry production and revealed that the cultivar Albion was proved to have the highest yield (2.47 kg/m^2) under hydroponic conditions.

Chavada *et al*. (2017) investigated the influence of different potting media on quality of rose cv. Top secret under protected conditions and observed that shelf life (7.35 days), vase life of flower (8.18 days), cut flower's fresh weight (11.69 g) and cut flower's dry weight (3.27 g) were obtained maximum under treatment soil + cocopeat + leaf mould (1:1:1) followed by soil + cocopeat + perlite (1:1:1).

Raja *et al*. (2018) obtained maximum weight (10.76 g), fruit length (29.89 mm) and fruit diameter (27.48 mm) with coco peat + vermiculite (25: 75). Shahzad *et al*. (2018) determined the influence of organic growth media viz., soil + peat moss, soil + poultry waste, soil + farm yard manure and their combination on the growth and yield of strawberry cv. Chandler. The results indicated that soil combined with peat moss was proved to be significantly best among all growth and fruit quality parameters. However,

peat moss substrate showed highest fruit size, fruit yield (531.56 g) and improved fruit quality (red colour with maximum sweetness).

Shi *et al*. (2018) examined the effect of culture media on growth, yield and photosynthetic capacity of tomato plants. Four tomato varieties (Xining, Jinbaolai, Kaidi, and Xiariyangguang) were grown in soil, hydroponics, and substrate culture. Due to higher dry weight accumulation, fruit weight, and net photosynthetic rate at the seedling and mature stages, it was observed that substrate cultivation and hydroponics obtained higher yield than soil treatment. The yield of tomato showed significant changes in Xinxing101, Jinbaolai and Kaidi by an increase of 64.87, 77.61, and 48.59%, respectively for substrate cultivation treatment with comparison to soil culture treatment. Furthermore, all tomato cultivars showed significant improvement in hydroponic treatment as compared to control, with a percentage increase of 107.41, 58.28, 73.19, and 120.29% in Xinxing101, Jinbaolai, Kaidi, and Xiariyangguang, respectively.

Draie (2019) experimented with three treatments of local strawberry cultivar i.e., hydroponic in the peatmoss substrate, hydroponic in the perlite substrate and field cultivation in the soil with three replicates per treatment. The results indicated that the treatment hydroponics in the peatmoss substrate was better than field cultivation in most of the studied parameters such as fruit length (2.7 cm), number of fruits per plant (10.3), fruit weight (9 g) and yield/m^2 (1854 g) etc. Total production in hydroponics (peatmoss substrate) was tripled as compared to the field cultivation.

Singh *et al.* (2019) experimented with different liquid nutrient concentrations, which resulted in number of changes in strawberry fruit yield and quality. The nutrient circulation was maintained at various intervals of 24, 18, and 12 hours. Plants with continuous nutrient circulation for 24 hours gave the highest results, with an average weight of 15.10 g, fruit length (50.33 mm) and fruit breadth (27.00 mm) and yield 1462 g. With an application of 1388.1 ml liquid nutrients followed by 24 hour continuous nutrient circulation, the plants obtained gross return (8217000 INR), net return (1910438.42 INR) and B:C ratio (1.30).

Maher *et al*. (2020) conducted an experiment to check the response of Strawberry cv. Chandler to different soilless substrates and concluded that perlite (75%) + cocopeat (25%) + jeevamrit resulted in the maximum fruit set (79.73), fruit size in terms of fruit length (40 mm) and breadth (26.55 mm) and recorded highest yield (210.09 g/ plant).

Subramani *et al*. (2020) investigated the influence of soilless growing media on tomato (*Solanum lycopersicum* L.) yield and quality under tropical island conditions. The results showed that among the different growing media, cocopeat + saw dust (1:1 v/v) produced the maximum fruits per plant (12.33), fruit weight (51.2 g/fruit) and fruit yield (631 g/plant) and was at par with cocopeat + vermiculite + saw dust (1:1:2).

Bio-chemical parameters

Arias *et al*. (2000) determined the fruit quality in comparison to hydroponically grown tomatoes ripened on and off vine. They found that tomatoes ripened on vine had significantly more lycopene (6.63 mg/100 g), carotene (0.18 mg/100 g), soluble solids (5.50 ºB), total solids (5.88 %) and ascorbic acid (20.17 mg/100 g) and were firmer as compared to tomatoes ripened off vine.

Joshi (2003) investigated the influence of growing media and nutrients on biochemical properties of Chandler strawberry and found higher TSS (9.82 ºB), total sugar (7.47 %), reducing sugars (5.56 %), non reducing sugars (1.84 %) and ascorbic acid content (49.87 mg/100 g) whereas, lower acidity (0.78 %) was observed under soil + FYM + vermiculite.

Ikeda *et al*. (2011) reported that anthocyanin content decreased in all three parts i.e. inner (pith), middle (cortex) and outer part of pot grown strawberry fruit at high temperature but was not affected by water stress, while ascorbic content remained unaffected by high temperature.

Ameri *et al*. (2012) studied the effects of various substrate media and cultivars on biochemical parameters of strawberry in soilless system. The results showed that highest total anthocyanin content (222.65 mg/100g) was found in Camarosa under substrate combination vermicompost + perlite + cocopeat (15:40:45), the highest TSS (8.66 ºB) in Selva under vermicompost + perlite + cocopeat (5:45:50) and the highest Vitamin C (108.05 mg/100cc) in Selva under vermicompost + perlite + cocopeat (15:40:45) whereas, the highest TA (2.87 mg/100g) was observed in Camarosa under substrate combination vermicompost + perlite + cocopeat (5:45:50) .

Ebrahimi *et al*. (2012) evaluated the effect of different types of substrate (peat + sand + perlite, cocopeat + perlite and sand + perlite), strawberry species (Camaosa, Silva and Parus) on quality parameters of strawberry in hydroponic system. The findings

revealed that the highest TSS (2.07 ºB), vitamin C content (41.18 mg/100cc) and TA (0.46 g/100cc) was obtained under peat + sand + perlite substrate.

Hesami *et al*. (2012) reported that the highest vitamin-C content (10.5 mg/ 100 g ml) was observed with perlite + cocopeat (3:1). They also reported that three parts of date-peat + one part of cocopeat and three parts of cocopeat + one part of date-peat as well, led to increase in total soluble solids (10.5 ºB). Karimi *et al*. (2013) investigated that highest TSS (10.61 ºB) was achieved in plants grown under open-trough system.

Bakshi *et al*. (2014) investigated the influence of various mulching material on quality of strawberry cultivar Chandler and found that black polythene mulch significantly increased total soluble solids (7.63 ºB), total sugars (7.00 %), vitamin-C (57.77 mg/100 g) in strawberry fruits whereas, higher acidity (0.80 %) was recorded in fruits grown without mulch.

Joseph and Muthuchamy (2014) carried out an experiment to establish low-cost aggregate hydroponic techniques for tomato production and revealed that treatment trough with cocopeat+gravel+silex stone produced the highest total soluble solids (12.5 ºB). For the same treatment, the highest (benefit cost) B/C ratio (4.52) was obtained. The B/C ratio of all hydroponic treatments was greater than 1.5. The treatment trough with cocopeat+gravel+silex stone outperformed all others in terms of productivity, quality and economics therefore, can be used for commercial tomato production.

Adak and Gubbuk (2015) studied the effect of different growing media i.e. peat, perlite, cocopeat, volcanic tuff and their combinations on yield and quality of camarosa strawberry plants grown under soilless culture. It was observed that highest total soluble solids (7.69 ºB) was recorded with coconut coir + volcanic tuff, whereas the lowest acidity (1.10 %) and vitamin-C (55.35 %) was recorded with peat + volcanic tuff.

Treftz and Omaye (2015) revealed that there was no significant change noticed in dry weight, while TSS values (28 % to 31 %), glucose (158 % to 175 %) and fructose (75 % to 102 %) content for strawberries and raspberries respectively were significantly higher in soil grown berries than soilless grown berries. However, they also reported that ascorbic acid (74 %), tocopherol (53 %) and total polyphenolic compounds (22 %) were recorded significantly higher in soilless grown strawberries as compared to soil grown strawberries.

Murthy *et al*. (2016) found that first tier showed significantly higher total soluble solids (10.51 ºB) with lower titrable acidity (0.81 %) as compared to the remaining tiers which were lower in the column under vertical soilless system in four tiers with soilless media.

Raja *et al*. (2018) revealed that coco peat + perlite + vermiculite (50: 25: 25) produced maximum TSS (10.8 ºB) whereas minimum acidity (0.86%) was recorded under sand in strawberry cv. Chandler. Singh et al. (2008) determined the effect of vermicompost on quality of strawberry fruits and found higher TSS (7.42 ºB) and ascorbic acid content (50.8 mg/100cc) whereas, lower acidity (1.10 %).

Shahzad *et al*. (2018) investigated the influence of different organic growth media and plant spacing on the quality of Chandler strawberry and found that peat moss amendment showed highest TSS (8.45 °B).

Kavana *et al*. (2019) determined the effect of potting media on reproductive and quality parameters of Nephrolepis undulate plants. It was observed that the plants grown in the substrate combination soil + cocopeat + FYM + vermicompost (2:1:1:1) recorded maximum number of leaflets (135.00), number of sori per leaflet (63.00), number of sporangia per sori (35.56) and number of spores per sporangia were (54.33). They also reported that higher total chlorophyll content (2.96 mg/g), shelf life (8 days) and vase life (20.33 days) was also recorded under soil + cocopeat + FYM + vermicompost (2:1:1:1).

Maher *et al*. (2020) conducted an experiment to check the response of Strawberry cv. Chandler to different soilless substrates and found maximum TSS (11.15 °B) under perlite (75%) + cocopeat (25%) + jeevamrit. Tehranifar et al. (2007) observed maximum TSS (9.5 ºB) under perlite 100 % in strawberry production.

Subramani *et al*. (2020) examined the influence of soilless growing media on tomato (*Solanum lycopersicum* L.) yield and quality under tropical island conditions. The results revealed that cocopeat + saw dust (1:1) showed the highest total soluble solids (TSS) of 6.75 ºB, while cocopeat + vermiculite (1:1) had the highest ascorbic acid (16.46 mg/100 g) and lycopene (6.8 mg/100 g) content.

Chapter-3

Materials and Methods

Chapter 3

MATERIALS AND METHODS

The present investigation entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** was carried out at experimental area in the Division Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21. The details of the required materials and procedure followed during the investigation was given below under the following heads:

3.1 Description of study area

3.1.1 Experimental site and location

The experiment was conducted from October 2020 to April 2021 in the Division of Plant Physiology at SKUAST-Jammu, Main Campus, Chatha. Geographically, the experimental site was located at 320-40' N latitude and 740-58' E longitude with an altitude of 332 meter above mean sea level in the Shiwalik foot hills of North-Western Himalayas.

3.1.2 Climate and Weather

Meteorological data on temperature, relative humidity and rainfall were obtained from the meteorological observatory of SKUAST-Jammu, located closer to the study area. The experimental site falls under the sub-tropical climatic conditions endowed with pleasant autumn, cold dry winters and sunny spring season. (Appendix-I)

3.2 Details of experiment

3.2.1 Hydroponic structure

In hydroponic system nutrient film technique (NFT) was used, which was carried out in a structure made with fine and strong PVC pipes. Total nine PVC pipes having 6 feet long length were placed in hydroponics system having 3 feet width and 5 feet height and 4 inches sized net pot holes (45) were made on pipes which were arranged in three tires using wooden angles.The hydroponic net pots were fitted in the holes. The nutrient solution was circulated through the hydroponic unit by the use of circulatory pump placed in the reservoir tank containing nutrition. The hydroponic structure was placed in natural growing/ ambient condition.

3.2.2 Substrates and nutrients supplement

The different substrate *viz.*, cocopeat, vermiculite, perlite and vermicompost were

used in the experiment. The Green loop Leafy-200 hydroponic nutrient was used in the experiment due to its versatile nature, mainly composed of both macro and micro nutrients. It is generally used for herbs, salad, all kind of leafy vegetables including strawberries and tomatoes. The nutrient was comprised of two sealed bottles A and B, each contained separate solid nutrient i.e. both macronutrients and micronutrients respectively. Every ml of stock A and B each per liter water, adds 101 TDS (total dissolved solids) to hydroponic solution. It is basically a ready mix which makes up to 200 liters of hydroponic solution. At monthly interval, the whole nutrition along with water was changed to ensure proper pH and EC of the solution.

3.2.2.1 Composition of pure hydroponic nutrient (Green loop Leafy-200)

3.2.2.1.1 Macronutrients

Nitrogen (23%), Phosphorous (7%), Potassium (32%), Calcium (23%), Magnesium (5.3%) and Sulphur (9%).

3.2.2.1.2 Micronutrients

Boron, Chlorine, Manganese, Zinc, Copper, Sodium, Molybdenum, Iron and Chlorine each at 0.7 per cent.

3.2.3 Cultivar

The cultivar of strawberry used for the purpose of study was Chandler.

3.2.4 Experimental trials conducted

I. Experiment No. 1: To study the production of strawberry cv. Chandler under soil and soilless medium.

Treatment code	Substrate
T_1	Cocopeat (100%)
T_2	Cocopeat + Vermiculite (1:1)
T_3	Cocopeat + Vermiculite + Vermicompost (1:1:1)
T_4	Cocopeat + Perlite (1:1)
T_5	Cocopeat + Perlite + Vermicompost (1:1:1)
T_6	Local soil + Vermicompost (1:1)
T_7	Local soil (control) (100%)

Treatments from T_1 to T_5 were conducted in the hydroponic system under soilless medium while, T_6 and T_7 (control) were carried out under potted soil medium.

No. of treatments = 07

No. of replications = 03

No. of plants per treatment = 09

Total no. of plants = 63

II. Experiment No. 2: To study economics for soil and soilless production of strawberry cv. Chandler. The economics of the previously mentioned treatments were analyzed by involving all the inputs for strawberry production viz. plant material, farm inputs, man power etc.

3.2.5 Procedure of planting in hydroponics

3.2.5.1 Experiment was executed on the basis of nutrient film technique

In this technique, runners of Chandler strawberry were first planted into hydroponic pots filled with separate combination of substrates and kept under room temperature for three days, then pots were placed in the hydroponic structure with the nutrient flow in it. There were total 9 pipes, in the first floor three pipes from the top were assigned to the second floor having three pipes in middle and further three pipes were assigned to third i.e., ground floor. The hydroponic nutrient solution was added into the tank that continuously cycled through the pipes. As per the requirement of plant system the electrical conductivity (EC) and pH of nutrient solution were also timely checked and maintained at a maximum of 1.2 dS m^{-1} EC and the pH of the draining water within a range of 5.5 to 6.5. Irrigation was managed as per the condition of moisture in upper layer of net pots as well as to fulfill the nutrient requirement of individual plant. Date of transplanting in hydroponics was 17th of October, 2020.

3.2.6 Conventional method

For comparison study, conventional method was used in which runners of Chandler cultivar were grown in pots with local soil medium and same nutrient medium was given to the plants through foliar spray at fortnightly intervals. Irrigation was assured as per the condition of moisture in upper layer of pots as well as to fulfill the nutrient requirement of individual plant. For the preparation of pots sized (6×6×6 inches), soil and vermicompost were used. Date of transplanting in pots was 17th of October, 2020.

3.3 Observations recorded

3.3.1 Physiological/ Growth parameters

3.3.1.1 Number of days taken for runner establishment

The period between the date of transplanting to the beginning of leaf emergence from the crown was recorded and termed as number of days taken for runner establishment.

3.3.1.2 Average numbers of leaves per plant

Data based on number of leaves per plant were recorded from each treatment and their average was expressed as average number of leaves per plant.

3.3.1.3 Average leaf area per plant

Leaf area of representative leaves was measured with the help of leaf area meter and their average leaf area per plant as obtained was expressed in square centimeter (cm^2).

3.3.1.4 Leaf chlorophyll content

Leaf chlorophyll content was recorded by using SPAD (Soil Plant Analysis Development).

3.3.1.5 Plant spread

Plant spread was measured in the both directions i.e. East-West and North-south and the mean was taken as actual plant spread. The result was expressed in centimeter (cm).

3.3.1.6 Root/ Shoot ratio

The root shoot ratios were recorded by using formulae:

$$\text{Root/ Shoot ratio} = \frac{\text{dry weight of roots of plant}}{\text{dry weight of shoots of plant}}$$

3.3.1.7 Days taken for first bud formation

The period between the date of transplanting to date of first bud formation was recorded for calculating the days taken to form first bud.

3.3.1.8 Days for the first flower initiation

The period between the date of transplanting to date of first flower bloom was recorded for calculating the days taken to initiate first flower.

3.3.1.9 Average number of buds per plant

The number of buds was calculated from each representative plant till end of the season and their average was taken as measure.

3.3.1.10 Number of flowers per plant

The number of flowers was calculated from each representative plant at monthly intervals after first flowering till end of the season.

3.3.1.11 Average number of flowers per plant

The average number of flowers was calculated from each representative plant till end of the season and their average was taken as measure.

3.3.2 Fruit quality parameters

3.3.2.1 Physical parameters

3.3.2.1.1 Fruit length

The length of fruit from each replication was measured with the help of digital Vernier caliper and was expressed in cms.

3.3.2.1.2 Fruit breadth

The breadth of fruit from each replication were measured with the help of digital Vernier caliper and was expressed in cms.

3.3.2.1.3 Fruit size

The size of the fruit was measured in terms of length and breadth. The length and diameter of representative fruit from each treatment were measured with the help of digital Vernier caliper in each harvesting. Measured length and breadth were multiplied and expressed in centimeter (cm^2).

3.3.2.1.4 Fruit colour

Fruit colour was determined by the use of different fruit grade (1-7) which represent whitish yellow to blackish red colour as per the standard of International union for the protection of new varieties of plants (UPOV) descriptor.

3.3.2.1.5 Fruit weight

The weight of the representative fruits from each plant was recorded and average fruit weight was calculated and expressed in grams (g).

3.3.2.1.6 Fruit volume

Fruit volume was calculated by water displacement method using a measuring cylinder and was expressed in terms of cubic centimeter (cc).

3.3.2.1.7 Specific gravity

Specific gravity was calculated by using the following formula and expressed in g/cc.

$$\text{Specific gravity} = \frac{\text{Weight of the fruit}}{\text{Volume of water displaced by the fruit}}$$

3.3.2.1.8 Number of fruits per plant

The number of fruits was counted per pedicel at the time of fruit maturity and the result was expressed in the terms of number of fruits per plant.

3.3.2.1.9 Yield per plant

The weight of the representative fruits from each plant was recorded and multiplied with number of fruits and the result was expressed as yield per plant (g).

3.3.2.2 Biochemical parameters

3.3.2.2.1 Total soluble solids

An erma hand refractometer was used to determine the total soluble solids content of fruits (0-32 ºB). When the temperature was above or below 20ºC, temperature modifications were made (AOAC, 1980). Before using the refractometer, it was cleaned with distilled water to ensure that its surface was clear, and then a few drops of fruit juice from each fruit were placed on it. A reading was taken from an average of five fruits that made up one sample. The degree brix was used to express the total soluble solids (ºB).

3.3.2.2.2 Titratable acidity

To determine titratable acidity, 0.5 g of fresh fruit pulp was thoroughly pulverized in an electric blender and a volume of 50 ml was made with distilled water. A 5 ml aliquot was taken for further analysis. The sample solution was titrated against 0.1 N NaOH solution using the phenolphthalein indicator. The titration continued until the final product was light pink in colour. The titratable acidity was calculated in terms of malic acid using the AOAC's formula, which was based on one ml of 0.1 N NaOH being equivalent to 0.0067 g of anhydrous malic acid (1980).

$$\text{Titratable acidity (\%)} = \frac{\text{Titre reading} \times \text{normality of NaOH} \times \text{volume made up} \times \text{equivalent weight} \times 100}{\text{Volume of sample taken} \times \text{weight of sample} \times 1000}$$

3.3.2.2.3 Total sugars

To determine total sugars, 25 gram of fruit pulp was thoroughly crushed in warring blender and the volume was made upto 250 ml of distilled water. Then, 2 ml of saturated lead acetate was added to 250 ml solution and kept as such for 10 minutes. Then after 10 minutes, 2 ml of potassium oxalate was added to remove the excess of lead. Before filtering, the solution was left alone for another 10 minutes. Then, 2 ml concentrated HCl was added to 100 ml of this filtered solution to hydrolyze it. Allow this solution to sit overnight to complete the sucrose inversion. After the hydrolysis was completed the next morning, saturated NaOH was used to neutralize the excess HCl. The solution was then titrated in a conical flask against 10 ml of boiling Fehling's solution (5 ml each of Fehling's solution A and B) with methylene blue as an indicator, against 10 ml of boiling Fehling's solution (5 ml each of Fehling's solution A and B). The appearance of

the brick red colour signalled the final point. According to the method given by AOAC (1980), total sugars were represented as a percentage of juice weight using the formula:

$$\text{Total sugars content} = \frac{0.05 \times \text{volume made up}}{\text{Weight of sample} \times \text{titre value}} \times 100$$

3.3.2.2.4 Reducing sugars

The reducing sugars were estimated by titrating against a boiling combination containing 5 ml each of Fehling A and Fehling B reagents against an un-hydrolyzed but de-leaded and clarified aliquot using methylene blue as an indicator. The arrival of brick red colour signalled the end of the path. The volume of the aliquot used was recorded, and the reducing sugars were calculated using the following procedure specified in A.O.A. C. (1990).

$$\text{Reducing sugar} = \frac{\text{Factor} \times \text{Dilution}}{\text{Aliquot used} \times \text{sample weight}} \times 100$$

3.3.2.2.5 Non reducing sugars

Non-reducing sugars were figured out by subtracting reducing sugars from total sugars and then multiplying the difference by a standard factor of 0.95. The calculation was completed following the steps described in (AOAC, 1990).

Non-reducing sugars (%) = (Total sugars – Reducing sugars) × Factor

3.3.2.2.6 Ascorbic acid

The ascorbic acid was determined by the method of AOAC (2007).

Reagents

Indophenol dye (0.04%):

Weighing 50 mg sodium salt of 2, 6-dichlorophenol indophenols, 150 ml distilled hot water and 42 ml sodium bicarbonate were mixed together. Before storing in the refrigerator, the contents were chilled and the volume was raised to 200 ml with distilled water.

Metaphosphoric acid (3%):

30 grams of metaphosphoric acid were dissolved in 1000 ml of water.

Standard ascorbic acid (0.1%):

100 mg ascorbic acid was dissolved in 100 ml of 3% MPA solution. Meta phosphoric acid (1 ml=0.1 mg ascorbic acid) was used to dilute 10 ml to 100 ml.

Standardization of dye:

Added 5 ml HPO_3 to 5 ml normal ascorbic acid. Dye was added to a microburette and dye equivalent was determined by titrating against dye solution to a light pink colour. Dye Equivalent = 0.5/Titre

Procedure

By macerating 10 g of material with metaphosphoric acid, ascorbic acid was recovered from the pulp (3 %). The extract was filtered, and the volume was increased to 100 millilitres. A standardised dye (2, 6 dicholorophenol indophenol) was used to titrate 10 ml of the aliquot until the bright pink colour showed at the end point. The results were expressed in milligrammes per 100 gm of fruit weight.

Calculation

$$\text{Ascorbic acid (mg 100g of pulp}^{-1}) = \frac{\text{Titre value x dye equivalent x dilution}}{\text{Weight of sample (g)}} \times 100$$

3.3.2.2.7 Anthocyanin content

Anthocyanin pigments of berry were determined by the methods given by Harborne (1973). One gram berry pulp was taken in a known quantity of methanol containing 1 per cent hydrochloric acid. The contents were allowed to stay overnight at sub-zero temperature in deep freezer. The absorbance of resultant red colored solution was recorded at 530 nm on Spectronic-20 colorimeter. The intensity of color was read and expressed in absorption units per gram of fresh berry.

3.3.2.2.8 Carotenoid content

The total carotenoids, Chl a, and Chl b, were determined by the method described by Yang *et al.* (1998). 1g of fresh weight of each strawberry fruit was separately homogenized with 10 ml of an acetone-water mixture (4:1) for 2 minutes to uniform mass. To keep the samples from overheating, they were kept in an ice-water bath. Homogenates were centrifuged at 5000 rpm for 10 minutes at 20 °C. The absorbance maxima were read at 663.6 nm, 646.6 nm and 470.0 nm for Chl a, Chl b and for carotenoids. The following equations were used to determine the contents of Chl a, Chl b and total carotenoids:

Chlorophyll a (µg/ ml) = $12.25\ A_{663.6} - 2.25\ A_{646.6}$

Chlorophyll b (µg/ ml) = $20.31\ A_{646.6} - 4.91\ A_{663.6}$

Total carotenoids (µg/ ml) = $\frac{1000\ A_{470} - 2.27\ (\text{Chl a}) - 81.4\ (\text{Chl b})}{227}$

The findings were reported in micrograms per gram of sample fresh weight.

3.3.2.3 Statistical method

The data obtained in the present study were analyzed using completely randomized design (CRD). Data recorded during the course of present investigations were subjected to statistical analysis as suggested by Panse and Sukhatme (2000). Treatment means were compared using critical difference (CD) at 5% level of significance. Data was subjected to analysis of variance (ANOVA) using Online Statistical Analysis Package (OPSTAT, Computer Section, CCS Haryana Agricultural University, Hisar 125004, Haryana, India).

Plate 1(a): Strawberry runners at time of planting in soilless medium

Plate 1(b): Strawberry runners at time of planting in potted soil medium

Plate 2: Complete over view of experimental site

Chapter-4

Results

Chapter 4

RESULTS

The present investigation entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** was carried out at experimental area in the Division Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21 has been presented in this chapter under following heads.

4.1 Physiological/ Growth parameters

4.1.1 Number of days taken for runner establishment

The data regarding the effect of different substrate combination on number of days taken for runner establishment is presented in Table 1 which showed a significant change in number of days taken for runner establishment. Minimum number of days (6.41) taken for runner establishment was recorded under treatment T_3 (cocopeat + vermiculite + vermicompost). Treatment T_5 (cocopeat + perlite + vermicompost) recorded 6.73 number of days followed by 7.12 in T_2 (cocopeat + vermiculite), 7.41 in cocopeat + perlite and 7.92 in T_6 (local soil + vermicompost). However, maximum number of days (8.32) taken for runner establishment was recorded under treatment T_7 (control).

4.1.2 Average number of leaves per plant

The data regarding average number of leaves per plant as influenced by different substrates combination is presented in Table 1 and Fig. 1 which showed that different substrates combination showed a significant influence on average number of leaves per plant. The substrate combination T_3 (cocopeat + vermiculite + vermicompost) resulted in maximum average number of leaves (28.64) per plant, followed by 27.18 in T_5 (cocopeat + perlite + vermicompost). However, minimum average number of leaves per plant i.e. 16.24 was recorded under treatment T_7 (control).

4.1.3 Average leaf area per plant

The data pertaining to the effect of different substrate combinations on average leaf area per plant was presented in Table 1. The substrate combination T_3 (cocopeat + vermiculite + vermicompost) resulted in maximum average leaf area (135.46 cm^2) per plant which was found to be statistically at par with 133.97 cm^2 in T_5 (cocopeat + perlite + vermicompost). Whereas, minimum average leaf area per plant i.e. 19.30 cm^2 was observed under treatment T_7 (control).

4.1.4 Leaf chlorophyll content (SPAD)

The data presented in the Table 1 showed that different substrate combinations showed a significant difference on leaf chlorophyll content. Among all substrates combination, substrate combination T_3 (cocopeat + vermiculite + vermicompost (1:1:1) resulted in maximum leaf chlorophyll content 55.35 followed by 52.74 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum leaf chlorophyll content 40.93 was recorded under treatment T_7 i.e. control.

4.1.5 Plant spread

The data pertaining to the influence of different substrate combinations on plant spread is revealed in the Table 1. The different substrate combinations significantly increased plant spread as compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) recorded maximum plant spread 42.47 cm followed by 40.84 cm under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum plant spread 20.33 cm was recorded under treatment T_7 (control).

4.1.6 Root/ shoot ratio

The data with respect to root/ shoot ratio as influenced by different substrates is presented in Table 1. The root/shoot ratio was significantly increased by all substrate combinations compared to control. The maximum root/shoot ratio 1.53 was recorded under substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) followed by 1.40 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) while, minimum root/shoot ratio 0.93 was observed under treatment T_7 (control).

4.1.7 Days taken for first bud formation

The data presented in the Table 2 revealed the effect of different substrate combinations on the days taken for first bud formation. The different substrate combinations showed significant difference among all treatments. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) resulted in taking minimum days for first bud formation 64.74 followed by 67.98 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, maximum days taken for first bud formation 78.72 was observed under treatment T_7 i.e. control.

4.1.8 Days taken for first flower initiation

The data presented in the Table 2 revealed the effect of different substrate combinations on the days taken for first flower initiation. The different substrate combinations showed significant difference among all treatments. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) resulted in taking

Table 1: Effect of substrate combinations on number of days taken for runner establishment, average number of leaves per plant, average leaf area per plant (cm^2), leaf chlorophyll content (SPAD), plant spread (cm) and root/shoot ratio

Treatments	Number of days taken for runner establishment	Average number of leaves per plant	Average leaf area per plant (cm^2)	Leaf chlorophyll content (SPAD)	Plant spread (cm)	Root/ Shoot ratio
T_1	7.77	21.13	125.39	45.24	30.89	1.07
T_2	7.12	24.38	132.35	50.18	37.84	1.27
T_3	6.41	28.64	135.46	55.35	42.47	1.53
T_4	7.41	23.73	131.79	46.71	34.99	1.22
T_5	6.73	27.18	133.97	52.74	40.84	1.40
T_6	7.92	19.13	120.27	44.34	24.24	0.98
T_7	8.32	16.24	119.30	40.93	20.33	0.93
$CD_{(0.05)}$	**0.13**	**0.76**	**1.52**	**0.75**	**0.75**	**0.09**
SE(m)	**0.04**	**0.25**	**0.50**	**0.24**	**0.25**	**0.03**

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local soil (control) (100%)

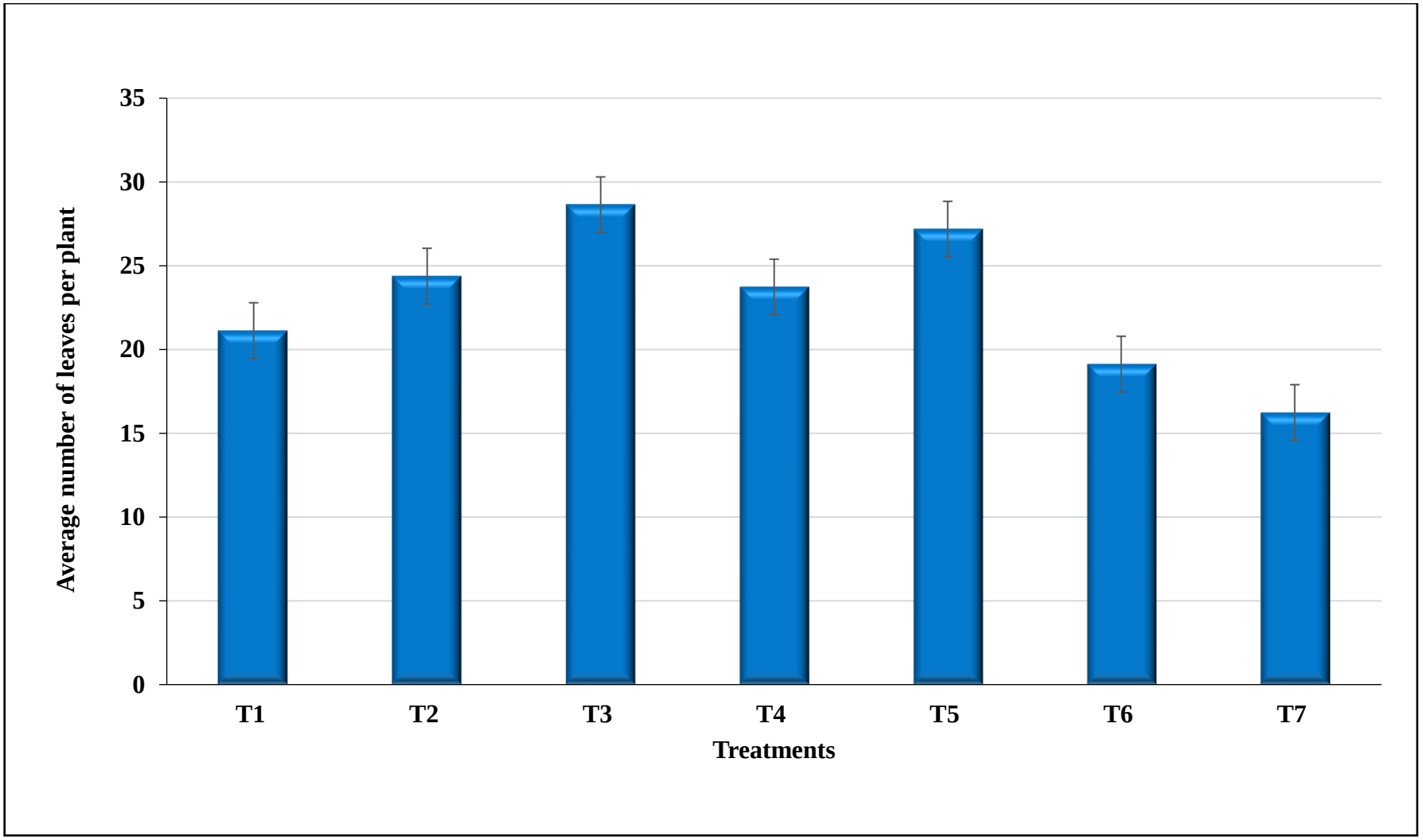

Fig. 1 Effect of different substrate combination on average number of leaves per plant

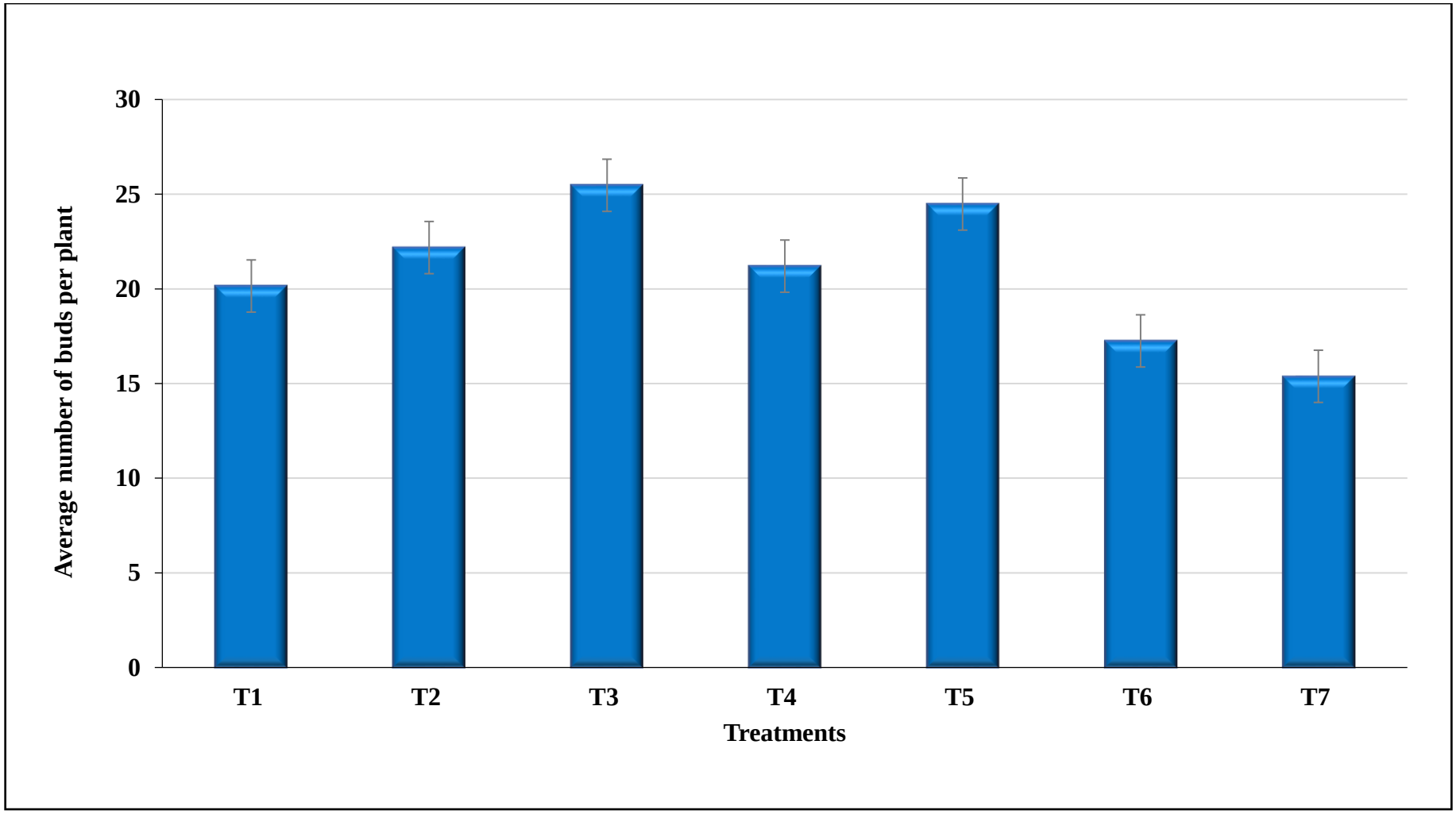

Fig. 2 Effect of different substrate combination on average number of buds per plant

Plate 3(a): Strawberry plants at flowering stage in soilless medium

Plate 3(b): Strawberry plants at flowering stage in potted soil medium

minimum days for first flower initiation 68.80 followed by 71.83 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, maximum days taken for first flower initiation 83.60 was recorded under treatment T_7 (control).

4.1.9 Average number of buds per plant

Table 2 and Fig. 2 show the data on the influence of different substrate combination on average number of buds per plant. The difference in average number of buds per plant was significant because of substrate combination from that of control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum average number of buds per plant 25.47 followed by 24.48 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and the minimum average number of buds per plant 15.38 was observed under treatment T_7 i.e. control.

4.1.10 Number of flowers per plant

The data pertaining the effect of number of flowers per plant is presented in Table 2 and Fig. 3. The data showed significant difference among different substrate comibations as compared to control. The number of flowers per plant was counted on a constant schedule at 30, 60 and 90 days interval after first flowering. At 30 days after first flowering, the substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum number of flowers per plant 8.44 followed by 8.04 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and the minimum number of flowers per plant 5.06 was observed under treatment T_7 (control).

At 60 days after first flowering, the substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) obtained maximum number of flowers per plant 9.98 followed by 9.57 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and the minimum number of flowers per plant 6.59 was observed under treatment T_7 (control).

At 90 days after first flowering, the substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) resulted in maximum number of flowers per plant 6.91 followed by 6.51 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and the minimum number of flowers per plant 3.53 was observed under treatment T_7 (control).

4.1.11 Average number of flowers per plant

Table 2 shows the data on the influence of different substrate combination on average number of flowers per plant. The difference in average number of flowers per plant was significant because of substrate combination from that of control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum average

number of flowers per plant 25.33 followed by 24.12 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and the minimum average number of flowers per plant 15.18 was observed under treatment T_7 (control).

4.2 Fruit quality parameters

4.2.1 Physical parameters

4.2.1.1 Fruit length (cm)

The data pertaining to the effect of different substrate combinations on fruit length is shown in the Table 3. The different substrate combinations significantly increased fruit length as compared to control. The fruit length was maximum 3.92 cm under treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) followed by 3.82 cm under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and minimum fruit length 2.73 cm was observed under treatment T_7 i.e. control.

4.2.1.2 Fruit breadth (cm)

The data presented in the Table 3 shows the influence of different substrate combinations on fruit breadth. The fruit breadth significantly increased among all the treatments compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum fruit breadth 3.40 cm followed by 3.22 cm under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum fruit breadth 2.23 cm was recorded under treatment T_7 (control).

4.2.1.3 Fruit size (cm^2)

The data presented in the Table 3 shows the influence of different substrate combinations on fruit size. The fruit size was significantly increased under different substrate combinations as compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum fruit size 13.32 cm^2 followed by 12.31 cm^2 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum fruit size 6.07 cm^2 was recorded under (T_7) control.

4.2.1.4 Fruit colour

The data pertaining to the effect of different substrate combinations on fruit colour is shown in the Table 3. The different substrate combinations significantly varied in fruit colour among all the treatments. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) and (T_5) cocopeat + perlite + vermicompost (1:1:1) were recorded with dark red colour whereas, orange red was observed under treatment T_7 (control).

4.2.1.5 Fruit weight (g)

Table 4 shows the data related to the effect of different substrate combinations on

Table 2: Effect of substrate combinations on days taken for first bud formation, days for the first flower initiation, average number of buds per plant, number of flowers per plant and average number of flowers per plant

Treatments	Days taken for first bud formation	Days for the first flower initiation	Average number of buds per plant	Number of flowers per plant			Average number of flowers per plant
				30 DAF	60 DAF	90 DAF	
T_1	73.66	78.83	20.15	6.64	8.17	5.11	19.92
T_2	68.83	73.10	22.18	7.29	8.83	5.76	21.88
T_3	64.74	68.80	25.47	8.44	9.98	6.91	25.33
T_4	70.89	75.71	21.20	6.99	8.52	5.45	20.97
T_5	67.98	71.83	24.48	8.04	9.57	6.51	24.12
T_6	75.83	80.67	17.25	5.66	7.20	4.13	16.99
T_7	78.72	83.60	15.38	5.06	6.59	3.53	15.18
$CD_{(0.05)}$	**1.02**	**1.05**	**0.73**	**0.22**	**0.24**	**0.34**	**0.64**
SE(m)	**0.33**	**0.34**	**0.24**	**0.07**	**0.08**	**0.11**	**0.21**

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

***DAF** – Days after first flowering

Table 3: Effect of substrate combinations on fruit length (cm), fruit breadth (cm), fruit size (cm^2) and fruit colour (UPOV)

Treatments	Fruit length (cm)	Fruit breadth (cm)	Fruit size (cm^2)	Fruit colour (grade)
T_1	3.21	2.73	8.77	4
T_2	3.52	3.07	10.82	5
T_3	3.92	3.40	13.32	6
T_4	3.40	3.00	10.19	5
T_5	3.82	3.22	12.31	6
T_6	3.03	2.52	7.63	5
T_7	2.73	2.23	6.07	4
$CD_{(0.05)}$	**0.08**	**0.08**	**0.43**	
SE(m)	**0.02**	**0.03**	**0.14**	

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

***UPOV** – International union for the protection of new varieties of plants

*** Fruit colour grade** – 4 = orange red, 5 = medium red, 6 = dark red (UPOV)

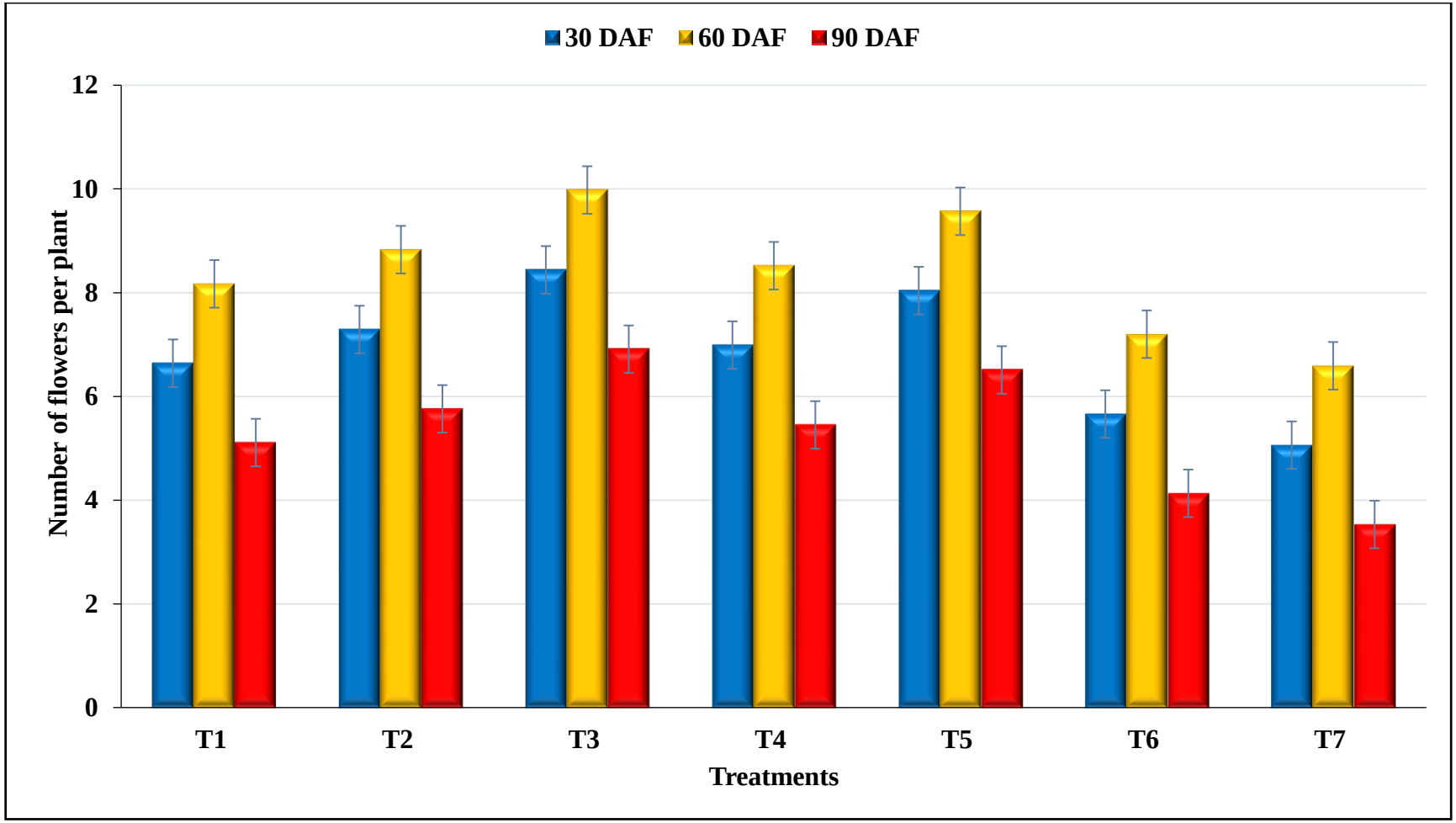

Fig. 3 Effect of different substrate combination on number of flowers per plant

fruit weight. The different substrate combinations significantly increased fruit weight compared to control. The fruit weight was recorded maximum 19.48 g under (T_3) cocopeat + vermiculite + vermicompost (1:1:1) followed by 18.43 g under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) while, minimum fruit weight 10.71 g was observed under treatment T_7 (control).

4.2.1.6 Fruit volume (cc)

The data presented in the Table 4 showed the effect of different substrate combinations on fruit volume. The fruit volume significantly increased the fruit volume among all the treatments compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum fruit volume 17.57 cc followed by 16.91 cc under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum fruit volume 10.64 cc was recorded under treatment T_7 i.e. control.

4.2.1.7 Specific gravity (g/cm^3)

The data pertaining to the effect of different substrate combinations on specific gravity is shown in the Table 4. The different substrate combinations significantly increased specific gravity among all the treatments compared to control. The specific gravity was recorded maximum 1.11 g/cm^3 with treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) which was statistically at par with (T_5) cocopeat + perlite + vermicompost (1:1:1) 1.09 g/cm^3 and minimum specific gravity 1.01 g/cm^3 was observed with treatment T_7 i.e. control.

4.2.1.8 Number of fruits per plant

Table 4 and Fig. 4 show the data related to the effect of different substrate combinations on number of fruits per plant. The different substrate combinations significantly increased number of fruits per plant compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum number of fruits per plant 25.19 followed by 23.89 under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum number of fruits per plant 14.86 was observed under treatment T_7 i.e. control.

4.2.1.9 Yield per plant (g)

Table 4 and Fig. 5 show the data related to the effect of different substrate combinations on yield per plant. The yield per plant was significantly increased in all the different substrate combinations as compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum yield per plant 490.69 g

followed by 440.28 g under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum yield per plant 159.12 g was recorded under treatment T_7 (control).

4.2.2 Biochemical parameters

4.2.2.1 Total soluble solids (^oB)

The data presented in the Table 5 showed the effect of different substrate combinations on total soluble solids. The different substrate combinations significantly increased the total soluble solids among all the treatments compared to the control. The highest total soluble solids 9.94 ^oB was observed with the treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) which was statistically at par with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) 9.35 ^oB whereas, lowest total soluble solids 6.48 ^oB was recorded under treatment T_7 (control).

4.2.2.2 Total sugars (%)

The data pertaining to the effect of different substrate combinations on total sugars is shown in the Table 5. The different substrate combinations significantly increased total sugars among all the treatments compared to control. The total sugars was recorded maximum 8.03 % with treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) followed by 7.60 % with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) and minimum total sugars 5.72 % was observed with treatment T_7 i.e. control.

4.2.2.3 Reducing sugars (%)

Table 5 shows the data related to the effect of different substrate combinations on reducing sugars. The reducing sugars was significantly increased in all the different substrate combinations as compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum reducing sugars 6.21 % followed by 5.92 % under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum reducing sugars 4.61 % was recorded under treatment T_7 (control).

4.2.2.4 Non reducing sugars (%)

The data presented in the Table 5 showed the effect of different substrate combinations on non reducing sugars. The different substrate combinations significantly increased the non reducing sugars among all the treatments compared to the control. The highest non reducing sugars 1.73 % was observed with the treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) which was statistically at par with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) 1.59 % whereas, lowest non reducing sugars 1.06 % was recorded under treatment T_7 i.e. control.

4.2.2.5 Titratable acidity (%)

Table 4: Effect of substrate combinations on fruit weight (g), fruit volume (cc), specific gravity (g/cm^3), number of fruits per plant and yield per plant (g)

Treatments	Fruit weight (g)	Fruit volume (cc)	Specific gravity (g/cm^3)	Number of fruits per plant	Yield per plant (g)
T_1	13.47	12.98	1.04	19.37	260.81
T_2	16.45	15.32	1.07	21.71	356.98
T_3	19.48	17.57	1.11	25.19	490.69
T_4	15.94	15.18	1.05	20.87	332.60
T_5	18.43	16.91	1.09	23.89	440.28
T_6	12.46	12.14	1.03	16.83	209.77
T_7	10.71	10.64	1.01	14.86	159.12
$CD_{(0.05)}$	**0.72**	**0.41**	**0.06**	**0.55**	**18.47**
SE(m)	**0.24**	**0.13**	**0.02**	**0.18**	**6.03**

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

Table 5: Effect of substrate combination on total soluble solids (ºB), total sugars (%), reducing sugars (%) and non reducing sugars (%)

Treatments	Total soluble solids (ºB)	Total sugars (%)	Reducing sugars (%)	Non reducing sugars (%)
T_1	7.34	6.23	4.91	1.26
T_2	8.42	7.20	5.68	1.45
T_3	9.94	8.03	6.21	1.73
T_4	7.97	6.57	5.16	1.34
T_5	9.35	7.60	5.92	1.59
T_6	7.15	6.04	4.85	1.13
T_7	6.48	5.72	4.61	1.06
$CD_{(0.05)}$	**0.93**	**0.12**	**0.08**	**0.15**
SE(m)	**0.30**	**0.04**	**0.03**	**0.05**

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

Table 6: Effect of substrate combination on titratable acidity (%), ascorbic acid (mg/100g), anthocyanin content (mg/100g) and carotenoid content (mg/g)

Treatments	Titratable acidity (%)	Ascorbic acid (mg/100g)	Anthocyanin content (mg/100g)	Carotenoid content (mg/g)
T_1	1.14	46.33	42.75	15.84
T_2	0.98	49.29	45.16	16.77
T_3	0.81	51.10	48.40	18.04
T_4	1.08	48.67	44.29	16.06
T_5	0.84	50.40	46.82	17.71
T_6	1.30	43.58	41.72	15.71
T_7	1.40	42.51	40.21	14.94
$CD_{(0.05)}$	**0.07**	**0.51**	**0.68**	**0.58**
SE(m)	**0.02**	**0.17**	**0.22**	**0.19**

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

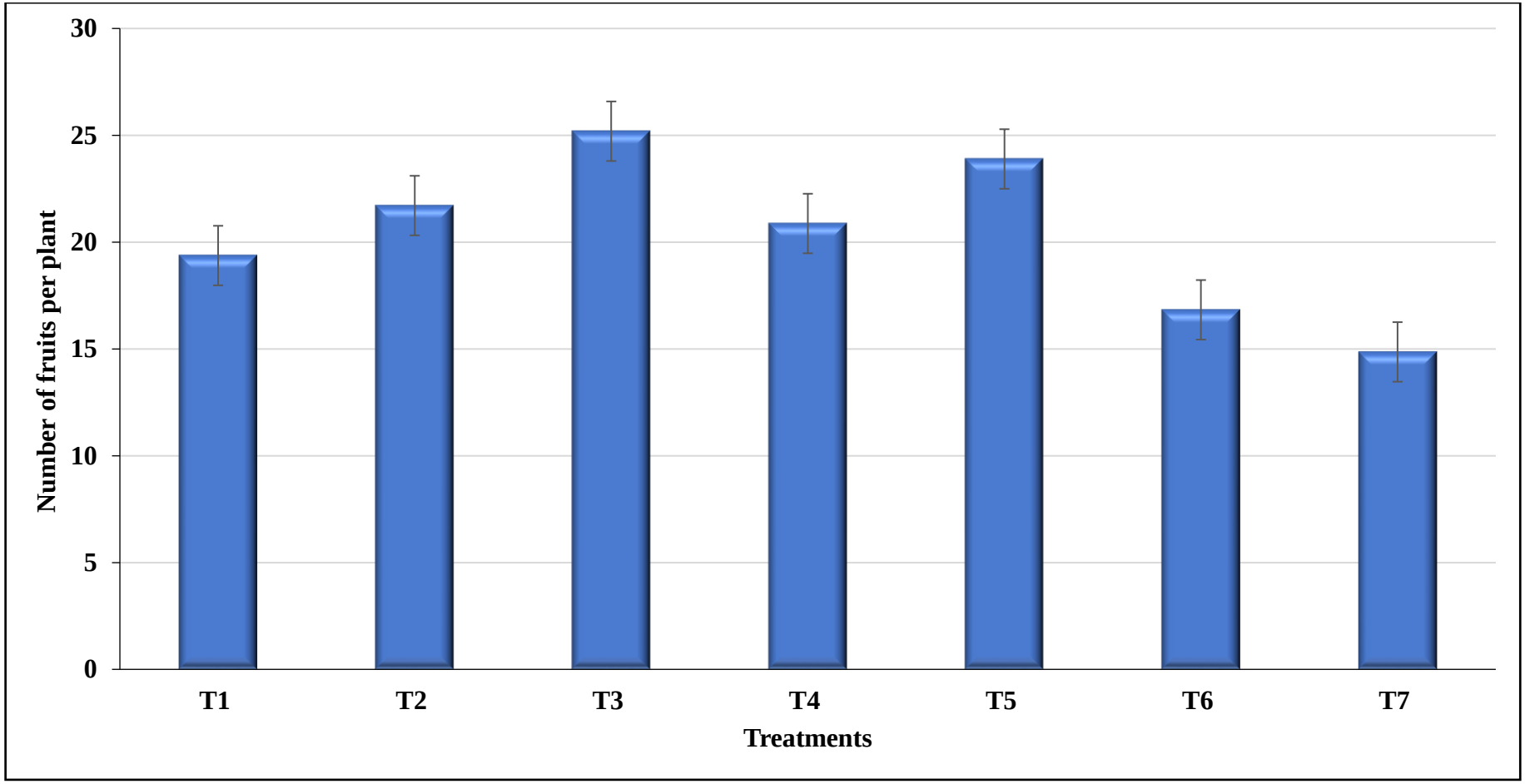

Fig. 4 Effect of different substrate combination on number of fruits per plant

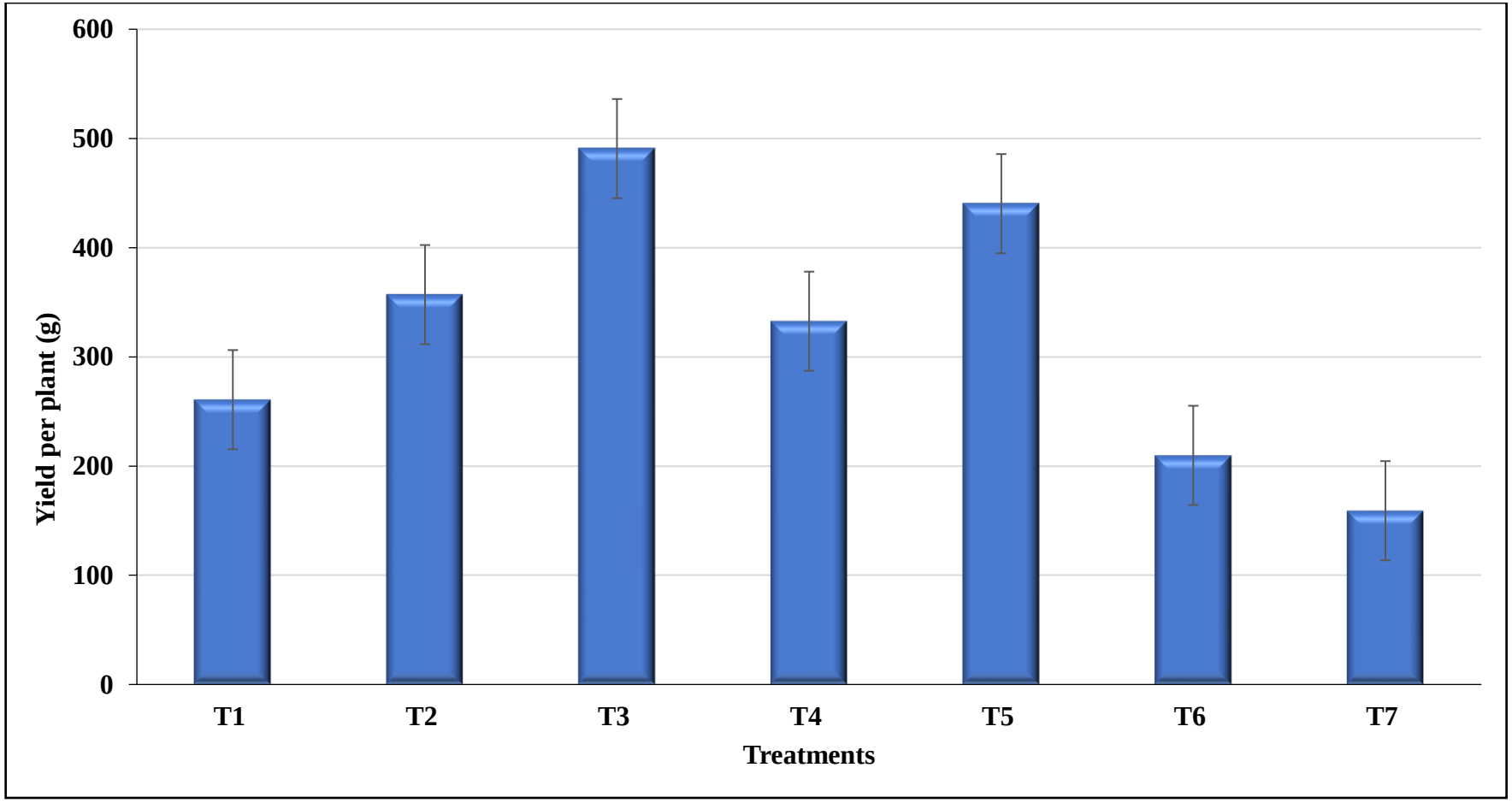

Fig. 5 Effect of different substrate combination on yield per plant (g)

The data pertaining to the effect of different substrate combinations on titratable acidity is shown in the Table 6. The different substrate combinations significantly reduced titratable acidity among all the treatments compared to control. The titratable acidity was recorded minimum 0.81 % with treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) which was statistically at par with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) 0.84 % and maximum titratable acidity 1.40 % was observed with treatment T_7 i.e. control.

4.2.2.6 Ascorbic acid (mg/100g)

Table 6 shows the data related to the effect of different substrate combinations on ascorbic acid. The ascorbic acid was significantly increased in all the different substrate combinations as compared to control. The substrate combination (T_3) cocopeat + vermiculite + vermicompost (1:1:1) gave maximum ascorbic acid 51.10 mg/100g followed by 50.40 mg/100g under treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, minimum ascorbic acid 42.51 mg/100g was recorded under treatment T_7 (control).

4.2.2.7 Anthocyanin content (mg/100g)

The data presented in the Table 6 showed the effect of different substrate combinations on anthocyanin content. The different substrate combinations significantly increased the anthocyanin content among all the treatments compared to the control. The highest anthocyanin content 48.40 mg/100g was observed with the treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) followed by 46.82 mg/100g with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) whereas, lowest anthocyanin content 40.21 mg/100g was recorded under treatment T_7 i.e. control.

4.2.2.8 Carotenoid content (mg/ g)

The data pertaining to the effect of different substrate combinations on carotenoid content is shown in the Table 6. The different substrate combinations significantly increased carotenoid content among all the treatments compared to control. The carotenoid content was recorded maximum 18.04 mg/g with treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) which was statistically at par with treatment (T_5) cocopeat + perlite + vermicompost (1:1:1) 17.71 mg/g and minimum carotenoid content 14.94 mg/g was observed with treatment T_7 (control).

4.3. Relative Economics

The actual costs were worked out for all the treatments which include labour charges, cost of different substrate combinations, cost of runner, hydroponics unit,

electricity, nutrition, net pots, muslin cloth, plastic pots were included.

The cost of cultivation for strawberry grown with different media combination is presented in Table 7. The table reveals that total cost of cultivation incurred for raising strawberry plant grown in (T_3) cocopeat + vermiculite + vermicompost (1:1:1) was (₹418.57), whereas (₹265.07) incurred under control. The cost of runner (₹18.00), labour (₹178.57) and nutrition (₹45.00) were same for all the treatments. The cost for growing strawberry per treatment in hydroponics unit (₹90.00) and the charges for electricity (₹6.00), net pots (₹9.00) and muslin cloth were (₹6.00) except for pot grown strawberries in which pots charged (₹22.50). The substrate charges for (T_3) cocopeat + vermiculite + vermicompost (1:1:1) were (₹48.51) while, (₹1.00) was for treatment T_7 (control).

The cost and return analysis of strawberry produced in different treatments of hydroponics and plastic pots is presented in Table 8. The maximum yield per treatment was observed under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (4.42 kg), followed by treatment T_5 i.e. cocopeat + perlite + vermicompost (3.96 kg) and minimum was in T_7 i.e. control (1.43 kg). Gross return on the basis of yield per plant was found to be maximum (₹993.65) in treatment T_3, followed by T_5 treatment (₹891.57) and minimum (₹322.22) was observed in control treatment (T_7). The net returns were found to be maximum in case of treatment T_3 (₹589.57) with B:C ratio of 1:2.5, followed by treatment T_5 (₹486.32) with B:C ratio of 1:2.2 and minimum was noted in treatment T_7 i.e. control (₹57.15) with B:C ratio of 1:1.2.

The cost benefit ratio ranged from 1:1.25 to 1: 2.5 between treatment control (T_7) and (T_3) cocopeat + vermiculite + vermicompost (1:1:1) as per the yield obtained. Highest cost benefit ratio of (1:2.5) was recorded in treatment (T_3) cocopeat + vermiculite + vermicompost (1:1:1) is because of the higher yield.

Table 7: Cost of cultivation for different substrate combination (₹/treatment)

Treatments	Substrate (₹)	Runner (₹)	Labour (₹)	Hydroponics (₹)	Electricity (₹)	Nutrition (₹)	Muslin cloth (₹)	Net pots (₹)	Plastic Pots (₹)	Cost of cultivation (₹)
T_1	63.00	18.00	178.57	90.00	6.00	45.00	9.00	9.00	0.00	418.57
T_2	65.70	18.00	178.57	90.00	6.00	45.00	9.00	9.00	0.00	421.27
T_3	48.51	18.00	178.57	90.00	6.00	45.00	9.00	9.00	0.00	404.08
T_4	67.50	18.00	178.57	90.00	6.00	45.00	9.00	9.00	0.00	423.07
T_5	49.68	18.00	178.57	90.00	6.00	45.00	9.00	9.00	0.00	405.25
T_6	4.50	18.00	178.57	0.00	0.00	45.00	0.00	0.00	22.50	268.57
T_7	1.00	18.00	178.57	0.00	0.00	45.00	0.00	0.00	22.50	265.07

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

Table 8: Cost and benefit analysis of strawberry production

Treatments	Yield per treatment (kg)	Gross return (₹)	Cost of cultivation (₹)	Net return (₹)	BC Ratio
T_1	2.35	528.14	418.57	109.57	1:1.3
T_2	3.21	722.88	421.27	301.61	1:1.7
T_3	4.42	993.65	404.08	589.57	1:2.5
T_4	2.99	673.52	423.07	250.45	1:1.6
T_5	3.96	891.57	405.25	486.32	1:2.2
T_6	1.89	424.78	268.57	156.21	1:1.6
T_7	1.43	322.22	265.07	57.15	1:1.2

***T_1** – Cocopeat (100%), **T_2** – Cocopeat + Vermiculite (1:1), **T_3 –** Cocopeat + Vermiculite + Vermicompost (1:1:1), **T_4** – Cocopeat + Perlite (1:1), **T_5** – Cocopeat + Perlite + Vermiculite (1:1:1), **T_6 –** Local soil + Vermiculite (1:1), **T_7** – Local **s**oil (control) (100%)

Chapter-5

Discussion

Chapter 5

DISCUSSION

The present investigation entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** was carried out at experimental area in the Division Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21. The results of investigation were discussed in this chapter to explain the observed effects in the light of available literature under the following heads.

5.1 Effect of different substrate combinations on vegetative growth parameters

The effect of different substrate combinations showed a significant influence on plant vegetative growth parameters. Minimum number of days taken for runner establishment (6.41), maximum average number of leaves per plant (28.64), leaf area per plant 135.46 cm^2, leaf chlorophyll content (55.35), plant spread (42.47 cm) and root/shoot ratio (1.53) was recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1) whereas, the maximum number of days taken for runner establishment (8.32), minimum average number of leaves per plant (16.24), average leaf area per plant (119.30 cm^2), leaf chlorophyll content (40.93), plant spread (20.33 cm) and root/shoot ratio (0.93) was observed under treatment T_7 (control).

The characteristics of different materials required as growing substrates have direct and indirect impact on plant growth, which might explain the difference in vegetative growth (Verdonck *et al*., 1981). The increase in vegetative growth parameters might be due to better aeration and water holding capacity offered by vermiculite which resulted in better root growth of the strawberry plants. Furthermore, vermiculite in combination with vermicompost comparised of greater organic matter than other substrate combination which provided enough nutrients to the plants to offer greater vegetative growth (Graves, 1983). According to Schie (1999), cocopeat is an organic substance with a medium ion absorption capability. It also has higher aerial porosity and a higher water and nutrient maintenance capacity (Por-Hossein *et al*., 2009 and Firoozabadi *et al*., 2009). Vermicompost is a medium that contains various types of nutrients for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium, and magnesium, as well as improved water retention capacity (Khalighi and Padasht-Dehkaee, 2000 and Fernandes and Eduardo-Cora, 2004). The utilisation of various organic and inorganic substrates in

the proper proportions optimises water and oxygen retention, as well as nutrient absorption and allowing for adequate growth and development (Bartczak *et al*., 2007, Albaho *et al*., 2009, Ayesha *et al*., 2011 and Hesami *et al*., 2012). Soltani (2004) reported that disruption in the plant photosynthetic system might be one of the physiological causes for growth reduction in the traditional system.

Cocopeat, according to Nourizadeh (2003), is beneficial in rooting owing to improved exchange of elements, particularly cations, within the substrate and correct moisture distribution, which enhances root system and, ultimately the plant height. Plant growth, as measured by plant height, stem diameter, and number of leaves, was greater in soilless culture than in soil cultivation, according to Rumple *et al*. (1996). Hassan *et al*. (2011) discovered that utilising coconut husk resulted in the most leaves and plant height, whereas, using soil cultivation resulted in the least. Similarly, Ericisli *et al*. (2005) found that soilless substrates were beneficial in promoting the growth of both root and shoot parts of strawberry cultivars.

Several research groups have also confirmed that soilless substrates, rather than soil, had a significant influence on plant growth (Tehranifar *et al*., 2007, Tzortzakis and Economakis, 2008, Singh *et al*., 2000, Kumar *et al*., 2011, Prasana et al., 2013, Marinou *et al*., 2013 and Kumar *et al*., 2014).

5.2 Effect of different substrate combinations on flowering characteristics

In present study, different flowering parameters such as days for first bud formation (64.74), days taken for first flower initiation (68.80) were minimum whereas, average number of buds per plant (25.47), number of flowers per plant (8.44, 9.98, 6.91) at 30, 60, 90 days after first flowering respectively and average number of flowers per plant (25.33) were recorded maximum under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1) while, the maximum days taken for first bud formation (78.72), days taken for first flower initiation (83.60) and minimum average number of buds per plant (15.38), number of flowers per plant (5.06, 6.59, 3.53) at 30, 60, 90 days after first flowering respectively, average number of flowers per plant (15.18) were observed under treatment T_7 i.e. control.

Nourizadeh (2003) also observed significant increase in the number of flowers in plants as a result of proper ventilation and water maintenance in a soilless substrate. The improved root zone environment due to cocopeat, vermicompost and vermiculite may

have contributed to the greater flowering results in artificial media as compared to soil. The physio-chemical characteristics of the growing media have an impact on plant growth and flowering (Wilkerson, 2002) and the composition of the growing media is a critical aspect to consider (Ingram *et al*., 2003). According to Arancon *et al*. (2004), organic matter (vermicompost) treatments enhanced strawberry flowering by 40 per cent. According to Ayesha *et al*. (2011), coconut coir and compost-based growth media may greatly increase the size of strawberry flowers, while Riaz *et al*. (2008) found comparable findings in zinnia.

5.3 Effect of different substrate combinations on physical characteristics

The different substrate combinations showed a significant influence on physical characteristics of strawberry fruit. The maximum fruit length (3.92 cm), fruit breadth (3.40 cm), fruit size (13.32 cm^2), fruit colour (dark red), maximum fruit weight (19.48 g), fruit volume (17.57 cc), specific gravity (1.11 g/cm^3), number of fruits per plant (25.19) and yield per plant (490.69 g) was with treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1), whereas, minimum fruit length (2.73 cm), fruit breadth (2.23 cm), fruit size (6.07 cm^2), fruit colour (orange red), minimum fruit weight (10.71 g), fruit volume (10.64 cc), specific gravity (1.01 g/cm^3), number of fruits per plant (14.86) and yield per plant (159.12 g) was under treatment T_7 i.e. control.

The appropriate combination of substrate provides a better environment for root growth and prevents water tension and increased water consumption, as well as increased fruit production in strawberry (Serrano *et al*., 1993, Ericisli *et al*., 2005, Mashadi *et al*., 2009 and Ebrahimi *et al*. 2012). The increase in fruit weight might be attributed to the organic substrate providing appropriate levels of manures, therefore making accessible sufficient and balanced amounts of macro and micro nutrients, resulting in an increase in the weight of the strawberry fruit via increasing carbohydrate synthesis (Ayeni *et al*. (2009). The findings of this study correlate with those of Ayesha *et al*. (2011), who found that tomato and strawberry crops grown in organic substrates produced higher fruit weight. The superior physical conditions, moisture retention and aeration characteristics of media may be responsible for the results. The current findings are consistent with those of Fornes *et al*. (2003) and Ayesha *et al*. (2011), who found that a manure-based medium enhanced strawberry fruit size, possibly due to its potential to supply necessary micronutrients to the plants. Ullah *et al*. (2008) and Gungor and Yildirim (2013) observed

comparable results, reporting that as compared to peat alone, mixed medium considerably enhanced fruit length, diameter and weight.

A mixture of substrates has been shown to enhance aeration and formation of root system (Yuan *et al*., 1996, Verdonck and Demeyer, 2004), resulting in greater production (Du *et al*., 2007, Albaho *et al*., 2009). Similarly, the findings are in accordance with those of Gracia and Deverde (1994) and Maher *et al*. (2008), who observed that root growth of tomato plant is faster in soilless culture, resulting in higher yield. In soilless culture, increased the vegetable growth leads to increased production, as stated (Economakis and Krulj, 2001, Waffa *et al*., 2009). Takeda (1999) also reported that using the right substrate mix in soilless culture within greenhouse systems, can prolong harvesting time, produce off-season strawberries and improve output. The findings are also consistent with those of Linardakis and Manios (1990), Cantliffe *et al*. (2008), Yavari *et al*. (2008), Mashadi *et al*. (2009) and Rostami *et al*. (2014), who found that substrates containing different ratios of cocopeat, perlite, pumice, vermicompost, saw dust, and zeolite significantly varied in strawberry yield. Further, in comparison to soilless media without vermicompost, the yield per plant was geater when vermicompost was used. These results correspond with those of Atiyeh *et al*. (2000) and Arancon *et al*. (2004), who found that using vermicompost as a plant growing medium increased yield significantly due to high porosity, good aeration, drainage, water holding capacity, extremely high microbial activity, plant growth hormones and humic acids. These findings corroborated with those of Edwards and Burrows (1988), Abad *et al*., (2002), Cantliffe *et al*., (2007) and Singh *et al*., (2010), who found that vermicompost contains accessible types of nutrients for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium, and magnesium.

5.4 Effect of different substrate combinations on biochemical characteristics

The different substrate combinations showed significant effect on biochemical characteristics of strawberry fruit. In present study, highest total soluble solids (9.94 ^{o}B), total sugars (8.03 %), reducing sugars (6.21 %), non reducing sugars (1.73 %), ascorbic acid (51.10 mg/100g), anthocyanin content (48.40 mg/100g), carotenoid content (18.04 mg/g) and lowest titratable acidity (0.81 %) was recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost whereas, lowest total soluble solids (6.48 ^{o}B), total sugars (5.72 %), reducing sugars (4.61 %), non reducing sugars (1.06 %), ascorbic acid (42.51 mg/100g), anthocyanin content (40.21 mg/100g), carotenoid content (14.94 mg/g) and highest titratable acidity (1.40 %) was recorded under treatment T_7 i.e.control.

Higher leaf area may have benefited photosynthetic rate, translocation and accumulation of sugars and metabolites in fruits during soilless culture, resulting in increase in TSS and total sugars in fruits (Ayesha *et al*., 2011). Similarly, the results were in accordance as stated by Ozdemir and Kaska (1997) who found that strawberries produced in soilless culture had higher TSS and better flavour than those grown in soil conditions. In soilless tomato cultivation, Gruda and Schnitzler (2004) found an increase in dry matter, sugars, soluble solids, vitamins and carotenoids content.

In present study, significant differences in TSS and sugars were found in various combinations of soilless medium. This might be because the varying proportions of cocopeat + vermiculite + vermicompost which alters the physical and chemical qualities of the substrates, affecting the qualitative attributes of strawberries fruit significantly.

Our results are in conformity with the results of Jafarnia *et al*. (2010), Inden and Torres (2004), and Ameri *et al*. (2012) who investigated the effect of different substrate combinations on TSS and sugar content. However, Fernandez *et al*. (2006) and Cantliffe *et al*. (2008) found that the key nutritional quality parameters such as TSS, organic acids, soluble sugars and minerals did not change significantly under the soil and soilless media.

The increased acidity may be due to the longer time necessary for harvestable fruit in soil, but in artificial media, plants are able to reach their full potential, resulting in earlier fruit maturation and ripening. Another cause for greater acidity in soil-grown fruits has been suggested: high EC, which resulted in low absorption of N, K^+ and better absorption of Ca^{2+} and Na^+ than anions like $SO4^{2-}$ Davis (1964). Similarly, Hassan *et al*. (2011) found more acidic fruits in soil and lower acidic fruits in coconut coir.

The acid content of strawberries varies considerably in the various combinations of soilless substrates used in this study. The findings are also consistent with those of Javanpour *et al*. (2005) who found that the presence of Perlite as a mineral in organic substrate combinations reduces cations exchange capacity and influences fruit acidity. Ameri *et al*. (2012) showed that decreased pH level led in increased titratable acidity content. Fernandez *et al*. (2006), on the other hand, observed no significant differences in acidity levels as a result of the farming approach, with or without soil.

This might be attributed to changes in the physicochemical characteristics of the substrate as a result of combining organic (cocopeat and vermicompost) and inorganic (vermiculite) substrates, which may have affected overall vitamin C content and fruit

quality. The findings are similar to those of Yavari *et al*. (2008) and Hassan *et al*. (2011), who found that fruits grown on coconut husk had the highest vitamin C content while those grown in soil had the lowest. The rise in ascorbic acid concentration might be attributed to better growth and fruiting, as well as physiological activities in the plant system such as carbohydrate synthesis (Alldredge *et al*., 2010).

According to Gregorioa and Vakits (1992); Ghazvini *et al*. (2007) and Ameri *et al*. (2012), the enhancement in anthocyanin pigment in strawberries might be related to the tendency of anthocyanin content to increase with higher sugar metabolism throughout the fruiting stage in soilless culture in comparison to soil. Different substrates have a significant influence on anthocyanin concentration in strawberry. Similarly, Schmitzer and Stampar (2009) found that the concentration of phenolic compounds, particularly anthocyanin, is affected by substrate pH, which progressively increases as the pH content of growth medium decreases. However, the findings contradict with those of Paroussi and Paroussis (1995), who found that soil and soilless cultivation had no significant influence on strawberry anthocyanin pigment.

Chapter-6

Summary and Conclusions

Chapter 6

SUMMARY AND CONCLUSIONS

The present investigation entitled **"Nutritional studies for soil and soilless production of strawberry (*Fragaria* × *ananassa*) cv. Chandler"** was carried out at experimental area in the Division Plant Physiology of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha during 2020-21. The results have clearly indicated that there was a positive effect on growing of strawberry in hydroponic system (NFT). The significant findings found during course of study are briefly summarized below:

The growth characteristics of strawberry plant differed significantly due to different substrate combinations. Minimum number of days taken for runner establishment (6.41), number of days taken for first bud formation (64.74), number of days taken for first flower initiation (68.80) were recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1). Furthermore, it also significantly increased average number of leaves (28.64) per plant, average leaf area (135.46 cm^2) per plant, leaf chlorophyll content (55.35), plant spread (42.47 cm), root/shoot ratio (1.53), average number of buds per plant (25.47), number of flowers per plant (8.44, 9.98, 6.91) at 30, 60, 90 days after first flowering respectively and average number of flowers per plant (25.33).

Physical characteristics were also influenced by the different substrate combinations. Maximum fruit length (3.92 cm), fruit breadth (3.40 cm), fruit size (13.32 cm^2), dark red colour, fruit weight (19.48 g), fruit volume (17.57 cc), specific gravity maximum (1.11 g/cm^3), number of fruits per plant (25.19) and yield per plant (490.69 g) was recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1).

The biochemical characteristics also greatly differed with various substrate combinations. Maximum total soluble solids (9.94 ^oB), total sugars (8.03 %), reducing sugars (6.21%), non reducing sugars (1.73%), ascorbic acid (51.10 mg/100g), anthocyanin content (48.40 mg/100g), carotenoid content (18.04 mg/g) and minimum titratable acidity (0.81%) was recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1).

As per economic analysis it was made clear that maximum B:C ratio (1:2.5) was recorded under treatment T_3 i.e. cocopeat + vermiculite + vermicompost (1:1:1) whereas, minimum B:C ratio (1:1.2) was found to be under treatment T_7 i.e. control.

Conclusion

From the present investigation, it is concluded that different substrate combinations significantly affect the growth, yield and quality parameters of strawberry. Application of treatment T_3 i.e. cocopeat + vermiculite + vermicompost in the ratio of 1:1:1 in nutrient film technique may be beneficial for better yield and nutritional quality production of strawberry cv. Chandler. Furthermore, B:C ratio (1:2.5) was obtained maximum under treatment cocopeat + vermiculite + vermicompost (1:1:1) and found to be economically feasible. This combination of growing media could be recommended to farmers. Nevertheless, the positive results with reference to cocopeat + vermiculite + vermicompost for strawberry is undoubtedly encouraging for making elaborate studies in the hydroponics with right combination of growing media. Thus, it was concluded that Hydroponics (nutrient film technique) is capable of achieving sustainable development goals by providing a higher production yield without any constrains of climate and weather conditions and lower water consumption when compared to soil. Therefore, hydroponic technique could be a way to achieve sustainable intensification.

References

REFERENCES

A.O.A.C (Association of Official Analytical Chemists). 1990. Official methods of analysis. Washington, D.C

A.O.A.C International. 2007. Official method of analysis, 18th ed. (2005) Current through revision 2, 2007 (on-line) AOAC International, Gaithersburg, MD.

A.O.A.C. 1980. Official Methods of Analysis. 13th. Ed. Association of Official Analytical Chemists. Washington, D.C

Abad, M., Noguera, P., Puchades, R., Maquieira, A. and Noguera, V. 2002. Physico-chemical and chemical properties of some coconut coir dust for use as a peat substitute for containerized ornamental plants. *Bioresource Technology*, **82**: 241–245.

Adak, N. and Gubbuk, H. 2015. Effect of planting systems and growing media on earliness, yield and quality of strawberry cultivation under soilless culture. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **43**(1): 204-209.

Albaho, M., Bhat, N., Abo-Rezq, H. and Thomas, B. 2009. Effect of three different substrates on growth and yield of two cultivars of strawberry. *European Journal of Scientific Research*, **28**(2): 227-233.

Alldredge, J.R., Ross, C.F., Davies, N.M. and Zhou, J. 2010. Fruit and soil quality of organic and conventional strawberry agro-ecosystems. *Fruit and Soil Quality*, **5**(9): 1234-1246.

Ameri, A., Tehranifar, A., Davarynejad, G.H and Shoor, M. 2012. Effect of substrate and cultivar in quality of Strawberry. *Journal of Biology and Environment Science*, **6**(17): 181-188.

Anagnostou, K. and Vasilakakis, M.D. 1993, September. Effect of substrate and cultivar on earliness, plant productivity, and fruit quality of strawberry. In *International Symposium on Quality of Fruit and Vegetables: Influence of Pre-and Post-Harvest Factors and Technology*, **379**: 267-274.

Anonymous, 2014. *The top five strawberries producing countries*. http://top5ofanything.com/index.php.

Anonymous, 2018. *Horticultural statistics at a glance*. Ministry of agriculture and farmer welfare, Government of India. pp. 9.

Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C. and Metzger, J.D. 2004. Influences of vermicomposts on fields strawberries on growth and yields. *Bioresource Technology*, **93**(2): 145-153.

Arias, R., Lee, T.C., Specca, D. and Janes, H. 2000. Quality comparison of hydroponic tomatoes (*Lycopersicon esculentum*) ripened on and off vine. *Journal of Food Science*, **65**(3): 545-548.

Asker, H.M., 2015 Hydroponic technology for lily flowers and bulbs production using rainwater and some common nutrient solutions. *African Journal of Biotechnology*, **14**(29)**:** 2307-2313.

Atiyeh, R.M., Arancon, N., Edwards, C.A. and Metzger, J.D. 2000. Influence of earthworm processed pig manure on the growth and yield of greenhouse tomatoes. *Bioresource Technology*, **75**: 175-180.

Awang, Y., Shaharom, A.S., Mohamad, R.B. and Selamat, A. 2009. Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Sciences*, **4**(1): 63-71.

Ayeni, L.S., Omole, T.O., Adeleye, E.O. and Ojeniyi, S.O. 2009. Comparative effect of poultrymanure and NPK fertilizer on performance of tomato in derived savannah transition zone of Southwest Nigeria. *American-Eurasian Journal of Sustainable Agriculture*, **3**: 850-853.

Ayesha, R., N. Fatima, N., Ruqayya, M., Faheem, H.,Qureshi, K.M., Hafiz, I. A., Khan, K.S., Ali, U and Kamal. A. 2011. Influence of different growth media on the fruit quality and reproductive growth parameters of strawberry (*Fragaria × ananassa*). *Journal of Medicinal Plants Research*, **5**(26): 6224-6232.

Bakshi, P., Bhat, D.J., Wali, V.K., Sharma, A. and Iqbal, M. 2014. Growth, yield and quality of strawberry (*Fragaria x ananassa*) cv. Chandler as influenced by various mulching materials. *African Journal of Agricultural Research*, **9**(7):701-706.

Barbosa, G. L., Gadelha, F. D. A., Kublik, N., Proctor, A., Reichelm, L., Weissinger, E., Wohlleb, G. M. and Halden, R. U. 2015. Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods. *International Journal of Environmental Research and Public Health*, **12**: 6879-6891.

Bartczak, M., Magelalena, P. and Knaflewski, M. 2007. Effect of substrate on vegetative quality of strawberry plants (*Fragaria* × *ananassa* Duch.) produced by a soilless method. *Folia Horticulturae Annals,* **19** (2): 39-46.

Bowling, B.L., 2000. The berry grower's companion. *Timber Press Inc.,* Portland, Oregon, USA.

Bradley, P. and Marulanda, C. 2000. Simplified hydroponics to reduce global hunger. *Acta Horticulturae*, **554**: 289-95.

Cantliffe, D.J., Paranjpe, A.V., Stoffella, P.J., Lamb, E.M. and Powell, C.A. 2007. Influence of soilless media, growing containers, and plug transplants on vegetative growth and fruit yield of Sweet Charlie strawberry grown under protected culture. In *Proceedings of the Florida State Horticultural Society*, **120**:142-150.

Cantliffe, D.J., Webb, J.E., Vansickle, J.J. and Shaw, N.L. 2008. Potential profits from greenhouse- grown organic strawberries are greater than conventional greenhouse or field grown strawberries in Florida. *Proceedings of the Florida State Horticultural Society,* **121**: 208-213.

Carmassi, G., Incrocci, L., Maggini, R., Malorgio, F., Tognoni, F. and Pardossi, A. 2005. Modeling salinity build-up in recirculating nutrient solution culture. *Journal of Plant Nutrition*, **28**(3): 431-445.

Castillo, F. S., Perez, E. C. and Magaa, E. C. 2012. Development of alternative crop systems for production of vegetables in hydroponics. *Acta Horticulturae,* **947**: 399- 408.

Chavada, J.R., Thumar, B.V., Vihol, A.N., Patel, V.S. and Padhiyar, B.M. 2017. Effect of potting media on growth, flower yield and quality of rose (*Rosa hybrida* L.) cv. Top Secret under protected condition. *International Journal of Pure and Applied Bioscience,* **5**(5): 821-827.

Childers, N.F., Morris, J.R. and Sibbett, G.S. 1995. Modern Fruit Science. *Horticulture Publication,*Gainesville, Florida, USA.

Colla, G., Saccardo, F., Rea, E., Pierandrei, F. and Salerno, A. 2002. Effects of substrates on yield, quality and mineral composition of soilless-grown cucumbers. In *VI International Symposium on Protected Cultivation in Mild Winter Climate: Product and Process Innovation*, **614**: 205-209.

Considine, M. 1982. Food and Food Products Encyclopedia. *Van Nostrad Company Inc*, New York, USA.

Darnell, R. 2003. Strawberry growth and development. In: *The Strawberry: A Book for Growers and Others* (Ed. Childers, N.F.). Horticultural Sciences Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Davis, J.N. 1964. Effect of nitrogen, phosphorous and potassium fertilizers on the non-volatile organic acids of tomato fruit. *Journal of the Science of Food Agriculture*, **15**: 665-73.

De, L.C. and Bhattacharjee, S.K. 2012. Handbook of Edible Fruits. *Aavishkar Publishers, Distributors*, Jaipur 302003 (Raj.), India, p 312.

De, L.C. and Bhattacharjee, S.K. 2014. *Handbook of Edible Fruits*. Aavishkar Publishers, Distributors.

Domingues, D.S., Takahashi, H.W., Camara, C.A.P. and Nixdorf, S.L. 2012. Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production. *Computers and Electronics in Agriculture* **84**: 53-61.

Draie, D.R.R. 2019. Are hydroponics of strawberry in home balconies a promising economic technique. *International Research Journal of Innovations in Engineering and Technology*, **3**(11): 10-18.

Du, G.D., Guo, X.W., Wu, J. and Cai, M. 2007. Effect of different media's aeration on growth and photosynthetic characteristic of strawberry. College of Horticulture Shenyang Agricultural University, Liaoning, Shenyang.

Ebrahimi, R., Ahmadizadeh, M. and Majdi, Y. 2012. Investigating the traits of green pepper in the three substrates in hydroponic system. *Current Research Journal of Biological Sciences*, **4**(4): 492-495.

Ebrahimi, R., Ebrahimi, F. and Ahmadizadeh, M. 2012. Effect of different substrates on herbaceous pigments and chlorophyll amount of strawberry in hydroponic cultivation system. *American-Eurasian Journal of Agricultural and Environmental Sciences*, **12**(2): 154-158.

Ebrahimi, R., Souri, M.K., Ebrahimi, F and Ahmadizadeh, M. 2012. Growth and Yield of Strawberries under Different Potassium Concentrations of Hydroponic System in Three Substrates. *World Applied Sciences Journal*. **16**(10): 1380-1386.

Economakis, C.D. and Krulj, L. 2001. Effect of root-zone warming on strawberry plants grown with Nutrient Film Technique (NFT). *Acta Horticulturae*, **548**: 189-196.

Edwards, C.A. and Burrows, I., 1988. The potential of earthworm compost as plant growth media. In: Edwards, C.A. Neuhauser, E.F. (Eds.), Earthworms in Waste and Environmental Management.*SPB Academic Publishers*, The Netherlands. pp: 21-32.

El-Behairy, U.A., Abou-Hadid, A.F., Medany, M.A. and Awad, M.M., 2001. The effect of different cultivars, orientation and soilless culture systems on production and quality of strawberry. *Acta Horticulturae*, 59-64.

EL-Sayed, S.F., Hassan, H.A., Abul-Soud, M and Gad, D.A.M. 2016. Effect of substrate mixtures and nutrient solutions sources on strawberry plants under closed hydroponic system. *Journal of Production & Development*, **21**(1): 97- 115.

Ericisli, S., Sahin, U., Esitken, A. and Anapali, O. 2005. Effects of some growing media on the growthof strawberry cvs. Camarosa and Fern. *Acta Agrobotanica*, **58**: 185-191.

Fernandes, C. and Eduardo-Cora, J. 2004. Bulk density and relationship air-water of horticultural substrate. *Scientia Agricola*, **61**(4): 446-450.

Fernandez, M.A., Hernanz, D., Toscano, G., Hernandez, M.C., Peralbo, A., Flores, F. and Lopez- Medina, J. 2006. Strawberry quality in soilless systems. *Acta Horticulturae*, **708**: 409-412.

Firoozabadi, M., Amrolahi, A. and Hokmabadi, H. 2009. Effect of different concentration of nitrogen, calcium, potassium in soilless growing strawberry (*Fragaria selva*). *Sixth Iranian Congress of Horticultural Science*, Guilan, Iran. pp: 123-124.

Fornes, F., Belda, R.M., Abad, M., Noguera, P., Puchades, R., Maquieira, A. and Noguera. V. 2003. The microstructure of coconut coir dusts for use as alternatives to peat in soilless growing media. *Australian Journal of Experimental Agriculture*, **43**: 1171-1179.

Ghazvini, R.F., Payvast, G. and Azarian, H. 2007. Effect of clinoptiloliticzeolite and perlite mixtures on the yield and quality of strawberry in soil-less culture. *International Journal of Agriculture and Biology*, **9**(6): 885-888.

Glanz, K., Basil, M., Maibach, E., Goldberg, J. and Snyder, D.A.N. 1998. Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. *Journal of the American Dietetic Association*, ***98***(10): 1118-1126.

Gracia, M. and Deverde, C., 1994. Le residu des fibres de coco a nouveau substrat pourla culture hors sol. PHM. *Horticulture Reviews*, **348**: 7-12.

Graves, C.J. 1983. The nutrient film technique. *Horticultural reviews*, **5**:1-44.

Gregorioa, C. and Vakits, J. 1992. Strawberry variety trials under cover. Miscellaneous reports 49, Ag. Res. Inst. M. Ag. and Nat. Res: Nicosia, Cyprus, p. 5.

Gruda, N. and Schnitzler, W.H. 2004. Suitability of wood fiber substrate for production of vegetable transplants. I. Physical properties of wood fiber substrates. *Scientia Horticulturae*, **100**: 309- 322.

Gul. A and Sevgican. A. 1994. Suitability of various soilless media for long term greenhouse tomato growing. *Acta Horticulturae*, **366.**

Gungor, F. and Yildirim, E. 2013. Effect of different growing media on quality, growth and yield of pepper (*Capsicum annuum* L.) under greenhouse conditions. *Pakistan Journal of Botany*, **45**(5): 1605-1608.

Harborne, J.B. 1973. Phytochemical Methods. *Chapman Hall, Toppan Co. Ltd.*, New York, USA.

Hassan, A.H., Khereba, A.H., El-Kattan, M.H., Noha, G. and El- Rahman, A. 2011. Effect of various organic substrate culture and container types on productivity and fruit quality of strawberry (*Fragaria* × *ananassa*) cv. Festival. *Research Journal of Agriculture and Biological Sciences*, **7**(5): 379-387.

Hesami, A., Khorami, S.S., Amini, F. and Kashkooli, A.B. 2012. Date-peat as an alternative in hydroponic strawberry production. *African Journal of Agricultural Research*, **7**(23): 3453-3458.

Ikeda, T., Suzuki, N., Nakayama, M. and Kawakami, Y. 2011. The effects of high temperature and water stress on fruit growth and anthocyanin content of pot-grown strawberry (*Fragaria*× *ananassa* Duch. cv. Sachinoka) plants. *Environmental Control in Biology*, **49** (4): 209-215.

Inden, H. and Torres, A. 2004. Comparison of four substrate on the growth and quality of tomatoes. *Acta Horticulturae*, **644**: 205-210.

Ingram, D.L., Henley, R.W. and Yeager, T.H., 2003. Growth Media for Container Grown Ornamental Plants (BUL 241). *Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida*.

Jafarnia, S., Khosrowshahi, S., Hatamzadeh, A. and Tehranifar, A. 2010. Effect of substrate and variety on some important quality and quantity characteristics of strawberry production in vertical hydroponics system. *Advances in Environmental Biology*, **4**(3): 360-363.

Javanpour, H., Babalar, R.M., Kashi, A., Mir-Abdolbagi, M. and Asgari, M. 2005. Effect of different nutrient solution and cultivation in the watery system on quantitative and qualitative traits of HAMRA greenhouse tomatoes. *Journal of Agricultural Science of Iran*, **36**(4): 939-946.

Joseph, A. and Muthuchamy, I., 2014. Productivity, quality and economics of tomato (Lycopersicon esculentum mill.) cultivation in aggregate hydroponics-a case study from coimbatore region of Tamil Nadu. *Indian Journal of Science and Technology*, **7**(8): 1078.

Joshi, P.S. 2003. *Effect of growing media, bioregulators and nutrients on growth, yield and quality of strawberry cv. Chandler*. PhD Thesis. Department of Fruit Science,

Dr YS Parmar University of Horticulture and Forestry, Solan, HP.

Karayamparambil, J. and Bhaskar, R. 2018. Hydroponic: the future of agriculture. *The free press journal*. https://www.freepressjournal.in/business/hydroponics-the-future-of-agriculture.

Karimi, F., Arunkumar, B., Asif, M., Murthy, B.N.S. and Venkatesha, K.T. 2013. Effect of different soilless culture systems on growth, yield and quality of strawberry cv. festival. *International Journal of Agricultural Sciences*, **9**(1): 366-372.

Kavana, G.B., Chandrashekar, S.Y., Hanumantharaya, L., Salimath, S.B. and Kumar, P.H. 2019. Effect of Potting Media on Reproductive and Quality Parameters of Nephrolepis undulate J. Sm under Protected Condition. *International Journal Current Microbiology and Applied Science*, **8**(8): 1208-1215.

Khalighi, A. and Padasht-Dehkaee, M.T. 2000. Effect of media produced by tree bark, tea waste, rice hull and Azolla as a substrate for peat, on growth and flowering of marigold (*Tagetes patula* "Golden Boy"). *Iranian Journal of Agricultural Sciences*, **31**(3): 557-565.

Kumar, A., Pandey, S.D., Kumar, V. and Nath, V. 2011. Evaluating potting media for production of quality planting materials of litchi (*Litchi chinensis* Sonn). *Bihar Journal of Horticulture*,**1**(1): 48-50.

Kumar, A., Pandey, S.D., Rai, R.R., and Vishal, N. 2014. Evaluation of alternate potting media mixtures for raising quality-planting material of litchi in polybags. *The Bioscan*, **9**(1): 381- 384.

Kumar, P. and Saini, S. 2020. Nutrients for hydroponic systems in fruit crops. In *Urban Horticulture-Necessity of the Future*, Intech Open.

Lee, Y.H., Yoon, C.S., Park, N. and Yeoung, Y.R. 2015. Influence of various nutrient concentrations on the growth and yield of summer strawberry cultivars cultivated in a hydroponic system. *Horticulture Environment and Biotechnology*, **56** (4): 421-426.

Linardakis, D.K. and Manios, V.I. 1990. Hydroponic culture of strawberries in plastic greenhouse in vertical system. *Acta Horticulturae*, **287**: 317-326.

Linsley-Noakes, G., Wilken, L. and Villiers, S. 2006. High density, vertical hydroponics growing system for strawberries. *Acta Horticulturae*, **708**: 365-370.

Luz, G. L. 2017. Action of the intervals between irrigations in the root system of lettuce in hydroponics. *Interciencia*, **42**: 370-374.

Maboko, M.M., Du Plooy, C.P. and Bertling, I. 2008, August. Comparative performance of tomato cultivars in soilless vs. in-soil production systems. In *International Symposium on Soilless Culture and Hydroponics*, **843**: 319-326.

Maboko, M.M., Du Plooy, C.P. and Bertling, I. 2011. Comparative performance of tomato cultivars cultivated in two hydroponic production systems. *South African Journal of Plant and Soil*, **28**(2): 97-102.

Maher, M., Prasad, M. and Raviv, M. 2008. *Organic Soilless Media Components*. Soilless culture: theory and practice, pp: 459-504.

Maher, M.M., Shylla, B., Sharma, D.D. and Sharma, U. 2020. Influence of different soilless substrates and jeevamrit on flowering and fruiting behaviour of strawberry (*Fragaria* X *ananassa* Duch.) cv. Chandler. *Journal of Pharmacognosy and Phytochemistry*, **9**(4): 428-432.

Manzocco, L., Foschia, M., Tomasi, N., Maifreni, M., Costa, L.D., Marino, M., Cortella, G. and Cesco, S. 2011. Influence of hydroponic and soil cultivation on quality and shelf life of ready-to-eat lamb's lettuce (*Valerianella locusta* L.). *Journal of the Science Food and Agriculture*, **91**(8): 1373-1380.

Marinou, E., Chrysargyris, A. and Tzortzakis, N. 2013. Use of sawdust, coco soil and pumice in hydroponically grown strawberry. *Plant Soil Environment*, **59**(10): 452–459.

Martins, C. M. 2009. Nutrient absorption curve in hydroponic lettuce. *Caatinga Magazine*, **22**: 123-128.

Mashadi, Jafarloo, A., Naseri, L., Samadi, A. and Hanare, M. 2009. The types of substrates used in hydroponics culture. *Proceedings of the First National Conference on Hydroponics and Greenhouse Productions*, 351-353.

Mohammed, S., 2018. Introduction to Nutrient Film Technique. In *Tomorrow's Agriculture*, 7-11.

Mohammed, S.B., Sooko, R., 2016. Nutrient Film Technique for Commercial Production. *Agricultural Science Research Journal*, **6(11):** 269-274.

Murthy, B.N.S., Karimi, F. and Laxman, R.H. 2016, August. Physiological performance reflecting in yield and quality of strawberry under vertical soilless culture system. In *VIII International Strawberry Symposium*, **1156**: 301-308.

Nafiye, A.D.A.K. and Gubbuk, H. 2015. Effect of planting systems and growing media on earliness, yield and quality of strawberry cultivation under soilless culture. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **43**(1): 204-209.

Nielsen, C.J., Ferrin, D.M. and Stanghellini, M.E. 2006. Efficacy of biosurfactants in the management of *Phytophthora capsici* on pepper in recirculating hydroponic systems. *Canadian Journal of Plant Pathology* **28**(3): 450-460.

Niu, F., Zhang, D., Li, Z., Iersel, M. V. and Alem, P. 2015. Morphological response of eucalypts seedlings to phosphorus supply through hydroponic system. *Scientia Horticulturae*, **194**: 295-303.

Nourizadeh, M. 2003. The effect of different substrate cultivation on the growth, performance and to evaluate the cold acclimation and freezing quality of greenhouse cucumber in without soil cultivation system. M.Sc thesis on horticulture, Guilan University, Iran.

Ozdemir, E. and Kaska, N. 1997. The production of early strawberries in new and reused growing media in sack under a walk-in-tunnel. *Acta Horticulturae*, **439**: 501-507.

Ozeker, E., Elter, R.Z., Tuzel, Y., Gul, A., Onal, K. and Tanrisever, A. 1999. Investigation on the effect of different growing media on the yield and quality of strawberries grown in vertical black bags. *Acta Horticulturae*, **486**: 409-413.

Panse, V. G. and Sukhatme, P. V. 2000. *Statistical Methods for Agricultural Workers.* Publication and Information Division, ICAR, New Delhi.

Paroussi, G. and Paroussis, E. 1995. Precocity, plant productivity and fruit quality of strawberry plants grown in soil and soilless culture. *Acta Horticulturae*, **408**: 109-117.

Polycarpou, P., Neokleous, D., Chimonidou, D. and Papadopoulos. 2005. A closed system forsoil less culture adapted to the Cyprus conditions. *Proceedings of ICID Conference.* pp. 231-241.

Por-Hossein, L., Ebadi, A. and Mostufi, Y. 2009. Effect of nutrient solutions EC levels and type of media on strawberry growth and yield in hydroponic system. *Abstract*

in Sixth Iranian Congress of Horticultural Science, Guilan, Iran.

Prasana, J.S., Leua, H.N. and Ray, N.R. 2013. Effect of different growing media mixtures on germination and seedling growth of mango (*Mangifera indica* L.) cultivars under net house conditions. *The Bioscan*, **8**(3): 897-900.

Raja, W.H., Kumawat, K.L., Sharma, O.C., Sharma, A., Mir, J.I., Nabi, S., Lal, S. and Qureshi, I. 2018. Effect of different substrates on growth and quality of strawberry cv. Chandler in soilless culture. *The Pharma Innovation Journal*, **7**(12): 449-453.

Resh, H. M. and Howard, M. 2012. Hydroponic Food Production: *A definitive guidebook for the advanced home gardener and the commercial hydroponic grower*. In Santa Bárbara, California EUA (Sixth).

Riaz, A., Arshad, M., Younis, A., Raza, A. and Hameed, M. 2008. Effects of different growing media on growth and flowering of *Zinnia elegans* cv. Blue Point. *Pakistan Journal of Botany*, **40**(4): 1579-1585.

Roosta, H. R and Afsharipoor, S. 2012. Effects of different cultivation media on vegetative growth, ecophysiological traits and nutrients concentration in strawberry under hydroponic and aquaponic cultivation systems. *Advances in Environmental Biology*. **6**(2): 543-555.

Rostami, Z., Ghahsare, A.M. and Kavoosi, B. 2014. Date palm waste application as culture media for strawberry and its impact on some growth indices and yield components. *Agricultural Communications*, **2**(3): 15-21.

Rouphael, Y. and Colla, G., 2005. Growth, yield, fruit quality and nutrient uptake of hydroponically cultivated zucchini squash as affected by irrigation systems and growing seasons. *Scientia Horticulturae*, **105**(2): 177-195.

Rumple, J., Felczynski, K., Aniszewski, S.K. and Vogel, G. 1996. Results of experiments with soilless open field tomato culture in Germany and Poland. *International Society for Soilless Culture*, 373-380.

Sardare, M.D. and Admane, S.V. 2013. A review on plant without soil-hydroponics. *International Journal of Research in Engineering and Technology*, **2**(3):299-304.

Schie, W.V. 1999. Standarization of substrstes. *Acta Horticulturae*, **481**: 71-78.

Schmitzer, V. and Stampar, F. 2009. Changes in anthocyanin and selected phenolics in Korcrisett rose flowers due to substrate pH and foliar application of sucrose. *Acta Horticulturae,* **870**: 89-96.

Selda, O. and Anapali, O., 2010. Effect of soil addition on physical properties of perlite based media and strawberry cv. Camarosa plant growth. *Scientific Research and Essays,* **5**(22): 3430-3433.

Sengupta, A. and Banerjee, H. 2012. Soil-less culture in modern agriculture. *World Journal Science Technology,* **2**(7): 103-108.

Serrano, L., Orozco, R., Martinez, A. and Marfa, O. 1993. The use of fine graded perlite in bag culture II. Yield and water consumption of lettuce. *Acta Horticulturae,* **335**: 109-113.

Shahzad, U., Ijaz, M., Noor, N., Shahjahan, M., Hassan, Z., Kahn, A.A. and Calica, P. 2018. Variations in growing media and plant spacing for the improved production of strawberry (*Fragaria* × *ananassa* cv. Chandler). *Philippine Journal of Science,* **147**(4): 711-719.

Sharma, R.R. 2002. Growing strawberries. International Book Distribution Co., Lucknow, 164.

Sharma, V.K. and Godara, A.K., 2019. Growth responses of strawberry (Fragaria× ananassa duch.) plants grown at different planting density using pvc pipe under protected cultivation. *Bangladesh Journal of Botany,* **48**(1): 1-7.

Sheikh, B.A., 2006. Hydroponics: key to sustain agriculture in water stressed and urban environment. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, ***22***(2): 53-57.

Shi, L., L.V, N., Nie, J., Tan, D., Zheng, J., Luo, G., Li, Y., Xhong, Y., Xie, Y., Wang, J., 2018. Effects of culture media on yield, growth, photosynthesis capacity and antioxidant enzyme of different tomato (*Solanum Lycoprsicum* L.) varieties. *Applied Ecology and Environmental Research,* **16**(5)**:** 5909-5919.

Shreshtha, A., and Dunn, B., 2013 Hydroponics. Oklahoma Cooperative Extension Services HLA-6442.

Shylla, B., Sharma, A., Thakur, M. and Handa, A., 2018. Perlite-An Effective Soilless Substrate for Producing Strawberry Plants Free from Nematode Transmitted

Viruses. *International Journal of Current Microbiology and Applied Sciences*, **7**(03): 398-403.

Singh, N., Mishra, S. and Bahadur, V., 2019. Production of strawberry through closed hydroponics system under NFT (Nutrient Film technique). *Journal of Pharmacognosy and Phytochemistry*, **8**(4): 2958-2960.

Singh, R., Gupta, R.K., Patil, R.T., Sharma, R.R., Asrey, R., Kumar, A. and Jangra, K.K., 2010. Sequential foliar application of vermicompost leachates improves marketable fruit yield and quality of strawberry (*Fragaria* × *ananassa* Duch.). *Scientia Horticulturae*, **124**: 34-39.

Singh, R., Sharma, R.R., Kumar, S., Gupta, R.K and Patil, R.T. 2008. Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Bioresource Technology*, 99: 8507–8511.

Singh, R.R., Kaushik, J.C. and Singh, I. 2000. Effect of media on germination, shoot and root length and number of nodules of three N-fixing tree species seedlings. *Indian Journal of Forestry*, **23**(2): 157-159.

Soltani, A., 2004. Chlorophyll fluorescence and its application. *Internal Press.* University of Agricultural Science and Natural Resource, Gorgan, Iran.

Spehia, R.S., Devi, M., Singh, J., Sharma, S., Negi, A., Singh, S., Chauhan, N., Sharma, D. and Sharma, J.C., 2018. Lettuce growth and yield in Hoagland Solution with an organic concoction. *International Journal of Vegetable Science*, **24**(7): 557-566.

Subramani, T., Gangaiah, B., Baskaran, V. and Swain, S., 2020. Effect of Soilless Growing Media on Yield and Quality of Tomato (*Solanum lycopersicum* L.) under Tropical Island Condition. *International Journal of Current Microbiology and Applied Sciences*, **9**(5): 2084-2090.

Sun, J., Chu, Y.F., Wu, X. and Liu, R.H., 2002. Antioxidants and anti-proliferative activities of common fruits. *Journal of Agriculture and Food Chemistry*, **17**: 38-40.

Takeda, F. 1999. Strawberry production in soilless culture systems. *Acta Horticulturae*, **481**: 289-295.

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

Thakur, M. and Shylla, B., 2018. Influence of different growing media on plant growth and fruit yield of strawberry (*Fragaria× ananassa* Duch.) cv. Chandler grown under protected conditions. *International Journal of Current Microbiology and Applied Science*, **7**(4): 2724-2730.

Touliatos, D., Dodd, I.C. and McAinsh, M. 2016. Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics. *Food and Energy Security*, **5**(3): 184-191.

Treftz, C. and Omaye, S.T. 2015. Nutrient analysis of soil and soilless strawberries and raspberries grown in a greenhouse. *Food and Nutrition Sciences*, **6**: 805-815.

Tzortzakis, N.G. and Economakis, C.D. 2008. Impacts of the substrate medium on tomato yield and fruit quality in soilless cultivation. *Journal of Horticultural Science*, **35**: 83-89.

Ullah, M.S., Islam, M.S., Islam, M.A. and Haque, T. 2008. Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties. *Journal of Bangladesh Agricultural University,* **6**: 271-276.

Valenzano, V., Parente, A., Serio, F., Sanatamaria, P., 2008. Effect of growing system and cultivar on yield and water-use efficiency of greenhouse-grown tomato. *Journal of Horticultural Science & Biotechnology,* **83**(1): 71-75

Verdonck, O. and Demeyer, P. 2004. The influence of the particle sizes on the physical properties of growing media. *Acta Horticulturae,* **644**: 99-101.

Verdonck, O., Vleeschauwer, D. and De-Boodt, M. 1981. The influence of the substrates on plant growth. *Acta Horticulturae,* **126**: 251-258.

Vikas, K.A., Kumar, A., Singh, A., Kumar, P., Rafie, J., Verma, P. and Kumar, A. 2017. Influence of different nutrient concentration on strawberry under hydroponic cultivation system. *International Journal of Current Microbiology and Applied Sciences*, **6**: 2999-3006.

Vincenzo, V., Angelo, P., Francesco, S. and Pietro, S. 2008. Effect of growing system and cultivar on yield and water-use efficiency of greenhouse-grown tomato. *Journal of Horticultural Sciences and Biotechnology*. **83** (1): 71-75.

Waffa, R.D., El-Gizawy, A.M., Zocchi, G. and El-Behairy, U.A. 2009. Studies on using different substrate mixes for producing green onion. *Journal of Biology, Chemistry and Environmental Science,* **4** (2): 665-672.

Wilkerson, D. 2002. *Growing Media*. Texas Greenhouse Management Handbook. Texas Agriculture Extension Service. (http://aggie-horticulture.tamu.edu/ greenhouse/ nursery/ guides/ green/ media.html).

Wysocki, K., Kopytowski, J., Bieniek, A. and Bojarska, J. 2017. The effect of substrates on yield and quality of strawberry fruits cultivated in a heated foil tunnel. *Zemdirbyste-Agriculture,* **104** (3): 283–286.

Yang, C.M., Chang, K.W., Yin, M.H. and Huang, H.M. 1998. Methods for the determination of the chlorophylls and their derivatives. *Taiwania,* **43** (2): 116-122.

Yau, P.Y., and Murphy, R.J. 2000. Biodegraded coco peat as a horticultural substrate. *Acta Horticulturae,* **517**: 275- 278.

Yavari, S., Eshghi, S., Tafazoli, E. and Yavari, S. 2008. Effects of various organic substrates and nutrient solution on productivity and fruit quality of strawberry "Selva" (*Fragaria× ananassa* Duch.). *Journal of Fruit and Ornamental Plant Research,* **16**: 167-178.

Yuan, L.P., Jaj, E.H. and Jonathan, P.L. 1996. Marigold growth and phosphorus leaching in a soilless medium amended with phosphorus charged alumina. *Journal of Horticulture Science,* **31**: 94- 98.

Zhang, Y., Guixia, W., Linlin, C., Jing, D., Chuanfei, Z. and Lina, W. 2014. current status of strawberry production and research in China. *Acta Horticulturea,* **1049**: 67-71.

Appendix

Appendix-I
Meteorological data during crop season (01 October, 2020 to 28 April, 2021)

Standard meteorological week	Temperature (^{0}C)		Humidity (%)		Rainfall (mm)
	Max.	Min.	Morning	Evening	
40 (01-07 October)	33.86	18.17	76.29	39.57	0.00
41 (08-14 October)	33.50	17.97	81.43	40.00	0.00
42 (15-21 October)	32.37	14.37	90.29	31.86	0.00
43 (22-28 October)	30.26	12.37	89.86	34.43	0.00
44 (29 Oct.-4 November)	28.66	10.84	85.71	32.43	0.00
45 (5-11 November)	27.90	9.61	88.43	39.57	0.00
46 (12-18 November)	23.21	9.84	92.71	58.00	3.97
47 (19-25 November)	20.60	8.51	91.86	55.86	0.00
48 (26 Nov.-02 December)	23.69	7.40	92.43	48.29	1.14
49 (03-09 December)	23.27	9.79	92.14	57.86	0.11
50 (10-16 December)	18.50	8.27	93.71	65.86	3.94
51 (17-23 December)	17.60	2.97	93.86	61.71	0.00
52 (24-30 December)	15.23	3.33	95.29	72.71	1.26
01 (31 Dec.-06 January)	17.93	7.16	93.14	73.71	12.60
02 (07-13 January)	15.40	9.10	94.86	80.00	0.00
03 (14-20 January)	18.06	6.00	94.14	71.43	0.00
04 (21-27 January)	17.31	5.24	93.29	66.14	0.54
05 (28 Jan.-03 February)	19.83	5.10	90.86	50.86	0.00
06 (04-10 February)	20.63	7.10	89.71	50.29	0.00
07 (11-17 February)	21.31	10.33	96.14	68.86	0.00
08 (18-24 February)	24.89	9.90	94.71	54.71	0.00
09 (25 Feb.-03 March)	26.96	11.06	83.00	47.43	0.00
10 (04-10 March)	28.57	10.94	82.29	39.86	0.00
11 (11-17 March)	26.81	12.47	83.57	50.43	0.51
12 (18-24 March)	27.06	13.71	80.29	48.43	2.17
13 (25-31 March)	30.71	13.94	78.00	37.43	0.00
14 (01-07 April)	30.63	11.76	60.71	26.71	0.23
15 (08-14 April)	33.97	13.46	59.29	19.00	0.23
16 (15-21 April)	29.60	15.93	59.86	40.43	1.57
17 (22-28 April)	33.46	14.61	61.29	24.00	1.14

Source: Agrometeorology centre, SKUAST- Jammu

Vita

VITA

Name of Student	:	Sanjay Kumar
Father's Name	:	Sudhir Kumar
Mother's Name	:	Krishna
Nationality	:	Indian
Date of birth	:	11-05-1997
Mobile	:	9530508053
Email	:	sanjaymalethia786@gmail.com
Permanent home address	:	V.P.O. Churi Wala Dhanna, Teh. Abohar, Dist. Fazilka, Punjab Pin 152122

EDUCATIONAL QUALIFICATION

Bachelor Degree	:	B.Sc. (Hons.) Agriculture
University and year of award	:	D.A.V. University, Jalandhar
Percentage of marks (OGPA)	:	6.6/10
Master's Degree	:	M.Sc. Ag. Horticulture (Fruit Science)
OGPA	:	8.0/10

CERTIFICATE- IV

Certified that all necessary corrections as suggested by the External examiner and advisory committee have been duly incorporated in the thesis entitled **"Nutritional Studies for Soil and Soilless Production of Strawberry (*Fragaria* × *ananassa*) cv. Chandler"**, submitted by **Mr. Sanjay Kumar,** Registration No. **J-19-M-657**.

Dr. Mahital Jamwal
Deputy Director (Research)/
Assoc. Prof. (Fruit Science),
Directorate of Research, Chatha
Major Advisor

Place: Jammu

Date: 13.12.2021

16/12/2021
Dr. Amit Jasrotia

Head of the Division